COURSE MATERIAL

III Year B. Tech I- Semester

MECHANICAL ENGINEERING

AY: 2025-26

METROLOGY AND MACHINE TOOLS

R22A0312

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MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

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www.mrcet.ac.in

CONTENTS

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

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VISION

- ❖ To establish a pedestal for the integral innovation, team spirit, originality and competence in the students, expose them to face the global challenges and become technology leaders of Indian vision of modern society.

MISSION

- ❖ To become a model institution in the fields of Engineering, Technology and Management.
- ❖ To impart holistic education to the students to render them as industry ready engineers.
- ❖ To ensure synchronization of MRCET ideologies with challenging demands of International Pioneering Organizations.

QUALITY POLICY

- ❖ To implement best practices in Teaching and Learning process for both UG and PG courses meticulously.
- ❖ To provide state of art infrastructure and expertise to impart quality education.
- ❖ To groom the students to become intellectually creative and professionally competitive.
- ❖ To channelize the activities and tune them in heights of commitment and sincerity, the requisites to claim the never - ending ladder of**SUCCESS**year after year.

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VISION

To become an innovative knowledge center in mechanical engineering through state-of-the-art teaching-learning and research practices, promoting creative thinking professionals.

MISSION

The Department of Mechanical Engineering is dedicated for transforming the students into highly competent Mechanical engineers to meet the needs of the industry, in a changing and challenging technical environment, by strongly focusing in the fundamentals of engineering sciences for achieving excellent results in their professional pursuits.

Quality Policy

- ✓ To pursuit global Standards of excellence in all our endeavors namely teaching, research and continuing education and to remain accountable in our core and support functions, through processes of self-evaluation and continuous improvement.
- ✓ To create a midst of excellence for imparting state of art education, industry-oriented training research in the field of technical education.

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Department of Mechanical Engineering

PROGRAM OUTCOMES

Engineering Graduates will be able to:

1. **Engineering knowledge:**Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and teamwork**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance**: Demonstrate knowledge and understanding of the engineering and managementprinciples and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1 Ability to analyze, design and develop Mechanical systems to solve the Engineering problems by integrating thermal, design and manufacturing Domains.

PSO2 Ability to succeed in competitive examinations or to pursue higher studies or research.

PSO3 Ability to apply the learned Mechanical Engineering knowledge for the Development of society and self.

Program Educational Objectives (PEOs)

The Program Educational Objectives of the program offered by the department are broadly listed below:

PEO1: PREPARATION

To provide sound foundation in mathematical, scientific and engineering fundamentals necessary to analyze, formulate and solve engineering problems.

PEO2: CORE COMPETANCE

To provide thorough knowledge in Mechanical Engineering subjects including theoretical knowledge and practical training for preparing physical models pertaining to Thermodynamics, Hydraulics, Heat and Mass Transfer, Dynamics of Machinery, Jet Propulsion, Automobile Engineering, Element Analysis, Production Technology, Mechatronics etc.

PEO3: INVENTION, INNOVATION AND CREATIVITY

To make the students to design, experiment, analyze, interpret in the core field with the help of other inter disciplinary concepts wherever applicable.

PEO4: CAREER DEVELOPMENT

To inculcate the habit of lifelong learning for career development through successful completion of advanced degrees, professional development courses, industrial training etc.

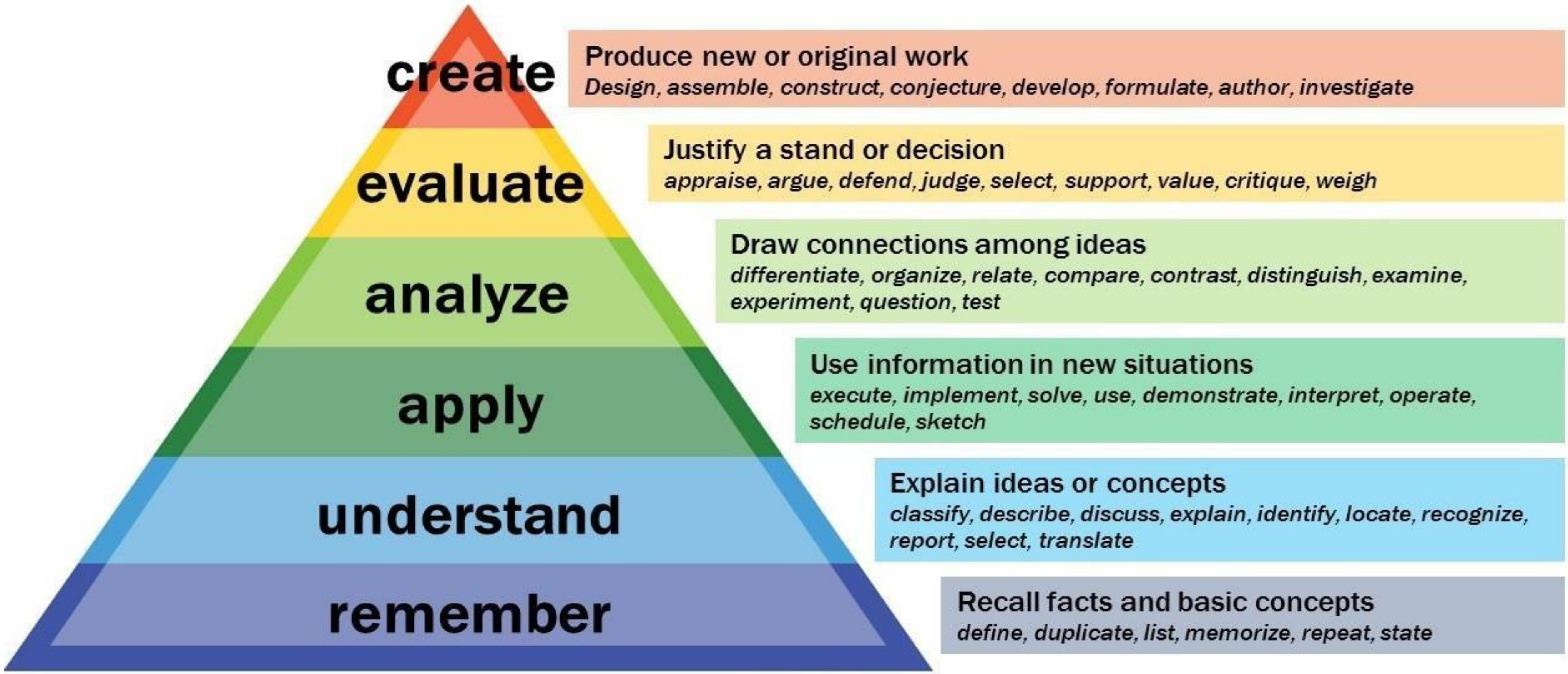
PEO5: PROFESSIONALISM

To impart technical knowledge, ethical values for professional development of the student to solve complex problems and to work in multi-disciplinary ambience, whose solutions lead to significant societal benefits.

Blooms Taxonomy

Bloom's Taxonomy is a classification of the different objectives and skills that educators set for their students (learning objectives). The terminology has been updated to include the following six levels of learning. These 6 levels can be used to structure the learning objectives, lessons, and assessments of a course.

1. **Remembering**: Retrieving, recognizing, and recalling relevant knowledge from long- term memory.
2. **Understanding**: Constructing meaning from oral, written, and graphic messages through interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining.
3. **Applying**: Carrying out or using a procedure for executing or implementing.
4. **Analyzing**: Breaking material into constituent parts, determining how the parts relate to one another and to an overall structure or purpose through differentiating, organizing, and attributing.
5. **Evaluating**: Making judgments based on criteria and standard through checking and critiquing.
6. **Creating**: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure through generating, planning, or producing.



create
Produce new or original work
Design, assemble, construct, conjecture, develop, formulate, author, investigate
evaluate
Justify a stand or decision
appraise, argue, defend, judge, select, support, value, critique, weigh
analyze
Draw connections among ideas
differentiate, organize, relate, compare, contrast, distinguish, examine, experiment, question, test
apply
Use information in new situations
execute, implement, solve, use, demonstrate, interpret, operate, schedule, sketch
understand
Explain ideas or concepts
classify, describe, discuss, explain, identify, locate, recognize, report, select, translate
remember
Recall facts and basic concepts
define, duplicate, list, memorize, repeat, state

MALLA REDDY COLLEGE OF ENGINEERING AND TECHNOLOGY

III Year B.Tech. ME- I Sem **L/T/P/C**

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(R22A0312) METROLOGY AND MACHINE TOOLS

Course Objectives:

1. Equip with knowledge of limits, fits, tolerances and gauging.
2. The principles of linear and angular measuring instruments for accurate measurement of a given component.
3. To impart knowledge of mechanism of metal cutting
4. To describe the mechanisms of the various metal cutting machines, types of machines, various operations that can be performed on them, machining time and force calculations etc.
5. To Learn about the ways to reduce the surface roughness by using different machines.

UNIT – I

Introduction to Metrology: Need, Types, Terminology, Methods of measurements, Selection of measuring Instruments Linear Measurement: Line and end standard, slip gauges, micrometers, spirit level.

Limits, fits and tolerances- Types of Fits - Unilateral and bilateral tolerance system, hole and shaftbasis system. Interchangeability and selective assembly.

UNIT-II

Limit Gauges: Taylor's principle, Design of GO and NO-GO gauges.

Measurement of angles using Bevel protractor and Sine bar. Measurement of flatness using straightedges, surface plates, optical flat and auto collimator.

Measuring Instruments: Surface Roughness Measurement: Factors affecting the surface roughness, reasons for controlling the surface texture, elements of surface texture-Roughness, Waviness, evaluation of surface roughness-CLA, RMS, Rz Values. Methods of measurement of surface finish, Talysurf. Screw threadmeasurement,

UNIT-III

Mechanism of Metal Cutting: Metal cutting: Introduction, elements of cutting process – Geometry of single point tool, Chip formationand types of chips, tool materials, tool life, tool wear, cutting fluids, Analysis of orthogonal cutting- Merchant's force diagram, Machinability.

Engine lathe – Principle of working, types of lathes, specifications, operations on lathe, Taper turning methods, Lathe attachments. Capstan and Turret lathe – Single spindle and multi-spindle automatic lathes — tool layouts.

UNIT-IV

Drilling & Boring machines: Principles of working, specifications, types, operations performed – tool holding devices – twist drill – deep hole Drilling Machine. Boring Machines – fine Boring Machines – jig boring machine & Broaching operations.

Milling Machines: Principles of working – specifications – classification of Milling Machines – Principle features of horizontal, vertical and universal Milling Machine, machining operations, types of cutters, geometry of milling cutters – methods of indexing, accessories of milling machines.

UNIT-V

Shaping, Slotting and Planning Machines: Principles of working, mechanisms, principal parts – specifications, operations performed, machining time calculations.

Surface Finishing Processes: Theory of grinding – classification of grinding machines, cylindrical and surface grinding machines, tool and cutter grinding machines, different types of abrasives, bonds, specification and selection of a grinding wheel. Lapping, Honing.

Text Books

1. "A Textbook of Metrology ", M Mahajan, Dhanpatrai, 5th edition, 2019
2. Manufacturing Technology II, P.N Rao. TMH Ltd 1998(Revised edition)
3. Production Engineering by P.C. Sharma, S. Chand and Company.

Reference Books

1. Geofrey, "Fundamentals of metal machining and machine tools", Tata McGraw Hill Education, 4th edition, 2019.
2. Process and Materials of Manufacture (4th Edition) by Roy A. Lindberg, Prentice-Hall of India Private Limited
3. Engineering Metrology, R. K. Jain, Khanna Publishers, 1st Edition, 2013.

Course Outcomes

CO1: Apply the various methods for the measurements of screw threads, surface roughness parameters and the working of optical measuring instruments.

CO2: Apply the principles of limits, fits and tolerance while designing and manufacturing the components of their requirement.

CO3: Understand the importance of geometry of cutting tools, coolants and tool materials for the analysis of material behavior during manufacturing processes and explain the operational principles of different lathe machines.

CO4: Explain the working principles of Milling, drilling machines for manufacturing the components of their requirement.

CO5: Identify different types of operations, specifications and principles of shaping, slotting, planning machines, finishing operations on grinders, lapping and honing.

UNIT 1
Introduction to Metrology

Technical Terms

Measurement

Measurement is the act, or the result, of a quantitative comparison between a predetermined standard and an unknown magnitude.

Range

It represents the highest possible value that can be measured by an instrument.

Scale sensitivity

It is defined as the ratio of a change in scale reading to the corresponding change in pointer deflection. It actually denotes the smallest change in the measured variable to which an instrument responds.

True or actual value

It is the actual magnitude of a signal input to a measuring system which can only be approached and never evaluated.

Accuracy

It is defined as the closeness with which the reading approaches an accepted standard value or true value.

Precision

It is the degree of reproducibility among several independent measurements of the same true value under specified conditions. It is usually expressed in terms of deviation in measurement.

Repeatability

It is defined as the closeness of agreement among the number of consecutive measurement of the output for the same value of input under the same operating conditions. It may be specified in terms of units for a given period of time.

Reliability

It is the ability of a system to perform and maintain its function in routine circumstances. Consistency of a set of measurements or measuring instrument often used to describe a test.

Systematic Errors

A constant uniform deviation of the operation of an instrument is known as systematic error. Instrumentation error, environmental error, Systematic error and observation error are systematic errors.

Random Errors

Some errors result through the systematic and instrument errors are reduced or at least accounted for. The causes of such errors are unknown and hence, the errors are called random errors.

Calibration

Calibration is the process of determining and adjusting instruments accuracy to make sure its accuracy is within the manufacturer's specifications.

General Concept

Introduction to Metrology

Metrology word is derived from two Greek words such as metro which means measurement and logy which means science. Metrology is the science of precision measurement. The engineer can say it is the science of measurement of lengths and angles and all related quantities like width, depth, diameter and straightness with high accuracy. Metrology demands pure knowledge of certain basic mathematical and physical principles. The development of the industry largely depends on the engineering metrology. Metrology is concerned with the establishment, reproduction and conservation and transfer of units of measurements and their standards. Irrespective of the branch of engineering, all engineers should know about various instruments and techniques.

Introduction to Measurement

Measurement is defined as the process of numerical evaluation of a dimension or the process of comparison with standard measuring instruments. The elements of measuring system include the instrumentation, calibration standards, environmental influence, human operator limitations and features of the work-piece. The basic aim of measurement in industries is to check whether a component has been manufactured to the requirement of a specification or not.

Types of Metrology

Legal Metrology

'Legal metrology' is that part of metrology which treats units of measurements, methods of measurements and the measuring instruments, in relation to the technical and legal requirements. The activities of the service of 'Legal Metrology' are:

(ii) Control of measuring instruments;

(iii) Testing of prototypes/models of measuring instruments;

(iv) Examination of a measuring instrument to verify its conformity to the statutory requirements etc.

Dynamic Metrology

'Dynamic metrology' is the technique of measuring small variations of a continuous nature. The technique has proved very valuable, and a record of continuous measurement, over a surface, for instance, has obvious advantages over individual measurements of an isolated character.

Deterministic metrology

Deterministic metrology is a new philosophy in which part measurement is replaced by process measurement. The new techniques such as 3D error compensation by CNC (Computer Numerical Control) systems and expert systems are applied, leading to fully adaptive control. This technology is used for very high precision manufacturing machinery and control systems to achieve micro technology and nanotechnology accuracies.

Objectives of Metrology

Although the basic objective of a measurement is to provide the required accuracy at a minimum cost, metrology has further objectives in a modern engineering plant with different shapes which are:

1. Complete evaluation of newly developed products.
2. Determination of the process capabilities and ensure that these are better than the relevant component tolerances.
3. Determination of the measuring instrument capabilities and ensure that they are quite sufficient for their respective measurements.
4. Minimizing the cost of inspection by effective and efficient use of available facilities.
5. Reducing the cost of rejects and rework through application of Statistical Quality Control Techniques.
6. To standardize the measuring methods
7. To maintain the accuracies of measurement.
8. To prepare designs for all gauges and special inspection fixtures.

Necessity and Importance of Metrology

1. The importance of the science of measurement as a tool for scientific research (by which accurate and reliable information can be obtained) was emphasized by Ga1ileo and Gvethe. This is essential for solving almost all technical problems in the field of engineering in general, and in production engineering and experimental design in particular. The design engineer should not only check his design from the point of view of strength or economical production, but he should also keep in mind how the dimensions specified can be checked or measured. Unfortunately, a considerable amount of engineering work is still being executed without realizing the importance of inspection and quality control for improving the function of product and achieving the economical production.

2. Higher productivity and accuracy is called for by the present manufacturing techniques. This cannot be achieved unless the science of metrology is understood, introduced and applied in industries. Improving the quality of production necessitates proportional improvement of the measuring accuracy, and marking out of components before machining and the in-process and post process control of the dimensional and geometrical accuracies of the product. Proper gauges should be designed and used for rapid and effective inspection. Also automation and automatic control, which are the modem trends for future developments, are based on measurement. Means for automatic gauging as well as for position and displacement measurement with feedback control have to be provided.

Methods of Measurements

These are the methods of comparison used in measurement process. In precision measurement various methods of measurement are adopted depending upon the accuracy required and the amount of permissible error.

The methods of measurement can be classified as:

l. Direct method
2. Indirect method
3. Absolute or Fundamental method
4. Comparative method
5. Transposition method
6. Coincidence method
7. Deflection method
8. Complementary method
9. Contact method
10. Contact less method
1. Direct method of measurement:

This is a simple method of measurement, in which the value of the quantity to be measured is obtained directly without any calculations. For example, measurements by using scales, vernier callipers, micrometers, bevel protector etc. This method is most widely used in production. This method is not very accurate because it depends on human insensitiveness in making judgment.

2. **Indirect method of measurement**: In indirect method the value of quantity to be measured is obtained by measuring other quantities which are functionally related to the required value. E.g. Angle measurement by sine bar, measurement of screw pitch diameter by three wire method etc.

3. Absolute or Fundamental method:

It is based on the measurement of the base quantities used to define the quantity. For example, measuring a quantity directly in accordance with the definition of that quantity, or measuring a quantity indirectly by direct measurement of the quantities linked with the definition of the quantity to be measured.

4. Comparative method:

In this method the value of the quantity to be measured is compared with known value of the same quantity or other quantity practically related to it. So, in this method only the deviations from a master gauge are determined, e.g., dial indicators, or other comparators.

5. Transposition method:

It is a method of measurement by direct comparison in which the value of the quantity measured is first balanced by an initial known value A of the same quantity, and then the value of the quantity measured is put in place of this known value and is balanced again by another known value B. If the position of the element indicating equilibrium is the same in both cases, the value of the quantity to be measured is AB. For example, determination of amass by means of a balance and known weights, using the Gauss double weighing.

6. Coincidence method:

It is a differential method of measurement in which a very small difference between the value of the quantity to be measured and the reference is determined by the observation of the coincidence of certain lines or signals. For example, measurement by vernier calliper micrometer.

7. Deflection method:

In this method the value of the quantity to be measured is directly indicated by a deflection of a pointer on a calibrated scale.

8. Complementary method:

In this method the value of the quantity to be measured is combined with a known value of the same quantity. The combination is so adjusted that the sum of these two values is equal to predetermined comparison value. For example, determination of the volume of a solid by liquid displacement.

9. **Method of measurement by substitution**:

It is a method of direct comparison in which the value of a quantity to be measured is replaced by a known value of the same quantity, so selected that the effects produced in the indicating device by these two values are the same.

10. Method of null measurement:

It is a method of differential measurement. In this method the difference between the value of the quantity to be measured and the known value of the same quantity with which it is compared is brought to zero.

Generalized Measurement System

A measuring system exists to provide information about the physical value of some variable being measured. In simple cases, the system can consist of only a single unit that gives an output reading or signal according to the magnitude of the unknown variable applied to it.

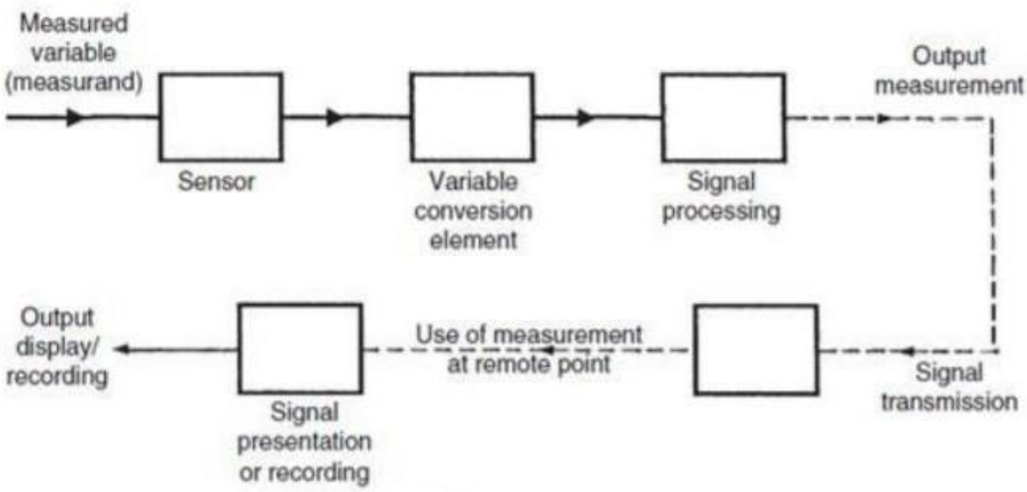


Fig 1.1 Generalised Measurement system

However, in more complex measurement situations, a measuring system consists of several separate elements as shown in Figure1.1.

Units

Table 1.1 Physical Quantities and its unit

Physical Quantity	Standard Unit	Definition
Length	Meter	Length of path traveled by light in an interval of 1/299,792,458 seconds
Mass	Kilogram	Mass of a platinum-iridium cylinder kept in the International Bureau of Weights and Measures, Sevres, Paris
Time	Second	$9.192631770 \times 10^{9}$ cycles of radiation from vaporized cesium 133 (an accuracy of 1 in 10^{12} or one second in 36,000 years)
Temperature	Degrees	Temperature difference between absolute zero Kelvin and the triple point of water is defined as 273.16 K
Current	Amphere	One ampere is the current flowing through two infinitely long parallel conductors of negligible cross section placed 1 meter apart in vacuum and producing a force of 2×10^{-7} newtons per meter length of conductor
Luminous intensity	Candela	One candela is the luminous intensity in a given direction from a source emitting monochromatic radiation at a frequency of 540 terahertz (Hz $\times 10^{12}$) and with a radiant density in that direction of 1.4641 mW/steradian (1 steradian is the solid angle, which, having its vertex at the centre of a sphere, cuts off an area of the sphere surface equal to that of a square with sides of length equal to the sphere radius)
Matter	Mole	Number of atoms in a 0.012-kg mass of carbon 12

Standards

The term standard is used to denote universally accepted specifications for devices. Components or processes which ensure conformity and interchange ability throughout a particular industry. A standard provide a reference for assigning a numerical value to a measured quantity. Each basic measurable quantity has associated with it an ultimate standard. Working standards, those used in conjunction with the various measurement making instruments. The national institute of standards and technology (NIST) formerly called National Bureau of Standards (NBS), it was established by an act of congress in 1901, and the need for such body had been noted by the founders of the constitution. In order to maintain accuracy, standards in a vast industrial complex must be traceable to a single source, which may be national standards. The following is the generalization of echelons of standards in the national measurement system.

1. Calibration standards
2. Metrology standards
3. National standards

1. Calibration standards:

Working standards of industrial or governmental laboratories.

2. **Metrology standards**:

Reference standards of industrial or Governmental laboratories.

3. **National standards:**

It includes prototype and natural phenomenon of SI (Systems International), the world wide system of weight and measures standards. Application of precise measurement has increased so much, that a single national laboratory to perform directly all the calibrations and standardization required by a large country with high technical development. It has led to the establishment of a considerable number of standardizing laboratories in industry and in various other areas. A standard provides a reference or datum for assigning a numerical value to a measured quantity.

Classification of Standards

To maintain accuracy and interchange ability it is necessary that Standards to be traceable to a single source, usually the National Standards of the country, which are further linked to International Standards. The accuracy of National Standards is transferred to working standards through a chain of intermediate standards in a manner given below.

•National Standards
•National Reference Standards
•Working Standards
•PlantLaboratory Reference Standards
•Plant Laboratory Working Standards
•Shop Floor Standards
Evidently, there is degradation of accuracy in passing from the defining standards to the shop floor standards. The accuracy of particular standard depends on a combination of the number of times it has been compared with a standard in a higher echelon, the frequency of such comparisons, the care with which it was done, and the stability of the particular standards itself.

Accuracy of Measurements

The purpose of measurement is to determine the true dimensions of a part. But no measurement can be made absolutely accurate. There is always some error. The amount of error depends upon the following factors:

• The accuracy and design of the measuring instrument
• The skill of the operator
• Method adopted for measurement
• Temperature variations
• Elastic deformation of the part or instrument etc.
Thus, the true dimension of the part cannot be determined but can only by approximate. The agreement of the measured value with the true value of the measured quantity is called accuracy. If the measurement of dimensions of a part approximates very closely to the true value of that dimension, it is said to be accurate. Thus the term accuracy denotes the closeness of the measured value with the true value. The difference between the measured value and the true

value is the error of measurement. The lesser the error, more is the accuracy.

Precision

The terms precision and accuracy are used in connection with the performance of the instrument. Precision is the repeatability of the measuring process. It refers to the group of measurements for the same characteristics taken under identical conditions. It indicates to what extent the identically performed measurements agree with each other. If the instrument is not precise it will give different (widely varying) results for the same dimension when measured again and again. The set of observations will scatter about the mean.

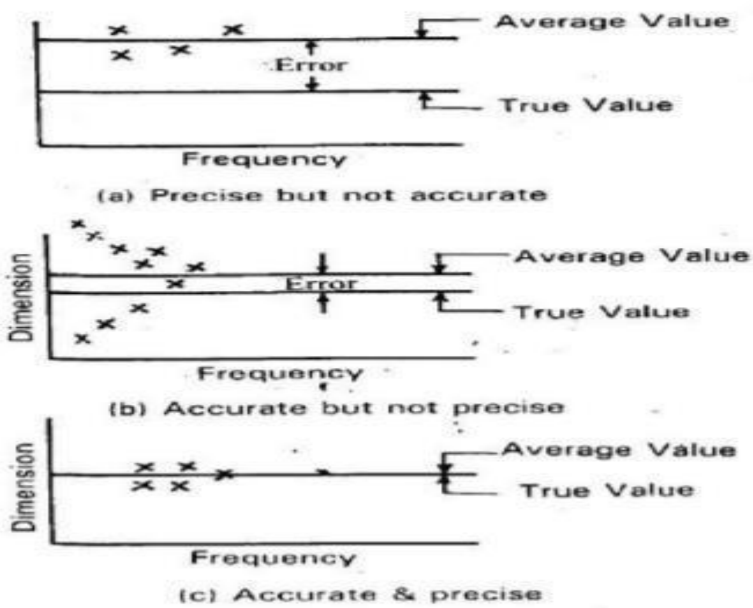
The scatter of these measurements is designated asσ, the standard deviation. It is used as an index of precision. The less the scattering more precise is the instrument. Thus, lower, the value ofσ, the more precise is the instrument.

Accuracy

Accuracy is the degree to which the measured value of the quality characteristic agrees with the true value. The difference between the true value and the measured value is known as error of measurement. It is practically difficult to measure exactly the true value and therefore a set of observations is made whose mean value is taken as the true value of the quality measured.

Distinction between Precision and Accuracy

Accuracy is very often confused with precision though much different. The distinction between the precision and accuracy will become clear by the following example. Several measurements are made on a component by different types of instruments (A, B and C respectively) and the results are plotted. In any set of measurements, the individual measurements are scattered about the mean, and the precision signifies how well the various measurements



(a) Precise but not accurate

(b) Accurate but not precise

(c) Accurate & precise

performed by same instrument on the same quality characteristic agree with each other. The difference between the mean of set of readings on the same quality characteristic and the true value is called as error. Less the error more accurate is the instrument. Figure shows that the instrument A is precise since the results of number of measurements are close to the average value. However, there is a large difference (error) between the true value and the average value hence it is not accurate. The readings taken by the instruments are scattered much from the average value and hence it is not precise but accurate as there is a small difference between the average value and true value.

Factors affecting the accuracy of the Measuring System

The basic components of an accuracy evaluation are the five elements of a measuring system such as:

• Factors affecting the calibration standards.
• Factors affecting the work piece.
• Factors affecting the inherent characteristics of the instrument.
• Factors affecting the person, who carries out the measurements,
• Factors affecting the environment.

1. **Factors affecting the Standard:** It may be affected by: -Coefficient of thermal expansion -Calibration interval -Stability with time -Elastic properties -Geometric compatibility

2. **Factors affecting the Work piece**: These are: -Cleanliness -Surface finish, waviness, scratch, surface defects etc., -Hidden geometry -Elastic properties,-adequate datum on the work piece -Arrangement of supporting work piece -Thermal equalization etc.

3. **Factors affecting the inherent characteristics of Instrument**: -Adequate amplification for accuracy objective -Scale error -Effect of friction, backlash, hysteresis, zero drift error -Deformation in handling or use, when heavy work pieces are measured - Calibration errors -Mechanical parts (slides, guide ways or moving elements) –Repeatability and readability -Contact geometry for both work piece and standard.

4. **Factors affecting person**:

-Training, skill -Sense of precision appreciation -Ability to select measuring instruments and standards –Sensible appreciation of measuring cost -Attitude towards personal accuracy achievements -Planning measurement techniques for minimum cost, consistent with precision requirements etc.

5. Factors affecting Environment:

-Temperature, humidity etc. -Clean surrounding and minimum vibration enhance precision –Adequate illumination -Temperature equalization between standard, work piece, and instrument - Thermal expansion effects due to heat radiation from lights -Heating elements, sunlight and people -Manual handling may also introduce thermal expansion. Higher accuracy can be achieved only if, ail the sources of error due to the above five elements in the measuring system are analysed and steps taken to eliminate them. The above analysis of five basic metrology elements can be composed into the acronym SWIPE, for convenient reference where, S – STANDARD W – WORKPIECE I – INSTRUMENT P – PERSON E – ENVIRONMENT

Sensitivity

Sensitivity may be defined as the rate of displacement of the indicating device of an instrument, with respect to the measured quantity. In other words, sensitivity of an instrument is the ratio of the scale spacing to the scale division value. For example, if on a dial indicator, the scale spacing is 1.0 mm and the scale division value is 0.01 mm, then sensitivity is 100. It is also called as amplification factor or gearing ratio. If we now consider sensitivity over the full range of instrument reading with respect to measured quantities as shown in Figure the sensitivity at any value of y=dx/dy, where dx and dy are increments of x and y, taken over the full instrument scale, the sensitivity is the slope of the curve at any value of y. The sensitivity may be constant or variable along the scale. In the first case we get linear transmission and in the second non-linear transmission. Sensitivity refers to the ability of measuring device to detect small differences in a quantity being measured. High sensitivity instruments may lead to drifts due to thermal or other effects, and indications may be less repeatable or less precise than that of the instrument of lower sensitivity.

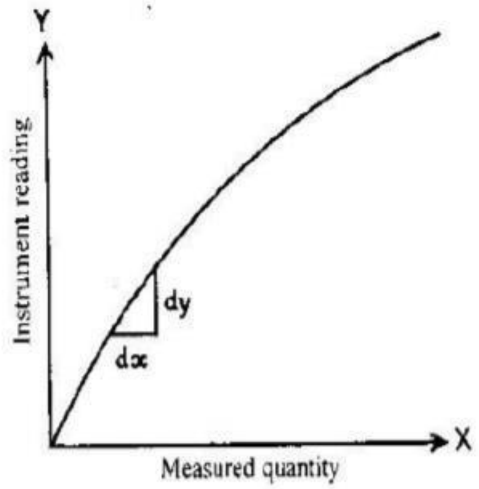


Fig 1.2 Sensitivity of Measurement

Readability

Readability refers to the case with which the readings of a measuring Instrument can be read. It is the susceptibility of a measuring device to have its indications converted into meaningful number. Fine and widely spaced graduation lines ordinarily improve the readability. If the graduation lines are very finely spaced, the scale will be more readable by using the microscope; however, with the naked eye the readability will be poor. To make micrometres more readable they are provided with vernier scale. It can also be improved by using magnifying devices.

Calibration

The calibration of any measuring instrument is necessary to measure the quantity in terms of standard unit. It is the process of framing the scale of the instrument by applying some standardized signals. Calibration is a pre measurement process, generally carried out by manufacturers. It is carried out by making adjustments such that the read out device produces zero output for zero measured input. Similarly, it should display an output equivalent to the known measured input near the full scale input value. The accuracy of the instrument depends upon the calibration. Constant use of instruments affects their accuracy. If the accuracy is to be maintained, the instruments must be checked and recalibrated if necessary. The schedule of such calibration depends upon the severity of use, environmental conditions, accuracy of measurement required etc. As far as possible calibration should be performed under environmental conditions which are very close to the conditions under which actual measurements are carried out. If the output of a measuring system is linear and repeatable, it can be easily calibrated.

Repeatability

It is the ability of the measuring instrument to repeat the same results for the measurements for the same quantity, when the measurement are carried out-by the same observer,-with the same instrument,-under the same conditions,-without any change in location,-without change in the method of measurement-and the measurements are carried out in short intervals of time. It may be expressed quantitatively in terms of dispersion of the results.

Reproducibility

Reproducibility is the consistency of pattern of variation in measurement i.e. closeness of the agreement between the results of measurements of the same quantity, when individual measurements are carried out: -by different observers –by different methods -using different instruments -under different conditions, locations, times etc.

Errors in Measurements

It is never possible to measure the true value of a dimension there is always some error. The error in measurement is the difference between the measured value and the true value of the measured dimension.

Error in measurement = Measured value - True value

The error in measurement may be expressed or evaluated either as an absolute error or as a relative error.

Absolute Error

True absolute error: It is the algebraic difference between the result of measurement and the conventional true value of the quantity measured.

Apparent absolute error: If the series of measurement are made then the algebraic difference between one of the results of measurement and the arithmetical mean is known as apparent absolute error.

Relative Error: It is the quotient of the absolute error and the value of comparison use or calculation of that absolute error. This value of comparison may be the true value, the conventional true value or the arithmetic mean for series of measurement. The accuracy of measurement, and hence the error depends upon so many factors, such as: -calibration standard -Work piece –Instrument -Person -Environment etc

Types of Errors

1. Systematic Error

These errors include calibration errors, error due to variation in the atmospheric condition Variation in contact pressure etc. If properly analysed, these errors can be determined and reduced or even eliminated hence also called controllable errors. All other systematic errors can be controlled in magnitude and sense except personal error. These errors results from irregular procedure that is consistent in action. These errors are repetitive in nature and are of constant and similar form.

2. Random Error

These errors are caused due to variation in position of setting standard and work-piece errors. Due to displacement of level joints of instruments, due to backlash and friction, these error are induced. Specific cause, magnitude and sense of these errors cannot be determined from the knowledge of measuring system or condition of measurement. These errors are non-consistent and hence the name random errors.

3. Environmental Error

These errors are caused due to effect of surrounding temperature, pressure and humidity on the measuring instrument. External factors like nuclear radiation, vibrations and magnetic field also leads to error. Temperature plays an important role where high precision is required. e.g. while using slip gauges, due to handling the slip gauges may acquire human body temperature, whereas the work is at 20°C. A 300 mm length will go in error by 5 microns which is quite a considerable error. To avoid errors of this kind, all metrology laboratories and standard rooms worldwide are maintained at 20°C.

1.7.3 Calibration

It is very much essential to calibrate the instrument so as to maintain its accuracy. In case when the measuring and the sensing system are different it is very difficult to calibrate the system as an whole, so in that case we have to take into account the error producing properties of each component. Calibration is usually carried out by making adjustment such that when the instrument is having zero measured input then it should read out zero and when the instrument is measuring some dimension it should read it to its closest accurate value.

It is very much important that calibration of any measuring system should be performed under the environmental conditions that are much closer to that under which the actual measurements are usually to be taken. Calibration is the process of checking the dimension and tolerances of a gauge, or the accuracy of a measurement instrument by comparing it to the instrument/gauge that has been certified as a standard of known accuracy. Calibration of an instrument is done over a period of time, which is decided depending upon the usage of the instrument or on the materials of the parts from which it is made. The dimensions and the tolerances of the instrument/gauge are checked so that we can come to whether the instrument can be used again by calibrating it or is it wear out or deteriorated above the limit value. If it is so then it is thrown out or it is scrapped. If the gauge or the instrument is frequently used, then it will require more maintenance and frequent calibration. Calibration of instrument is done prior to its use and afterwards to verify that it is within the tolerance limit or not. Certification is given by making comparison between the instrument/gauge with the reference standard whose calibration is traceable to accepted National standard.

Introduction to Dimensional and Geometric Tolerance

General Aspects

In the design and manufacture of engineering products a great deal of attention has to be paid to the mating, assembly and fitting of various components. In the early days of mechanical engineering during the nineteenth century, the majority of such components were actually mated together, their dimensions being adjusted until the required type of fit was obtained.

These methods demanded craftsmanship of a high order and a great deal of very fine work was produced. Present day standards of quantity production, interchangeability, and continuous assembly of many complex compounds, could not exist under such a system, neither could many of the exacting design requirements of modern machines be fulfilled without the knowledge that certain dimensions can be reproduced with precision on any number of components. Modern mechanical production engineering is based on a system of limits and fits, which while not only itself ensuring the necessary accuracies of manufacture, forms a schedule or specifications to which manufacturers can adhere. In order that a system of limits and fits may be successful, following conditions must be fulfilled:

1. The range of sizes covered by the system must be sufficient for most purposes.

2. It must be based on some standards; so that everybody understands alike and a given dimension has the same meaning at all places.
3. For any basic size it must be possible to select from a carefully designed range of fit the most suitable one for a given application.
4. Each basic size of hole and shaft must have a range of tolerance values for each of the different fits.
5. The system must provide for both unilateral and bilateral methods of applying the tolerance.
6. It must be possible for a manufacturer to use the system to apply either a hole-based or a shaft-based system as his manufacturing requirements may need.
7. The system should cover work from high class tool and gauge work where very wide limits of sizes are permissible.

Nominal Size and Basic Dimensions

Nominal size: A 'nominal size' is the size which is used for purpose of general identification. Thus the nominal size of a hole and shaft assembly is 60 mm, even though the basic size of the hole may be60 mm and the basic size of the shaft 59.5 mm. Basic dimension: A 'basic dimension' is the dimension, as worked out by purely design considerations. Since the ideal conditions of producing basic dimension, do not exist, the basic dimensions can be treated as the theoretical or nominal size, and it has only to be approximated. A study of function of machine part would reveal that it is unnecessary to attain perfection because some variations in dimension, however small, can be tolerated size of various parts. It is, thus, general practice to specify a basic dimension and indicate by tolerances as to how much variation in the basic dimension can be tolerated without affecting the functioning of the assembly into which this part will be used.

Definitions

The definitions given below are based on those given in IS: 919 Shaft: The term shaft refers not only to diameter of a circular shaft to any external dimension on a component.

Hole: This term refers not only to the diameter of a circular hole but to any internal dimension on a component.

Basics of Fit

A fit or limit system consists of a series of tolerances arranged to suit a specific range of sizes and functions, so that limits of size may. Be selected and given to mating components to ensure specific classes of fit.

This system may be arranged on the following basis:
1. Hole basis system
2. Shaft basis system.

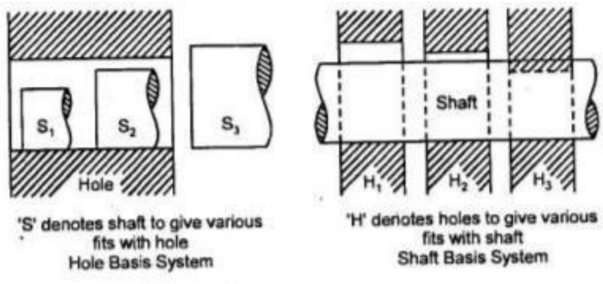


Fig 1.6 Nominal & Basic Dimension

Hole basis system:
'Hole basis system' is one in which the limits on the hole are kept constant and the variations necessary to obtain the classes of fit are arranged by varying those on the shaft. Shaft basis system: 'Shaft basis system' is one in which the limits on the shaft are kept constant and the variations necessary to obtain the classes of fit are arranged by varying the limits on the holes. In present day industrial practice hole basis system is used because a great many holes are produced by standard tooling, for example, reamers drills, etc., whose size is not adjustable. Subsequently the shaft sizes are more readily variable about the basic size by means of turning or grinding operations. Thus the hole basis system results in considerable reduction in reamers and other precision tools as compared to a shaft basis system because in shaft basis system due to nonadjustable nature of reamers, drills etc. great variety (of sizes) of these tools re required for producing different classes of holes for one class of shaft for obtaining different fits.

1.8.4 Systems of Specifying Tolerances

The tolerance or the error permitted in manufacturing a particular dimension may be allowed to vary either on one side of the basic size or on either side of the basic size. Accordingly two systems of specifying tolerances exit.

1. Unilateral system
2.Bilateral system.

In the unilateral system, tolerance is applied only in one direction.

	+ 0.04		-0.02
Examples:	40.0	or	40.0
	+ 0.02		-0.04

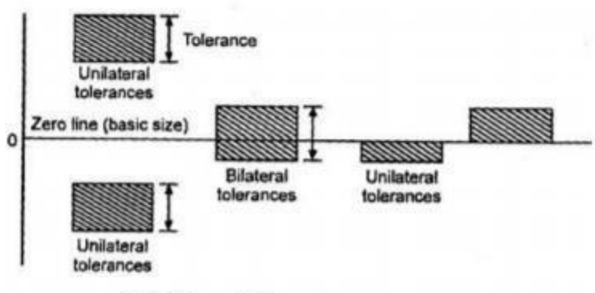


Fig 1.7 Types of Tolerances

In the bilateral system of writing tolerances, a dimension is permitted to vary in two directions.

	+ 0.02
Examples:	40.0
	-0.04

Interchange ability

It is the principle employed to mating parts or components. The parts are picked at random, complying with the stipulated specifications and functional requirements of the assembly. When only a few assemblies are to be made, the correct fits between parts arc made by controlling the sizes while machining the parts, by matching them with their mating parts. The actual sizes of the parts may vary from assembly to assembly to such an extent that a given part can fit only in its own assembly. Such a method of manufacture takes more time and will therefore increase the cost. There will also be problems when parts arc needed to be replaced. Modern production is based on the concept of interchangeability. When one component assembles properly with any mating component, both being chosen at random, then this is interchangeable manufacture. It is the uniformity of size of the components produced which ensures interchange ability.

The advantages of interchange ability are as follows:

1. The assembly of mating parts is easier. Since any component picked up from its lot will assemble with any other mating part from another lot without additional fitting and machining.
2. It enhances the production rate.
3. The standardization of machine parts and manufacturing methods is decided.
4. It brings down the assembling cost drastically.
5. Repairing of existing machines or products is simplified because component parts can be easily replaced. Replacement of worn out parts is easy

2. Linear and Angular Measurements

Technical Terms

- **Comparators**

Comparators are one form of linear measurement device which is quick and more convenient for checking large number of identical dimensions.

- **Least count**

The least value that can be measured by using any measuring instrument known as least count. Least count of a mechanical comparator is 0.0 1 mm.

- **Caliper**

Caliper is an instrument used for measuring distance between or over surfaces comparing dimensions of work pieces with such standards as plug gauges, graduated rules etc.

- **Interferometer**

They are optical instruments used for measuring flatness and determining the length of the slip gauges by direct reference to the wavelength of light.

- **Sine bar**

Sine bars are always used along with slip gauges as a device for the measurement of angles very precisely.

- **Auto-collimator**

Auto-collimator is an optical instrument used for the measurement of small angular differences, changes or deflection, plane surface inspection etc.

Linear Measuring Instruments

Linear measurement applies to measurement of lengths, diameter, heights and thickness including external and internal measurements. The line measuring instruments have series of accurately spaced lines marked on them e.g. Scale.

The dimensions to be measured are aligned with the graduations of the scale. Linear measuring instruments are designed either for line measurements or end measurements. In end measuring instruments, the measurement is taken between two end surfaces as in micrometers, slip gauges etc.

The instruments used for linear measurements can be classified as:

1. Direct measuring instruments
2. Indirect measuring instruments

The Direct measuring instruments are of two types:

1. Graduated
2. Non Graduated

The graduated instruments include rules, vernier calipers, vernier height gauges, vernier depth gauges, micrometers, dial indicators etc.

The non graduated instruments include calipers, trammels, telescopic gauges, surface gauges, straight edges, wire gauges, screw pitch gauges, radius gauges, thickness gauges, slip gauges etc.

They can also be classified as

1. Non precision instruments such as steel rule, calipers etc.,
2. Precision measuring instruments, such as vernier instruments, micrometers, dial gauges etc.

Scales

- The most common tool for crude measurements is the scale (also known as **rulers**).
- Although plastic, wood and other materials are used for common scales, precision scales use tempered steel alloys, with graduations scribed onto the

surface.

- These are limited by the human eye. Basically they are used to compare two dimensions.
- The metric scales use decimal divisions, and the imperial scales use fractional divisions.
- Some scales only use the fine scale divisions at one end of the scale. It is advised that the end of the scale not be used for measurement. This is because as they become worn with use, the end of the scale will no longer be at a `zero' position.
- Instead the internal divisions of the scale should be used. Parallax error can be a factor when making measurements with a scale.

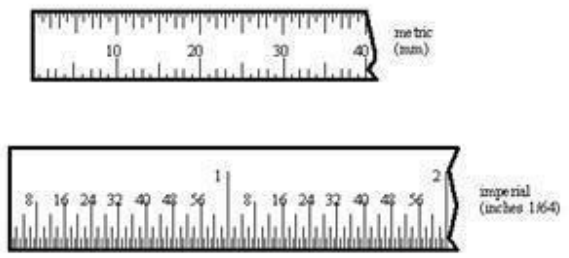


Fig 2.1 Scale

Calipers

Caliper is an instrument used for measuring distance between or over surfaces comparing dimensions of work pieces with such standards as plug gauges, graduated rules etc. Calipers may be difficult to use, and they require that the operator follow a few basic rules, do not force them, they will bend easily, and invalidate measurements made. If measurements are made using calipers for comparison, one operator should make all of the measurements (this keeps the feel factor a minimal error source). These instruments are very useful when dealing with hard to reach locations that normal measuring instruments cannot reach. Obviously the added step in the measurement will significantly decrease the accuracy.

Vernier Calipers

The vernier instruments generally used in workshop and engineering metrology have comparatively low accuracy. The line of measurement of such instruments does not coincide with the line of scale.

The accuracy therefore depends upon the straightness of the beam and the squareness of the sliding jaw with respect to the beam. To ensure the squareness, the sliding jaw must be clamped before taking the reading.

The zero error must also be taken into consideration. Instruments are now available with a measuring range up to one meter with a scale value of 0.1 or 0.2 mm.

Types of Vernier Calipers

According to Indian Standard IS: 3651-1974, three types of vernier calipers have been specified to make external and internal measurements and are shown in figures respectively. All the three types are made with one scale on the front of the beam for direct reading.

Type A: Vernier has jaws on both sides for external and internal measurements and a blade for depth measurement.

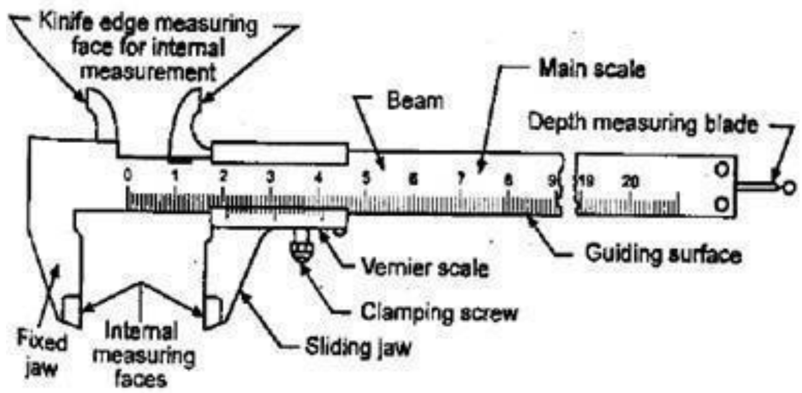


Fig 2.2 Vernier Caliper - Type A

Type B: It is provided with jaws on one side for external and internal measurements.

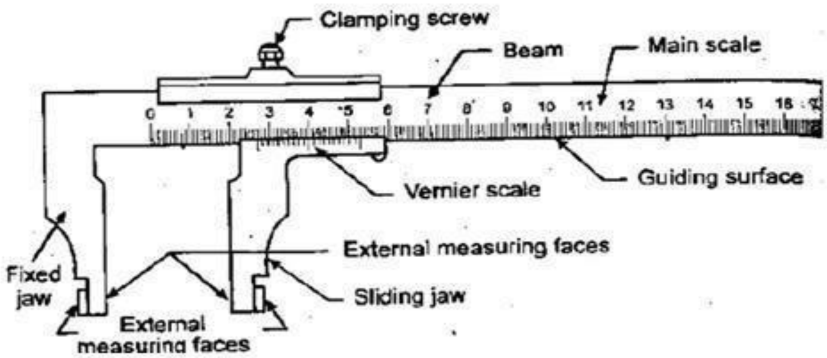


Fig 2.3 Vernier Caliper - Type B

Type C: It has jaws on both sides for making the measurement and for marking operations

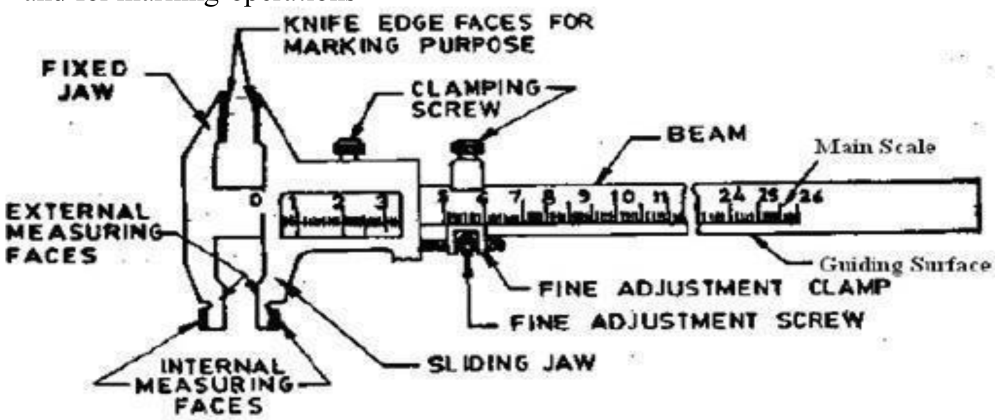


Fig 2.4 Vernier Caliper - Type C

Errors in Calipers

The degree of accuracy obtained in measurement greatly depends upon the condition of the jaws of the calipers and a special attention is needed before proceeding for the measurement. The accuracy and natural wear, and warping of Vernier caliper jaws should be tested frequently by closing them together tightly and setting them to 0- 0 point of the main and Vernier scales.

MICROMETERS

There are two types in it.

(i) Outside micrometer — To measure external dimensions.

(ii) Inside micrometer — To measure internal dimensions.

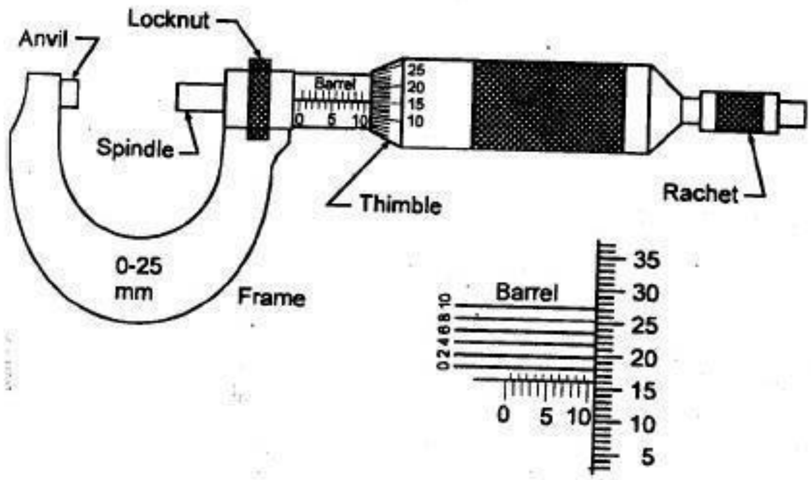


Fig 2.5 Micrometer

An outside micrometer is shown. It consists of two scales, main scale and thimble scale. While the pitch of barrel screw is 0.5 mm the thimble has graduation of 0.01 mm. The **least count** of this micrometer is 0.01 mm.

The micrometer requires the use of an accurate screw thread as a means of obtaining a measurement. The screw is attached to a spindle and is turned by movement of a thimble or ratchet at the end. The barrel, which is attached to the frame, acts as a nut to engage the screw threads, which are accurately made with a pitch of 0.05mm. Each revolution of the thimble advances the screw 0.05mm. On the barrel a datum line is graduated with two sets of division marks.

Slip Gauges

These may be used as reference standards for transferring the dimension of the unit of length from the primary standard to gauge blocks of lower accuracy and for the verification and graduation of measuring apparatus.

These are high carbon steel hardened, ground and lapped rectangular blocks, having cross sectional area 0f 30 mm and 10mm. Their opposite faces are flat, parallel and are accurately the stated distance apart. The opposite faces are of such a high degree of surface finish, that when the blocks are pressed together with a slight twist by hand, they will wring together.

They will remain firmly attached to each other. They are supplied in sets of 112 pieces down to 32 pieces. Due to properties of slip gauges, they are built up by, wringing into combination which gives size, varying by steps of 0.01 mm and the overall accuracy is of the order of 0.00025mm.

Slip gauges with three basic forms are commonly found, these are rectangular, square with center hole, and square without center hole.

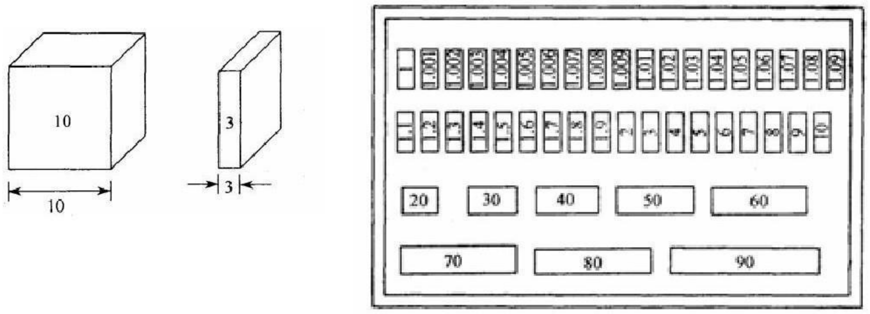


Fig 2.6 Slip Gauge

Wringing or Sliding is nothing but combining the faces of slip gauges one over the other. Due to adhesion property of slip gauges, they will stick together. This is because of very high degree of surface finish of the measuring faces.

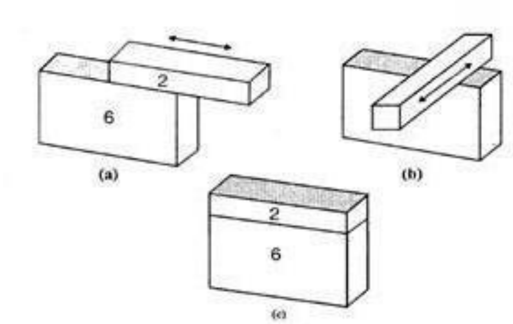


Fig 2.7 Wringing of slip gauge

Classification of Slip Gauges

Slip gauges are classified into various types according to their use as follows:

1) Grade 2

2) Grade 1

3) Grade 0

4) Grade 00

5) Calibration grade.

1) Grade 2:

It is a workshop grade slip gauges used for setting tools, cutters and checking dimensions roughly.

2) Grade 1:

The grade I is used for precise work in tool rooms.

3) Grade 0:

It is used as inspection grade of slip gauges mainly by inspection department.

4) Grade 00:

Grade 00 mainly used in high precision works in the form of error detection in instruments.

5) Calibration grade:

The actual size of the slip gauge is calibrated on a chart supplied by the manufactures.

Manufacture of Slip Gauges

The following additional operations are carried out to obtain the necessary qualities in slip gauges during manufacture.

i. First the approximate size of slip gauges is done by preliminary operations.

ii. The blocks are hardened and wear resistant by a special heat treatment process.

iii. To stabilize the whole life of blocks, seasoning process is done.

iv. The approximate required dimension is done by a final grinding process.

v. To get the exact size of slip gauges, lapping operation is done.

vi. Comparison is made with grand master sets.

Slip Gauges accessories

The application slip gauges can be increased by providing accessories to the slip gauges. The various accessories are

- Measuring jaw
- Scriber and Centre point.
- Holder and base

1. **Measuring jaw**:

It is available in two designs specially made for internal and external features.

2. **Scriber and Centre point**:

It is mainly formed for marking purpose.

3. **Holder and base**:

Holder is nothing but a holding device used to hold combination of slip gauges. Base in designed for mounting the holder rigidly on its top surface.

Interferometers

They are optical instruments used for measuring flatness and determining the length of the slip gauges by direct reference to the wavelength of light. It overcomes the drawbacks of optical flats used in ordinary daylight. In these instruments the lay of the optical flat can be controlled and fringes can be oriented as per the requirement. An arrangement is made to view the fringes directly from the top and avoid any distortion due to incorrect viewing.

Optical Flat and Calibration

1. Optical flat are flat lenses, made from quartz, having a very accurate surface to transmit light.
2. They are used in interferometers, for testing plane surfaces.
3. The diameter of an optical flat varies from 50 to 250 nun and thickness varies from 12 to 25 mm.
4. Optical flats are made in a range of sizes and shapes.
5. The flats are available with a coated surface.
6. The coating is a thin film, usually titanium oxide, applied on the surface to reduce the light lost by reflection.
7. The coating is so thin that it does not affect the position of the fringe bands, but a coated flat. The supporting surface on which the optical flat measurements are made must provide a clean, rigid platform. Optical flats are cylindrical in form, with the working surface and are of two types are i) type A, ii) type B.

i) Type A:

It has only one surface flat and is used for testing flatness of precision measuring surfaces of flats, slip gauges and measuring tables. The tolerance on flat should be 0.05 µm for type A.

ii) Type B:

It has both surfaces flat and parallel to each other. They are used for testing measuring surfaces of micrometers, Measuring anvils and similar length of measuring devices for testing flatness and parallelism. For these instruments, their thickness and grades are important. The tolerances on flatness, parallelism and thickness should be 0.05 µm.

Interference Bands by Optical Flat

Optical flats arc blocks of glass finished to within 0.05 microns for flatness.

When art optical flat is on a flat surface which is not perfectly flat then optical flat will not exactly coincide with it, but it will make an angle e with the surface as shown in Figure 2.8.

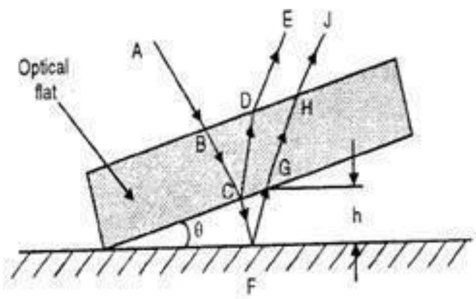


Fig 2.8 Optical Flat

Limit Gauges

- A limit gauge is not a measuring gauge. Just they are used as inspecting gauges.
- The limit gauges are used in inspection by methods of attributes.
- This gives the information about the products which may be either within the prescribed limit or not.
- By using limit gauges report, the control charts of P and C charts are drawn to control invariance of the products.
- This procedure is mostly performed by the quality control department of each and every industry.
- Limit gauge are mainly used for checking for cylindrical holes of identical components with a large numbers in mass production.

Purpose of using limit gauges

- Components are manufactured as per the specified tolerance limits, upper limit and lower limit. The dimension of each component should be within this upper and lower limit.
- If the dimensions are outside these limits, the components will be rejected.

- If we use any measuring instruments to check these dimensions, the process will consume more time. Still we are not interested in knowing the amount of error in dimensions.
- It is just enough whether the size of the component is within the prescribed limits or not. For this purpose, we can make use of gauges known as limit gauges.

The common types are as follows:

1) Plug gauges.

2) Ring gauges.

3) Snap gauges.

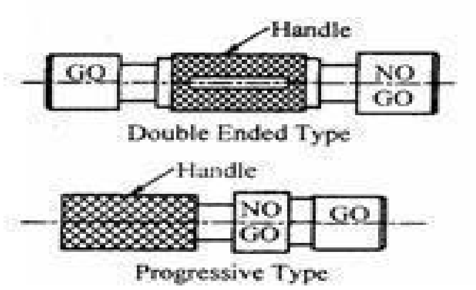


Fig 2.9 Plug Gauge

Plug Gauges

- The ends are hardened and accurately finished by grinding. One end is the GO end and the other end is NOGO end.
- Usually, the GO end will be equal to the lower limit size of the hole and the NOGO end will be equal to the upper limit size of the hole.
- If the size of the hole is within the limits, the GO end should go inside the hole and NOGO end should not go.
- If the GO end and does not go, the hole is under size and also if NOGO end goes, the hole is **over size**. Hence, the components are rejected in both the cases.

1. **Double ended plug gauges**

In this type, the GO end and NOGO end are arranged on both the ends of the plug. This type has the advantage of easy handling.

2. **Progressive type of plug gauges**

In this type both the GO end and NOGO end are arranged in the same side of the plug. We can use the plug gauge ends progressively one after the other while checking the hole. It saves time. Generally, the GO end is made larger than the NOGO end in plug gauges.

Taper Plug Gauge

Taper plug gauges are used to check tapered holes. It has two check lines. One is a GO line and another is a NOGO line. During the checking of work, NOGO line remains outside the hole and GO line remains inside the hole.

They are various types taper plug gauges are available as shown in fig. Such as

1) Taper plug gauge — plain

2) Taper plug gauge — tanged.

3) Taper ring gauge

4) Taper ring gauge —

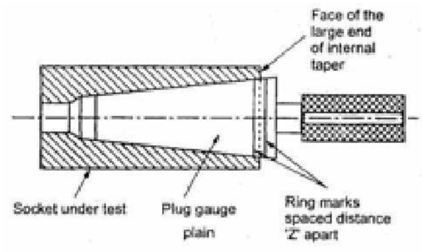


Fig 2.10 Taper Gauge

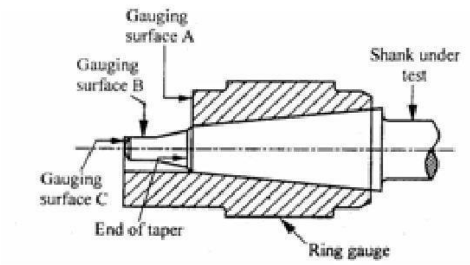


Fig 2.11 Taper ring Gauge plain

Ring Gauges

- Ring gauges are mainly used for checking the diameter of shafts having a central hole. The hole is accurately finished by grinding and lapping after taking hardening process.
- The periphery of the ring is knurled to give more grips while handling the gauges. We have to make two ring gauges separately to check the shaft such as GO ring gauge and NOGO ring gauge.
- But the hole of GO ring gauge is made to the upper limit size of the shaft and NOGO for the lower limit.
- While checking the shaft, the GO ring gauge will pass through the shaft and NOGO will not pass.

- To identify the NOGO ring gauges easily, a red mark or a small groove cut on its periphery.

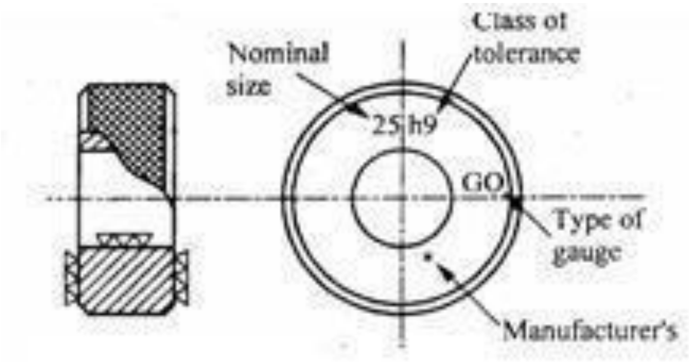


Fig 2.12 Ring Gauge

Snap Gauge

Snap gauges are used for checking external dimensions. They are also called as gap gauges. The different types of snap gauges are:

1. **Double Ended Snap Gauge**

This gauge is having two ends in the form of anvils. Here also, the GO anvil is made to lower limit and NOGO anvil is made

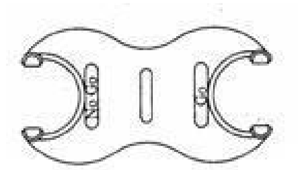


Fig 2.13 Double ended Snap Gauge

to upper limit of the shaft. It is also known as solid snap gauges

2. Progressive Snap Gauge

This type of snap gauge is also called caliper gauge. It is mainly used for checking large diameters up to 100mm. Both GO and NOGO anvils at the same end. The GO anvil should be at the front and NOGO anvil at the rear. So, the diameter of the shaft is checked progressively by these two ends. This type of gauge is made of horse shoe shaped frame with I section to reduce the weight of the snap gauges.

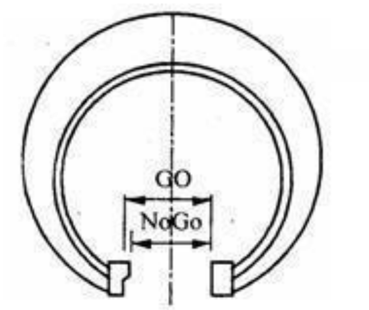


Fig 2.14 Progressive Snap Gauge

3. Adjustable Snap Gauge

Adjustable snap gauges are used for checking large size shafts made with horseshoe shaped frame of I section. It has one fixed anvil and two small adjustable anvils. The distance between the two anvils is adjusted by adjusting the adjustable anvils by means of setscrews. This adjustment can be made with the help of slip gauges for specified limits of size.

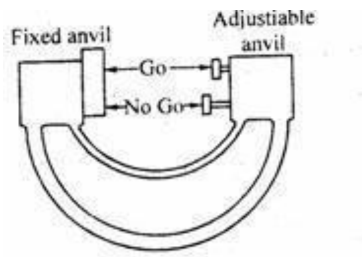


Fig 2.15 Adjustable Snap Gauge

4. Combined Limit Gauges

A spherical projection is provided with GO and NOGO dimension marked in a single gauge. While using GO gauge the handle is parallel to axes of the hole and normal to axes for NOGO gauge.

5. **Position Gauge**

It is designed for checking the position of features in relation to another surface. Other types of gauges are also available such as contour gauges, receiver gauges, profile gauges etc.

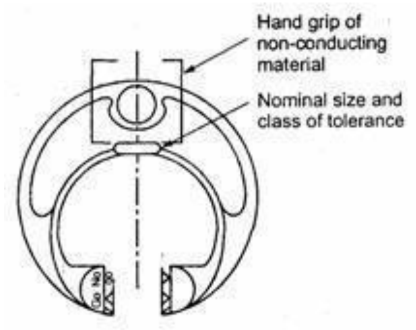


Fig 2.17 Position Gauge

Taylor' S Principle

It states that GO gauge should check all related dimensions. Simultaneously NOGO gauge should check only one dimension at a time.

Maximum metal condition

It refers to the condition of hole or shaft when maximum material is left on i.e. high limit of shaft and low limit of hole.

Minimum metal condition

If refers to the condition of hole or shaft when minimum material is left on such as low limit of shaft and high limit of hole.

Applications of Limit Gauges

1. Thread gauges
2. Form gauges
3. Screw pitch gauges
4. Radius and fillet gauges
5. Feeler gauges
6. Plate gauge and Wire gauge

Comparators

Comparators are one form of linear measurement device which is quick and more convenient for checking large number of identical dimensions. Comparators normally will not show the actual dimensions of the work piece. They will be shown only the deviation in size. i.e.

During the measurement a comparator is able to give the deviation of the dimension from the set dimension. This cannot be used as an absolute measuring device but can only compare two dimensions.

Comparators are designed in several types to meet various conditions. Comparators of every type incorporate some kind of magnifying device. The magnifying device magnifies how much dimension deviates, plus or minus, from the standard size.

The comparators are classified according to the principles used for obtaining magnification. The common types are:

1) Mechanical comparators
2) Electrical comparators
3) Optical comparators
4) Pneumatic comparators

Mechanical Comparators

Mechanical comparator employs mechanical means for magnifying small deviations. The method of magnifying small movement of the indicator in all mechanical comparators are effected by means of levers, gear trains or a combination of these elements. Mechanical comparators are available having magnifications from 300 to 5000 to 1. These are mostly used for inspection of small parts machined to close limits.

1. Dial indicator

A dial indicator or dial gauge is used as a mechanical comparator. The essential parts of the instrument are like a small clock with a plunger projecting at the bottom as shown in fig. Very slight upward movement on the plunger moves it upward and the movement is indicated by the dial pointer. The dial is graduated into 100 divisions.

A full revolution of the pointer about this scale corresponds to 1mm travel of the plunger. Thus, a turn of the pointer b one scale division represents a plunger travel of 0.01mm.

Experimental setup

The whole setup consists of worktable, dial indicator and vertical post. The dial indicator is fitted to vertical post by on adjusting screw as shown in fig. The vertical post is fitted on the work table; the top surface of the worktable is finely finished. The dial gauge can be adjusted vertically and locked in position by a screw.

Procedure

Let us assume that the required height of the component is 32.5mm. Initially this height is built up with slip gauges. The slip gauge blocks are placed under the stem of the dial gauge. The pointer in the dial gauge is adjusted to zero. The slip gauges are removed.

Now the component to be checked is introduced under the stem of the dial gauge. If there is any deviation in the height of the component, it will be indicated by the pointer.

Mechanism

The stem has rack teeth. A set of gears engage with the rack. The pointer is connected to a small pinion. The small pinion is independently hinged. I.e. it is not connected to the stern. The vertical movement of the stem is transmitted to the pointer through a set of gears. A spring gives a constant downward pressure to the stem.

A full revolution of the pointer about this scale corresponds to 1mm travel of the plunger. Thus, a turn of the pointer b one scale division represents a plunger travel of 0.01mm.

Experimental setup

The whole setup consists of worktable, dial indicator and vertical post. The dial indicator is fitted to vertical post by on adjusting screw as shown in fig. The vertical post is fitted on the work table; the top surface of the worktable is finely finished. The dial gauge can be adjusted vertically and locked in position by a screw.

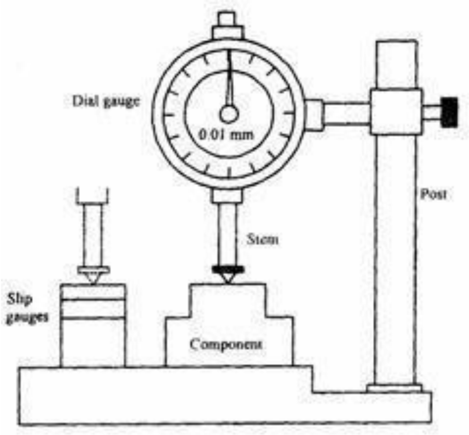


Fig 2.18 Dial Indicator

Procedure

Let us assume that the required height of the component is 32.5mm. Initially this height is built up with slip gauges. The slip gauge blocks are placed under the stem of the dial gauge. The pointer in the dial gauge is adjusted to zero. The slip gauges are removed.

Now the component to be checked is introduced under the stem of the dial gauge. If there is any deviation in the height of the component, it will be indicated by the pointer.

Mechanism

The stem has rack teeth. A set of gears engage with the rack. The pointer is connected to a small pinion. The small pinion is independently hinged. I.e. it is not connected to the stern. The vertical movement of the stem is transmitted to the pointer through a set of gears. A spring gives a constant downward pressure to the stem.

2. Read type mechanical comparator

In this type of comparator, the linear movement of the plunger is specified by means of read mechanism. The mechanism of this type is illustrated in fig. A spring-loaded pointer is pivoted. Initially, the comparator is set with the help of a known dimension eg. Set of slip gauges as shown in fig. Then the indicator reading is adjusted to zero. When the part to be measured is kept under the pointer, then the comparator displays the deviation of this dimension either in ± or— side of the set dimension.

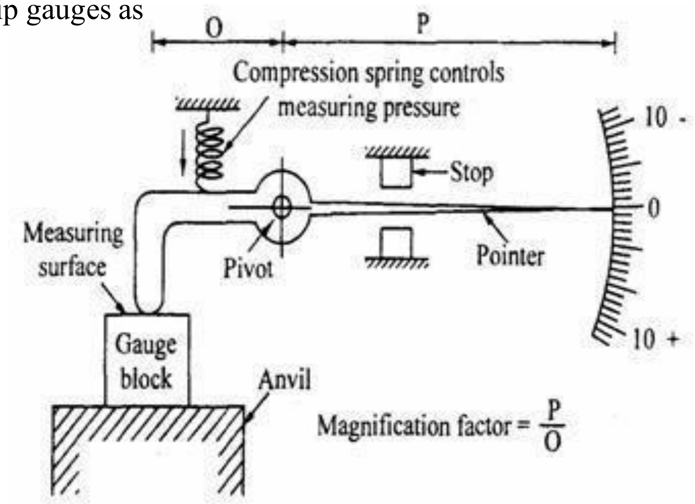


Fig 2.18 Read type Mechanical Comparator

Advantages

1) It is usually robust, compact and easy to handle.
2) There is no external supply such as electricity, air required.
3) It has very simple mechanism and is cheaper when compared to other types.
4) It is suitable for ordinary workshop and also easily portable.

Disadvantages

1. Accuracy of the comparator mainly depends on the accuracy of the rack and pinion arrangement. Any slackness will reduce accuracy.
2. It has more moving parts and hence friction is more and accuracy is less.
3. The range of the instrument is limited since pointer is moving over a fixed scale.

Electrical Comparator:

An electrical comparator consists of the following three major part such as

1) Transducer

2) Display device as meter

3) Amplifier

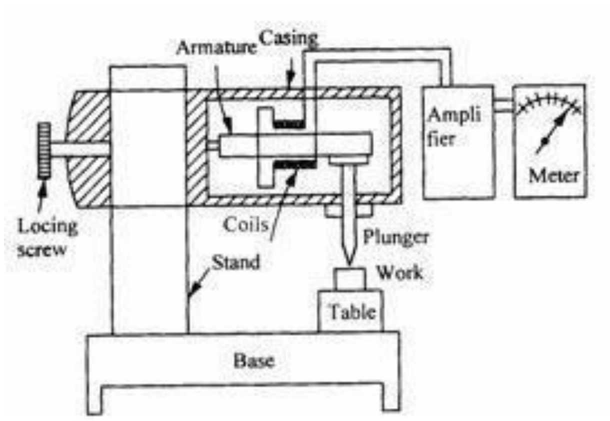


Fig 2.19 Electrical Comparator

Transducer

An iron armature is provided in between two coils held by a lea spring at one end. The other end is supported against a plunger. The two coils act as two arms of an A.C. wheat stone bridge circuit.

Amplifier

The amplifier is nothing but a device which amplifies the give input signal frequency into magnified output

Display device or meter

The amplified input signal is displayed on some terminal stage instruments. Here, the terminal instrument is a meter.

Working principle

If the armature is centrally located between the coils, the inductance of both coils will be equal but in opposite direction with the sign change. Due to this, the bridge circuit of A.C. wheat stone bridge is balanced. Therefore, the meter will read zero value. But practically, it is not possible.

In real cases, the armature may be lifted up or lowered down by the plunger during the measurement. This would upset the balance of the wheat stone bridge circuit. Due to this effect, the change in current or potential will be induced correspondingly. On that time, the meter will indicate some value as displacement. This indicated value may be either for larger or smaller components. As this induced current is too small, it should be suitably amplified before being displayed in the meter.

Checking of accuracy

To check the accuracy of a given specimen or work, first a standard specimen is placed under the plunger. After this, the resistance of wheat stone bridge is adjusted so that the scale reading shows zero. Then the specimen is removed. Now, the work is introduced under the plunger. If height variation of work presents, it will move the plunger up or down. The corresponding movement of the plunger is first amplified by the amplifier then it is transmitted to the meter to show the variations. The least count of this electrical comparator is **0.001mm (one micron).**

ELECTRONIC COMPARATOR

In electronic comparator, transducer induction or the principle of application of frequency modulation or radio oscillation is followed.

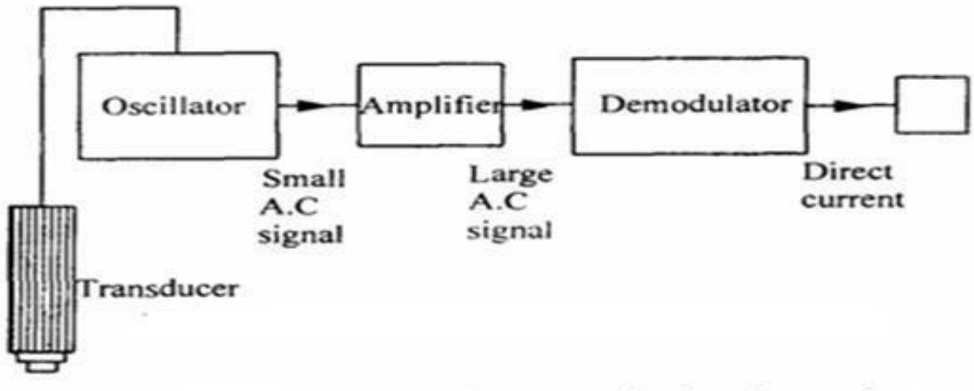


Fig 2.20 ***Principle of operation in electric gauging***

Construction details

In the electronic comparator, the following components are set as follows:

i. Transducer

ii. Oscillator

iii. Amplifier

iv. Demodulator

v. Meter

(i) Transducer

It converts the movement of the plunger into an electrical signal. It is connected with oscillator.

(ii) Oscillator

The oscillator which receives electrical signal from the transducer and raises the amplitude of frequency wave by adding carrier frequency called as modulation.

(iii) Amplifier

An amplifier is connected in between oscillator and demodulator. The signal coming out of the oscillator is amplified into a required level.

(iv) Demodulator

Demodulator is nothing but a device which cuts off external carrier wave frequency. i.e. It converts the modulated wave into original wave as electrical signal.

(v) Meter

This is nothing but a display device from which the output can be obtained as a linear measurement.

Principle of operation

The work to be measured is placed under the plunger of the electronic Comparator. Both work and comparator are made to rest on the surface plate. The linear movement of the plunger is converted into electrical signal by a suitable transducer.

Then it sent to an oscillator to modulate the electrical signal by adding carrier frequency of wave. After that the amplified signal is sent to demodulator in which the carrier waves are cut off. Finally, the demodulated signal is passed to the meter to convert the probe tip movement into linear measurement as an output signal. A separate electrical supply of D.C. is already given to actuate the meter.

Advantages of Electrical and Electronic comparator

1) It has less number of moving parts.
2) Magnification obtained is very high.
3) Two or more magnifications are provided in the same instrument to use various ranges.
4) The pointer is made very light so that it is more sensitive to vibration.
5) The instrument is very compact.

Disadvantages of Electrical and Electronic comparator

1) External agency is required to meter for actuation.
2) Variation of voltage or frequency may affect the accuracy of output.
3) Due to heating coils, the accuracy decreases.
4) It is more expensive than mechanical comparator.

Sine Bar

Sine bars are always used along with slip gauges as a device for the measurement of angles very precisely. They are used to

1) Measure angles very accurately.
2) Locate the work piece to a given angle with very high precision.

Generally, sine bars are made from high carbon, high chromium, and corrosion resistant steel. These materials are highly hardened, ground and stabilized.

In sine bars, two cylinders of equal diameter are attached at lie ends with its axes are mutually parallel to each other. They are also at equal distance from the upper surface of the sine bar mostly the distance between the axes of two cylinders is 100mm, 200mm or 300mm. The working surfaces of the rollers are finished to 0.2µm R value. The cylindrical holes are provided to reduce the weight of the sine bar.

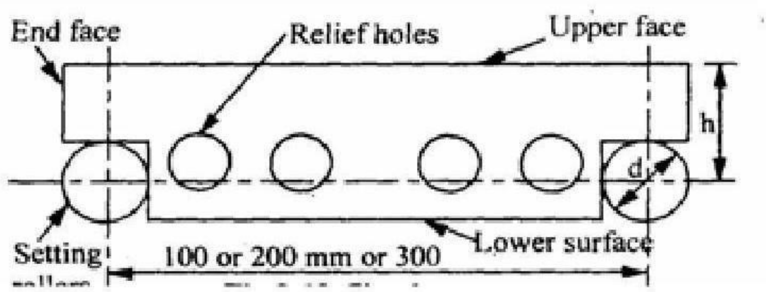


Fig 2.21 Sine Bar

Working principle of sine bar

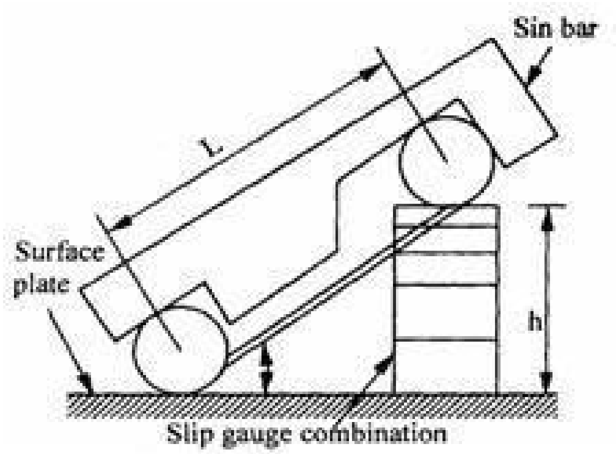


Fig 2.22 Principle of Sine bar

The working of sine bar is based on **trigonometry principle**. To measure the angle of a given specimen, one roller of the sine bar is placed on the surface plate and another one roller is placed over the surface of slip gauges. Now, 'h is the height of the slip gauges and 'L' be the distance between roller centers, then the angle is calculated as

$$\sin\theta = \frac{h}{L}$$

$$\therefore \theta = \sin^{-1}(h/L)$$

i. To set at a given angle θ, first '*h*' of slip gauge is calculated by the formula $\sin\theta = h/L$

ii. After calculating the height '*h*', the required height '*h*' is made by using suitable slip gauge combinations.

iii. After this, one of the rollers is placed on the top of the sine bar and the other one is placed on the top of the slip gauge combination.

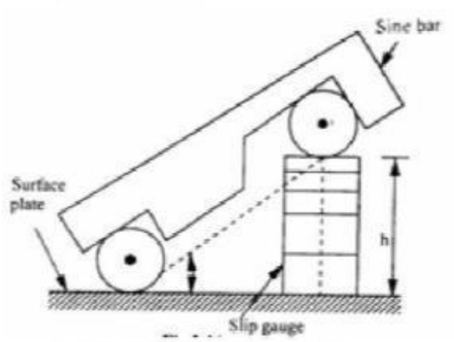


Fig 2.23 Work Location

Use of Sine Bar

Locating any' work to a given angle

1. Before checking the unknown angle of the specimen, first the angle (0) of given specimen is found approximately by bevel protractor. 2. Then the sine bar is set at angle of 0 and clamped on the angle plate. 3. Now, the work is placed on the sine bar and the dial indicator set at one end of the work is moved across the work piece and deviation is noted. 4. Slip gauges are adjusted so that the dial indicator reads zero throughout the work surface.

Limitations of sine bars

1) Sine bars are fairly reliable for angles than 15°.

2) It is physically difficult to hold in position.

3) Slight errors in sine bar cause larger angular errors.

4) A difference of deformation occurs at the point of roller contact with the surface plate and to the gauge blocks.

5) The size of parts to be inspected by sine bar is limited.

Sources of error in sine bars

The different sources of errors are listed below:

1) Error in distance between roller centers.

2) Error in slip gauge combination.

3) Error in checking of parallelism.

4) Error in parallelism of roller axes with each other.

5) Error in flatness of the upper surface of sine bar.

Bevel Protractors

Bevel protractors are nothing but angular measuring instruments.

Types of bevel protractors:

The different types of bevel protractors used are:

1) Vernier bevel protractor
2) Universal protractor
3) Optical protractor

2.11.1 Vernier Bevel Protractor:

Working principle

A vernier bevel protractor is attached with acute angle attachment. The body is designed its back is flat and no projections beyond its back. The base plate is attached to the main body and an adjustable blade is attached to the circular plate containing Vernier scale. The main scale is graduated in degrees from 0° to 90° in both the directions. The adjustable can be made to rotate freely about the center of the main scale and it can be locked at any position.

For measuring acute angle, a special attachment is provided. The base plate is made fiat for measuring angles and can be moved throughout its length. The ends of the blade are beveled at angles of 45° and 60°. The main scale is graduated as one main scale division is 1° and Vernier is graduated into 12 divisions on each side of zero. Therefore the least count is calculated as

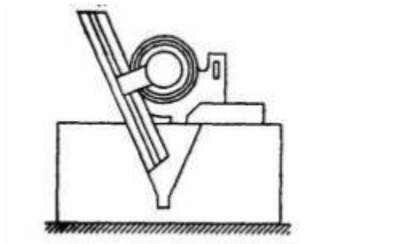
$$Least\ count = \frac{One\ main\ scale\ division}{No.\ of\ divisions\ on\ vernier\ scale}$$
$$= \frac{1^\circ}{12}(\deg rees)$$
$$= \frac{1}{12} \times 60 = 5 \min utes$$

Thus, the bevel protractor can be used to measure to an accuracy of 5 minutes.

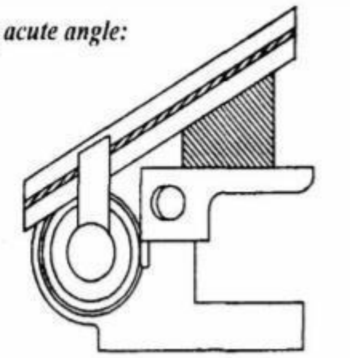
Applications of bevel protractor

The bevel protractor can be used in the following applications.

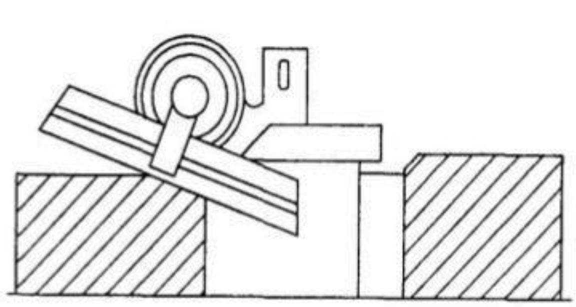
1. For checking a 'V' block:



2. For measuring acute angle:



3. For checking in inside beveled face of a ground surface.



Auto- Collimator

Auto-collimator is an optical instrument used for the measurement of small angular differences, changes or deflection, plane surface inspection etc. For small angular measurements, autocollimator provides a very sensitive and accurate approach. An auto-collimator is essentially an infinity telescope and a collimator combined into one instrument

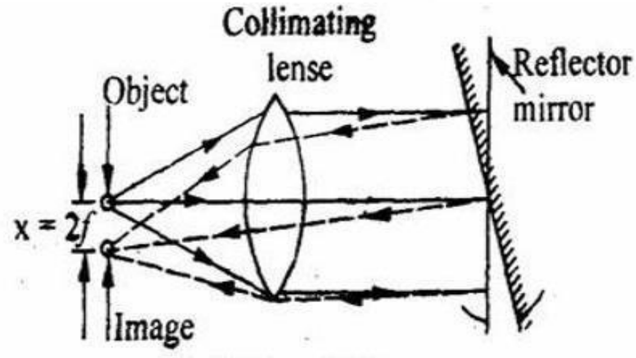


Fig 2.25 Auto-Collimator

Basic principle

If a light source is placed in the flows of a collimating lens, it is projected as a parallel beam of light. If this beam is made to strike a plane reflector, kept normal to the optical axis, it is

reflected back along its own path and is brought to the same focus. The reflector is tilted through a small angle
'0'. Then the parallel beam is deflected twice the angle and is brought to focus in the same plane as the light source.

The distance of focus from the object is given by

$$x = 2\theta . f$$

Where, f = Focal length of the lens

θ = Fitted angle of reflecting mirror.

Working of Auto-Collimator:

There are three main parts in auto-collimator.

1. Micrometer microscope.
2. Lighting unit and
3. Collimating lens.

Figure shows a line diagram of a modern auto-collimator. A target graticule is positioned perpendicular to the optical axis. When the target graticule is illuminated by a lamp, rays of light diverging from the intersection point reach the objective lens via beam splitter. From objective, the light rays are projected as a parallel rays to the reflector.

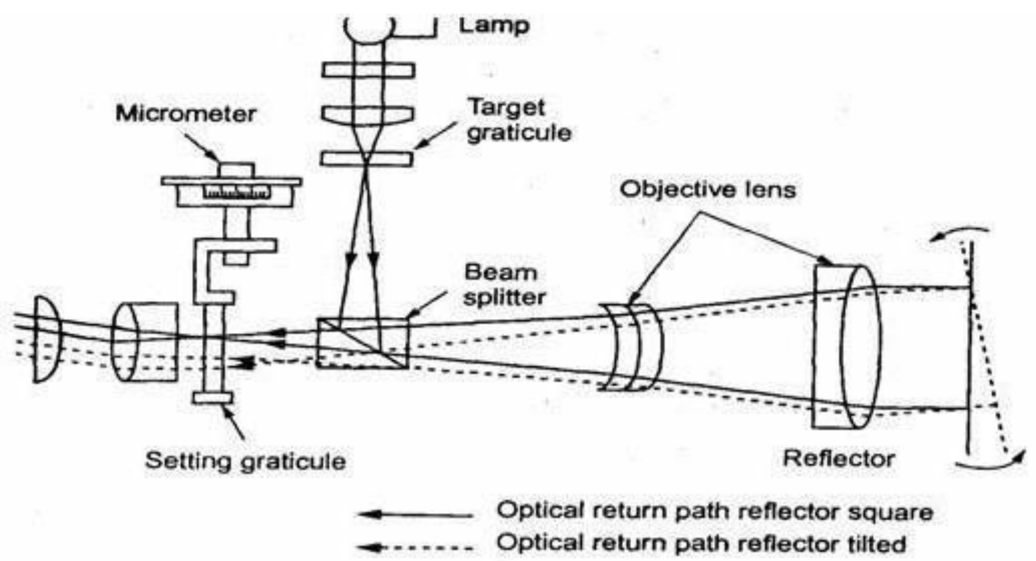


Fig 2.26 Line diagram of an injected graticule auto-collimator

A flat reflector placed in front of the objective and exactly normal to the optical axis reflects the parallel rays of light back along their original paths. They are then brought to the target graticule and exactly coincide with its intersection.

A portion of the returned light passes through the beam splitter and is visible through the eyepiece. If the reflector is tilted through a small angle, the reflected beam will be changed its path at twice the angle. It can also be brought to target graticule but linearly displaced from the actual target by the amount 2θxf. linear displacement of the graticule image in the plane tilted angle of eyepiece is directly proportional to the reflector. This can be measured by optical micrometer.

The photoelectric auto- collimator is particularly suitable for calibrating polygons, for checking angular indexing and for checking small linear displacements.

Applications of Auto-Collimator

Auto-collimators are used for

1) Measuring the difference in height of length standards.
2) Checking the flatness and straightness of surfaces.
3) Checking square ness of two surfaces.
4) Precise angular indexing in conjunction with polygons.
5) Checking alignment or parallelism.
6) Comparative measurement using master angles.
7) Measurement of small linear dimensions.
8) For machine tool adjustment testing.

2.11 Angle Dekkor

This is also a type of auto-collimator. There is an illuminated scale in the focal plane of the collimating lens. This illuminated scale is projected as a parallel beam by the collimating lens which after striking a reflector below the instrument is refocused by the lens in the filed of view of the eyepiece. In the field of view of microscope, there is another datum scale fixed across the center of screen.

The reflected image of the illuminated scale is received at right angle to the fixed scale as shown in fig. Thus the changes in angular position of the reflector in two planes are indicated by changes in the point of intersection of the two scales. One division on the scale is calibrated to read 1 minute.

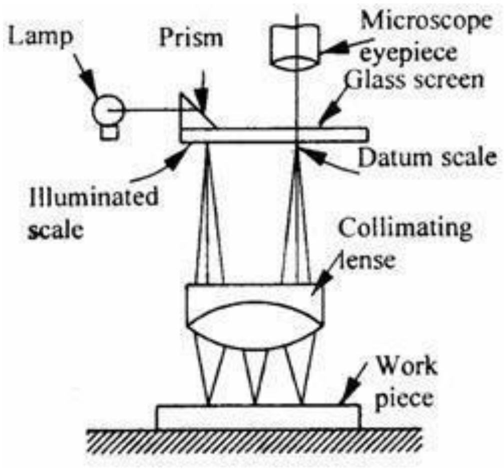


Fig 2.27 Angle Dekkor

Uses of Angle Dekkor

(i) Measuring angle of a component

Angle dekkor is capable of measuring small variations in angular setting i.e. determining angular tilt. Angle dekkor is used in combination with angle gauge. First the angle gauge combination is set up to the nearest known angle of the component. Now the angle dekkor is set to zero reading on the illuminated scale. The angle gauge build up is then removed and replaced by the component under test. Usually a straight edge being used to ensure that there is no change in lateral positions. The new position of the reflected scale with respect to the fixed scale gives the angular tilt of the component from the set angle.

(ii) Checking the slope angle of a V-block

Figure shows the set up for checking the sloping angle of V block. Initially, a polished reflector or slip gauge is attached in close contact with the work surface. By using angle gauge zero reading is obtained in the angle dekkor. Then the angle may be calculated by comparing the reading obtained from the angle dekkor and angle gauge.

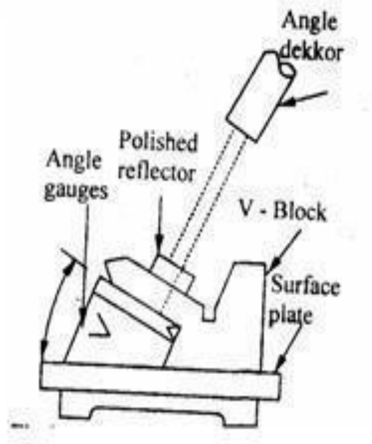


Fig 2.28 Checking of V-Slope Angle Dekkor

(iii) To measure the angle of cone or Taper gauge

Initially, the angle dekkor is set for the nominal angle of cone by using angle gauge or sine bar. The cone is then placed in position with its base resting on the surface plate. A slip gauge or reflector is attached on the cone since no reflection can be obtained from the curved surface. Any deviation from the set angle will be noted by the angle dekkor in the eyepiece and indicated by the shifting of the image of indicated by the shifting of the image of illuminated scale.

UNIT 2

Measuring Instruments

Technical Terms

- **Pitch**

It is the distance measured parallel to the screw threads axis between the corresponding points on two adjacent threads in the same axial plane. The basic pitch is equal to the lead divided by the number of thread starts.

- **Lead:**

The axial distance advanced by the screw in one revolution is the lead.

- **Addendum**

Radial distance between the major and pitch cylinders for external thread. Radial distance between the minor and pitch cylinder for internal thread.

- **Dedendum**

It is the radial distance between the pitch and minor cylinders for external thread. Also radial distance between the major and pitch cylinders for internal thread.

- **Pressure angle (a)**

It is the angle making by the line of action with the common tangent to the pitch circles of mating gears.

- **Module(m)**

It is the ratio of pitch circle diameter to the total number of teeth

- **Lead angle**

It is the angle between the tangent to the helix and plane perpendicular to the axis of cylinder.

- **Straightness**

A line is said to be straight over a given length, if the variation of the distance of its from two planes perpendicular to each other and parallel to the general direction of the line remains within the specified tolerance limits

- **Roundness** Roundness is defined as a condition of a surface of revolution. Where all points of the surface intersected by any plane perpendicular to a common axis in case of cylinder and cone.

Introduction

Threads are of prime importance, they are used as fasteners. It is a helical groove, used to transmit force and motion. In plain shaft, the hole assembly, the object of dimensional control is to ensure a certain consistency of fit. The performance of screw threads during their assembly with nut depends upon a number of parameters such as the condition of the machine tool used for screw cutting, work material and tool.

- Form measurement includes
- Screw thread measurement
- Gear measurement
- Radius measurement
- Surface Finish measurement
- Straightness measurement
- Flatness and roundness measurements

Screw Thread Measurement

Screw threads are used to transmit the power and motion, and also used to fasten two components with the help of nuts, bolts and studs. There is a large variety of screw threads varying in their form, by included angle, head angle, helix angle etc. The screw threads are ainly classified into 1) External thread 2) Internal thread.

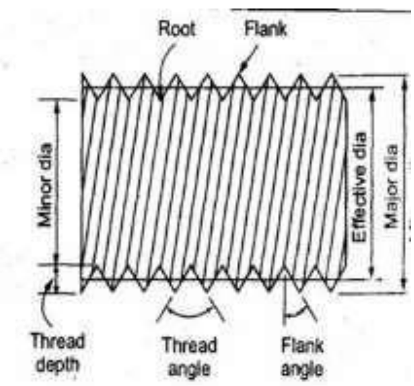


Fig 3.1 External Thread

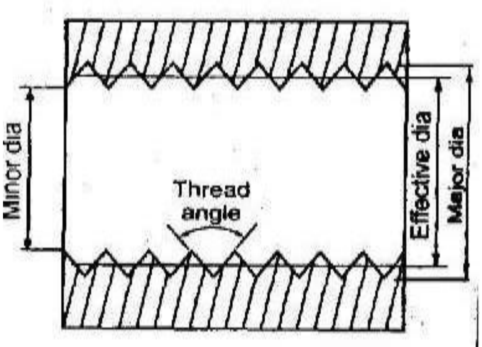
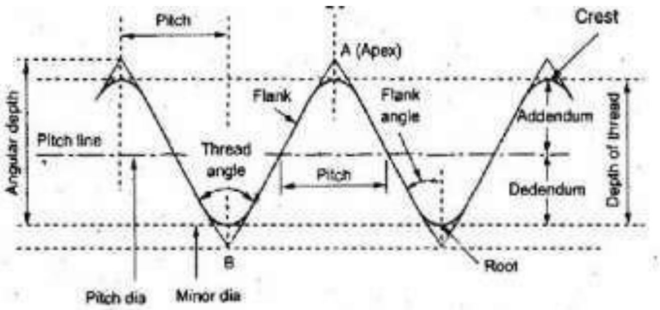


Fig 3.2 Internal Thread

Screw Thread Terminology



- **Pitch**

It is the distance measured parallel to the screw threads axis between the corresponding points on two adjacent threads in the same axial plane. The basic pitch is equal to the lead divided by the number of thread starts.

- **Minor diameter:**

It is the diameter of an imaginary co-axial cylinder which touches the roots of external threads.

- **Major diameter:**

It is the diameter of an imaginary co-axial cylinder which touches the crests of an external thread and the root of an internal thread.

- **Lead:**

The axial distance advanced by the screw in one revolution is the lead.

- **Pitch diameter:**

It is the diameter at which the thread space and width are equal to half of the screw thread

- **Helix angle:**

It is the angle made by the helix of the thread at the pitch line with the axis. The angle is measured in an axial plane.

- **Flank angle:**

It is the angle between the flank and a line normal to the axis passing through the apex of the thread.

- **Height of thread:**

It is the distance measured radially between the major and minor diameters respectively

- **Addendum:**

Radial distance between the major and pitch cylinders for external thread.

Radial distance between the minor and pitch cylinder for internal thread.

- **Dedendum:**

It is the radial distance between the pitch and minor cylinders for external thread. Also radial distance between the major and pitch cylinders for internal thread.

Error in Thread

The errors in screw thread may arise during the manufacturing or storage of threads.
The errors either may cause in following six main elements in the thread.

1) Major diameter error
2) Minor diameter error
3) Effective diameter error

4) Pitch error
5) Flank angles error
6) Crest and root error

1) Major diameter error

It may cause reduction in the flank contact and interference with the matching threads.

2) Minor diameter error

It may cause interference, reduction of flank contact.

3) Effective diameter error

If the effective diameter is small the threads will be thin on the external screw and thick on an internal screw.

4) Pitch errors

If error in pitch, the total length of thread engaged will be either too high or too small. The various pitch errors may classified into

1. Progressive error
2. Periodic error
3. Drunken error
4. Irregular error

1) Progressive error

The pitch of the thread is uniform but is longer or shorter its nominal value and this is called progressive.

Causes of progressive error:

1. Incorrect linear and angular velocity ratio.
2. In correct gear train and lead screw.
3. Saddle fault.
4. Variation in length due to hardening.

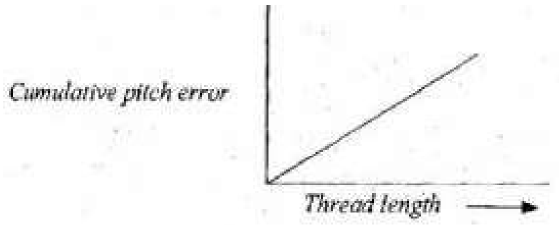


Fig 3.4 Progressive Error

2) **Periodic error**

These are repeats itself at regular intervals along the thread

Causes of periodic error:

1. Un uniform tool work velocity ratio.
2. Teeth error in gears.
3. Lead screw error.
4. Eccentric mounting of the gears.

3) **Drunken error**

Drunken errors are repeated once per turn of the thread in a drunken thread. In Drunken thread the pitch measured parallel to the thread axis. If the thread is not cut to the true helix the drunken thread error will form

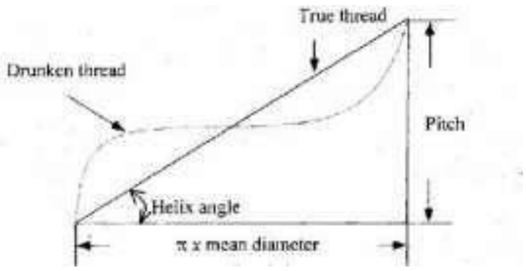


Fig 3.5 Drunken Error

4) **Irregular errors**

It is vary irregular manner along the length of the thread.

Irregular error causes:

1. Machine fault.
2. Non-uniformity in the material.
3. Cutting action is not correct.
4. Machining disturbances.

Effect of pitch errors

- Increase the effective diameter of the bolt and decreases the diameter of nut.
- The functional diameter of the nut will be less.
- Reduce the clearance.
- Increase the interference between mating threads.

Measurement of various elements of Thread

To find out the accuracy of a screw thread it will be necessary to measure the following:

1. Major diameter.
2. Minor diameter.
3. Effective or Pitch diameter.
4. Pitch
5. Thread angle and form

1. Measurement of major diameter:

The instruments which are used to find the major diameter are by

- Ordinary micrometer
- Bench micrometer.

- **Ordinary micrometer**

The ordinary micrometer is quite suitable for measuring the external major diameter. It is first adjusted for appropriate cylindrical size (S) having the same diameter (approximately).This process is known as 'gauge setting'. After taking this reading 'R the micrometer is set on the major diameter of the thread, and the new reading is 'R2.

- **Bench micrometer**

For getting the greater accuracy the bench micrometer is used for measuring the major diameter. In this process the variation in measuring Pressure, pitch errors are being neglected. The fiducial indicator is used to ensure all the measurements are made at same pressure. The instrument has a micrometer head with a vernier scale to read the accuracy of 0.002mm. Calibrated setting cylinder having the same diameter as the major diameter of the thread to be measured is used as setting standard. After setting the standard, the setting cylinder is held between the anvils and the reading is taken. Then the cylinder is replaced by the threaded work piece and the new reading is taken.

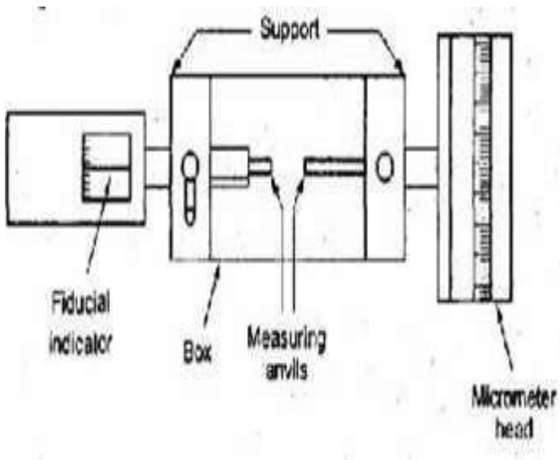


Fig 3.6 Bench Micrometer

∴ The major diameter of screw thread

$= S \pm (D_2 - D_1)$

Where, S = Diameter of the setting cylinder.

R_2 = Micrometer Reading on screw thread

R_1 = Micrometer reading on setting cylinder.

- **Measurement of the major diameter of an Internal thread**

The Inter thread major diameter is usually measured by thread comparator fitted with ball-ended styli. First the Instrument is set for a cylindrical reference having the same diameter of major diameter of i n t e r n a l thread and the reading is taken. Then the floating head is retracted to engage the tips of the styli at the root of spring under pressure. For that the new

major diameter of internal thread is $= D \pm (R_2 - R_1)$

D = Cylindrical standard diameter

R_2 = Thread reading

R_1 = Dial Indicator reading on the standard.

reading is taken,

2. **Measurement of Minor diameter**

The minor diameter is measured by a comparative method by using floating carriage diameter measuring machine and small V pieces which make contact with the root of the thread. These V pieces are made in several sizes, having suitable radii at the edges. V pieces are made of hardened steel. The floating carriage diameter-measuring machine is a bench micrometer mounted on a carriage.

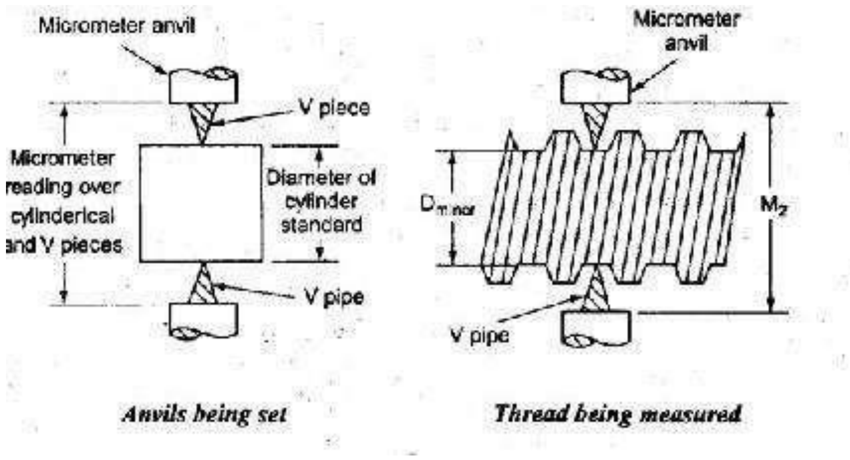


Fig 3.7 Measurement of Minor diameter

- **Measurement process**

The threaded work piece is mounted between the centers of the instrument and the V pieces are placed on each side of the work piece and then the reading is noted. After taking this reading the work piece is then replaced by a standard reference cylindrical setting gauge.

The minor diameter of the thread $= D \pm (R_2 - R_1)$

Where, D = Diameter of cylindrical gauge

R_2 = Micrometer reading on threaded work piece.

R_1 = Micrometer reading on cylindrical gauge.

- **Measurement of Minor diameter of Internal threads**

The Minor diameter of Internal threads are measured by

1. Using taper parallels
2. Using Rollers.

- **Using taper parallels**

For diameters less than 200mm the use of Taper parallels and micrometer is very common. The taper parallels are pairs of wedges having reduced and parallel outer edges. The diameter across their outer edges can be changed by sliding them over each other.

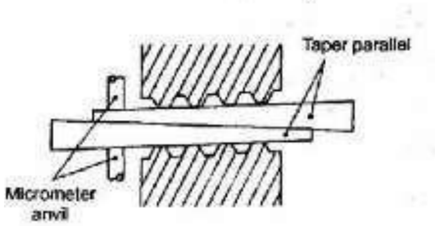


Fig 3.8 Taper parallels

- **Using rollers**

For more than 20mm diameter this method is used. Precision rollers are inserted inside the thread and proper slip gauge is inserted between the rollers. The minor diameter is then the length of slip gauges plus twice the diameter of roller.

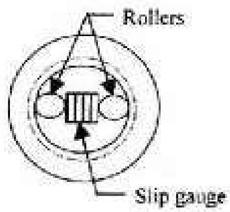


Fig 3.9 Roller gauge

3. **Measurement of effective diameter**

Effective diameter measurement is carried out by following methods.

1. One wire,
2. Two wires, or
3. Three wires method.
4. Micrometer method.

a) One wire method

The only one wire is used in this method. The wire is placed between two threads at one side and on the other side the anvil of the measuring micrometer contacts the crests. First the micrometer reading dl is noted on a standard gauge whose dimension is approximately same to be obtained by this method.

i.e. 'd_2' then effective diameter = $D \pm (d_1 - d_2)$

When D = Size of setting gauge

Actual measurement over wire on one side and threads on other

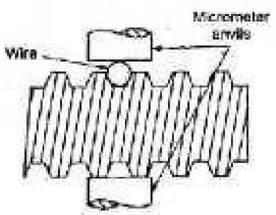


Fig 3.10 One wire method

b) Two wire method

Two-wire method of measuring the effective diameter of a screw thread is given below. In this method wires of suitable size are placed between the standard and the micrometer anvils. First the micrometer reading is taken and let it be R. Then the standard is replaced by the screw thread to be measured and the new reading is taken.

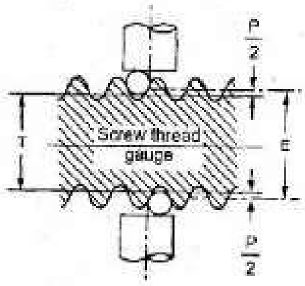
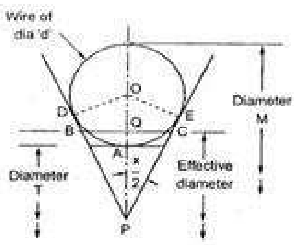


Fig 3.11 Two Wire Method



From the above reading

The effective diameter E is calculated by $E = T + P$

Where, T = Dimension under the wires = $M - 2d$

M = Dimension over the wires

d = diameter of each wire

If P' = Pitch of thread then

$$P = 0.9605\,P' - 1.1657d \Rightarrow \text{Whitworth thread.}$$

$$P = 0.866\,P' - d \Rightarrow \text{For metric thread.}$$

Here, P = The difference between the effective diamet and the diameter under the wires.

The diameter under the wires 'T' also can be determined by

$$T = S - (R_1 - R_2)$$

Where, S = The diameter of the standard.

The P value can be derived in terms of P (Pitch), d (Diameter of wire) and x thread angle is as follows

BC lies on the effective diameter.

$$\therefore BC = \frac{1}{2} Pitch = \frac{1}{2} P$$

$$\text{Next } OP = \frac{d\, Co\sec(x/2)}{2}$$

And $AQ = PQ - AP$

Where,

$$PQ = QC\, Cot\,(x/2) = P/4\, Cot\,(x/2)$$

$$\boxed{PQ = \frac{P}{4}\, Cot(x/2)}$$

c)Three-Wire method

The three-wire method is the accurate method. In this method three wires of equal and precise diameter are placed in the groves at opposite sides of the screw. In this one wire on one side and two on the other side are used. The wires either may held in hand or hung from a stand. This method ensures the alignment of micrometer anvil faces parallel to the thread axis.

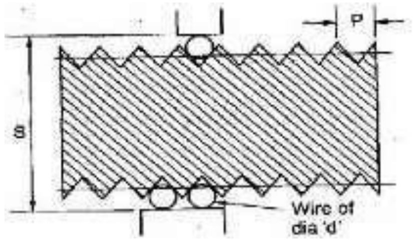
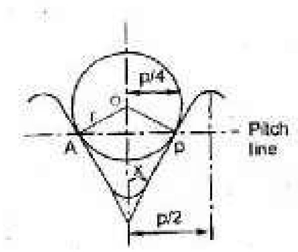


Fig 3.12 Three-Wire Method

- **BEST WIRE SIZE-DEVIATION**

Best wire diameter is that may contact with the flanks of the thread on the pitch line. The figure shows the wire makes contact with the flanks of the thread on the pitch.

Hence best wire diameter,



$$db = 2Ap\; secx$$

Where, db = Wire diameter

x = Included angle

$AP = p/4$

$$\therefore db = 2\, p/4\; sec\, x$$

$$\boxed{db = p_2\; secx}$$

4. Pitch measurement

The most commonly used methods for measuring the pitch are

1. Pitch measuring machine

2. Tool maker’s microscope

3. Screw pitch gauge

- **Pitch measuring machine**

The principle of the method of measurement is to move the stylus along the screen parallel to the axis from one space to the next. The pitch-measuring machine provides a relatively simple and accurate method of measuring the pitch. Initially the micrometer reading is near the zero on the scale, the indicator is moved along to bring the stylus, next the indicator adjusted radially until the stylus engages between the thread flank and the pointer ‘K’is opposite in the line L. To bring T in opposite in its index mark a small movement is necessary in the micrometer and then the reading is taken next. The stylus is moved along into the next space by rotation of the micrometer and the second reading is taken. The difference between these two- measured readings is known as the pitch of the thread.

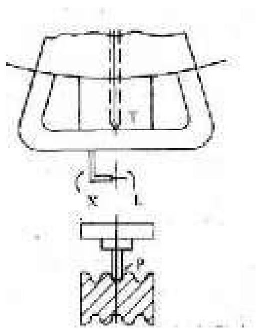
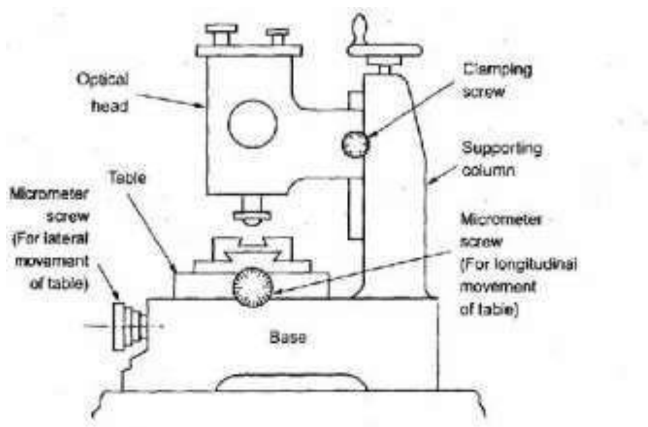


Fig 3.13 Pitch Measuring Machine

- **Tool makers microscope**

  Working

Worktable is placed on the base of the base of the instrument. The optical head is mounted on a vertical column it can be moved up and down. Work piece is mounted on a gla ss p l a t e . A l i ght s o u r c e provides horizontal beam of light which is reflected from a mirror by 900 upwards towards the table. Image of the outline contour of the work piece passes through the objective of the optical head. The image is projected by a system of three prisms to a ground glass screen. The measurements are made by means of cross lines engraved on the ground glass screen. The screen can be rotated through 360°.



Different types of graduated screens and eyepieces are used.

Fig 3.14 Tool Makers Microscope

Applications

- o Linear measurements.
- o Measurement of pitch of the screw.
- o Measurement of pitch diameter. o Measurement of thread angle.
- o Comparing thread forms.
- o Centre to center distance measurement.
- o Thread form and flank angle measurement

- **Thread form and flank angle measurement**

The optical projections are used to check the thread form and angles in the thread. The projectors equipped with work holding fixtures, lamp, and lenses. The light rays from the lens are directed into the cabinet and prisons and mirrors. The enlarged image of thread is drawn. The ideal and actual forms are compared for the measurement.

GEAR MEASUREMENT

Introduction

Gear is a mechanical drive which transmits power through toothed wheel. In this gear drive, the driving wheel is in direct contact with driven wheel. The accuracy of gearing is the very important factor when gears are manufactured. The transmission efficiency is almost 99 in gears. So it is very important to test and measure the gears precisely. For proper inspection of gear, it is very important to concentrate on the raw materials, which are used to manufacture the gears, also very important to check the machining the blanks, heat treatment and the finishing of teeth. The gear blanks should be tested for dimensional accuracy and tooth thickness for the forms of gears.

The most commonly used forms of gear teeth are

1. Involute
2. Cycloidal

The involute gears also called as straight tooth or spur gears. The cycloidal gears are used in heavy and impact loads. The involute rack has straight teeth. The involute pressure angle is either 20° or 14.5°.

Types of gears

1. **Spur gear**

Cylindrical gear whose tooth traces is straight line. These are used for transmitting power between parallel shafts.

2. **Spiral gear**

The tooth of the gear traces curved lines.

3. **Helical gears**

These gears used to transmit the power between parallel shafts as well as nonparallel and non-intersecting shafts. It is a cylindrical gear whose tooth traces is straight line.

4. **Bevel gears**:

The tooth traces are straight-line generators of cone. The teeth are cut on the conical surface. It is used to connect the shafts at right angles.

5. **Worm and Worm wheel**:

It is used to connect the shafts whose axes are non-parallel and non-intersecting.

6. **Rack and Pinion**:

Rack gears are straight spur gears with infinite radius.

Gear terminology

1. **Tooth profile**

It is the shape of any side of gear tooth in its cross section.

2. **Base circle**

It is the circle of gear from which the involute profile is derived. Base circle diameter Pitch circle diameter x Cosine of pressure angle of gear

3. **Pitch circle diameter (PCD)**

The diameter of a circle which will produce the same motion as the toothed gear wheel.

4. **Pitch circle**

It is the imaginary circle of gear that rolls without slipping over the circle of its matiug gear.

5. **Addendum circle**

The circle coincides with the crests (or) tops of teeth.

6. **Dedendum circle (or) Root circle**

This circle coincides with the roots (or) bottom on teeth.

7. **Pressure angle (a)**

It is the angle making by the line of action with the common tangent to the pitch circles of mating gears.

8. **Module(m)**

It is the ratio of pitch circle diameter to the total number of teeth. Where, d = Pitch circle diameter. n = Number f teeth.

9. **Circular pitch**

It is the distance along the pitch circle between corresponding points of adjacent teeth.

10. Addendum

Radial distance between tip circle and pitch circle. Addendum value = 1 module.

11 Dedendum

Radial distance between itch circle and root circle, Dedendum value = 1 .25module.

12. Clearance (C)

Amount of distance made by the tip of one gear with the root of mating gear. Clearance = Difference between Dedendum and addendum values.

13. Blank diameter:

The diameter of the blank from which gear is out. Blank diameter = PCD + 2m

14. Face:

Part of the tooth in the axial plane lying between tip circle and pitch circle.

15. Flank:

Part of the tooth lying between pitch circle and root circle.

16. Top land:

Top surface of a tooth.

17. Lead angle

The angle between the tangent to the helix and plane perpendicular to the axis of cylinder.

18. Backlash:

The difference between the tooth thickness and the space into which it meshes.

$$\text{Back lash} = t_2 - t_1$$

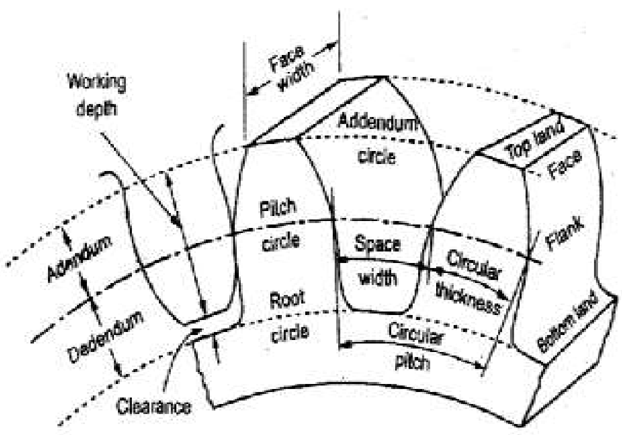


Fig 3.15 GearProfile

Gear errors

1. **Profile error**: - The maximum distance of any point on the tooth profile form to the design profile.
2. **Pitch error**: - Difference between actual and design pitch
3. **Cyclic error**: - Error occurs in each revolution of gear
4. **Run out**: - Total range of reading of a fixed indicator with the contact points applied to a surface rotated, without axial movement, about a fixed axis.
5. **Eccentricity**: - Half the radial run out
6. **Wobble**: - Run out measured parallel to. the axis of rotation at a specified distance from the axis
7. **Radial run out**: - Run out measured along a perpendicular to the axis of rotation.
8. **Undulation**: - Periodical departure of the actual tooth surface from the design surface.
9. **Axial run out**: - Run out measured parallel to the axis of rotation at a speed.
10. **Periodic error**: -Error occurring at regular intervals.

Gear Measurement

The Inspection of the gears consists of determine the following elements in which manufacturing error may be present.

1. Runout.
2. Pitch
3. Profile
4. Lead
5. Back lash
6. Tooth thickness

7. Concentricity

8. Alignment

1. **Runout**:

It means eccentricity in the pitch circle. It will give periodic vibration during each revolution of the gear. This will give the tooth failure in gears. The run out is measured by means of eccentricity testers. In the testing the gears are placed in the mandrel and the dial indicator of the tester possesses special tip depending upon the module of the gear and the tips inserted between the tooth spaces and the gears are rotated tooth by tooth and the variation is noted from the dial indicator.

2. **Pitch measurement**:

There are two ways for measuring the pitch.

1. Point to point measurement (i.e. One tooth point to next toot point)
2. Direct angular measurement

1. **Tooth to Tooth measurement**

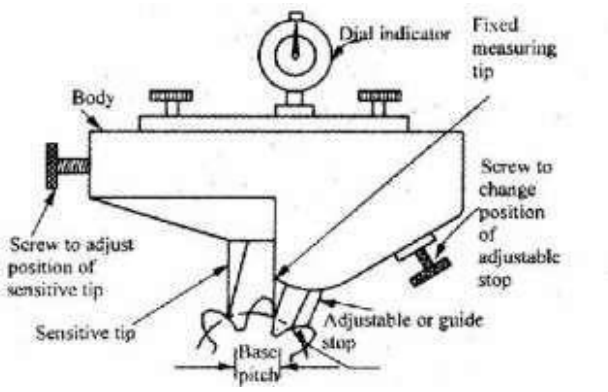


Fig 3.16 Tooth to tooth measurement

The instrument has three tips. One is fixed measuring tip and the second is sensitive tip, whose position can be adjusted by a screw and the third tip is adjustable or guide stop. The distance between the fixed and sensitive tip is equivalent to base pitch of the gear. All the three tips are contact the tooth by setting the instrument and the reading on the dial indicator is the error in the base pitch.

2. **Direct Angular Measurement**

It is the simplest method for measuring the error by using set dial gauge against a tooth. in this method the position of a suitable point on a tooth is measured after the gear has been indexed by a suitable angle. If the gear is not indexed through the angular pitch the reading differs from the original reading. The difference between these is the cumulative pitch error.

3. **Profile checking**

The methods used for profile checking is

1. Optical projection method.

2. Involute measuring machine.

1. Optical projection method:

The profile of the gear projected on the screen by optical lens and then projected value is compared with master profile.

2. Involute measuring machine:

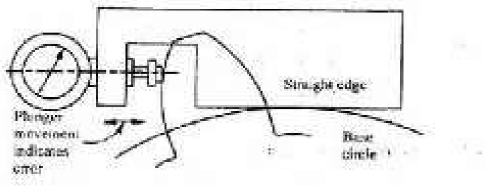


Fig 3.17 Involute Measuring Machine

In this method the gear is held on a mandrel and circular disc of same diameter as the base circle of gear for the measurement is fixed on the mandrel. After fixing the gear in the mandrel, the straight edge of the instrument is brought in contact with the base circle of the disc. Now, the gear and disc are rotated and the edge moves over the disc without sleep. The stylus moves over the tooth profile and the error is indicated on the dial gauge.

4. **Lead checking**:

It is checked by lead checking instruments. Actually lead is the axial advance of a helix for one complete turn. The lead checking instruments are advances a probe along a tooth surface, parallel to the axis when the gear rotates.

5. **Backlash checking**:

Backlash is the distance through which a gear can be rotated to bring its nonworking flank in contact with the teeth of mating gear. Numerical values of backlash are measured at the tightest point of mesh on the pitch circle.

There are two types of backlash

1.Circumferential backlash

2.Normal backlash

The determination of backlash is, first one of the two gears of the pair is locked, while other is rotated forward and backward and by the comparator the maximum displacement is measured. The stylus of comparator is locked near the reference cylinder and a tangent to this is called circular backlash.

6. **Tooth thickness measurement**:

Tooth thickness is generally measured at pitch circle and also in most cases the chordal thickness measurement is carried out i.e. the chord joining the intersection of the tooth profile with the pitch circle.

The methods which are used for measuring the gear tooth thickness is

a) Gear tooth vernier caliper method (Chordal thickness method)

b) Base tangent method.

c) Constant chord method.

d) Measurement over pins or balls.

a) Gear tooth vernier method

In gear tooth vernier method the thickness is measured at the pitch line. Gear tooth thickness varies from the tip of the base circle of the tooth, and the instrument is capable of measuring the thickness at a specified position on the tooth. The tooth vernier caliper consists of vernier scale and two perpendicular arms. In the two perpendicular arms one arm is used to measure the thickness and other arm is used to measure the depth. Horizontal vernier scale reading gives chordal thickness (W) and vertical vernier scale gives the chordal addendum. Finally the two values compared.

The theoretical values of W and d can be found out by considering one tooth in the gear and it can be verified. In fig noted that w is a chord ADB and tooth thickness is specified by AEB. The distance d is noted and adjusted on instrument and it is slightly greater than addendum CE.

∴ 'W' is chordal thickness and 'd' is named as chordal addendum.

So, $W = AB = 2AD$

And angle, $AOD = \theta = \dfrac{360}{4n}$

Where, n = Number of teeth.

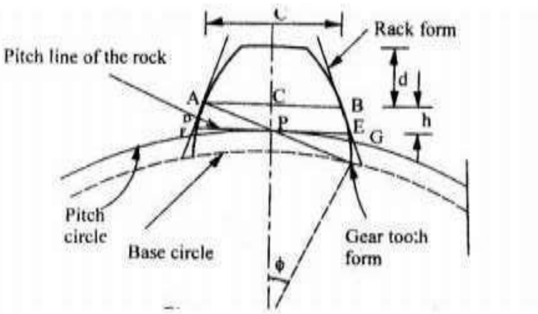
$W = 2AD = 2 \times AO\, Sin\theta$

$= 2R\, Sin\, 360/4n$ ......

Where, R = Pitch circle radius

Module, $m = \dfrac{P.C.D}{No.\, of\ teeth} = \dfrac{2R}{n}$

$\therefore R = \dfrac{nm}{2}$



And $OD = R\,Cos\theta = \dfrac{nm}{2} Cos\left(\dfrac{90}{n}\right)$

$$\boxed{OD = \frac{nm}{2} Cos\left(\frac{90}{n}\right)}$$

Vernier method like the chordal thickness and chordal addendum are dependent upon the number of teeth. Due to this for measuring large number of gears different calculations are to be made for each gear. So these difficulties are avoided by this constant chord method.

b) Measurement over Rolls or balls

A very good and convenient method for measuring thickness of gear. In this method two or three different size rollers are used for checkup the vibrations at several places on the tooth.

7. **Measurement of concentricity**

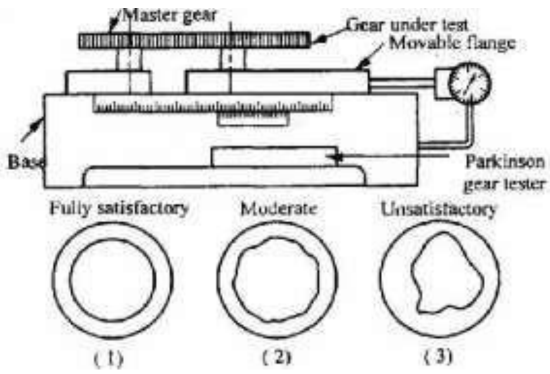
In setting of gears the centre about which the gear is mounded should be coincident with the centre from which the gear is generated. It is easy to check the concentricity of the gear by mounting the gear between centers and measuring the variation in height of a roller placed between the successive teeth. Finally the variation in reading will be a function of the eccentricity present.

8. **Alignment checking**

It is done by placing a parallel bar between the gear teeth and the gear being mounted between centres. Finally the readings are taken at the two ends of the bar and difference in reading is the misalignment.

Parkinson Gear Tester Working principle

The master gear is fixed on vertical spindle and the gear to be tested is fixed on similar spindle which is mounted on a carriage. The carriage which can slide either side of these gears are maintained in mesh by spring pressure. When the gears are rotated, the movement of sliding carriage is indicated by a dial indicator and these variations arc is measure of any irregularities. The variation is recorded in a recorder which is fitted in the form of a waxed circular chart. In the gears are fitted on the mandrels and are free to rotate without clearance and the left



mandrel move along the table and the right mandrel move along the spring-loaded carriage.

Fig 3.18 Parkinson Gear Tester

The two spindles can be adjusted so that the axial distance is equal and a scale is attached to one side and vernier to the other, this enables center distance to be measured to within 0.025mm. If any errors in the tooth form when gears are in close mesh, pitch or concentricity of pitch line will cause a variation in center distance from this movement of carriage as indicated to the dial gauge will show the errors in the gear test. The recorder also fitted in the form of circular or rectangular chart and the errors are recorded.

Limitations of Parkinson gear tester:

1. Accuracy±0.001mm
2. Maximum gear diameter is 300mm
3. Errors are not clearly identified:

4. Measurement dependent upon the master gear.

5. Low friction in the movement of the floating carriage.

RADIUS MEASUREMENT

In radius measurement we are going see about two methods namely.

1 Radius of circle and

2. Radius of concave surface

1. **Radius of circle**

This radius measurement requires the use of vernier caliper, C- Clamp, surface plate and two pins. This method is very much use in measuring the cap of bearing. Initially the job is fixed on surface plate with the help of C-clamp. So that the central position of the circular part is touch with the surface plate. Next the two balls are placed on both side of the work and using the vernier caliper readings are taken.

Let, R = Radius of job, I = The reading between two balls

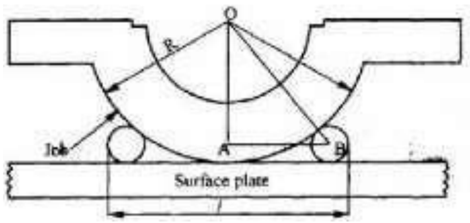


Fig 3.19 Radius Measurement

Now, from fig. $OB^2 = OA^2 + AB^2$

It is written like this

$$(R+d/2)^2 = (R-d/2)^2 + \left(\frac{l-d}{2}\right)^2$$

$$R^2 + (d/2)^2 + 2Rd/2 = R^2 + d^2/4 - 2Rd/2 + \left(\frac{l-d}{2}\right)^2$$

$$2Rd = \frac{(l-d)^2}{4}$$

$$\therefore Rd = \frac{(l-d)^2}{8}$$

$$\therefore \boxed{d = \frac{(l-d)^2}{8d}}$$

2. **Radius of concave surface**

Here there are two methods

- Edges are well defined.
- Edges are rounded up

1. **Edges are well defined**

In this method radius is calculated by using surface plate, height gauge, angle plate,C-clamp and slip gauges. First the Job placed on the surface plate and then by using depth micrometer the depth is measured and it is h. Next in such a way that cavity is resting against an angle plate and the part is clamped in this position. By using a height gauge edge to edge size of hole is measured and this is diameter of d.

From the above fig.

Let, O = Centre of the cavity

From the above fig.

$OA^2 = AB^2 + BO^2$ Here, $OA = R$

$$R^2 = \left(\frac{d}{2}\right)^2 + (R-h)^2$$

$$= \frac{d^2}{4} + R^2 + h^2 - 2Rh$$

$$R = \frac{\frac{d^2}{4} + h^2}{2h} = \frac{d^2}{8h} + \frac{h}{2}$$

$$\therefore \text{Radius} \quad \boxed{R = \frac{d^2}{8h} + \frac{h}{2}}$$

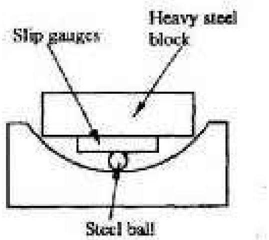


Fig 3.20 Radius of Concave surface

When cavities are rounded up the radius is measured by depth micrometer and slip gauges. First the width of the micrometer is measured by slip gauges and it is let ‘ d’. Thenit is placed in the cavity and measuring tip is lowered down to touches the base. From this condition the reading is noted and it be h and the radius is measured by using the formula

2) Edges are rounded up

When cavities are rounded up the radius is measured by depth micrometer and slip gauges.

First the width of the micrometer is measured by slip gauges and it islet ‘d’. Thenit is placed in the cavity and measuring tip is lowered down to touches the base. From this condition the reading is noted and it be h and the radius is measured by using the formula

$$R = \frac{d^2}{8h} + \frac{h^2}{2}$$

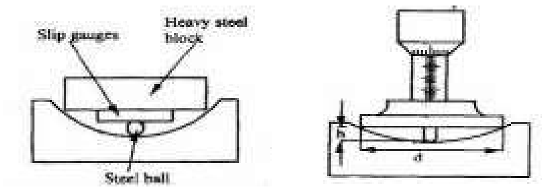


Fig 3.21 Edges round up

Surface Finish Measurement

Introduction

When we are producing components by various methods of manufacturing process it is not possible to produce perfectly smooth surface and some irregularities are formed. These irregularities are causes some serious difficulties in using the components. So it is very important to correct the surfaces before use. The factors which are affecting surface roughness are

1. Work piece material
2. Vibrations
3. Machining type
4. Tool and fixtures

The geometrical irregularities can be classified as

1. First order
2. Second order

3.3 Third order

4.Fourth order

1. First order irregularities

These are caused by lack of straightness of guide ways on which tool must move.

2. Second order irregularities

These are caused by vibrations

3. Third order irregularities

These are caused by machining.

4. Fourth order irregularities

These are caused by improper handling machines and equipments.

Elements of surface texture

1. **Profile**: - Contour of any section through a surface.
2. **Lay**: - Direction of the 'predominate surface pattern'
3. **Flaws**: - Surface irregularities or imperfection, which occur at infrequent intervals.
4. **Actual surface**: - Surface of a part which is actually obtained,
5. **Roughness**: - Finely spaced irregularities. It is also called primary texture.
6. **Sampling lengths**: - Length of profile necessary for the evaluation of the irregularities.
7. **Waviness**: - Surface irregularities which are of greater spacing than roughness.
8. **Roughness height**: - Rated as the arithmetical average deviation.
9. **Roughness width**: - Distance parallel to the normal surface between successive peaks.
10. **Mean line of profile**: - Line dividing the effective profile such that within the sampling length.
11. **Centre line of profile**: - Line dividing the effectiveness profile such that the areas embraced b profile above and below the line are equal.

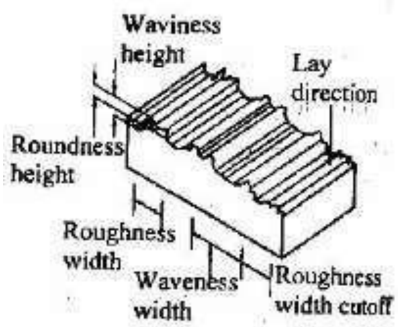


Fig 3.22 Surface Texture

Analysis of surface finish

The analyses of surface finish being carried out by

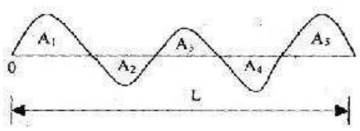
1. The average roughness method.
2. Peak to valley height method
3. From factor

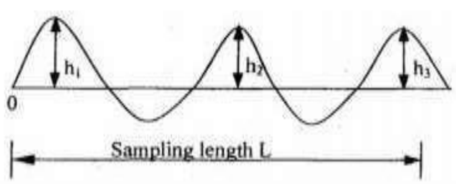
1. Average roughness measurement

The assessment of average roughness is carried out by a Centre line average (CLA). b Root mean square (RMS) c Ten point method

a.C.L.A. method

The surface roughness is measured as the average deviation from the nominal surface.





$$\text{C. L. A. Value} = \frac{A_1 + A_2 + A_3 + \dots A_n}{L}$$

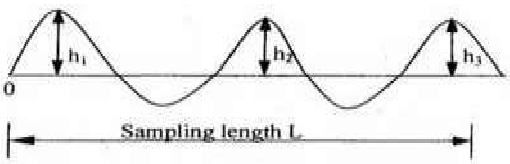
$$\boxed{\text{C. L. A.} = \frac{\sum A}{L}}$$

Where, $\sum A$ = Average area

L = Total length

b. .M.S. method

The roughness is measured as the average deviation from the nominal surface. Let, h1, h2, are the heights of the ordinates and L is the sampling length

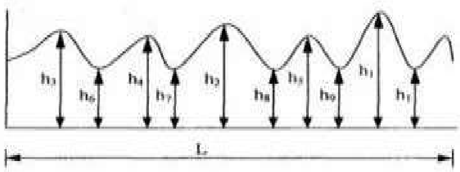


$$\text{R.M.S. average} = \frac{\sqrt{h_1^2 + h_2^2 + h_3^2 + \dots + h_n^2}}{n}$$

c. Ten point height method

The average difference between five highest peaks and five lowest valleys of surface is taken and irregularities are calculated by

$$S_2 = \frac{1}{5}(h_1 + h_2 + h_3 + h_4 + h_5) - (h_6 + h_7 + h_8 + h_9 + h_{10})$$



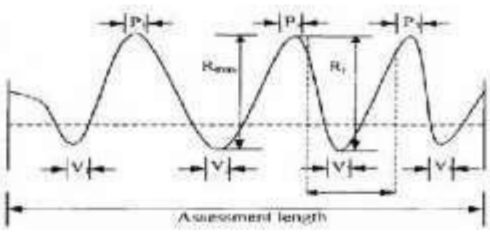
2. Peak to valley height method

Peak to valley height measures the maximum depth of the surface irregularities over a given sample length and largest value of the depth is accepted for the measurement.

Here, = Maximum peak to valley height in one sampling lengths. R = Maximum peak to valley height

V=Valley P = Peak

Here, R is the maximum peak to valley height within the assessment length and the disadvantages of R, and is only a single peak or valley which gives the value is not a true picture of the actual profile of the surface



3. Form factor

It is obtained by measuring the area of material above the arbitrarily chosen base line in the section and the area of the enveloping rectangle.

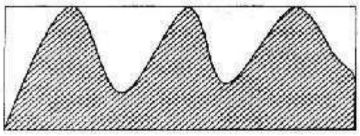


Fig 3.23 Form factor

$$\text{Degree of fullness } (F) = \frac{\text{Metal Area}}{\text{Enveloping rectangle Area}}$$

$$\boxed{\text{Degree of emptiness, } (E_b) = 1 - F}$$

Methods of measuring surface finish

The methods used for measuring the surface finish is classified into

1. Inspection by comparison
2. Direct Instrument Measurements

1. Inspection by comparison methods:

In these methods the surface texture is assessed by observation of the surface. The surface to be tested is compared with known value of roughness specimen and finished by similar machining process.

The various methods which are used for comparison are

1. Touch Inspection.
2. Visual Inspection.
3. Microscopic Inspection.
4. Scratch Inspection.
5. Micro Interferometer.
6. Surface photographs.
7. Reflected Light Intensity.
8. Wallace surface Dynamometer.

- **Touch Inspection**

It is used when surface roughness is very high and in this method the fingertip is moved along the surface at a speed of 25mm/second and the irregularities as up to 0.0125mm can be detected.

- **Visual Inspection**

In this method the surface is inspected by naked eye and this measurement is limited to rough surfaces.

- **Microscopic Inspection**

In this method finished surface is placed under the microscopic and compared with the surface under inspection. The light beam also used to check the finished surface by projecting the light about 60° to the work.

- **Scratch Inspection**:

The materials like lead, plastics rubbed on surface are inspected by this method. The impression of this scratches on the surface produced is then visualized.

- **Micro-Interferometer**

Optical flat is placed on the surface to be inspected and illuminated by a monochromatic source of light.

- **Surface Photographs**

Magnified photographs of the surface are taken with different types of illumination. The defects like irregularities are appear as dark spots and flat portion of the surface appears as bright.

- **Reflected light Intensity**

A beam of light is projected on the surface to be inspected and the light intensity variation on the surface is measured by a photocell and this measured value is calibrated

- **Wallace surface Dynamometer**:

It consists of a pendulum in which the testing shoes are clamped to a bearing surface and a pre determined spring pressure can be applied and then, The pendulum is lifted to its initial starting position and allowed to swing over the surface to be tested.

2. Direct instrument measurements

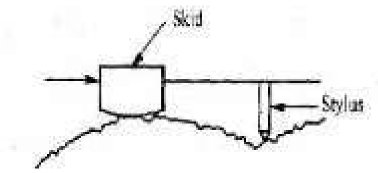
Direct methods enable to determine a numerical value of the surface finish of any surface. These methods are quantitative analysis methods and the output is used to operate recording or indicating instrument. Direct Instruments are operated by electrical principles. These instruments are classified into two types according to the operating principle. In this is operated by carrier-modulating principle and the other is operated by voltage-generating principle, and in the both types the output is amplified.

Some of the direct measurement instruments are

1. Stylus probe instruments.
2. Tomlinson surface meter.
3. Profilometer.
4. Taylor-Hobson Talysurf

1. Stylus probe type instrument Principle

When the stylus is moved over the surface which is to be measured, the irregularities in the surface texture are measured and it is used to assess the surface finish of the work piece.



Working

The stylus type instruments consist of skid, stylus, amplifying device and recording device.The skid is slowly moved over the surface by hand or by motor drive. The skid follows the irregularities of the surface and the stylus moves along with skid. When the stylus moves vertically up and down and the stylus movements are magnified, amplified and recorded to produce a trace. Then it is analyzed by automatic device.

Advantage

Any desired roughness parameter can be recorded.

Disadvantages

1. Fragile material cannot be measured.
2. High Initial cost.
3. Skilled operators are needed to operate.

2. Tomlinson Surface meter

This instrument uses mechanical-cum-optical means for magnification.

Construction

In this the diamond stylus on the surface finish recorder is held by spring pressure against the surface of a lapped cylinder. The lapped cylinder is supported one side by probe and other side by rollers. The stylus is also attached to the body of the instrument by a leaf spring and its height is adjustable to enable the diamond to be positioned and the light spring steel arm is attached to the lapped cylinder. The spring arm has a diamond scriber at the end and smoked glass is rest on the arm.

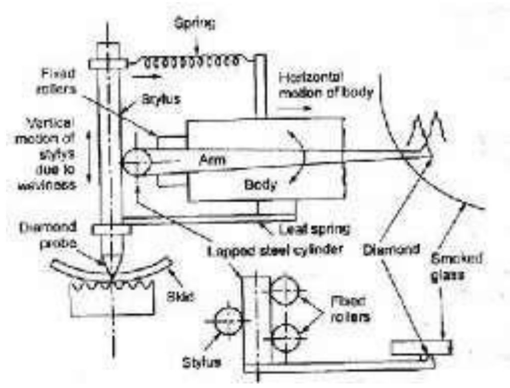


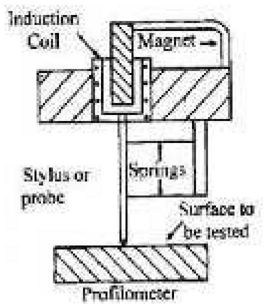
Fig 3.24 Tomlinson Surface meter

Working

When measuring surface finish the body of the instrument is moved across the surface by a screw rotation. The vertical movement of the probe caused by the surface irregularities makes the horizontal lapped cylinder to roll. This rolling of lapped cylinder causes the movement of the arm. So this movement is induces the diamond scriber on smoked glass. Finally the movement of scriber together with horizontal movement produces a trace on the smoked glass plate and this trace is magnified by an optical projector.

3. **Profilometer**

It is an indicating and recording instrument to measure roughness in microns. The main parts of the instrument are tracer and an amplifier. The stylus is mounted in the pickup and it consists of induction oil located in the magnet. When the stylus is moved on the surface to be tested, it is displaced up and down due to irregularities in the surface. This movement induces the induction coil to move in the direction of permanent magnet and produces a voltage. This is amplified and



recorded.

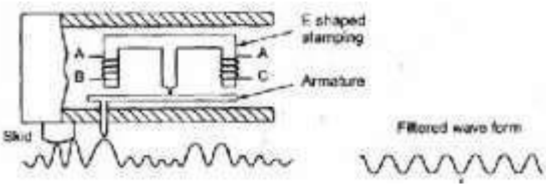
Fig 3.25 Profilometer

4. **Talyor-Hobson-Talysurf**

It is working a carrier modulating principle and it is an accurate method comparing with the other methods. The main parts of this instrument is diamond stylus (0.002mm radius) and skid

Principle

The irregularities of the surface are traced by the stylus and the movement of the stylus is converted into changes in electric current.



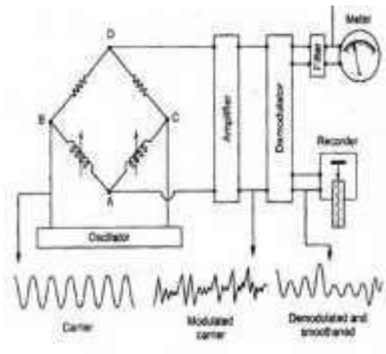


Fig 3.26 Talyor-Honson Instrument

Working

On two legs of the E-shaped stamping there are coils for carrying an A.C. current and these coils form an oscillator. As the armature is pivoted about the central leg the movement of the stylus causes the air gap to vary and thus the amplitude is modulated. This modulation is again demodulated for the vertical displacement of the stylus. So this demodulated output is move the pen recorder to produce a numerical record and to make a direct numerical assessment.

Straightness Measurement

A line is said to be straight over a given length, if the variation of the distance of its from two planes perpendicular to each other and parallel to the general direction of the line remains within the specified tolerance limits. The tolerance on the straightness of a line is defined as the maximum deviation in relation to the reference straight line joining the two extremities of the line to be checked.

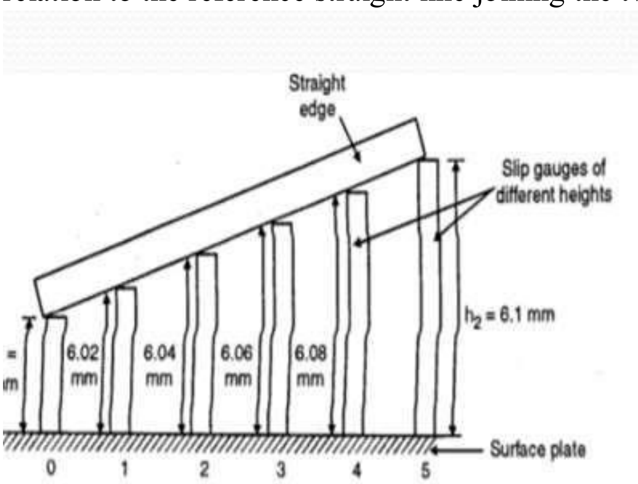


Fig 3.27 Straightness Measurement

Straight edge

A straight edge is a measuring tool which consists of a length of a length of a steel of narrow and deep section in order to provide resistance to bending in the plane of measurement without excessive weight. For checking the straightness of any surface, the straight edge is placed over the surface and two are viewed against the light, which clearly indicate the straightness. The gap between the straight edge and surface will be negligibly small for perfect surfaces. Straightness is measured by observing the colour of light by diffraction while passing through the small gap. If the colour of light be red, it indicates a gap of 0.0012 to 0.0075mm. A more accurate method of finding the straightness by straight edges is to place it in equal slip gauges at the correct point for minimum deflection and to measure the uniformity of space under the straight edge with slip gauges.

Test for straightness by using spirit level and Autocollimator

The straightness of any surface could be determined by either of these instruments by measuring the relative angular positions of number of adjacent sections of the surface to be tested. First straight line is drawn on the surface then it is divided into a number of sections the length of each section being equal to the length of sprit level base or the plane reflector' s basein case of auto collimator. The bases of the spirit level block or reflector are fitted with two feet so that only feet have line contact with the surface and the surface of base does not touch the surface to he tested. The angular division obtained is between the specified two points. Length of each section must be equal to distance between the centerlines of two feet. The special level can be used only for the measurement of straightness of horizontal surfaces while auto- collimator can be used on surfaces are any plane. In case of spirit level, the block is moved along the line equal to the pitch distance between the centerline of the feet and the angular variation of the direction of block. Angular variation can be determined in terms of the difference of height between two points by knowing the least count of level and length of the base.

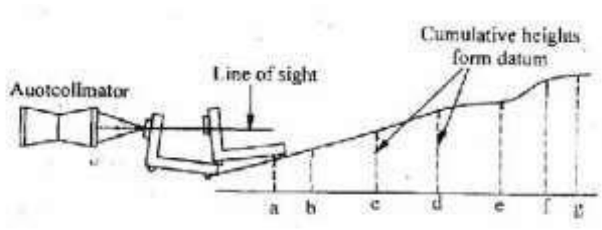


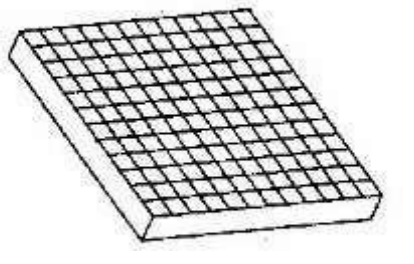
Fig 3.28 Straightness using Auto-Collimator

In case of autocollimator the instrument is placed at a distance of 0.5 to 0.75m from the surface to be tested. The parallel beam from the instrument is projected along the length of the surface to be tested. A block fixed on two feet and fitted with a plane vertical reflector is placed on the surface and the reflector face is facing the instrument. The image of the cross wires of the collimator appears nearer the center of the field and for the complete movement of reflector along the surface straight line the image of cross wires will appear in the field of eyepiece. The reflector is then moved to the other end of the surface in steps equal to. The center distance between the feet and the tilt of the reflector is noted down in second from the eyepiece.

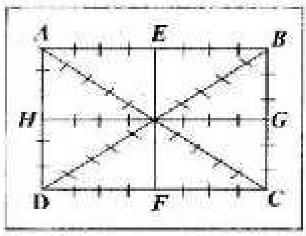
Flatness Testing

Flatness testing is possible by comparing the surface with an accurate surface. This method is suitable for small plates and not for large surfaces. Mathematically flatness error of a surface states that the departure from flatness is the minimum separation of a pair of parallel planes which will contain all points on the Surface. The figure which shows that a surface can be considered to be composed of an infinitely large number of lines. The surface will be flat only if all the lines are straight and they lie in the same plane. In the case of rectangular table arc the lines are straight and parallel to the sides of the rectangle in both the perpendicular direction. Even it is not plat, but concave and convex along two diagonals. For verification, it is essential to measure the straightness of diagonals in addition to the lines parallel to the sides.

Thus the whole of the surface is divided by straight line. The fig, shows the surface is divided by straight line. The end line AB and AD etc are drawn away from the edges as the edges of the surface are not flat but get worn out by use and can fall off little in accuracy. The straightness of all these lines is determined and then those lines are related with each other in order to verify



whether they lie in the same plane or not.



Procedure for determining flatness

The fig. shows the flatness testing procedure.

(i) Carry out the straightness test and tabulate the reading up to the cumulative error column.

(ii) Ends of lines AB, AD and BD are corrected to zero and thus the height of the points A, B and D are zero.

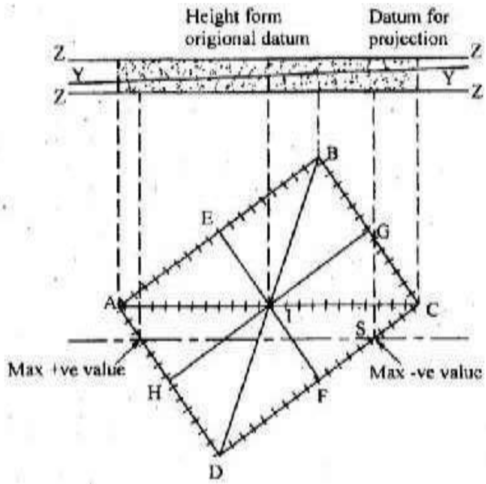


Fig 3.29 Flatness Testing

The height of the point I is determined relative to the arbitrary plane ABD = 000. Point C is now fixed relative to the arbitrary plane and points B and D are set at zero, all intermediate points on BC and DC can be corrected accordingly. The positions of H and G, E and F are known, so it is now possible to fit in lines HG and EF. This also provides a check on previous evaluations since the mid-point of these lines should coincide with the position of mid-point I. In this way, the height of all the points on the surface relative to the arbitrary plane ABD is known.

Roundness Measurements

Roundness is defined as a condition of a surface of revolution. Where all points of the surface intersected by any plane perpendicular to a common axis in case of cylinder and cone.

Devices used for measurement of roundness

1) Diametral gauge.

2) Circumferential conferring gauge => a shaft is confined in a ring gauge and rotated against a set indicator probe.

3) Rotating on center

4) V-Block

5) Three-point probe.

6) Accurate spindle.

1. Diametral method

The measuring plungers are located 180° a part and the diameter is measured at several places. This method is suitable only when the specimen is elliptical or has an even number of lobes. Diametral check does not necessarily disclose effective size or roundness. This method is unreliable in determining roundness.

2. **Circumferential confining gauge**

Fig. shows the principle of this method. It is useful for inspection of roundness in production. This method requires highly accurate master for each size part to be measured. The clearance between part and gauge is critical to reliability. This technique does not allow for the measurement of other related geometric characteristics, such as concentricity, flatness of shoulders etc.

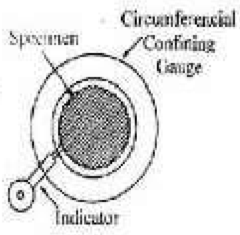


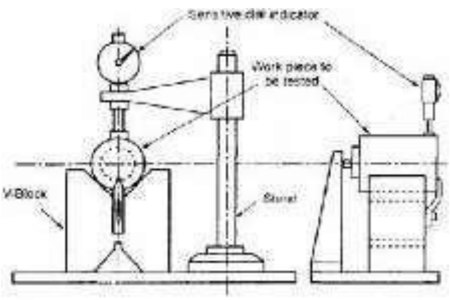
Fig 3.30 Confining Gauge

Rotating on centers

The shaft is inspected for roundness while mounted on center. In this case, reliability is dependent on many factors like angle of centers, alignment of centres, roundness and surface condition of the centres and centre holes and run out of piece. Out of straightness of the part will cause a doubling run out effect and appear to be roundness error.

3. **V-Block**

The set up employed for assessing the circularity error by using V Block is shown in fig. The V block is placed on surface plate and the work to be checked is placed upon it. A diameter indicator is fixed in a stand and its feeler made to rest against the surface of the work. The work is rotated to measure the rise on fall of the workpiece. For determining the number of lobes on the work piece, the work piece is first tested in a 60° V-Block and then in a 90° V- Block. The number of lobes is then equal to the number of times the indicator pointer deflects through 360° rotation of the work



piece.

Fig 3.31 V-Block

Limitations

a) The circularity error is greatly by affected by the following factors.

(i) If the circularity error is i\e, then it is possible that the indicator shows no variation.

(ii) Position of the instrument i.e. whether measured from top or bottom.

(iii) Number of lobes on the rotating part.

b) The instrument position should be in the same vertical plane as the point of contact of the part with the V-block.

c) A leaf spring should always be kept below the indicator plunger and the surface of the part.

4. **Three point probe**

The fig. shows three probes with 120° spacing is very, useful for determining effective size they perform like a 60° V- block. 60° V-block will show no error for 5 a 7 lobes magnify the error for 3-lobed parts show partial error for randomly spaced lobes.

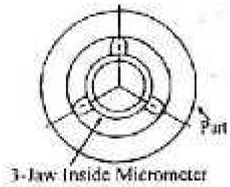


Fig 3.32 Three Point Probe

Roundness measuring spindle

There are following two types of spindles used.

1. **Overhead spindle**

Part is fixed in a staging plat form and the overhead spindle carrying the comparator rotates separately from the part. It can determine roundness as well as camming (Circular flatness). Height of the work piece is limited by the location of overhead spindle. The concentricity can be checked by extending the indicator from the spindle and thus the range of this check is limited.

2. **Rotating table**

Spindle is integral with the table and rotates along with it. The part is placed over the spindle and rotates past a fixed comparator

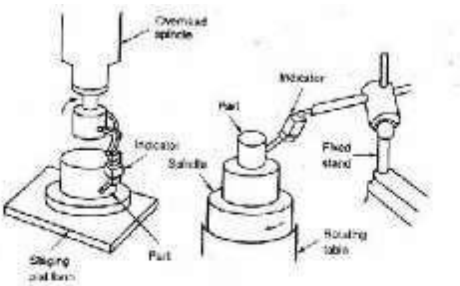


Fig 3.32 Rotating Table

Roundness measuring machine

Roundness is the property of a surface of revolution, where all points on the surface are equidistant from the axis. The roundness of any profile can be specified only when same center is found from which to make the measurements. The diameter and roundness are measured by different method and instruments. For measurement of diameter it is done statically, for measuring roundness, rotation is always necessary.

Roundness measuring instruments are two types.

1. Rotating pick up type.
2. Turn table type

weight of the work piece, being stationary and is easy to make. In the turn table type the pickup is not associated with the spindle. This is easier to measure roundness. Reposition the pickup has no effects on the reference axis.

The pickup converts the circuit movement of the stylus into electrical signal, which is processed and amplified and fed to a polar recorder. A microcomputer is incorporated with integral visual display unit and system is controlled from compact keyboards, which increases the system versatility, scope and speed of analysis. System is programmed to access the roundness of work piece with respect to any four of the internationality recognized reference circles. A visual display of work piece profile can be obtained. Work piece can be assessed over a circumference, and with undercut surface or an interrupted surface with sufficient data the reference circle can be fitted to the profile. The program also provides functions like auto centering, auto ranging, auto calibration and concentricity.

Modern Roundness Measuring Instruments

This is based on use of microprocessor to provide measurements of roundness quickly and in a simple way; there is no need of assessing out of roundness. Machine can do centering automatically and calculate roundness and concentricity, straightness and provide visual and digital displays. A computer is used to speed up calculations and provide the stand reference circle.

(i) Least square circle

The sum of the squares of a sufficient no. of equally spaced radial ordinates measured from the circle to the profile has minimum value. The center of such circle is referred to as the least square center. Out of roundness is defined as the radial distance of the maximum peak from the circle (P) plus the distance of the maximum valley from this circle.

(ii) Minimum zone or Minimum radial separation circle

These are two concentric circles. The value of the out of roundness is the radial distance between the two circles. The center of such a circle is termed as the minimum zone center. These circles can be found by using a template.

(iii) Maximum inscribed circle

This is the largest circle. Its center and radius can be found by trial and error by compare or by template or computer. Since V = 0 there is no valleys inside the circle.

(iv) Minimum circumscribed circles

This is the smallest circle. Its center and radius can be found by the previous method since P = 0 there is no peak outside the circle. The radial distance between the minimum circumscribing circle and the maximum inscribing circle is the measure of the error circularity. The fig shows the trace produced by a recording instrument.

This trace to draw concentric circles on the polar graph which pass through the maximum and minimum points in such way that the radial distance be minimum circumscribing circle containing the trace or the n inscribing circle which can fitted into the trace is minimum. The radial distance between the outer and inner circle is minimum is considered for determining the circularity error. Assessment of roundness can be done by templates. The out of roundness is defined as radial distance of the maximum peak (P) from the least square circle plus the distance of maximum valley (V) from the least square circle. All roundness analysis can be performed by harmonic and slope analysis.

MACHINE TOOLS

UNIT-3

CH – I

MECHANISM AND METAL CUTTING

Elementary Treatment of Metal cutting theory

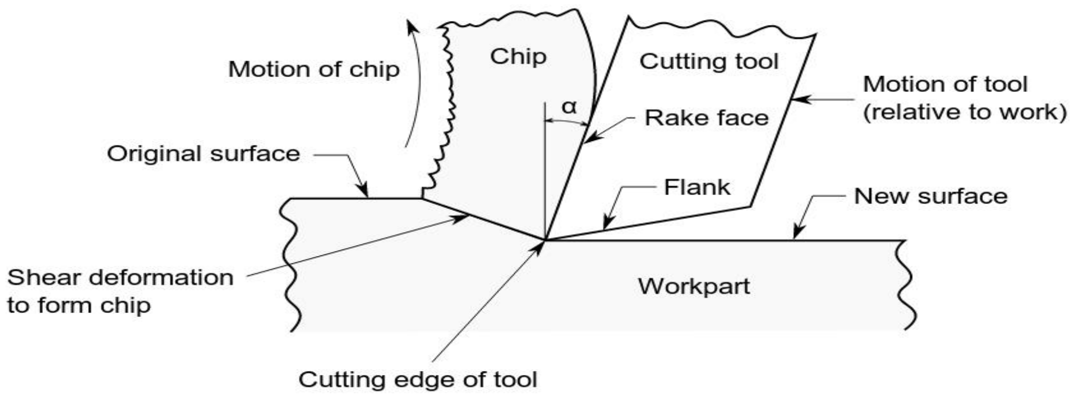
1. Economical manufacture of Machine parts ----------- Growing competition.

2. Basic objectives of efficient and Economical machining practice.

   a) Quick metal removal.
   b) High class of surface finish.
   c) Economy in tool cost.
   d) Less power consumption.
   e) Economy in the cost of replacement and sharpening tools.
   f) Minimum idle time of machining tools.

3. Basic elements of machining.

   a) Work piece b) Tool and c) Chip.



The relative motion between the tool and work piece is necessary for effecting the cutting action. The relative motion can be provided by both keeping the work piece stationary and moving the tool or by keeping the tool stationary and moving the work or by moving both in relation to one another.

The work piece provides the parent metal, from which unwanted metal is removed by cutting action of tool to obtain shape and size of the component. Chemical composition and physical properties of work piece material will have significant effect in machining.

The type and geometry of chip formed are greatly affected by the metal of work piece, geometry of cutting tool and method of cutting. Chemical composition and rate of flow of cutting fluid have considerable influence over the machining operation.

ORTHOGANAL AND OBLIQUE CUTTING:

The process of metal cutting is divided in to two main classes: Orthogonal and Oblique cutting

In Orthogonal cutting, cutting edge of tool remains normal to the direction of tool feed or work feed.

The direction of chip flow velocity is normal to the cutting edge of the tool.

The angle of inclination 'i' of the cutting edge of the tool with normal to the velocity v_c is zero.

The chip flow angle β i.e the angle between the direction of chip flow and normal to the cutting edge of the tool is zero.

Cutting edge is longer than the width of the cut.

Oblique cutting:

The cutting edge of the tool always remains inclined at an acute angle to the direction of tool feed or work feed.

The direction of chip flow velocity is at an angle β with normal to the cutting edge of the tool. The angle is known as chip flow angle.

The cutting edge of the tool is inclined at an angle 'i' with the normal to the direction of tool feed or work feed.

Three mutually perpendicular components of the cutting forces act at the cutting edge of the tool.

The cutting edge may or may not be longer than the width of cut.

Most of the metal cutting is carried out through oblique method.

CLASSIFICATION OF CUTTING TOOLS

Single point tools: Those having only one cutting edge.

Ex. Lathe tools, Shaper tools, Planer tools, Boring tools etc.

Multi-Pont tools:- Those having more than one cutting edge

Ex. Milling cutters, Drills, Broachers, Grinding wheels.

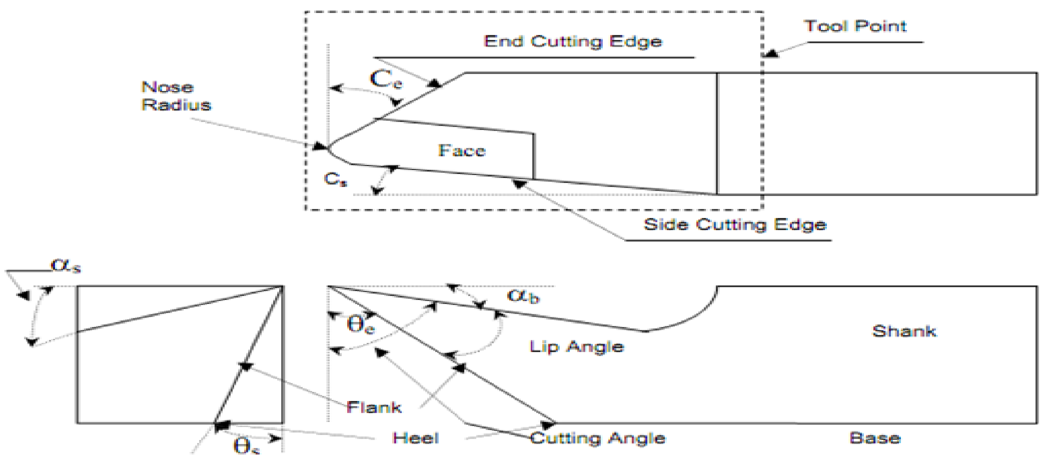
Cutting tools can also be classified according to the motion as:

Linear motion tools: Lathe, Boring, Broaching, Planning and Shaping tools.

Rotary motion tools: Milling cutters, grinding wheels.

Linear and Rotary tools: Drills, Honing tools, Boring heads etc.

GEOMETRY OF SINGLE POINT TOOLS:



1. Rake angle: It is the angle formed between face of the tool and plane parallel to its base. If this inclination is towards shank, it is known as back rake or top rake. When it is measured towards side of the tool, it is called side rake. These rake angles guide the chips away from the cutting edge, thereby reducing the chip pressure on the face and increasing the keenness of the tool, so that less power is required for cutting. An increased rake angle will reduce the strength of cutting edge. Therefore tools used for cutting hard materials are given small rake angles, whereas those used for soft metals contain large rake angles.

Negative rake angle: The above rake angles are called positive rake angles. When no rake is provided on the tool, it is said to have zero rake angle. When the face of the tool is so ground that it slopes upwards from the point, it is said to contain a negative rake. It reduces keenness of the tool and increases the strength of cutting edge. Such rake is usually provided on carbide tipped tools when they are used for machining extra- hard surfaces, hardened steel parts and for taking intermittent cuts. The values of negative rake on these tools normally vary from 5° to 10°.

2. Lip angle: The angle between the face and flank of the tool is known as Lip angle. It is also called angle of keenness of the tool. Strength of the cutting edge or point of the tool is directly affected by this angle. Larger the lip angle, stronger will be cutting edge and vice-versa. This angle varies inversely as the rake angle. It is only for this reason that when harder metals are to be machined a stronger tool is required, the rake angle is reduced and consequently the lip angle is increased. This calls for reduced cutting speeds, which is dis-advantage. The lip angle is therefore kept as low as possible without making the cutting edge so weak that it becomes unsuitable for cutting.

3. Clearance angle: It is the angle formed by the front or side surface of the tool which are adjacent and below the cutting edge when the tool is held in a horizontal position. It is the angle between one of these surfaces and a plane normal to the base of the tool. When the front surface is considered it is called front clearance and when the surface below cutting edge is considered, the angle formed is known as side clearance angle. The purpose of providing front clearance is to allow the tool to cut freely without rubbing against the surface of the job. The side clearance is to direct the cutting thrust to the metal area adjacent to the cutting edge.

4. Relief angle: It is the angle formed between flank of the tool and a perpendicular drawn from the cutting point to the base of the tool.

5. Cutting angle: The total cutting angle of the tool is the angle formed between the tool face and a line drawn through the point, which is a tangent to the machined surface of the work at that point. Its correct value depends upon the position of the tool in which it is held in relation to the axis of the job.

6. Nose radius: If the cutting tip of a single point tool carries a sharp cutting point, the cutting tip is weak. It is therefore highly stressed during the operation, may fail or loose its cutting ability soon and produces marks on the machined surface. In order to prevent these harmful effects the nose is provided with a radius, called Nose radius. It enables greater strength to cutting tip, a prolonged tool life and superior surface finish on the work piece. As the value of this radius increases, a higher cutting speed can be used. If it is too large, it may lead to chatter.

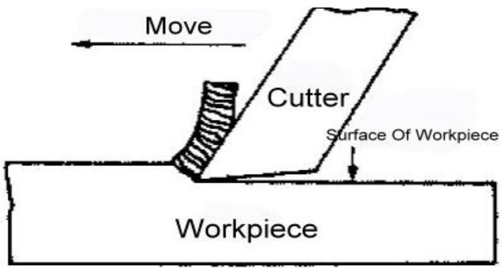
So a balance has to be maintained. Its value normally varies from 0.4mm to 1.6mm depending upon several factors like depth of cut, amount of feed, type of cutting and type of tool.

CHIP FORMATION

Chips are formed due to tearing and shearing. In the chip formation by tear, the work piece material adjacent to the tool face is compressed and crack runs ahead of the cutting tool and towards body of the work-piece. The chip is highly deformed and the work-piece material is relatively under formed. Cutting takes place intermittently and there is no movement of the work piece material over the tool face.

In chip formation by shear, there is a general movement of the chip over tool face.

The grains of metal ahead of cutting edge of tool start elongating along line AB and continue to do so until they are completely deformed along line CD. The region between the lines AB and CD is called shear zone. After passing over shear zone, the deformed metal slides along the tool face due to the velocity of the cutting tool.



Chip Formation

The angle made by plane of shear with the direction of tool travel is known as shear angleφ. Its value depends on the material being cut and the cutting conditions. If φ is small, path of shear will be long, chips will be thick and the force required to remove the layer of metal of given thickness will be high and vice-versa.

Types of chips:

Every machining operation involves the formation of chips, the nature of chips differs from operation to operation, properties of work-piece material and cutting condition. Chips are formed due to cutting tool, which is harder and more wear resistant than the work-piece material, relative motion between tool and work-piece, sufficient force and power to overcome the resistance of work-piece material. The chips are formed by the deformation of the metal lying ahead of cutting tool edge by a process of shear. Basically there are three types of chips.

1. Discontinuous chips: This type of chips is produced during machining of brittle materials like cast-iron and bronze. These chips are produced in the form of small segments. In machining of such materials, as the tool advances forward, the shear-plane angle gradually reduces until the value of compressive stress acting on the shear plane becomes too low to prevent rupture. At this stage, any further advancement of the tool results in the fracture of the metal ahead of it, thus producing a chip. With further advancement of the tool, the processes of metal fracture and production of chips goes on repeatedly producing discontinuous chips. Such chips are also sometimes produced in machining of ductile materials, when low cutting speeds are used and adequate lubrication is not provided. This causes excessive friction between the chip and tool face, leading to fracture of chip in small segments. This will also result in excessive wear on the tool and poor surface finish on the work-piece. Other factors responsible for production of discontinuous chips are smaller rake angle on the tool and too much depth of cut.

2. Continuous chip: This type of chip is produced while machining a ductile material, like mild steel and copper at very high cutting speed and minimum friction between the chip and the tool face. The friction at the chip-tool inter face can be minimized by polishing the tool face and adequate use of coolant. The basis of production of a continuous chip is the continuous plastic deformation of the metal ahead of the cutting tool, the chip moving smoothly up the tool face. Other factors responsible are bigger rake angle, finer feed and keen cutting edge of the tool.

3. Continuous chip with built-up edge: It is very similar to the continuous type and not as smooth as continuous chip. It has a built-up edge adhering on nose of the tool, which changes the effective geometry of cutting. It is obtained by machining ductile metals with high speed tools at ordinary cutting speeds, thus introducing high friction between the chip and tool face. The form and size of such an edge depends largely on the cutting speed, being absent at very low and very high cutting speeds. This type of chip results in poor surface finish. The normal reaction of the chip on the tool face is quite high, and is maximum at the cutting edge or nose of the tool. This gives rise to an excessively high temperature and the compressed metal adjacent to tool nose gets welded to it. The chip is also sufficiently hot and gets oxidized as it comes off the tool and turns blue in colour. The extra metal welded to tool nose or point of the tool is called **built-up edge**.

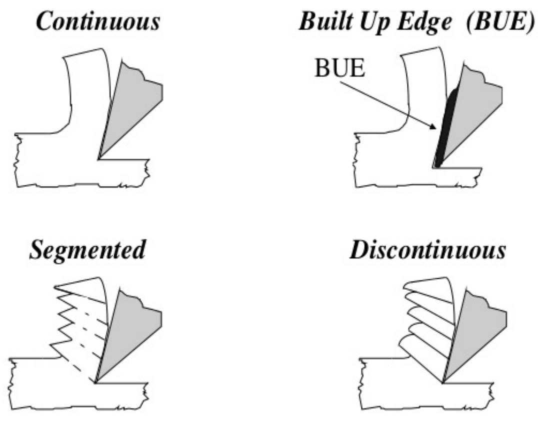
This metal is highly strain hardened and brittle. With the result, as the chip flows up the tool, the built-up edge is broken and carried away with the chip while the rest of it adheres to the surface of the work-piece, making it rough. Due to the built-up edge the rake angle is also altered and so is the cutting force. The common factors responsible for formation of built-up edge are low cutting speed, excessive feed, small rake angle and lack of lubricant.

Adverse effects of built-up edge formation:

a) Rough surface finish on the work-piece.

b)Fluctuating cutting force, causing vibrations in cutting tool.

c) Chances of carrying away some material from the tool by the built-up surface, producing crater on the tool face and causing tool wear.



Precautions for avoiding the formation of built-up

edge:

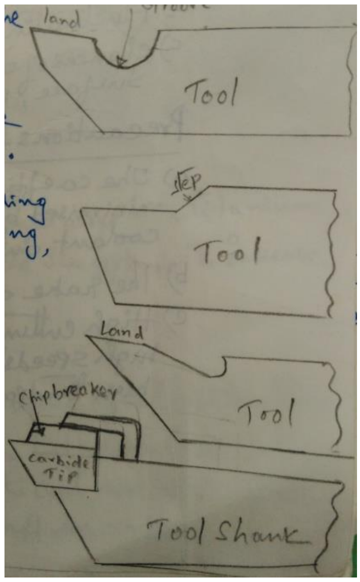
a) The co-efficient of friction at the chip-tool interface should be minimized by means of polishing the tool face and adequate supply of coolant during the cutting operation.

b) The rake angle should be kept large.

c) High cutting speeds and low feeds should be used, because at high speeds the strength of the weld becomes low. Similarly, at very high temperature also the strength of the weld becomes low.

CHIP-BREAKERS:

The chips produced during machining at higher speeds in machining of high tensile strength materials, need to be effectively controlled. Carbide tipped tools are used in case of higher speeds and due to high temperature the chip will be continuous of blue colour and take the shape of coil. Such a chip, if not broken in to parts and removed from the surroundings of the metal cutting area, will adversely affect the machining in the fallowing way.



a) Adversely affect tool life by spoiling the cutting edge, creating crater and raising the temperature.

b) Lead to poor surface finish on the work-piece.

c) The chips get curled around the rotating work-piece and cutting tool, it may be hazardous to the machine operator.

d) If large and continuous coil is allowed to be formed it may endanger the machine and even the work place.

e) Very large coils offer a lot of difficulty in their removal.

While machining materials like brass and cast-iron continuous chips of above type are not produced. But in case of continuous chips, by using chip breakers, we can overcome the above difficulties and adverse affects. The chip breakers break the produced chips in to small pieces. The work hardening of the material of the chip makes the work of the chip breakers easy.

The common methods used for chip breaking are:

i) By control of tool geometry i.e. grinding proper back rake and side rake angles according to the speeds and feeds used.

ii) By obstruction method i.e. by inters posing a metallic obstruction in the path of the coil.

The fallowing types of chip breakers are commonly used:

a) Groove type: It consists of a grinding groove on the face of the tool, behind the cutting edge, leaving a small land near the tip.

b) Step type: It consists of a grinding a step on the face of the tool, adjacent to the cutting edge.

c) Secondary rake type: It consists of providing a secondary rake on the tool, through grinding, together with a small step.

d) Clamp type: This type of chip breaker is very common with the carbide tipped tools. The chip breaker is a thin and small plate, which is either brazed to or held mechanically on the tool face.

CUTTING SPEED, FEED AND DEPTH OF CUT

Cutting speed of a tool can be defined as the rate at which its cutting edge passes over the surface of the work-piece in unit time. It is normally expressed in terms of surface speed in meters per minute.

In machining it is important as it considerably affects the tool life and efficiency of machining. Selection of proper cutting speed has to be made very judiciously. If it is too high, the tool gets over heated and its cutting edge may fail, needing regrinding. If it is too low, too much time is consumed in machining and full cutting capacities of the tool and machine are not utilized, resulting in lowering of productivity and increasing the production cost.

Feed of the cutting tool can be defined as the distance it travels along or in to the work-piece for each pass of its point through a perpendicular position in unit time. In turning operation of lathe, it is equal to the advancement of the tool corresponding to each revolution of work. In planning it is the work, which is fed and not the tool. In milling work, the feed is considered per tooth of the cutter.

The cutting speed and feed of a cutting tool is largely influenced by the following factors:

1. Material being machined.
2. Material of the cutting tool.
3. Geometry of the cutting tool.
4. Required degree of surface finish.
5. Rigidity of the machine tool being used
6. Type of coolant being used

Depth of cut: It is indicative of the penetration of the cutting edge of the tool in to the work-piece material in each pass, measured perpendicular to the machined surface i.e. it determines the thickness of metal layer removed by the cutting tool in one pass.

Example: In turning operation on a lathe it is given by

Depth of cut $=\frac{D-d}{2}$

Where D = Original diameter of the work-piece in mm

D = Diameter obtained after turning in mm in one pass.

<u>Coolants</u> used in metal machining to perform the following main functions.

1. They cool the tool and the work piece.

2. They provide lubrication between the tool and work piece and tool and chips.

3. They prevent the adhesion of chips to the tool or work piece or both.

Cooling of the tool and work piece in required in order todissipate the heat generated during machining. The sources of heat generation during metal cutting are the following.

1 Friction: A lot of friction always takes place between the cutting tool and the work piece and between the tool face and the chips passing over it. The total amount of heat generated depends upon many factors viz. cutting speed, feed, tool material, depth of cut and metal being machined. The heat so generated is known as heat of friction.

2. Plastic deformation of metal: Cutting tool exerts high pressure on the adjacent metal grains which due to this pressure start slipping along their planes of weakness. This causes deformation of all of them. The action of slipping of these grains in contact with one another causes friction, leading to the generation of the heat of deformation. The total amount of heat generated again depends upon the cutting speed, feed, depth of cut and the metal being machined. Higher speeds, feeds, more depth of cut, tougher materials contribute to greater heat generation.

3. Chip distortion: In machining, as the cut proceeds and the chips curl out, the inside and the outside grain of the chip metal are subjected to compression and tension respectively. This causes distortion of the chip grains are the chips leading to a sort of internal friction amongst the grains and consequently generation of heat of chip distortion. The amount of heat generated depends on feeds and depth of cut. Heavier the feed and deeper the cut, the longer will be the area of cross-section of the chip and more distortion amongst the grains, resulting in higher amount of heat generation.

<u>Machinability</u>: Gives the idea of ease with which it can be machined. The parameters influencing the machinability of a material are:

1. Physical Properties of material.
2. Mechanical Properties of material.
3. Chemical composition of material.
4. Micro-Structure of material
5. Cutting conditions.

Machinability of the material depends on various variable factors such as

1. Tool Life: Longer tool life, it enables at a given cutting speed on the speed the better is the machinability.

2. Surface finish: It indirectly proportional, i.e. better surface finish the higher in machinability.

3. Power Consumption: Lower power consumption per unit of metal removal-better machinability.

4. Cutting Forces: Lesser amount of cutting force required for removal of higher volume of metal under standard conditions, the higher will be the machinability.

5. Shear angle: Larger shear angle denotes better machinability.

6. Rate of metal removal under standard cutting conditions.

TOOL LIFE

Tool life can be defined on the time interval for each tool works satisfactorily between into successive grindings. These are three common ways of expressing Tool life.

1. As time period in minutes between two successive grindings.

2. In terms of no. of components machined between two successive grindings.

3. In terms of the volume of the material removed between two successive grindings.

The method of assessing tool life in terms of the volume material removed per unit of time in a practical one.

Volume of metal removed/min = $\prod$ D t f N mm^3 / min

Where D = Dia of work piece in mm

t = depth of cut in mm

f = feed rate mm/rev

N = no. of revolutions of work per min.

If T be the times in minutes to tool failure = ∏ D t f N T mm^3

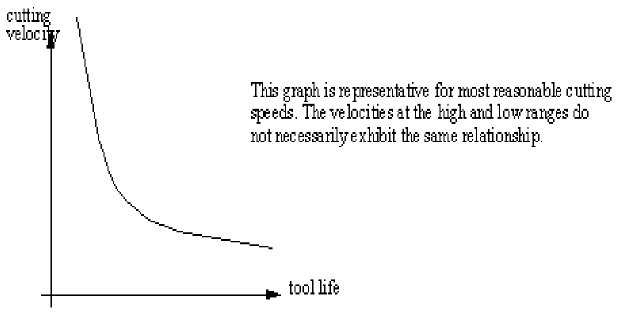
We know the cutting speed $V = \frac{\prod DN}{1000}$ ∏DN = V*1000

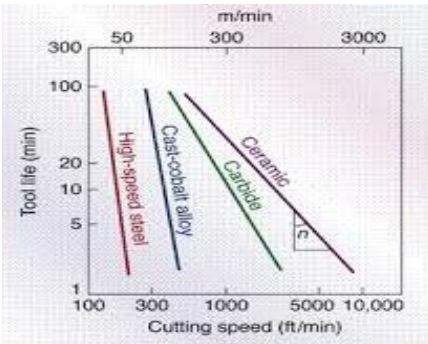
Total Volume of metal removed to tool life = V 1000 t f T mm^3

Therefore Tool life $T_L = V \times 1000 \times t \times f \times T$ (mm^3)

Factors affecting Tool Life

1. Cutting Speed.
2. Feed and Depth of cut.
3. Tool Geometry.
4. Tool Material.
5. Work Material.
6. Nature of Cutting.
7. Rigidity Machine tool and work.
8. Use of cutting fluids.





1. <u>Effect of cutting speed</u>:

The tool life varies inversely on cutting speed i.e. higher the cutting speed the smaller the tool life.

$$V T^n = C$$

V = Cutting speed m/min.

T = Tool life minutes.

n = An exponent – Its value depends on the tool material.

C = Machining Constant.

n = 0.1 to 0.15	HSS Tools
= 0.2 to 0.5	Carbide Tools
= 0.6 to 1.0	Ceramic Tools.

2. <u>Effect of feed rate and depth of cut</u>: It will appreciably effect in reduction in tool life.

$$V = \frac{257}{T^{0.19}\ f^{0.36}\ t^{0.8}}\ \text{m/min}$$

V = Cutting Speed m/min

T = Tool Life in min

F = Feed rate mm/min

t = Depth of a cut in mm

For a given Tool life $V = \frac{C}{f^a\ t^b}$ C = Constant

If the tool life in considered on constant, the cutting speed will decrease if the feed rate and depth of cut are increased.

3. <u>The Geometry</u>: Geometrical parameters (Tool angles) of a cutting tool influence its performance. The Rake angle has mixed effect. If it is increased, the amount of heat generated are reduced and help in increasing the life of cutting tool. But if it is very large the cutting edge is weakened and also its capacity to conduct the heat is reduced results in reduction in mechanical strength and lowering tool life. For effective economical tool life it is necessary to strike a balance. The optimum value of rake angle needs to be used. This value varies from -5^0 to $+10^0$. The minus sign indicates negative rake i.e. rake angle sloping up words from Tip. Tools carrying negative rake angle provide a stronger cutting edge and hence a stronger tool. Carbide and ceramic tools are generally provided – ve angle.

Similarly relief angle or clearance angle bn influence the tool performance. These angles are provided on cutting tools to prevent the rubbing of tool flank against the machine work surface. They thus help in lowering the amount of heat generated and therefore increasing the tool life. But very large relief angles beyond certain level results in weakening of tool resulting in reduction of tool life. Therefore a balance needs to be struck and only optimum value should be used. The angles normally vary from 5^0 to 8^0 but in special causes as carbide tipped tools up to 10^0.

The two cutting edge angels also have their influence on tool performance. The front cutting edge angle/end cutting edge angle effects the tool wear. Up to a certain optimum value an increase in this angle permits the higher speeds without an adverse effect on tool life. But an increase beyond certain value will result in reduction of tool life. It generally varies from 5^0 to 8^0. If the side cutting edge angle is smaller the higher speeds can be used. However it has complex effect on Tool life. A larger end cutting edge angle increases tool life.

I. Inclination angle: Tool life increases with the increase in this angle up to an optimum value.
II. Nose radius: While it increases the abrasion, it also helps in improving surface finish and tool strength and hence tool life.

4. Tool material: The main characteristics of good cutting tool material are its hot hardness, wear resistance, impact resistance, abrasion resistance, heat conductivity and strength etc. An ideal tool material is the one which will remove the largest volume of work material at all speeds. It is not possible to get truly ideal tool material. The tool material which can with stand max cutting temperature without loosing its principal mechanical properties (splly hardness) and geometry will ensure max tool life. The higher hot hardness and toughness in tool material, the longer the tool life.

5. Work Material: The micro-structure of work material is significant as it directly effects the hardness of material. Higher the hardness of the work material greater will be the tool wear and shorter will be the tool life. In machining pure metals, because of their tendency to stick to the tool face. Specially at high temperatures results in more friction and high amount wear on tool and therefore shorter tool life.

6. Nature of cutting: Tool life is affected by nature of cutting i.e. whether it is continuous or intermittent. In the intermittent cutting the tool is subjected to impact loads and may give away much earlier than expected until it is made strong and tough. In continuous cutting similar tool will have relatively longer life.

7. Rigidity of machine tool and work : Both the machine tool and work – piece should remain rigid during the machining operation. If not vibrations will take place and the cutting tool will be subjected to intermittent cutting, instead of continuous cutting. This will result in impact loading of tool and therefore shorter life.

8. Use of cutting fluids: Cutting fluids are used in machining work for helping the efficient performance of the operation. They are used either in liquid or gaseous form. They assist the operation by cooling the tool and work, reducing the friction, improving the surface finish, helping in breaking the chips and washing them away etc. These factors help in improving the tool life, permitting higher metal removal rate and improving the quality of surface finish.

<u>CHARACTERISTICKS OF CUIING TOOL MATERIALS</u>:

The materials used for manufacture of cutting tools should possess the following characteristics:

1. Ability to retain its hardness at elevated temperatures called hot hardness.

2. Ability to resist shock, called toughness.

3. High resistance to wear to ensure longer tool life.

4. Low co-efficient of friction at the chip –tool interface, so that the surface finish good and wear in minimum.

5. Should be cheap.

6 Should be able to be fabricated and shaped easily.

7. If it is to be used in the form of brazed tips, its other physical properties like tensile strength, thermal conductivity, co efficient of thermal expansion and modulus of elasticity etc. should be as close to the shank material as possible to avoid cracking.

CUTTING TOOL MATERIALS

The following materials are commonly used for manufacturing the cutting tools, selection of a particular material will depend on the type of service it is expected to perform.

1. High Carbon Steel: Plain carbon steels having a carbon percentage as high as 1.5% are in common use as tool materials for general class of work. For high production work they are not considered as they are not able to withstand very high temperature, hence they can't be used at high speeds. The required hardness is lost by them at temperature 200^0- 250^0 C. They are also not highly wear resistant. They are used mainly for hand tools as they are less costly, easily forgeable and easy to heat treat.

High carbon medium alloy steels are more effective than plain high carbon steels. These steels in additions to carbon content are provided better hot hardness, higher impact resistance, higher wear resistance by adding small amount of Tungsten, Chromium, Molybdenum, Vanadium etc. Which improves the performance and able to operate temperatures of 350^0C.

2. High Speed Steel: It is a special alloy-steel containing the alloying elements like Tungsten, Chromium, Vanadium, Cobalt and Molybdenum up to 25%. These alloying elements increase its strength, toughness, wear resistance, cutting ability and retains it's hardness at elevated temperature of 550^0c -600^0 c on account of these added properties the high speed steel tools are capable of operating at 2 to 3 times higher cutting speeds than high carbon steel tools.

The most commonly used high speed steel has composition alloying elements as 18-4-1 i.e. 18%W, 4%Cr, and 1%V.

3. Cemented Carbides: These Carbides are formed by the mixture of Tungsten, Titanium with Carbon. The carbides in the powder form are mixed with Cobalt which acts as binder. The mixture with powder metallurgy process, sintered at high pressures of 1500kg/sq cm to 4000kg/sq cm and temperatures of above 1500^0C is shaped in to desired forms of tips. These Carbide tips are then brazed or fastened mechanically to the shank made of medium Carbon steel. These cemented carbides possess a very high degree of hardness and wear resistance. They are able to retain this hardness at temperature up to 1000^0C with the result, the tools tipped with cemented carbide tips are capable of operating at speeds 5 to 6 times higher than those of high speeds.

4. Stellite: It is a non ferrous alloy mainly of Cobalt, Tungsten and Chromium. Other elements added in varying proportions are Tantalum, Molybdenum and Boron. It has good shock and wear resistance and retains its hardness at a red heat up to 920^{0}C. It is used for machining materials like hard bronzes, cast and malleable Iron etc. Tools made of Stellite are capable of operating at speed up to 2 times more than those of common high speed steel tools. Only grinding can be used for machining it effectively.

A satellite may contain 40-50% Co, 15-35%Cr, 12-25%W and 1-4%Carbon.

5. Ceramics: The introduction of ceramic material as a cutting tool material is a latest development in the field of tool metallurgy. It mainly consists of Aluminum oxide which is comparatively much cheaper than any of the chief constituents of cemented Carbides. Boron nitrides in powdered form are added and mixed with Aluminum oxide powder and sintered together at a temperature of 1700^{0}C. They are then compacted in to different tip shapes. Tools made of ceramic material are capable of withstanding high temperatures, without loosing their hardness up to 1200^0 C. They are much more wear resistant than cemented carbide tools. They are more brittle and low resistance to bending. They can't be used for rough machining work and mainly used for finishing operations. They are capable of removing 4 times more material than Tungsten carbide tools and2-3 times high cutting speeds under similar conditions. No coolant is needed while machining with ceramic tools.

6. Diamond: It is the hardest material known and used as cutting tool material. It is brittle and low resistance to shock but it is highly wear resistant. Diamonds are used for only light cuts on materials like Bakelite, Carbon, Plastics, Aluminum and Brass etc. Because of low co efficient of friction they produce a high grade of surface finish. Because of high cost only limited use in tool industry.

CARBIDE TIPS

Q : What are the throw away carbide tips? What are their advantages? What are the basic requirements?

Throw away Carbide tips are made in a variety of shapes and vary in thickness from 3mm to 12mm and size from 10 to 15mm^2 (mm square). Proper arrangements in the form of holes etc are made to secure them on the tool holders.

Positive rake Carbide tips have 3 or 4 cutting edges, which are ground to produce 5 to 8 ^{0} relief angle. These can be used individually before tip becomes unusable.

In negative rake Carbide tips, the relief angle in created by placing them suitably on the tool holder. These thus have the advantage of providing 6to 8 usable edges, because all the edges are prepared at right angles. However the second side of the tip can be used only if the first side has not become rough due to wear as otherwise it can't be flat against the loading surface on the tool holder.

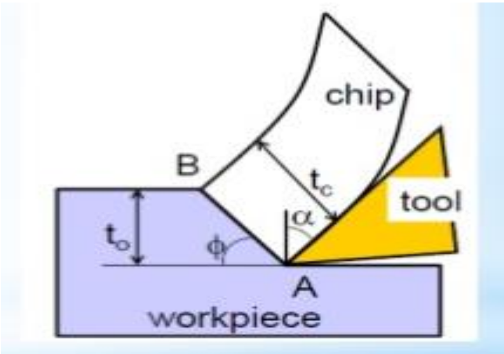
Throw away Carbide tips are quite cheap and as 4 to 6 edges can be used before it is thrown, there is lot of economy in using them.

The basic requirements of Carbide tips are:

I. A pocket on the tool holder to locate the carbide tip positively and take the side longitudinal and end radial thrust from the cutting forces and also to ensure that new tip will cut to the same size.
II. A solid seat for the bottom of the carbide tip to take the tangential force and also to ensure that new tip will cut to the same size.
III. A clamp to hold the tip formally against the bottom of the pocket and it form being pulled out.

CHIP THICKNESS RATIO

During cutting action of a metal, the thickness of the deformed or upward flowing chip in more than the actual depth of cut. It is because the chip flows upwards at a slower rate than the velocity of the cut. The velocity of the chip flow is directly effected the shear plane angle. The smaller the shear plane angle the slower will be the chip flow – velocity and therefore longer will be the thickness of the chip.



t = chip thickness prior to deformation

t_c = chip thickness after deformation

$$t_c > t$$

The chip thickness ratio $r = \frac{t}{t_c}$

Since t_c in always greater than t, the value of chip thickness ratio r is always less than unity. The higher the value of r, the better is supposed to be cutting action. The reverse of r is known as chip reduction co efficient. If k is the chip reduction co efficient

$$K = \frac{i}{r}$$

In orthogonal cutting the width of the chip equals the width of the cut. Considering specific gravity of the metal as constant, the volume of the chip produced will be equal to the volume of the metal cut. Width of both being equal, the product of the chip thickness and its length will, therefore be equal to the product of the thickness of the metal cut and length of metal cut. If L_1 and L_2 are lengths of the metal cut and chip respectively.

$$t \times L_1 = t_c \times L_2$$

$$\frac{t}{t_c} = \frac{L_2}{L_1} \qquad \text{But} \qquad \frac{t}{t_c} = r$$

$$r = \frac{t}{t_c} = \frac{L_2}{L_1}$$

$$k = \frac{1}{r} = \frac{t}{t_c} = \frac{L_2}{L_1}$$

We have two right angled triangles OAP and OBP

Considering the orthogonal triangle OAP

$$\frac{AP}{OP} = \text{Sin}\emptyset \qquad OP = \frac{AP}{\text{Sin}\emptyset} = \frac{t}{\text{Sin}\emptyset} \qquad \text{———} \quad (1)$$

Considering the right angled triangle OBP

$$\frac{BP}{OP} = \text{Sin BOP} = \text{Sin}(90 - \emptyset + \propto) = \text{Cos}(\emptyset - \propto)$$

$$OP = \frac{BP}{\text{Cos}(\emptyset - \propto)} = \frac{t_c}{\text{Cos}(\emptyset - \propto)} \qquad \text{———} \quad (2)$$

Now by equations (1) & (2)

$$OP = \frac{t}{\text{Sin}\emptyset} = \frac{t_c}{\text{Cos}(\emptyset - \propto)}$$

$$\frac{t}{t_c} = \frac{\text{Sin}\emptyset}{\text{Cos}(\emptyset - \propto)} \qquad \text{i.e. } r = \frac{\text{Sin}\emptyset}{\text{Cos}(\emptyset - \propto)} \qquad \text{———} \quad (3)$$

$$r = \frac{\text{Sin}\emptyset}{\text{Cos}\emptyset\text{Cos}\propto + \text{Sin}\emptyset\text{Sin}\propto}$$

$$r\,(\text{Cos}\emptyset\text{Cos} \propto) + r\,(\text{Sin}\emptyset\text{Sin} \propto) = \text{Sin}\emptyset$$

$$r\,\frac{\text{Cos}\emptyset\text{Cos}\propto}{\text{Sin}\emptyset} + r\,\frac{\text{Sin}\emptyset\text{Sin}\propto}{\text{Sin}\emptyset} = 1$$

$$r\,\frac{\text{Cos}\propto}{\tan\emptyset} + r\,\text{Sin}\propto = 1$$

$$r\,\frac{\text{Cos}\propto}{\tan\emptyset} = 1 - r\,\text{Sin}\propto$$

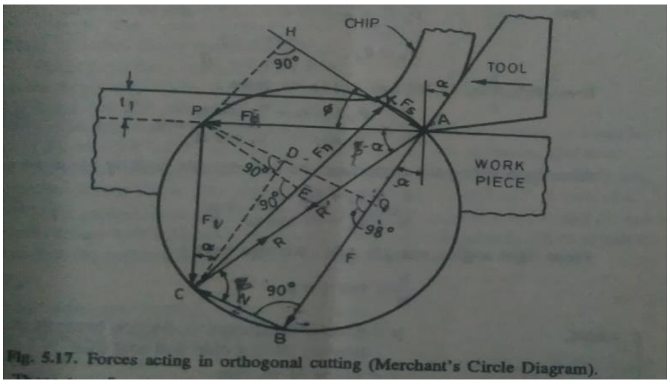
$$\tan\emptyset = \frac{r\,\text{Cos}\propto}{1 - r\,\text{Sin}\propto} \qquad \text{———} \quad (4)$$

$$\tan\emptyset = \frac{\frac{t}{t_c}\cos\propto}{1-\frac{t}{t_c}\sin\propto} \qquad \text{\_\_\_\_\_\_\_\_\_\_ (5)}$$

MERCHANTS FORCE DIAGRAM:

F_H = Horizontal cutting force exerted by the tool on work piece.

F_V = Vertical or tangential force which helps in holding the tool in position and acts on tool nose.



Merchant force diagram

$F = AQ - QB = AQ - DC = F_H \sin\propto - F_V \cos\propto$ ________ (1)

$N = QD = PQ\text{-}PD = F_H \cos\propto - F_V \sin\propto$ ________ (2)

$F_S = AH - HK = AH - PE = F_H \cos\emptyset - F_V \sin\emptyset$

$N_s = CE + EK = CE + PH = F_V \cos\emptyset + F_H \sin\emptyset$

$F_H = AC\cos(\beta-\alpha) = R\cos(\beta-\alpha)$

$F_S = R\cos(\emptyset+\beta-\alpha)$

$$\frac{F_H}{F_S} = \frac{R\cos(\beta-\alpha)}{R\cos(\emptyset+\beta-\alpha)}$$

$$F_H = F_S\,\frac{\cos(\beta-\alpha)}{\cos(\emptyset+\beta-\alpha)}$$

The tool face components are importance they enable the co efficient to friction for the tool face ($\mu = \tan\beta$) to be determines β is the angle of friction at the rank surface.

$$\mu = \frac{F}{N} = \frac{F_A \, Sin\propto + F_V Cos\propto}{F_H Cos\propto - F_V Sin\propto} \quad \frac{Cos\propto}{Cos\propto}$$

$$= \frac{F_H \tan\propto + F_V}{F_H - F_V \tan\propto}$$

μ is co efficient of friction between tool face and upward sliding chip.

$$\frac{F_V}{F_H} = \tan(\beta - \alpha)$$

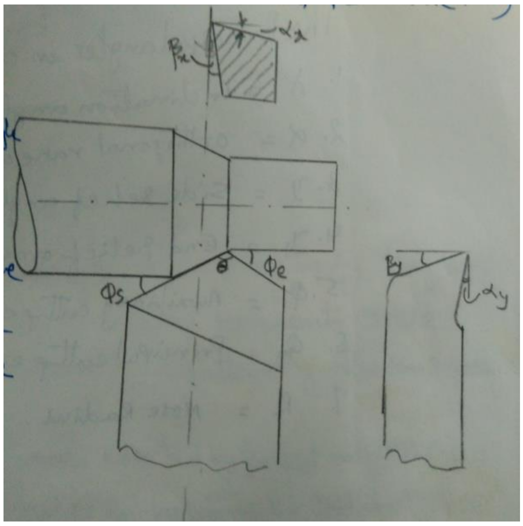
F_V and F_H can be easily measured by strain gauges or force dynamo meters.

TOOL SIGNATURE

The term tool signature is used to denote a standardized system of specifying the principle tool angels of a single point cutting tool.

Some common systems are:

1. American (ASA) System.
2. British System.
3. Continental System.
4. International System.



I. Reference Planes: The following two systems of references planes are used to describe the geometry and locate the different parameters of a single point cutting tool.

1. The Co-Ordinate System: This system consist of three principal reference planes. The horizontal plane which contains the base of the shank of the cutting tool is known as the **Base Plane**. The second reference plane is a vertical plane, normal to the base plane, and parallel to the direction of feed (f) of the cutting tool. It is called **Longitudinal Plane** (x, x^I). The third reference plane called the **Transverse Plane** (y, y^1) is perpendicular to both the above reference planes and is parallel to the transverse motion of the tool. i.e. the depth of cut(d). This combination of reference planes is known as co ordinate system of reference planes. This system having been adopted by American **Standard Association (ASA)** is known as ASA System.

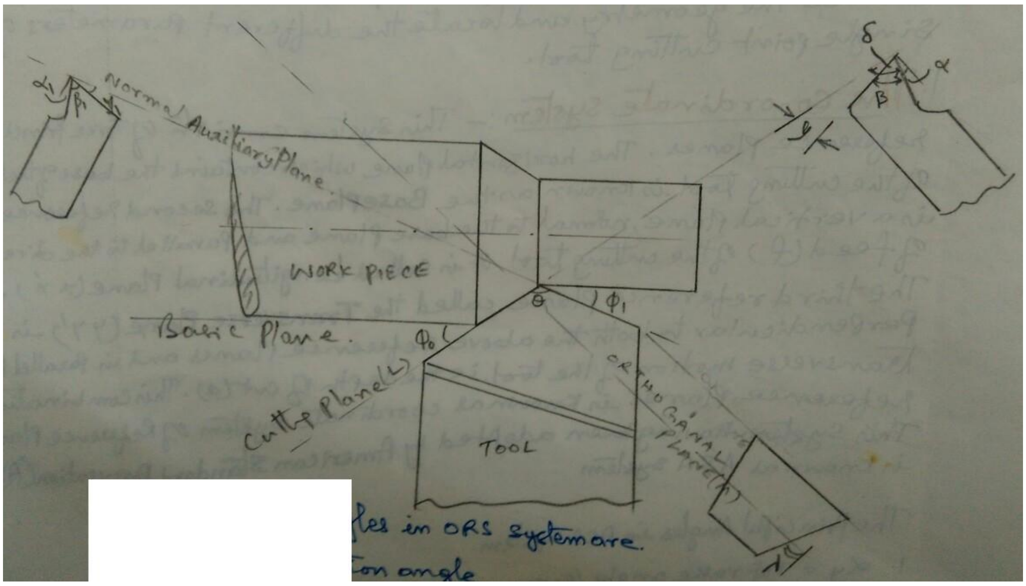
The principal angels in ASA System.

1. α_y = Top rake angle / Back rake angle.
2. α_x = Side rake angle.
3. β_y = End relief / Clearance angle.
4. β_x = Side relief / Clearance angle.
5. $\emptyset_e$ = End cutting edge angle.

6. $\emptyset_s$ = Side cutting edge angle.
7. θ = Nose radius / angle.

2. **<u>THE ORTHOGONAL SYSTEM</u> :(OR)<u> ORTHOGONAL RAKE SYSTEM(ORS)</u>**:

In this system of reference planes it is assumed that the cutting tool is operating against the work piece. There are three main reference planes. The Horizontal Plane, contains the base of the cutting tool and is known as **Base Plane.** The second plane, which is perpendicular to the base plane, contains the principal cutting edge (c) and is called the **Cutting Plane.** The third plane which is perpendicular to both the above planes, is known as Orthogonal System of Reference Planes or Orthogonal Rake System (ORS).

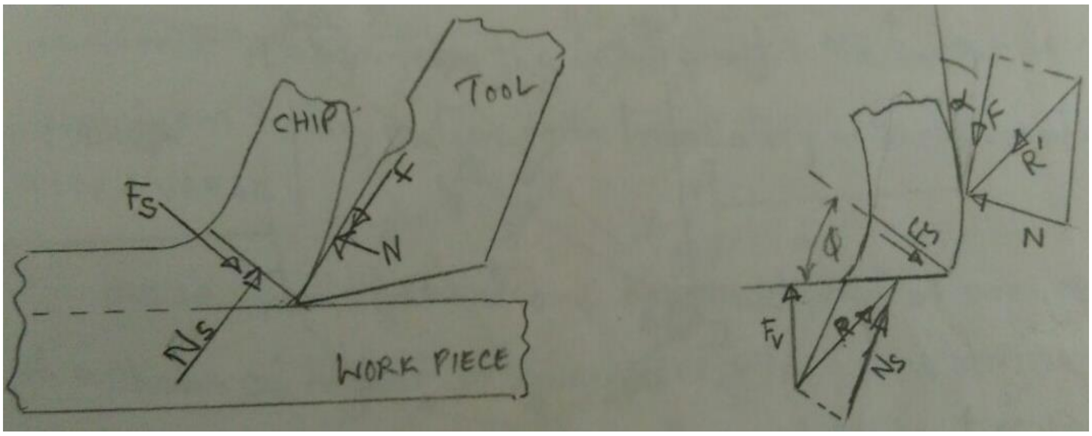


The principal angles in ORS System are.

1. λ = Inclinational angle.
2. α = Orthogonal Rake Angle.
3. y = Side relief angle.
4. y_1 = End relief angle.
5. $\emptyset_1$ = Auxiliary cutting edge angle.
6. $\emptyset_0$ = Principal cutting edge angle/approach angle.
7. R = Nose Radius.

<u>FORCE RELATIONSHIP IN ORTHOGONAL CUTTING</u>:

A number of forces act on the chip during metal cutting. The relationship among these forces were established by merchant.



The forces acting on the chip in orthogonal cutting are represented as follows.

F_S = Metal resistance to shear in chip formation, acting along shear plane.

N_S = Backing up force exerted by the work piece on the chip, acting normal to shear plane.

N = Force exerted by the tool on the chip, acting normal to tool face.

F = μN = Frictional resistance of the tool against the chip flow, acting along the tool face. μ being the co-efficient of friction between tool face and chip.

$$\mu = \frac{F}{N}$$

It will be observed that F_S and N_S can be easily replaced by their resultant r and force F and N by their resultant R^I. Thus all these forces are resolved to only two forces R and R^I. For equilibrium, these forces R and R^I should be equal, act opposite to each other and should be collinear i.e.

$$\overrightarrow{R^I} = \vec{F} + \vec{N}$$

$$\vec{R} = \overrightarrow{F_S} + \overrightarrow{N_S}$$

$$= \overrightarrow{F_H} + \overrightarrow{F_V}$$

$$\vec{R} = \overrightarrow{R^I}$$

The two triangles of forces of the above free body diagram have been combined together one called “Merchant Circle Diagram” of cutting forces in which the following new components figure.

F_H = Horizontal cutting force exerted by the tool on work piece.

F_V = Vertical force which helps in holding the tool in position and acts on the tool nose.

These two forces can be easily be found out with the help of strain guages or

Force dynamometers. The angle is also is a known quantity.

α is the rake angle of the tool. ∅ also can be determined with the help of the equation $\text{Tan}\emptyset = \frac{r\ \text{Cos}\alpha}{1 - r\ \text{Sin}\alpha}$. When all these four values i.e. F_H, F_v, α and ∅ are known, all other forces can be easily calculated with the help of merchant circle diagram.

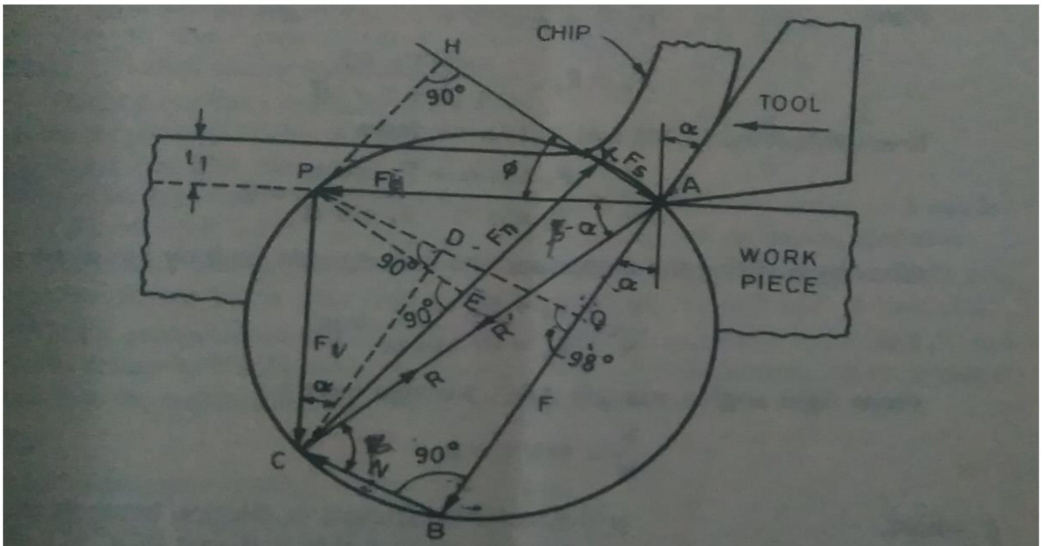


Fig. 5.17. Forces acting in orthogonal cutting (Merchant's Circle Diagram).

$$F = AQ+QB = AQ + DC = F_H\ \text{Sin}\alpha + F_V\ \text{Cos}\alpha \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(1)$$

$$N = QD = PQ - PD = F_H\text{Cos}\alpha - F_V\text{Sin}\alpha \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(2)$$

$$F_S = AH - HK = AH - PE = F_H\text{Cos}\emptyset - F_V\text{Sin}\emptyset \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(3)$$

$$N_S = CE + EK = CE + PH = F_V\text{Cos}\emptyset + F_H\text{Sin}\emptyset \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(4)$$

$$F_H = AC\ \text{Cos}\ (\beta-\alpha) = R\ \text{Cos}\ (\beta-\alpha) \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(5)$$

$$F_S = AC\ \text{Cos}\ (\emptyset+\beta-\alpha) = R\ \text{Cos}\ (\emptyset+\beta-\alpha) \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(6)$$

$$\frac{F_H}{F_S} = \frac{R\ \text{Cos}(\beta-\alpha)}{R\ \text{Cos}(\emptyset+\beta-\alpha)} \qquad F_H = F_S\ \frac{\text{Cos}(\beta-\alpha)}{\text{Cos}(\emptyset+\beta-\alpha)} \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(7)$$

Equation (1) & (2) we have

$$\frac{F}{N} = \frac{F_H\ \text{Sin}\alpha + F_V\ \text{Cos}\alpha}{F_H\text{Cos}\alpha - F_V\text{Sin}\alpha}\,\frac{\text{Cos}\alpha}{\text{Cos}\alpha} = \frac{F_V + F_H\text{Tan}\alpha}{F_H - F_V\text{Tan}\alpha} \qquad \_\_\_\_\_\_\_\_\_\_\_\_\_\_(8)$$

From ΔABC $\frac{F}{N} = \text{Tan}\beta = \mu$ ____________(9)

$\beta = \text{Tan}^{-1}\frac{F}{N} = \text{Tan}^{-1}\mu$

μ = Kinetic co efficient of friction between chip and tool face.

β = Angle of friction

Further $\frac{CP}{AP} = \text{TanPAC}$ $\frac{F_V}{F_H} = \tan(\beta - \alpha)$ _________(10)

KINEMATIC DRIVES OF MACHINE TOOLS:

Every machine tool is required to perform one or both of the following functions kinematic functions:

1. To transmit motion from the input shaft to the output spindle.

2. To transform rotary motion in to translator or reciprocating motion or vice - versa

These transformations in a machine tool are achieved through a chine higher or lower pairs, which consist of the machine tool drive or drive mechanism. The term **"Drive"** includes all the systems of the transmission used in a machine tool to import cutting and feeding motions.

Types of Drives: Machine tool drives, based on different criteria, can be classified as follows:

1. According to the mode of power supply:

a) Individual Drive or Self-Contained Drive

b) Group Drive or Common Drive

2. According to the system of transmission:

a) Mechanical Drives – Belt & pulleys, Gear trains, Power Screws and nuts, Chains etc.
b) Electrical Drives
c) Hydraulic Drives
d) Pneumatic Drives

3. According to the type of motion imported by the drive:

a) Rectilinear Drive – Straight line Motion.
b) Rotary Drive – Circular Motion.

4. According to the regulation of spindle speeds:

a) Stepped Drive.

b) Stepless Drive.

Selection of drive depends upon production time, surface finish and accuracy required, optimum efficiency, power to weight ratio, simplicity of design with respect to maintenance, repair and control.

FEED GEAR BOX

The gear mechanism operated by means of the feed reverse lever is called the tumbler reversing mechanism. This is used for providing power feeds to the carriage. The motion from the spindle to the lead screw or feed rod is transmitted through thin mechanism.

The gear G_1 is mounted on the rear end of the spindles. The feed mechanism consists of feed reverse lever F. when lever f is moved from the central position to either the top or the bottom position, one of the gears G_2 or G_3 will mesh with gear G_1 where as these two gears always mesh with each other mutually . Thus it will be seen that in the top position of lever F motion is transmitted from gear G_1 to G_4, through gear G_3 and gear G_2 plays no role. With the result the gear G_4 will have same direction of rotation as the spindle. Against this is the lower position of lever F motion from G_1 is transmitted to G_4 through G_2 and G_3 respectively. This will enable G_4 to rotate in a direction opposite to that of the spindles. When the lever f is in its central position, neither of the gears G_2 and G_3 will be meshing with G_1 and thus the feed mechanism will be disengaged. The above mechanism is usually enclosed in the head stock except the lever F which is kept projecting outside.

On the same end, as the above mechanism, but outside the head stock, there is another set of gears called **Change Gears**. This consists of gears G_5, G_6, G_7 and G_8 etc. Gear G_5 is mounted on the same spindle as G_4 and thus rotates at the same speed. This transmits motion to gear G_8 through G_6 and G_7. Which further transmits it to the lead screw or feed rod. These four gears are known as **Change Gear** for the reason that they can be removed and replaced by other gears having different number of teeth. Gears G_6 and G_7 are usually mounted on a stud and are known as **Stud Gears.** Gear G_8 is mounted directly on the lead screw on those lathes which do not have a feed gear box, where as it is mounted on the gear box driving shaft is those lathes which early the feed gear box.

SPEED GEAR BOX:

In lathe the spindle is required to operate at various different speeds. For this the head stock is equipped with either a cone pulley drive and back gears, or on all geared head stock which is very common in all modern lathes. In this method the desired speeds are obtained by simply shifting the position of sliding gears by speed change levers. The main driving motor runs always at a constant speed and the desired variations in spindle speeds are obtained through the shifting gears. The head stock has a rigid construction and incorporates a number of sliding clutches and brakes etc.

Some lathes are provided with a two speed motor to have wider range of spindle speeds from the same head stock.

The gear box is designed to arrange the spindle speeds in a Geometrical progression, which means that each spindle speed when multiplied by a constant number gives next higher speed.

If S be the first or lowest speed and C the constant number, then:

2^{nd} speed = S C

3^{rd} speed = S C^2

n^{th} speed = S C^{n-1}

Now if n be the total number of speeds and N be maximum speed, then

$$N = S\,C^{n-1}$$

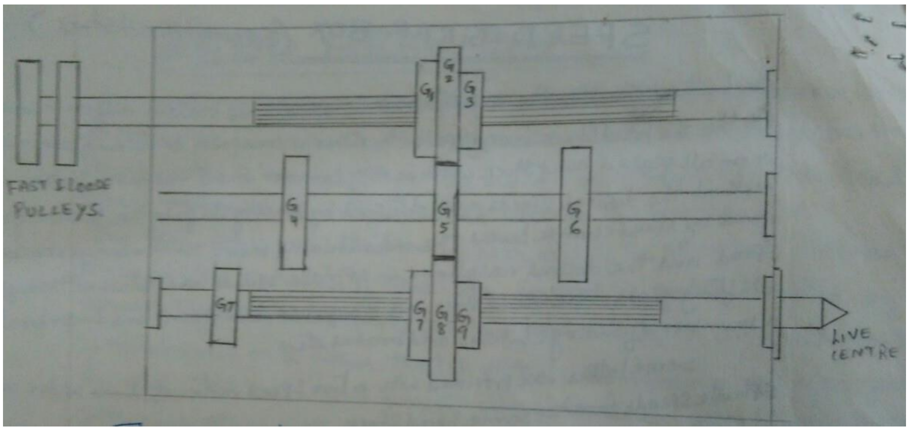
$$C = \sqrt[n-1]{\frac{N}{S}}$$

Internationally the standard values of C has fixed as 1.12, 1.25, 1.4, 1.6 and 2.

Let us consider a simple design of a speed all geared speed gear box.

It consists of a splined shaft S_1 and an intermediate shaft S_2 and lathe spindle S_3. Shaft S_1 carries the fast and loose pulleys on its outside end, through which it receives the power from the driving motor. Gears G_1, G_2 and G_3 are mounted on shaft S_1, gears G_4, G_5 and G_6 on shaft S_2 and gears G_7, G_8 and G_9 on the spindle S_3 which is also splined. Gear G_7 is called **Translating Gear,** flitted on the main spindle for transmitting motion to the lead screw and feed shaft.

The splined shaft provide the sliding gear mechanism, as the changes in spindle speeds are obtained by sliding a set of gears over a splined shaft to bring it in mesh with a cluster (combination) of gears mounted on the other shaft.



The power is transmitted to shaft S_1 from driving motor through the fast pulleys mounted on the shaft extension. Gears G_1, G_2 and G_3 can be brought in mesh respectively with gears G_4, G_5 and $G_6$by sliding the former over spline shaft S_1-by means of a lever. Similarly another lever can be used to slide gears G_7, G_8 and G_9 over spindle S_3 to bring these gears in mesh respectively with G_4, G_5 and G_6. The power is thus transmitted from S_1 to S_2 and then to S_3. Gears G_4, G_5 and G_6 rotate freely on shaft S_2 in their own positions, as they can't be shifted axially. The above shifting of gears enables & different gear combinations to give a different spindle speeds as follows.

1) $\frac{G_1}{G_4} \times \frac{G_4}{G_7}$ 2) $\frac{G_1}{G_4} \times \frac{G_5}{G_8}$ 3) $\frac{G_1}{G_4} \times \frac{G_6}{G_9}$

4) $\frac{G_2}{G_5} \times \frac{G_4}{G_7}$ 5) $\frac{G_2}{G_5} \times \frac{G_5}{G_8}$ 6) $\frac{G_2}{G_5} \times \frac{G_6}{G_9}$

7) $\frac{G_3}{G_6} \times \frac{G_4}{G_7}$ 8) $\frac{G_3}{G_6} \times \frac{G_5}{G_8}$ 9) $\frac{G_3}{G_6} \times \frac{G_6}{G_9}$

Geared drive has the following advantages over cone pulley drive:

1. It is more compact and wide range of spindle speeds.

2. Power available at the tool is almost constant for all speeds but where as in a cone pulley drive it varies with the speed.

3. The spindle speeds can be changed easily by simply moving a lever.

4. Power is obtained directly from an independent motor housed in machine itself.

5. Less vibrations in spindle since driving pulley is not mounted directly over it.

Disadvantages:

1. The lathe of this type is costlier.

2. There is powerless due to friction in gears can be minimized by lubrications.

3. This being a positive drive, the changes of prevention of damage due to over loading are very bleak.

CH – II

LATHE MACHINESS

Lathe removes undesired material from a rotating work piece in the form of chips with the help of a tool which in traversed a cross the work and can be fed deep in work. The tool material should be harder than the work piece. The work piece in held securely and rigidly on the machine. The cutting tool is rigidly held and supported in a tool post and is fed against the revolving work while the work revolves about its own axis the tool is made to move either parallel to it or at an inclination with their axis to cut the desired material. It produces cylindrical surface if it is fed at an inclination.

Specification of a Lathe: A lathe is generally designed by

a) Swing i.e. the largest work diameter that can be swing over the lathe bed.

b) Distance between head stock centers.

Classification of a Lathe: According to size, design, method of drive, arrangement of gears, different precision classes and purpose.

i) Speed Lathe: It is so named because of the very high speed of head stock spindle. It is a simplest form of lathe and consists a simple head stock, a tail stock and tool post. It has no gear box, lead screw and carriage. Tools are hand operated. Cone-pulley is the only source provided for the speed variation of the spindle. Mainly used for wood turnig, metal spinning and polishing operations.

ii) Engine Lathe or Centre Lathe: It is most widely used one. Its name is derived from the fact that early machine tools were driven by a separate engine or from a central engine with over head belts and shafts. The stepped cone- pulley or geared head are often used for varying the speed of lathe spindle. A tail stock is provided to facilitate holding the work between the centers and permit the use of tools like drills and taps etc. The cutting tools are controlled either by hand or by power and can be fed both in cross and longitudinal directions with ref to lathe axis with the help of a carriage feed rod and lead screw. A wide range of attachments can be fitted on it to increase its utility. These are available in sizes to handle up to 1 m dia jobs and 1 to 4 m long.

iii) Turret Lathe: It is a production machine used to perform a large number of operations simultaneously. Several tools are set on a revolving turret to facilitate doing large number of operations on a job in minimum time. An index able square tool post is provided on the cross slide for mounting the turning and parting off tools.

The turret usually accommodates six tools for different operations like drilling counter sinking, reaming, tapping etc, which can be successively brought in to working positions by indexing the turret. Some special tool holders to perform simultaneous multi tool operations are also available. They are widely used be repetitive batch production.

iv) Capstan Lathe: It is similar to turret lathe and incorporate capstan slide which moves on an auxiliary slide and can be clamped in any position. It is best suited for fast production of small parts because of its light weight and short stroke of capstan slide.

v) Tool room Lathe: It is the modern engine lathe which is equipped with all necessary accessories for accurate tool room work. It is a geared head driven machine with considerable range in spindle speeds and feeds. It is suited for production of small tools, dies, gauges etc.

vi) Bench Lathe: It is a small lathe which can be mounted on the work bench for doing small precision and light jobs.

vii) Gap bed Lathe: In these lathes, a gap is provided on the bed near the head stock with a view to handle jobs having flanges or some other producing parts. Very often q removable portion is provided in the bed so that when not required, it can be inserted.

viii) Hollow Spindle Lathe: These lathes are provided with spindles having large through bores in order to facilitate turning the ends of long tubular work pieces. The long jobs are supported on a steady or some other out board support.

ix) Vertical turret Lathes: These have vertical orientation and are use for turning large components which can be conveniently mounted on the machine table. The turret head moves in two axes to enable turning, boring and facing.

x) Automatic Lathes: They are designed for all working and job handling movements of the complete manufacturing a job are done automatically. Operator participation is not required during the operation. In semi-automatic lathes, mounting and removal of work is done by the operator and all other operations are performed by the machine automatically.

xi) Special purpose Lathes: These are desired to suit a definite class of work and to perform a specific operation only. They prove to be more efficient and effective as compared to the common engine lathe.

WORK HOLDERS

1. CHUCKS:

It is the most important device for holding the work pieces, particularly of short length or larger diameter.

a) Independent or Four Jaw Chuck: It has four jaws and each jaw is independently actuated and adjusted by a key for holding the job. This type of chuck is used for irregular shapes, rough casting.

b) Three Jaw or Universal Chuck: In this all the three jaws move simultaneously by turning a key and thus the work piece may be automatically held in the centre of chuck-opening. It is used for holding round, hexagonal bar or other symmetrical work.

c) Collect Chuck: It is mostly used for holding bars of small sizes(below 63 mm) and is normally used where production work is required such on capstan lathe or automates.

d) Magnetic Chuck: They are either electrically operated or of permanent magnet type.

2. LATHE CENTRES:

Lathe centers are used for work holding during turning operation. A centre hole of particular depth and shape is made at each end of work piece. The lathe centers acts as the supports for the work piece and take up the thrust due to metal cutting. These are made of very hard materials to with stand wear and resists the deflection. The included angle of the centre is 60^0 for general purpose work and 75^0 for heavy work.

<u>The various types of centers are:</u>

i. Ordinary centre, which is used for most general work.
ii. Tipped centre, which contains a hard alloy tip brazed in to a steel shank.
iii. Ball centre, which has a ball shape at the end of the centre, instead of a sharp point and is used to minimize the wear and strain on the ordinary centre while taper turning.
iv. Half centre in which case less than half of the centre is ground away, thus facilitating facing of bar ends without removal of centers.
v. Rotating dead centre is used in tail stock for supporting heavy work revolving at high speed.

3. COLLETTS:

A collet is used for holding small semi finished or finished parts so that additional operations may be performed. It is a practical device for quickly and accurately chucking symmetrical work pieces. Collets are available in several shapes i.e. round, square and hexagonal holes to accommodate corresponding shapes of work pieces. The front portion is made conical and transverses slope is made in ¾ this length. The other end is threaded and was a key way to prevent the collet from turning in the collet sleve

i) Draw in type: Which exerts the grip over the bar when it is drawn in.

ii) Push out type: Which exerts the grip over the bar when it is pushed out wards.

4. FACE PLATE:

It is a circular cast iron dies having a threaded hole at its centre so that it can be screwed to the treaded nose of the spindle. It consists of holes and slots by means of which the work can be secured to it. Both, nuts washers clamping plates and metallic packing pieces etc. are required for holding the work properly on a face plate.

5. ANGLE PLATE:

It is used for holding work in conjunction with a face plate. When the size or a shape of the work is such that it is not possible to mount the work directly on the face plate, the angle plate is secured to the face plate and the work is mounted on it.

6. LATHE MANDRELS:

A mandrels is a solid shaft or spindle used for holding bored parts for machining their outside surface on lathe. The mandrel is fitted in to the hole tightly and supports the job during machining of the outer surface. Mainly used for small jobs as bigger jobs will rotates over the mandrels. The solid or plain mandrel is ground to have a shape and a standard taper of 0.5 mm per meter is provided. The milled flat portions at the ends enable the screw of the dog to have a firm grip. Both the ends are made to have centers. The above taper facilitates an easy fitting of the mandrel in to the job hole and also allows for a little variation in the hole dimensions.

The collar mandrel enables a considerable reduction is weight. It is normally used for job above 100 mm dia. The stepped mandrel facilitates use of the same mandrel for various jobs having different size of holes which correspond to the step dimensions.

7. RESTS:

When a very long job is to be turned between centers on a lathe, due to its own weight it provides a springing action and carries a lot of bending movement which results in turning tool spoil and many even break. To avoid this, such jobs are always supported on an attachment known as steady rest or centre rest. This prevents the deflection of job and enables the operator to take heavy cuts.

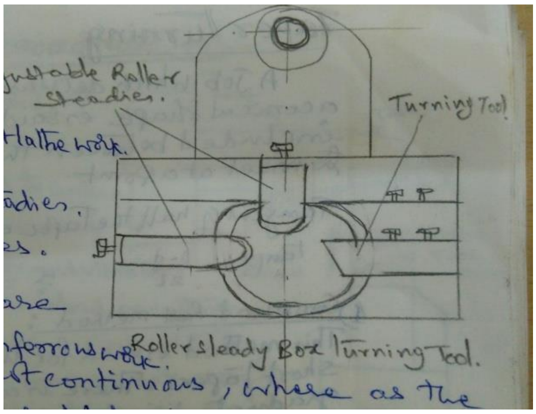
8. JIGS AND FIXTURES:

They are used in conjunction with the face plate on a lathe for supporting and holding add shaped and eccentric jobs during the operation. Their specific use is in mass production of identical parts. If a single item is to be made the cost of product on of jigs or fixtures itself will be too high, prevent their use.

9. DRIVING PLATE:

It is cast circular disc having a projected Boss at its rear. The boss carries internal threads so that it can be screwed on to the spindle nose. It also carries a hole to accommodate a pin which engages with the tail of lathe dog or carrier when the job is held in the lathe dog or carrier. When a bent tail dog is used their pin is taken out and the bent portion of tail inserted in the hole, which serves the same purpose, or else the bent tail can be engaged in the slot made in the plate opposite to the pin hole.

BOX TOOLS



A large number of box tools are in application in capstan and turret lathe work. The common types are.

1. Those having V- shaped steadies.
2. Those having Roller steadies.

V-shapes steadies are mainly used for brass and nonferrous work. Where chips produced are not continuous, where as the roller steadies is mainly used for steel work, where continuous chips are produced. Except difference in the types of steadies, the rest of the mechanical features are same in both types of box tools.

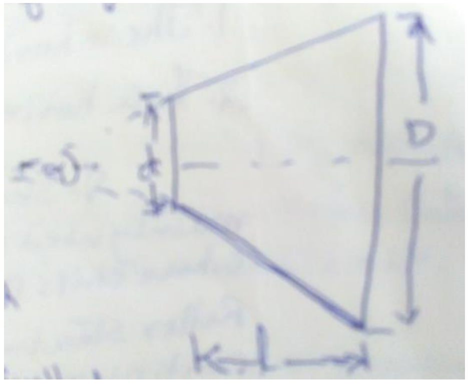
Roller-steady box turning tool consists of a strong body, fitted with two adjustable slides, which carry hardened roller each. By moving the slides, the rollers can be adjusted at any desired distance from the centre of the work to act as travelling steadies during the operation. a single cutting tool is mounted in front of the attachment. In case of heavier type of such tools a supporting bush is fitted at the top to accommodate the pilot bar. This bush can be fitted either in front or back of the body according to the requirement. It is unavoidable when very heavy cuts are to be taken, to prevent vibrations.

The rollers, apart from acting as steadies, provide a burnishing action on the machined surface to give fine finish. The use of these tools some time enables the job to be finished in a single cut only. They facilitate the application of very high speeds.

Some imported designs of box tools take use of ball bearings as steadies in place of the rollers. These tools are normally of V-shape. One arm of these carries the shank and other opposite to it, the ball bearing, which is concentric with the shank. A bush is fitted in the bearing, which is a sliding fit on the bar to be turned. The bush and inner race of the bearing rotate with the bar as the tool is moved forward. The tool is fitted inside the ‘V’ construction to act radically on the job.

TAPER TURNING

A job which decreases in diameter gradually so that assumes a conical shape is said to be tapered. Taper angle is the angle included between the tapering sides of the job when extended to meet at a point.



Tangent of half the taper angle = $\frac{\mathrm{D-d}}{2l}$

$$\tan\left(\frac{\propto}{2}\right) = \frac{D-d}{2l}$$

$$\frac{\propto}{2} = \tan^{-1}\left(\frac{\mathrm{D-d}}{2}\right)$$

1. Compound Rest Method:

This method is used for turning steep and short tapers. There is a circular base graduated in degrees which can be swiveled at any angle from the centre line of the lathe centers.

While turning a taper, the base of compound rest is swiveled through an angle equal to the half of the taper angle. In this case, feed of the tool is given with the compound rest feed handle. This method is used for internal tapers.

2. Tail Stock Set over Method:

This method is used for turning small tapers on long jobs is confined to external tapers only. In this case tail stock may be set over by loosening the nut of the clamping bolt. Then by means of set screws, provided on the both the front and rear sides of the tail stock, the dead centre is shifted from the original position by a predetermined amount of set over. If the larger dia. of the tapered part is to be obtained on the tail stock side, the centre will be shifted away from the operator and if the same is to be obtained on the head stock side the dead centre should be shifted towards the operator. Graduations provided on the flat surface of the tail stock, facing the head stock help in adjusting the required set over. However in the absence of such graduations a steel rule can be used for this purpose.

The required amount of tail stock set over can be calculated as follows:

Set over = taper length × sine of half the taper angle

$$\frac{\mathrm{D-d}}{l} = l \times \sin\frac{\propto}{2}$$

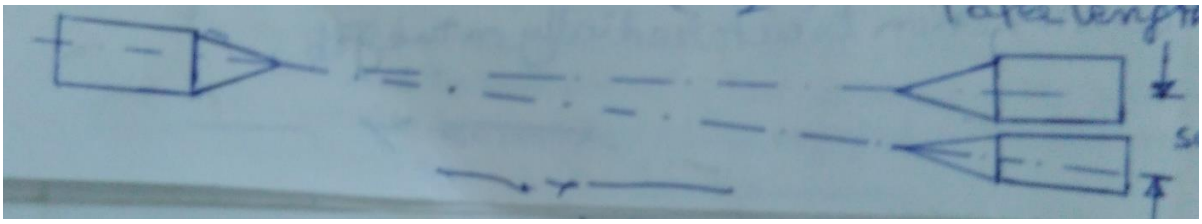
Where D = Lager dia.

d = Smaller dia.

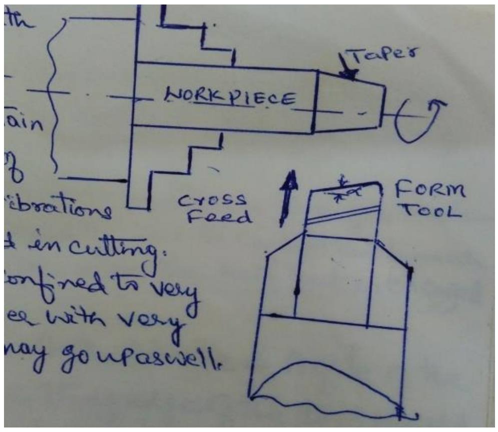
l = Length of taper.

When a part of length of job is to be given tape

$$\text{The tail stock set over } = \left(\frac{D-d}{2}\right) \times \frac{\text{Total length of Job}}{\text{Taper Length}}$$



<u>Taper Turning by form or Broad Nose Tool:</u>



Very sharp tapers can easily be turned with a form or broad nose tool in which the cutting edge of the tool is ground to contain the half taper angle α. However use of this tool will cause a lot of chatter and vibrations because the full cutting edge of tool is involved in cutting. Therefore this method of taper turning is confined to very short tapers of length max 20 mm. However with very heavy and rigid type of lathes their limit may go up as well.

<u>Taper turning attachment:</u>

This attachment is confined to give external tapers only. It is bolted on the back of the lathe and has a guide bar which may be set at the desired angle of taper. As the carriage moves along the lathe bed length, a slide over the bar causes the tool to move in and out according to the setting of the bar. i.e. the taper setting of the bar in duplicated on the work. The main advantage of this system is that the lathe centers are kept in alignment, and the same taper may be turned on various pieces, even though they vary in length.

Advantages of using taper turning attachment:

1. Its setting is very easy and can be done very quickly.
2. Its use does not call for too much of skill on the part of the operator.
3. Accurate tapers can be readily obtained in single setting.
4. Normal set up and alignment of lathe and its main parts is not disturbed during the operation.
5. It is equally suitable for external and internal tapers.
6. It gives better surface finish and increased rate of production because longitudinal power feeds can easily be employed.

In some taper turning attachments instead of graduations in degrees, carries divisions in millimeters. In such cases it is required to find out, the no. of mm divisions through which the guide plate should be swiveled. These divisions can be found out from the formula.

$$M = \frac{D-d}{2} \times C$$

M = Required no. of mm divisions.

D = Larger dia.

d = Smaller dia.

L = Length of Taper.

C = Half the total length of guide plate in mm

THREAD CUTTING ON LATHE

Internal and external threads are cut either with the help of a threading tool or with the help of tap and die respectively. While cutting threads with the help of a tool, the following requirement are fulfilled.

1. There should be a certain relation between the job revolutions and the revolutions of the lead screw to control the linear movement of the tool parallel to the job when the half nut is engaged with the lead screw.

2. The tool should be ground to the proper shape or profile of the thread to be cut. i.e. the tip or cutting edge of the tool should have an included angle corresponding to the included angle of the particular type of thread to be produced.

Irrespective of the shapes and sizes the common factor in all the threads is they are formed on the principle of helix and have a specified longitudinal movement of the cutting tool as the work revolves.

Both external and internal threads can be cut on the lathe. For both of these, the main requirement is to have a proper system of gearing between the lathe spindle and the lead screw so as to establish the required ratio of speeds between the two. For this some lathes are provided with quick-change gear box which provides required speed ratio quickly. This is done by simply shifting the position of the gear change lever. Such gear boxes are made to have a no. of gears inside them, mounted on two or three or more shifts and the different combinations of these gears provide different speed ratios. These combinations are obtained by shifting the gear change lever to different positions. A chart is provided on the gear box which carries the complete information of speed and recommended feed corresponding to a particular position of the said lever.

In the absence of such gear box, the change gears, provided at the left hand side of the head stock are used to obtain the said ratio of speeds.

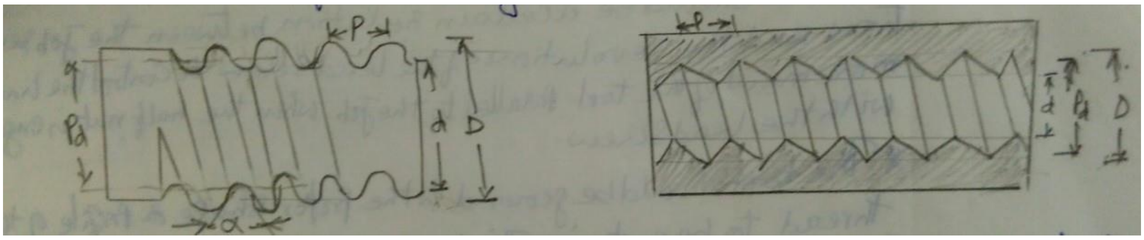
The chief elements of all the screw threads are:

1. Pitch (P): It is the distance from the one point on one thread to the corresponding point on the adjacent thread. This distance is measured parallel to the axis of the job and is expressed in mms in metric threads and inches for other threads.

2. Major Diameter (D): it is the largest diameter of a screwed part, measured at right angle to the axis of the piece.

3. Minor Diameter (D): It is the smallest diameter of the screwed part measured normal to the axis of the piece.

4. Pitch Diameter (P_d): For cylindrical screw parts this dimensions represents the diameter of the imaginary cylinder of which the surface will intersect the threads at such points, where the width of the threads is equal to the adjacent width of spaces between them.



5. Depth of threads (t): It is the distance, measured normal to the axis of the part, between the crest and root of the thread. Mathematically, it can be expresses as $t = \frac{D-d}{2}$

6. Thread angle (α): It is the total included angle between the flanks of a thread or two adjacent flanks of two threads.

<u>RIGHT AND LEFT – HAND THREADS</u>

When we look at a screwed part in a direction normal to its axis its threads will be found sloping downwards from top, either from left to right or from right to left. The former case represents the right handed threads and the latter left-hand threads.

A similar distinction can be observed and the hand of threads reckoned readily by observing the direction of movement when one member, out of the two mating screwed components is rotated. Hold a bolt in your left hand and try to screw on a nut on the same way by your right hand. Note the direction of rotating of the nut and its corresponding axial movement. If the nut advances axially when rotated in a clock wise direction it indicates right hand threads.

If this advancement is attained by rotating the nut in an anti clock wise direction, presence of left-hand threads is indicated. Right hand threads are most commonly employed in engineering practice.

<u>START OF THREADS:</u>

It is the no. of separate threads grooves running parallel to each other along the surface of the screwed part. The threads can be single or multiple starts. In case of single start, the thread is cut with only one thread groove all along its length. When the threads are cut with two, three or more separate thread grooves, each having same dimensions and being equip distance from one another, they are known as double, triple or multiple starts respectively. The advancement for the same amount of rotation of the screw part as compared to the single start threads. If the pitch in both cases remains the same, the axial advancement for the same amount of rotation will become as many times of the single start as the no. of start of the threads. The axial advancement in one rotation of the screwed part is known as lead of the threads or screw. It will obviously, be the distance measured parallel to the axis, between two corresponding points on the same thread.

Pitch in the case of multiple starts threads = $\frac{\text{lead}}{\text{no.of starts}}$

i.e. the pitch will be equal to the lead in case of single start threads.

<u>Lathe setting for screw cutting:</u>

When the lathe is not equipped with a quick change gearbox, a suitable set of gears have to be fondant and mounted at the proper position for cutting the threads of different pitches. Setting up of lathe for such work includes proper holding of the job, concentric with the lathe centers, setting of tool at proper height and mounting of the calculated change gears at proper location.

For cutting threads it is necessary that for every revolution of the spindle or the work, the tool should move parallel to the axis of the job by a distance equal to the lead of the longitudinal feed of the tool and the speed of the spindle. The desired ratio is obtained with the help of lead screw by connecting it to the spindle through a train of gears.

The speed of the lead screw will be as many times lower than that of spindle as its pitch is greater than that of the screw to be cut.

To affect the variant on in speeds, change gears are employed and the amount by which the speed of the lead screw should be higher or lower than that of the work is determined by gear ratio.

$$\text{Gearing ratio} = \frac{\text{Speed of the lead screw}}{\text{Speed of the work}}$$

The pitch of the screw to be cut and the pitch of the lead screw determines the gear ratio of speeds.

$$\text{Gearing ratio} = \frac{\text{Pitch of the screw to be cut}}{\text{pitch of lead screw}}$$

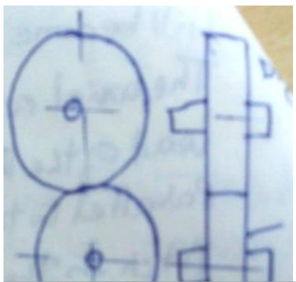
$$= \frac{\text{Lead of screw to be cut}}{\text{Lead of lead screw threads}}$$

$$= \frac{\text{No.of teeth of driver(slide grar)}}{\text{No.of teeth of driven(lead screw gear)}}$$

Or simply $= \frac{\text{Driver}}{\text{Driven}}$

Simple Gear train:

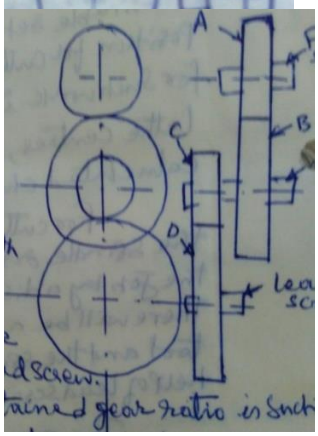
It consists of a driving gear (mounted on the stud), A driven gear (mounted on the lead screw), and oneor two intermediate gears. The intermediate gears (idle gears) have no effect on the speed ratio but are used only



i) to fill the gap between the driver and driven gears, and

ii) to obtain desired direction of rotation of the screw.

Compound gear train:



It consists of two studs instead of one. The second stud is suitably mounted on the bracket or quadrant carrying the change gears. The first driver A is mounted on the first stud, which masher with the first driven Bon the second stud. The second driver C is also mounted on the second stud and it meshes with the second driven D mounted on the lead screw. Such gear train is employed when the obtained gear ratio is such that it is not possible to arrange a simple gear train out of the given set of gear trains. it is not possible to arrange a simple gear train out of the given set of gear trains.

Cutting Metric threads on English standard Lead Screw or Vice-Versa:

When it is required to cut metric threads on a lathe having British standard lead screw i.e. pitch in inches. The relation for conversion

$$\frac{\text{Driver}}{\text{Driven}} = \frac{5}{127} \times \frac{\text{Lead of the screw to be cut in mm}}{\text{Lead of the threads on lead screw in inches}}$$

In case of reverse requirement i.e. when threads of British standard pitcher are to be cut on the lathe having leads screw of metric pitch.

$$\frac{\text{Driver}}{\text{Driven}} = \frac{127}{5} \times \frac{\text{Lead of the screw to be cut in inches}}{\text{Lead of the threads on lead screw in mm}}$$

$\frac{5}{127} = \frac{1}{25.4}$ or $\frac{127}{5} = 25.4$ is the multiplied ratio for conversion from British standard to metric and vice-versa.

Setting Tools for Threading:

In cutting threads, the cutting tools should be carefully set exactly at the height of the centers and normal to the axis of the work. If it is incorrectly set, the thread angle will not be correct and the flanks formed will not be proper. This setting is essential both for external and internal threads. A centre gauge is always used for setting the threading tool correctly.

Feeding the tool in thread cutting:

Two methods are commonly used for feeding the tool in thread cutting. In one case, the tool is set normal to the axis of the work and is fed straight in to the job. Once a cut is complete, the tool is withdrawn from the formed groove, the carriage returned to the starting position and then the tool is fed forward for the next cut. The graduated dial provided on the crops feed screw helps in adjusting the required depth of each cut. The operation is repeated till full depth thread is obtained. In this case, the tool cuts the threads uniformly in each successive cut as both of its sides and its tip do the cutting. If this method is used for cutting coarse threads, the amount of material removed in the form of chips will be too much and it many ultimately jamming the tool and the flanks of the threads will be rough. It is advisable to confine its use only to finishing cuts on coarse threads. However it can be safely used for threads having below 2 mm pitch.

The second method is to feed the tool at any angle to the axis of the work. This angle is half of the total included angle of the thread. The tool is set as usual and required inclination is obtained by swiveling the compound rest to this angle. After every cut the tool is withdrawn by means of cross slide and then set for the next cut. In this case most of the cutting is done by the left edge and tip of the tool.

When threading is to be done large scale, the cutting tool will be provided with top rake angle for easy flow of chips on the tool face and "digging-in" tenderly of the tool is required.

Providing Under Cut:

Under cuts are necessary when cutting threads on stepped work. When the job has two different diameters and the threads are to be cut on smaller dia. it is essential to provide an undercut where two steps meet. It allows for the over run of the tool after one cut is over. In the absence of this undercut there is always a likely hood of the tool running in to the larger dia. after finishing the cut. This will lead to tool to dig which result is riding of the job over tool, bending of job, breaking of job and breaking of tool.

Thread Catching:

The complete depth of the thread can't be obtained in a single cut. Several cuts have to be taken, one after the other, till the required depth is obtained. For this, the tool has to be withdrawn from the thread groove after completing each cut and then brought to the starting position. Then we have to use some suitable method to take the tool fallow the previously cut thread groove. In case it does not follow this path, the threads will be spoiled. The process of engaging the tool with the some groove in all the cuts is called thread catching or thread chasing. The following methods can be used for returning the tool to the starting position.

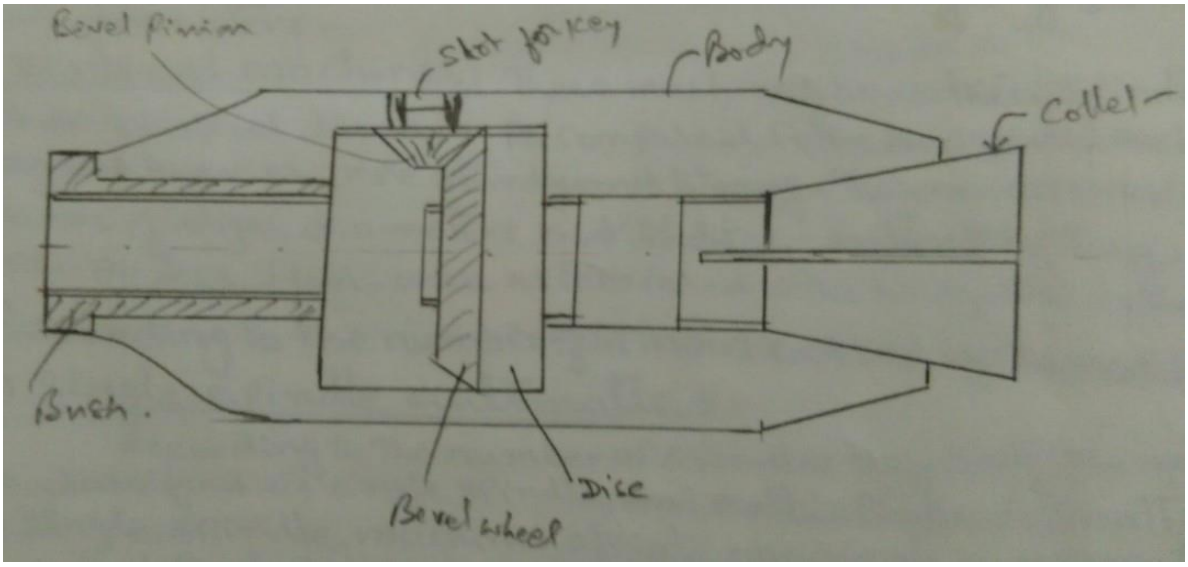
1. After a cut is over the tool is abruptly withdrawn and the machine stopped. The carriage is disengaged from the lead screw by disengaging the half nut and then brought to the starting point by hand. This is usually done in case of long threaded length.
2. When a very short length is to be threaded an alternate method is that, at the end of the cut we do not disengage the carriage from the lead screw. At the end of the cut the tool is withdrawn as usual and the machine stopped. Then the carriage is brought back to its starting position by reversing the direction of rotation of the lead screw. This method is very advantageously used for threading blind holes or for cutting such threads of which the pitch does not allow the use of chasing dial also. Since the carriage and lead screw are never disengaged, the tool automatically follows the previous path.

Correct engagement of the tool with the previously cut thread groove is a must for cutting the threads successfully.

COLLET CHUCK

It can be used with equal advantage on a centre lathe, capstan lathe or turret lathe for producing items from bar stock. It consists of the main body having a tapered inside surface which corresponds to the outside tapered surface of collet. A disc is in corporate in the chuck which carries inside threads to receive the rear threaded end of the collet on the outside surface of the disc, teeth are cut to form a bevel wheel which meshes with the bevel pinion, operated by hand by means of a key. Usually an adopter bush is fitted to the rear side of the chuck which carries internal threads. The assembly is then screwed on to the nose of the lathe spindle.

In operation, when the key is rotated, the disc rotates and in doing so, it either draws in or pushes out the collet, depending upon the direction of its rotation. When the collet is drawn in its spitted body in pressed against the tapered in side surface of the chuck, making a firm grip over the bar. When the collet is pushed out, the pressure on its body relieved and it opens out, releasing the grip on bar, which can be then fed forward.



AUTOMATIC LATHES

Automatic lathes are best suited for production of identical parts on mass scale. They require the application of large number of tools. Once they are properly set, they produce the components at 3 times the rate of the turret lathe of same capacity.

Classification of Automatic Lathes:

Classified according to the type of stock material they use, the operations performed on them, principle of operation and number and position of spindles etc. The main classifications are:

1. According to the type of stock material used:

a) Bar Automatics: The machines designed to produce various components using bar or pipe stock are known as bar automatics.

b) Chucking Machines: These machines are used for machining separate blanks like forgings and castings etc and are also known as magazine loaded automatics.

2. According to the direction of the axis of the Machine Spindle:

a) Horizontal Machines: This classification is according to the arrangement of spindles. These machines have their spindles in a horizontal direction and are used for machining long job of small diameters.

b) Vertical Machines: These machines have their spindles set in a vertical direction. As compared to the horizontal machines, they are heavier, more sturdy and strong. They can accommodate blanks of larger diameters but shorter in length. They occupy less floor area as compared to the horizontal lathes.

3. According to the number of spindles carried by the Machine:

a) Single Spindle automatic: According to the no. of spindles they carry, the machines are classified as single spindle and multi spindles automatics. The single spindle machines are classified as single spindle machines operate on a single component at a time and include some cutting off machines and Swiss type automatic screw machines etc. The automatic cutting off machine is designed to produce short components, requiring turning, forming, drilling, threading, cutting off etc.

Two cross-slides are provided, which are operated by means of cams mounted on a cam shaft. A longitudinal slide is also mounted to carry tools for drilling, remaining, threading etc. All the operations are performed automatically.

The Swiss type automatically screw machines are used for machining slender parts of small diameter. They have a capacity to machine components of 2 to 25 mm dia. they differ from the above machine in that the longitudinal feed are obtained by moving the headstock with the bar instead of tools.

Automatic screw machine is fully automatic bar type turret lathe. They are used for manufacturing screw, both and pins etc from the bar stock. Ten different tools can be mounted at a time. The collet, bar feed mechanism, cross slide and turret slides etc are controlled and operated automatically.

b) Multi-spindle automatics: They are the improved types of single of spindle automatics. They are made to have 2 to 8 spindles, but 4 and 6 spindles are commonly used. The spindles are arranged in a carrier which is periodically indexed from position. The indexing takes place through 90^0 or 60^0, depending upon whether there are 4 or 6 spindles. A gear is centrally mounted in the carrier which drives all the spindles, which are free to rotate in the carrier. This gear rotates independent of carrier. Out of all the positions, one position of the bar forms, cutting off positions, where the finished component in cut off and the bar fed forward up to the stop for the neat operation to be performed at the following position station. At each station(position) the work is machined by tools from two sides, i.e. the cross slide and the main or longitudinal slide. The spindles rotate at constant speed in all the positions. Operating parts of the machine are controlled by means of cams, mounted on a cam shaft. The rate of production increases with multi spindle machines but the machining accuracy of single spindle automatic lathe is much higher.

In automatic machines, cams play the important role and they operate various tool slides, turret and working features of automatic machines. The cams may be made from circular discs or segmental form mounted on circular drums.

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LATHE BED

The bed of the lathe acts as the base on which different fixed and operating parts of the lathe are mounted. It provides for location of fixed parts and controlled movement of the operating part(carriage). It has to with stand the various forces during the cutting tool operation. It must be very rigid and robust construction.

Lathe beds are made as single piece casting of semi-steel (i.e. toughened cast Iron) with the addition of small quantity of steel scrap to the cast Iron during melting. Cast Iron facilitates an easy sliding action & high vibration damping quality. In case of large machines the bed may be made two or more pieces, bolted together. Bed castings usually made to have a box section with cross ribs.

During solidification of the casting, distortion takes place due to cooling stresses. To avoid this natural seasoning called ageing is done. For this the bed castings are rough machined to the required size for final assembly accurately and finely finished. The common bed casting are fine grained with a hardness of 200 ± 10% BHN.

The additional steps taken to improve the wear resistance are:

1. Chilling of Castings.

2. Increasing the hardness of the wearing surfaces by flame hardening.

3. Super imposing separately hardened steel slide ways and prismatic (Inverted ‘V’) ways over the top of the bed casting.

The prismatic ways are preferred over flat ways as their construction totally disallows the entry of chips and dirt etc between the saddle and bed and thus preventing scratching. They provide very efficient guiding surfaces and the wear of the bed does not have any appreciable effect on the overall alignment to the lathe. In most cases the combination of the flat and prismatic shapes of bed ways are adopted. The flat ways acts as supports i.e. taking max load and stress and prismatic shapes act as guide ways. Tail stock is usually guided along the bed way by a combination of one prismatic and one flat way.

Proper leveling of the bed during installation and afterward is very important as this will affect the accuracy of the work very seriously. Therefore the bed should be tested for level both length wise as well as cross wise.

HEAD STOCK

The headstock serves as a housing for the driving pulleys and back gears, provides bearing for the machine spindle and keeps alignment with bed. It consists of the following main parts:

1. Cone pulley
2. Back gears and back gear lever
3. Main spindle or Head stock spindle
4. Live Centre
5. Feed reverse lever

Need for change of speed

There are several reasons due to which different spindle speeds are needed, because the work piece has to be rotated at different speeds under different machining conditions. The main parameters are

1. Work material: Harder and tougher materials need slower speeds while softer materials are machined at faster speeds.

2. Cutting tool material: The harder the cutting tool material the higher is the cutting speed, to take full advantage of higher hot hardness

3. Types of operation: Operations like external and internal threading by means of single point tools, tapping, dicing, remaining etc on lathe need much slower speeds than many other operations like turning, drilling boring, facing, under-cutting etc.

4. Work piece Size: Larger the dia. of work piece to be turned the slower is spindle speed required and smaller the work dia. the higher rotating speed.

5. Surface Finish: Rough machining, where the main requirement is to remove maximum amount of material, needs a deeper cut and slower speed. Against this in finish machining the depth of cut is less and a higher sped used.

6. Cutting Fluid: Use of proper cutting fluid, depending upon the cutting tool and work piece materials and other parameters, facilitates the use of higher cutting speeds and thus increased rate of production and reduction in machining time.

7. Rigidity of Machine Tool: A rigid machine tool in perfect running condition enables use of higher spindle speeds.

TOOL – LAYOUT (for Turret & Capstan Lathes)

Tools for Capstan and Turret Lathe are similar in construction to those of centre lathe tools, except material. The tools used are made of H.S.S or Tungsten Carbide because the machines are more rigid and also operated at higher cutting speeds. The tools mounted on cross slide are used for turning, facing, necking, parting etc, and those mounted on the Turret head are used for drilling, boring remaining etc.

The tool layout for a job constitutes the pre-determined plan for machining operations of a particular component. The layout independent upon the no. of pieces to be manufactured i.e. lot size. As a general rule standard tools should be used as much possible and also for small batcher of work, the layout should be simple. For large quantities and long run special tools should be used as they minimize machining time and retain their cutting qualities for the maximum period. The accuracy and cost of component largely depends upon the tool layout.

For preparation of tool layout, it is necessary to have the finished drawings of the part to be machined and if it is a forging or casting, the forged or cast blank will determine, how much machining has to be done on various faces.

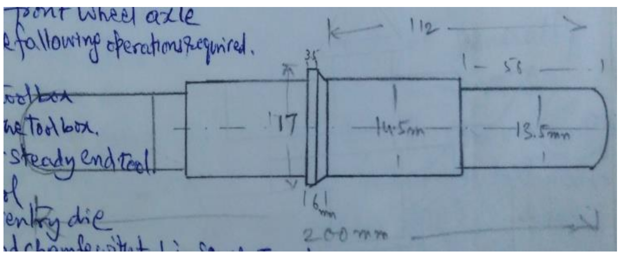
After preliminary list-giving the order of operations has been decided upon with details as the tools required, a tool layout to the scale is prepared on the tracing paper by super-imposing the layout of the machine capacity chart, drawn to the same scale with the component in position. A simple preliminary trial is conducted on the drawing board before it is put on the machine.

Ex: Tool Layout for front wheel Axle.

Tool layout shows types of tools required and the sequence in which they are to be used. While preparing the tool layout the capacity chart of the machine shoeing the capabilities should not be lost sight of. It also ensures that tool movements and turret indexing etc clear the various machine parts. Machining time can be established by listing the operations required systematically in the form of tool – layout.

To machine the front wheel axle from 18 mm steel bar, the following operations required.

1. Feed out the bar
2. Turn 14.5 mm dia. with tool box
3. Turn 13.5 mm dia. with the tool box
4. Round end with roller steady end tool
5. Centre with centre tool
6. Cut thread with Coventry die
7. Form 17 mm diameter and chamfer with tool in square turret
8. Part off with stepped cut off tool in the rear tool post



TOOL POSTS

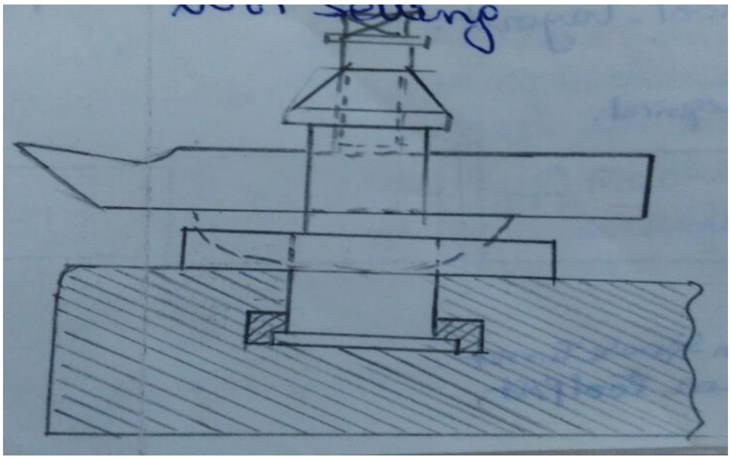
Tool posts are the device used on various machines for holding the tools in position and providing a rigid support to them during the operation.

American type single tool post is used for holding a single tool holder or a solid forged tool only. It is commonly used in light work. It consists of a vertical body having a slot to accommodate the tool shank and a flange at its bottom. The collar carries a spherical groove in which a rocker is placed. This rocker can be tilted to adjust the height of the cutting edge of the tool.

Open side tool post is a better form of a single tool post. The main clamping bolt is used for securing the tool post and the adjusting screws for gripping the tool in position. Height of the tool is adjusted by using flat packing pieces under the tool. This form of tool post used as rear tool post on lathes.

Another useful form of tool Post usually employed on heavy duty lathes. It is provided with 4 bolts, each carrying a coiled spring. Two tools can be simultaneously mounted on it. The tools are held between the bases and clamping bars and gripped firmly by tightening the bolts. The springs help in keeping the bars in position when the tools have been withdrawn.

A square tool post vastly used in mass production. I can accommodate 4 tools at a time. It is also called a turret tool post. It facilitates mounting of 4 different tools prior to starting the operation and bringing them to the desired position, one after the other, by rotating the handle. Such arrangement is an asset and a vital necessity in repetition work, because it saves a lot of time in tool setting.



LAYOUT OF SPINDLE SPEEDS

The following factors have to be decided for designing any stepped drive:

a) Max. output RPM(N_{max})

b) Min. output RPM (N_{min})

c) No. of steps of the transference(n)

d) No. of sub-divisions of steps

e) No. of stages in which steps are to be mounted

In multipurpose machines the selection of speeds in very complex, as correct speed depends upon various factors i.e. the proper toes of job material, shape of the cutting tools, wear resistance of tool material, type of operation to be performed and the process capability of the machine. However in single purpose machine the selection of particular speed depends upon the machining characteristics of that process only. In case of cylindrical work piece, the cutting speed V_C is related to the diameter of the work (D) and the spindle speed(N) by the relation,

$$V_C = \frac{\pi DN}{1000} \qquad \text{Spindle speed } N = \frac{1000V}{\pi D} \qquad \text{\_\_\_\_\_\_\_\_\_\_\_\_ (1)}$$

From the above equation the min. speed of the spindle in depend upon the max. dia of work that can be accommodated in the machine. Also depend upon the min. speed required for screw cutting and tapping.

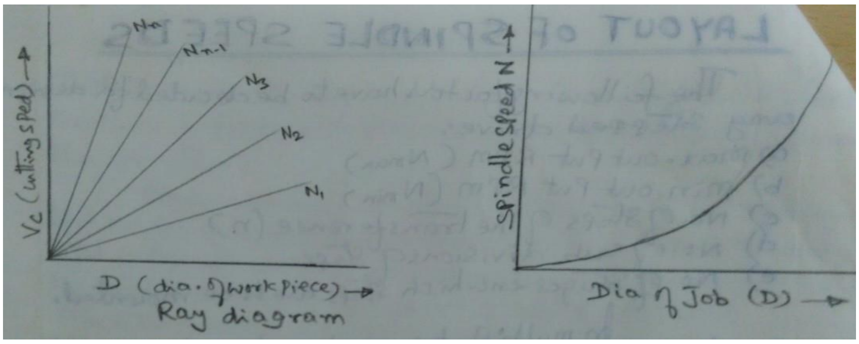
Again from the above equation the max. Speed (N_{max}) depend upon

i) The greatest possible cutting speed (V_C) and

ii) When the diameter is minimum possible.

For design purpose the value of minimum diameter is taken as = (η/8) where η is the height of the centers above the bed.

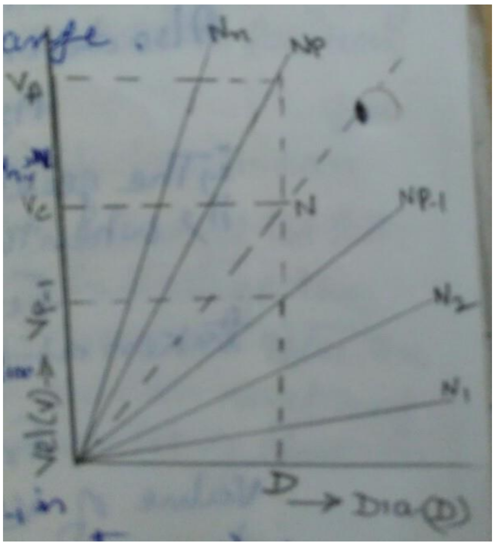
From the above equation it is also obvious that for constant value of V_C as the diameter increases, the speed N should decrease and vice-versa. The output spindle speeds generally form a series which may be in arithmetical progression (A.P), Geometrical Progression (G.P) or Logarithmic Progression (L.P). It is now obvious that for constant N the relation between V_C and D is a straight line. Graphically, the relation between V_C, D and N is represented by Ray diagram.



Let us study the most suited series in all respects for machine tools. Let us assume that a bar in to be machined on a lathe and its diameter D varies from some min.dia to some max.dia. Assuming V_C to be constant, the variant on of spindle speed with change in job diameter is observed.

Initially as the dia of job increases the speed change is not much, but after words, even for small changes in diameter the spindle speed changes rapidly. This condition is fulfilled by G.P. series. Whereas A.P. series follows a straight line an can't fulfill this requirement. This G.P. series is preferred as it can provide more number of ranges of speed at lower range.

Kinematic Advantages of Geometric Progression:



The various speeds in some progression in several steps be N_1, N_2,- - - - - N_{n-1} ,V. Corresponding to certain dia D, the required RPM(N) for accurate cutting velocity(V_C) is not available.

We have select lower speed V_{p-1}. In that case

Loss of Speed = V_C - V_{p-1}

and percentage loss of speed = $\frac{V_c - V_{p-1}}{V_c} \times 100$

$$= \frac{\pi DN - \pi DN_{p-1}}{\pi DN} \times 100 = \left(1 - \frac{N_{p-1}}{N}\right) \times 100$$

Max. Possible speed loss in between two steps N_p and N_{p-1} is = $\left(1 - \frac{N_{p-1}}{N}\right) \times 100$. This loss should be constant for any two available ranges of speeds and for that $\frac{N_{p-1}}{N}$ should be a constant (Say $=\frac{1}{Q}$). This is possible if $\frac{N_{p-1}}{N} = Q$ or if it follows G.P. If N_{max} and N_{min} are max. and min rotational speeds and these are achieved in steps then$\frac{N_{max}}{N_{min}}$ = Range. Range Ratio →40-60 for lathes, 80-100 for capstan lathe, 40 for shapes Range Ratio(R) =Q^{n-1} or $Q = \frac{1}{n-1} \log_e R$ further max. Loss = $1 - \frac{1}{Q} = \frac{Q-1}{Q}$. 20-30 for drilling machines 30-50 mille machines 1-10 grinders for an efficiency of 50% $\frac{Q-1}{Q} = \frac{1}{2}$ or Q=2, for steps less output Q→1 and loss of velocity in that case=0. Thus for G.P. the useful value of common ratio lies between 1 and 2 i.e. 1<Q<2. Value of Q 1.12, 1.26, 1.41, 1.56 & 2 Automatic lathes 1-10.

TOOL LAYOUT FOR AUTOMATIC LATHES

Tool layout is a definite schedule or sequence of different operations to be performed for producing a job and preparing a list and sequence of application of the tools to be used. The important points to be considered are

1. To minimize machining time, try to put as many tools to operate simultaneously. This can be done by over lapping the corresponding machining operators.
2. The job handling operations should also be over lapped with machining operations. This will reduce manufacturing time and increase rate of production.
3. Cutting tools should be planned that during the operation the cutting forces are counter balanced by one another. This will increase tool life and surface finish on the job.
4. If several tools are used separately for rough turning a surface. This will minimize un evenness of the surface.
5. In order to maintain perfect concentricity between external and internal surfaces of a part, these surfaces should be finish machined out the same station.
6. To have a better finished component, avoid over lapping of roughing and finishing operations.
7. In planning the drilling operations the following points taken care
   a) Centre drill should always be used for spot drilling (centering) before hole is drilled.
   b) Deep holes should not be drilled continuously, it should be taken out of the hole many times during the operation in order to break the chips and allow the drill to cool. This will improve tool life and give better finish.
   c) When a hole of varying diameter is to be drilled, always use the drills in a descending order of their diameters. This will minimize total drilling time.

8. Cutting of deep grooves and pasting off should in variably be the last but one and last operations respectively.
9. The operations are planned in such a way that the machining time taken at each station is nearly the same and particularly in multi spindle automatics.
10. Extra ordinarily long single operation should be divided in too many small operations in order to meet the requirement of proceeding point q.

Exp: <u>Producing a Circular Pin on a Capstan lathe from bar stock</u>

The tooling layout for producing the above part is

Procedure:

1. Feed the bar against stop.
2. Rough turn the pin with roller steady box tool.
3. Finish turns the pin with roller steady box tool.
4. Chamfer the pin end.
5. Knurl with concentric knurling tool
6. Cutoff by using the parting off tool in the rear tool post.

Exp: <u>Making a hex. Head bolt on a Capstan lathe from hexagonal bar stock</u>

The tooling layout for producing the given bolt. The operations at station 4 and 5 can be done simultaneously

Procedure:

1. Feed the bar against stop.
2. Rough turn the bolt dia. with a roller steady box tool.
3. Finish turns the bolt dia. with a roller steady box tool.
4. Cut threads with self opening dia. head.
5. Face and from turn the head by the tools mounted on the front tool post.
6. Cutoff parting off tool held in the rear tool post.

MILLING MACHINE

Milling is a machining process of metal removal due to cutting action of a revolving cutter, when the work is fed past it. The revolving cutter is held on a spindle or arbor and the work clamped on the machine table, fed past the revolving cutter. In doing so, the teeth of the cutter remove the metal, in the form of chips, from the surface of the work to produce the desired shape.

It has a capability to perform large number of operations, which no other single machine tool can perform. It gives high production rate, with in very close limits of dimensions. that is why it has largely replaced other machine tools like shaper, planer, slotter etc for small and medium size jobs only. It is too slow for machining very long jobs. For small and medium jobs, the milling machine gives the fastest production with a very high accuracy. It has very wide application in mass production work.

Working Principle:

The metal removing operation on a milling machine, the work is rigidly clamped on the table of the machine and the revolving multi teeth cutter mounted on a spindle or an arbor. The cutter revolves at a high speed and the work fed slowly past the cutter. The work can be fed in a vertical, longitudinal or cross direction. As the work advantages, the cutter teeth remove the metal from the work surface to produce the desired shape.

Size and Specification:

Size of the milling machine is usually denoted by the dimensions (length and breadth) of the table of the machine. Different manufactures, denote these sizes by different numbers 0,1,2,3,4,5,6 etc. each of these numbers indicates a particular standard size. Other main specifications are the Horse power of driving motor, number of spindle speeds, feeds, drive, taper of spindle nose, required floor area etc.

Types of Milling Machines:

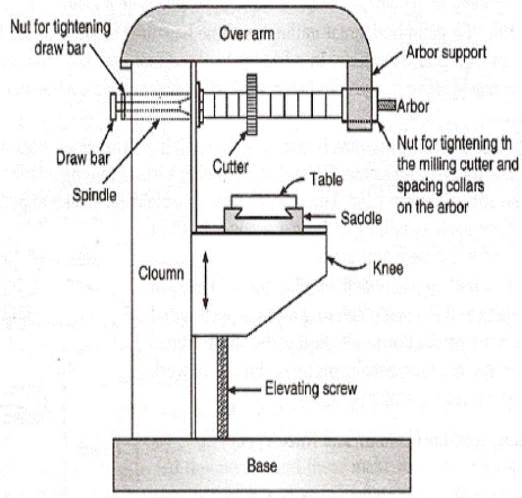
A large variety of different types of milling machines are available, the broad classification of these machines is as follows:

1. Column and knee type milling machines.
2. Fixed bed type or manufacturing type milling machines.
3. Planer type milling machines.
4. Production milling machines.
5. Special purpose machines.

1. Column and knee type Milling Machines

These machines are all general purpose machines and have a single spindle only. They derive their name "column and knee" type from the fact that the work table is supported on a knee like casting, which can slide in vertical direction a long a vertical column. These machines depending up on the spindle position and table movements are further classified as follows:

a) Hand Milling Machine.
b) Plain or Horizontal Milling Machine.
c) Vertical Milling Machine.
d) Universal Milling Machine.
e) Omniversal Milling Machine.



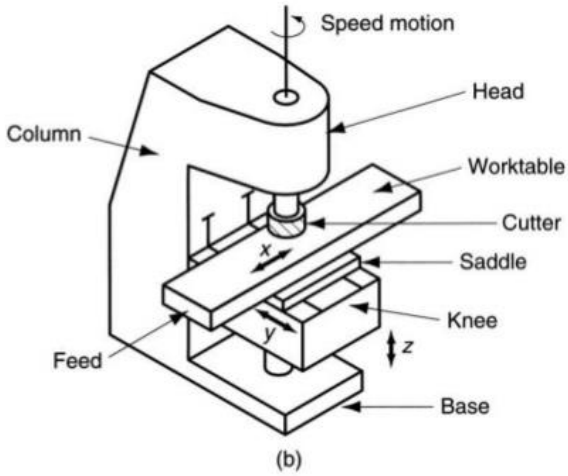


Fig. (b) vertical knee-and-column milling machine

2. Fixed bed type or manufacturing type Milling Machines:

These machines, in comparison to the column and knee type, are more sturdy and rigid, heavier in weight and larger in size. They are not suitable for tool room work. Most of these machines are either automatic or semi-automatic in operation. They may carry single or multiple spindles. The common operations performed on these machines are slot cutting, grooving, gang milling and facing. They facilitate machining of many jobs together, called multi-piece milling. Their further classification is as follows:

- **a)** Plain type (having single horizontal spindle)
- **b)** Duplex head (having double horizontal spindles)
- **c)** Triplex head (having two horizontal and one vertical spindle)
- **d)** Rise and fall type (for profile milling)

3. Planer type Milling Machines:

They are used for heavy work. Up to a maximum of four tool heads can be mounted over it, which can be adjusted vertically and transverse directions. It has robust and massive construction like a planer.

4. Production Milling Machines:

These are also manufacturing machines, but differ from the above machines in that they do not have fixed bed. They include the following machines.

a) Rotary table or Continuous type. **b)** Drum type.

c) Tracer controlled.

5. Special purpose machines:

These machines are designed to perform specific type of operation only

a) Thread Milling Machine
b) Profile Milling Machine
c) Gear Milling or Gear hobbling Machine
d) Cam Milling Machine
e) Planetary type Milling Machine
f) Double end Milling Machine
g) Skin Milling Machine and
h) Spar Milling Machine.

a) Hand Milling Machine:

It is the simplest of all the milling machines and smallest in size. All the operations, except the rotation of arbor, are performed by hand. The table carrying the work over it is moved by hand to feed the work. This machine is especially useful in producing small components like hexagonal or square heads on bolts, cutting slots on screw heads, cutting key ways etc.

b) Plain or Horizontal Milling Machine:

The vertical column serves as a housing for electricals, the main drive, spindle bearing etc. The knee acts as a support for the saddle, work table and other accessories like indexing head etc. Over arm provides support for the yoke which in turn supports the free end of the arbor. The arbor carrying the cutter rotates about a horizontal axis. The table can be given straight motions in three directions, longitudinal, cross and vertical (up and down) but can't be swivelled. For giving vertical movement to the table the knee itself, together with the whole unit above it, slide up and down along the ways provided in front of the column. For giving cross movement to the table the saddle is moved towards or away from the column along with the whole unit above it. A brase is employed to provide additional support and rigidity to the arbor, when a long arbor is used. Both hand and power feeds can be used for the work.

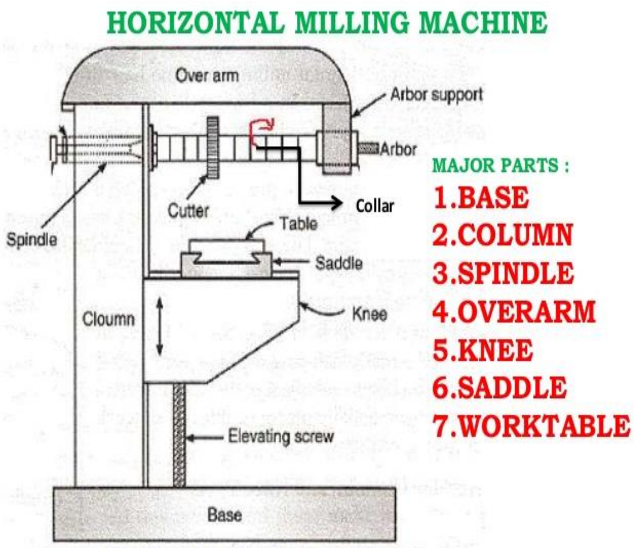


FIG. HORIZONTAL MILLING MACHINE

c) Vertical Milling Machine:

It derives its name from the vertical position of the spindle. This machine is available in both types, the fixed bed type as well as column and knee type.

It carries a vertical column on a heavy base. The over arm in this machine is made integral with the column and carries a housing at its front. This housing called head can be fixed type or swiveling type. In fixed type, the spindle always remains vertical and can be adjusted up and down. In swiveling type, the head can be swiveled to any desired angle to machine the inclined surfaces.

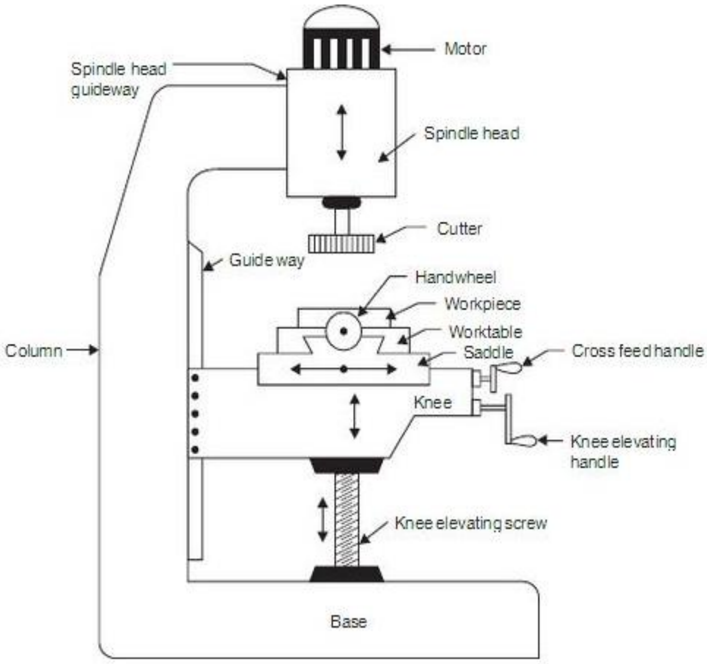


Fig. 4.10 Vertical milling machine

The knee carries an enclosed screw jack, by means of which it is moved up and down along the parallel vertical guide ways provided on the front side of the column. The saddle is mounted on the knee and can be moved, along the horizontal guide ways provided on the knee, towards or away from the column. This enables the table to move in cross-direction. The table is mounted on guide ways, provided on the saddle, which are in a direction normal to the direction of the guide ways on the knee. By means of the lead-screw, provided under the table, the table can be moved in the longitudinal direction. Thus the work gets up and down movement by the knee, cross movement by saddle and longitudinal movement by the table. Power feeds can be used to both the saddle and the table. Mostly face milling cutters and shell-end type cutters are used on these machines.

d) Universal Milling Machine:

It is the most versatile of all the milling machines and after lathe it is the most useful machine tool as it is capable of performing most of the machining operations. With its application the use of a large number of other machine tools can be avoided. It differs from the plain milling machine only in that, the tool can be given one more additional movement. Its table can be swilled on the saddle in a horizontal plane. For this circular guide ways are provided on the saddle along which it can be swilled. A graduated circular base is incorporated under the table, with a datum-mark on the saddle, to read directly the angle through which the table has been swiveled. This special feature enables the work to be set at an angle with the cutter for milling helical and spiral flutes and grooves. It’s over arm can be pushed back or moved and a vertical milling head can be fitted in place of the arbor to use it as a vertical milling machine.

e) Omniversal Milling Machine: This is a modified form of plain milling machine and is provided with two spindles, of which one is horizontal, as in plain milling and the other is carried by a universal swiveling head and can be fixed in vertical position or can be set any desired angle up to 90^0 on both sides of vertical i.e. in a plane parallel to the front face of the column, and up to 45^0 in a plane perpendicular to the former direction i.e. towards or away from the column. Another special feature of this machine is that it carries, in addition to all the possible adjustments provided in a universal milling machine, two more adjustments. These adjustments are of the knee which can be swiveled about a horizontal axis to tilt the table and can be moved horizontally also. These special features make it a very useful machine tool for tool room work as it facilitates various operations to be carried out in different planes and at different angles in a single setting of the work.

PRINCIPAL PARTS OF COLUMN AND KNEE TYPE MILLING MACHINES

Main parts of all the column and knee type milling machines are similar, the movements of the moving parts differ in then. All these machines essentially consists the following main parts:

1. BASE: It is heavy casting provided at the bottom of the machine. It is accurately machined on both the top and bottom surfaces. It actually acts as a load bearing member for all other parts of the machine. Column of the machine is secured to it carries the screw jack, which supports and moves the knee. It also serves as a reservoir for the coolant.

2. COLUMN: It a very prominent part of a milling machine and is produced with enough care. Various parts and controls are fitted to this. On the front face of the column are made the vertical parallel ways in which the knee slides up and down. At its rear side, it carries the enclosed motor drive. A cover is provided on this side, which can be opened to enable accessibility to the drive. Top of the column carries dove-tail horizontal ways for the over arm.

3. KNEE: It is a rigid casting, which is capable of sliding up and down along the vertical ways on the front face of the column. This enables the adjustment of the table height. The adjustment is provided by operating the elevating jack provided below the knee, by means of a hand wheel or application of power feed. Machined horizontal ways are provided on the top surface of the knee for the cross traverse of the saddle and hence the table. For efficient operation of the machine, rigidity of the knee and accuracy of its ways play an important role. On the front face of the knee two bolts are usually provided for securing the braces to it to ensure greater rigidity under heavy loads.

4. SADDLE: it is the intermediate part between the knee and the table and acts as a support for the table. It can be adjusted cross wise, along the ways provided on the top of the knee, to provide cross feed to the table. At its top, it carries horizontal ways along which table moves during longitudinal traverse.

5. TABLE: It acts as a support for the work. The work is mounted on it either directly or held in the dividing head. It is made of Cast Iron, with its top surface accurately machined and carries longitudinal T-slots to accommodate the clamping bolts for fixing the work. Longitudinal feed is provided to it by means of a hand wheel fitted on one side of the feed screw. Cross feed is provided by moving the saddle and vertical feed by raising or lowering the knee. Both hand feed and power feed can be employed the adjustable stops should be used to trip out the same at the correct movement.

Modern milling machines provide rapid traverse in all the three directions to effect saving in time. In universal milling machines, the table can be swiveled in horizontal plane and the graduations on circular base help in adjusting required swivel.

6. OVER ARM: It is the heavy support provided on the top of both plain and universal milling machines it can slide horizontally, along the ways provided on the top of the column, and adjusted to a desired position in order to provide support to the projecting arbor, by accommodating its free end in yoke. If further support is needed, to have additional rigidity, braces can be employed to connect these when many cutters are used simultaneously.

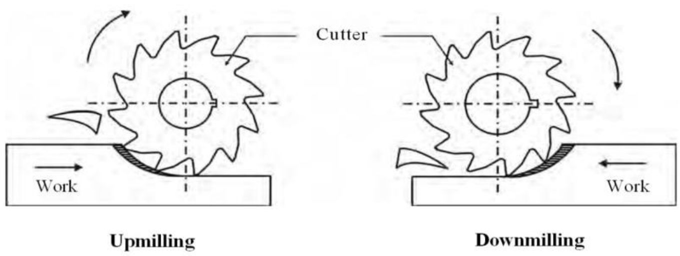
Milling Methods

Milling is a process of metal cutting by means of a multi-teeth rotating tool, called cutter. The form of each tooth of the cutter is the same as that of single point tool. Each tooth after taking a cut comes in operation again after some interval of time. This allows the tooth to cool down before the next cutting operation is done by it. This minimizes the effect of the heat developed in cutting on the cutting edge. With cylindrical cutters, the following two methods are commonly used for cutting operation.

1. Up or Conventional Milling: In this method of milling, the cutter rotates in a direction opposite to that in which work is fed.

2. Down or Climb Milling: In this method the direction of rotation of the cutter coincides with the direction of work feed.

The relative directions of movements of the cutter and work should be noted at the point of contact between the two. In the conventional milling the chip thickness increases as the cut proceeds and in case of climb milling the chip thickness decreases as the cut proceeds. I.e. the chip thickness is zero at start of the cut and maximum at the end of the cut in conventional milling where as it is a reverse case in climb milling.



Upmilling and Down Milling

The section of a particular method of the above two, depends upon the nature of work. The conventional milling is commonly used for machining castings and forgings since this method enables the cutter to dig in and start the cut below the hard upper surface. The climb milling is particularly useful for finishing operations and small work, such as slot cutting, milling grooves, slitting etc. It gives a better surface finish if there is no backlash in feeding mechanism of the table and the work is rigidly held.

MILLING CUTTERS

The milling cutters may have either straight tooth i.e. parallel to the axis of rotation or in helical shape. The helix angle may be right hand or left hand and this will decide the direction of rotation of the cutter for performing the cutting operation. A milling cutter may be made of single piece of steel or having the cutting portion welded to a tough shank or having removable cutting teeth (bits) inserted in a solid body. The broad classification of milling cutter is according to the shape of the teeth they carry, such as plain, inserted, formed or saw teeth etc.

Common types of milling cutters are the following:

1. Plain Milling Cutters
2. Side Milling Cutters
3. End Milling Cutters
4. Face Milling Cutters
5. Metal slitting Cutters (Slitting Saws)
6. Angle Milling Cutters
7. Formed Milling Cutters
8. T-slot Milling Cutters
9. Wood ruff-key Milling Cutters
10. Fly Cutter

1. PLAIN MILLING CUTTERS: These milling cutters may have the cutting teeth on their periphery and they may be either straight or helical. Their end faces are either ground square with the axis or slightly concave to reduce friction. Thus, no cutting action is provided by the side faces. These cutters are employed for milling flat surfaces parallel to the axis of rotation.

The milling cutters are made to have either fine pitch or coarse pitch. Fine pitch teeth cutters are used for light work and finishing work. The coarse pitch teeth cutters are called heavy duty slab milling cutters. They carry less number of teeth, having a steep helix angle. They are commonly used where very heavy cuts are to be used, since they are capable of removing more material with less power consumption.

2. SIDE MILLING CUTTERS: these cutters, apart from having teeth on the periphery, also have cutting teeth on one side or both sides. They are always provided with central hole for the purpose of mounting them on the arbor. They are also called staddle mills when used in pairs. The main types of side milling cutters are the following.

a) Plain side Milling Cutters: They are made to have cutting teeth on the periphery as well as on both sides. They are normally used for cutting slots or in face milling. These cutters are in different widths from 5mm to 25mm and dia up to 200mm.

b) Half side Milling: These cutters have teeth on the periphery and on one side only. They can be used for face milling. The teeth may be either straight or helical. Also they can be either left hand or right hand. Actual cutting action is performed by the teeth provided on the periphery while side teeth do the finishing and sizing work.

c) Staggered teeth side Milling Cutters: The cutters carry alternate teeth on the periphery only. These alternate teeth are of opposite helix angle, staggered from side to side, just as the teeth of wood saw, and cut alternately on one side and then on the other. They are commonly used for key-way cutting and slot cutting.

d) Interlocking side Milling Cutters: These cutters are similar in design to the side milling cutters but are used as a unit, consisting of two cutters joined together such that their teeth interlock. They can be adjusted to aquire the required width by inserting shims or spacers between them to make good the reduction in width of the cutters due to wear and frequent sharpening of the teeth. These cutters are used for milling wider slots to exact width.

3. END MILLING CUTTERS: These are solid circular cutters which are manufactured in two different varieties; those having shank and others which do not have shank. They carry teeth on the periphery as well as on the end. These teeth may be straight or helical. Helical teeth may be right hand and left hand. End milling cutters are used for milling slots, key ways, grooves and irregular shaped surfaces. Shank type end mills may have either taper shank or straight shank and diameters from 3mm to 50 mm.

4. FACE MILLING CUTTERS: These cutters are made in two common forms. The smaller type is known as shell-type-face milling cutter. It carries teeth on periphery as well as on end face. Maximum cutting is done by the teeth on the periphery and those on the end face perform finishing operation. The larger type of cutter, called the **built up face** milling cutter, consists of a steel body, along the periphery of which are inserted cutting teeth. The shell type face milling cutters are used for small work where as built up face milling for larger surfaces. The shell type cutter is usually held in a stub arbor and larger type can be mounted directly on the spindle.

5. METAL SLITTING CUTTERS: These cutters are also called metal slitting saws. They are used for cutting thin slots or parting off. They are very thin. They are in two varieties.

a) Plain Slitting Saws: They are plain milling cutters, which are very thin. Their teeth are provided with some side relief in order to prevent rubbing. They are made in different widths 1mm to 5mm.

b) Staggered teeth Milling Cutter (Saw): These saws are used for comparatively heavier work. They have their teeth staggered alternately and have side teeth also. These saws are in different widths, ranging between 4mm and 10mm.

6. ANGLE MILLING CUTTERS: These cutters carry sharp angular teeth which are neither parallel nor normal to their axes. Their specific use is in milling V-grooves, notches, dovetail slots, reamer teeth and other angular surfaces. The following two types of angular cutters are in common use:

a) Single Angle Cutter: these cutters may have their teeth either only on the angular face or on both, the angular face and side, which enables milling of both flank of the included angular groove simultaneously. Their teeth may have an included angle of 45° or 60°.

b) Double angle cutters: These cutters differ from the single angle cutters in that they have two angular faces which join together to form V-shaped teeth. The included angle of this ‘V’ is either 45^0, 60^0, or 90^0, though it is not necessary that the angle of both the faces should be equal.

7. FORM MILLING CUTTERS: These are also known as form relieved milling cutters or radius cutters. This category includes large variety of milling cutters used for producing different shaped contours. Their teeth are provided with a certain angle of relief, so that their form and size are retained even after resharpening. The common types of form relieved cutters are:

a) Corner rounding cutters: For milling edges and corners of the jobs

b) Concave and convex cutters: Concave cutter for milling convex surface and convex cutter for milling concave surface

c) Gear cutters: For milling gear teeth

d) Tap and reamer fluting cutters: For milling flutes on reamers and taps

e) Gear hobs: For cutting teeth of worm wheels, helical and spur gears

f) Thread milling cutters: For milling different types of threads.

8. WOOD RUFF-KEY MILLING CUTTER: It is a small type of end milling cutter, up to 50mm dia. are to have solid shank, to be fitted in the machine spindle, where as larger sizes are provided with a hole for mounting the same on an arbor. Smaller sizes have straight teeth on the periphery with the sides having little clearance. Larger sizes are usually made to have staggered teeth both on the periphery as well as the sides.

9. T-SLOT MILLING CUTTER: It is a single operation cutter, which is used only for cutting T-slots. In similar sizes it is made to have the shank integral with the cutter. Large size cutters are mounted on a separate shank. In operation, the narrow groove at the top is first milled by means of a slotting cutter or end mill cutter. The T-slot milling cutter is then used for milling the wider groove.

10. FLY CUTTER: It is a single point tool, mounted on a cylindrical body, held in a stub arbor or held in a bar. Screws are used for tightly holding the tool in the holders. Cutting edge of the tool can be ground to any desired shape and is capable of producing a very accurate surface.

MATERIALS FOR MILLING CUTTERS

Materials used for manufacturing the milling cutters are the same as for lathe tools. The common materials used are:

1. High Carbon Steel
2. High Speed Steel
3. Stellite
4. Cemented Carbides
5. Ceramics

High carbon steel is used for small scale production.

High speed steel is extensively used for solid type cutters.

Stellite is used for milling cutters for machining hard metals, forgings, castings etc.

Cemented Carbides are used in the form of bits for milling cutters when high speeds are used.

Ceramics are used for milling bronze and cast Iron. Twice the speed of Carbides.

ANGLES OF A PLAIN MILLING CUTTER:

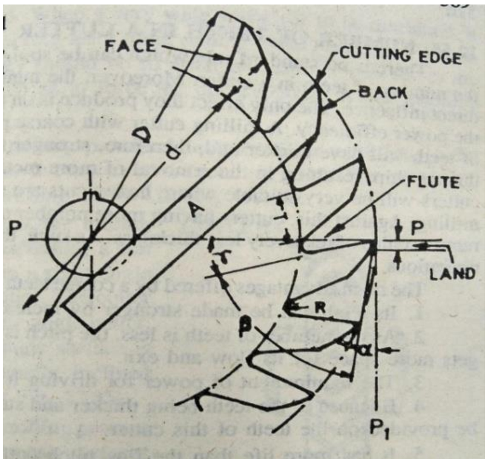


Fig. 12.62. Angles of plain milling cutter. D = Outside dia., d = Root dia., R = Fillet radius, t = Depth of tooth, γ = Rake angle, α = Relief angle, β = Lip angle, T = Max. tooth thickness.

A milling cutter can be considered as a built up unit of a number of single point cutting tools, such that each tooth of the cutter is a single point cutting tool. The relief angle α is the angle between the plain P1, which is normal to the axial plane PP at a point on the cutting edge, and the tangent to the relieved land of the outer tooth. This angle is measured in a plane perpendicular to the axis of the cutter. Higher the value of this angle, lessor will be the friction and hence less wear on the land. A larger relief angle will increase the tool life between two grinds and ensure better surface finish, but at the same time, due to consequent reduction in the lip angle (β), it will make the tooth weak. Normally relief angle ranges between 10^0 to 30^0.

The rake angle (γ) is the angle between the axial plane PP and the face of the cutter tooth, measure in a plane normal to the cutting edge. Rake angle facilitates free cutting by the tool by allowing the chips to flow smoothly. This ensures the less consumption of power, better surface finish, less wear on the tool face and consequently a greater life of the tool between two grinds. However, it should not be increased beyond 20^0 otherwise, the resulting smaller lip angle will again weaken the tool.

The angle between the face and the land of the cutter tooth is called lip angle (β). It value depends upon the values of rake and relief angles. Larger lip angle ensures stronger tooth and helps in milling harder metals and when deeper cuts are used.

INDEXING OR DIVIDING HEADS:

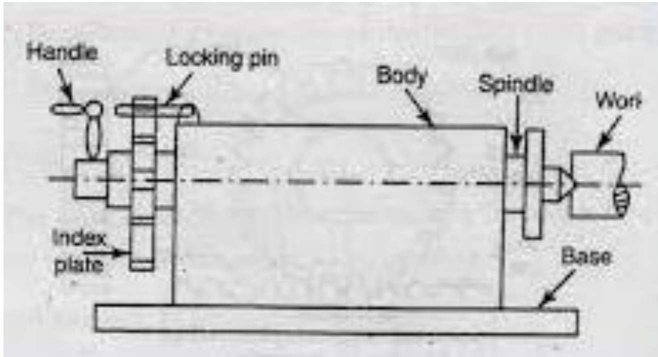
It helps in changing the angular position of the component in relation to the cutter. With their use, it is possible to divide the periphery of the work piece in to any number of equal parts. These heads are generally of the following three types.

1. Plain dividing head
2. Universal dividing head
3. Optical dividing head

Out of these, the optical dividing head is the most precision attachment and is therefore, used for very precision indexing work or for checking the indexing accuracy of the other types of dividing heads.

1. PLAIN DIVIDING HEADS: These dividing heads are mainly of two types. The first type carries the indexing plate directly mounted on its spindle and has no use of the worm and worm wheel. It is the simplest of all the dividing heads and is used in direct indexing. The index plate carries 12 or 24 equal spaced slots on its periphery. The job is held between two centers, one on the dividing head spindle and the other on the tail stock. The hand lever is used for locking the spindle in position. In operation, a lug engages the desired slot of the indexing plate. By means of this dividing head 2,3,4,6,8,12 and 24 divisions can be obtained when 24 slots plate is used and 2,3,4,6 and 12 divisions, when a 12 slot plate is used. The plate, tighter with the spindle, can be rotated by means of the handle provided on the left side of the dividing head.

Another useful form of the plain dividing head is the one used in simple indexing. It consists of a cast body, carrying the spindle. On the front end of the spindle are mounted the index plate, having different hole circles on its face and teeth on its periphery. The plate gets movement through a worm by rotating the handle. The crank, carrying the pin , is mounted on a bolt about which it can be swung to any desired position to bring the pin in front of the desired hole. Usually, plates having 3 circles of 16, 42 and 60 or 24, 30 and 36 holes are provided on these heads. The job is held between the centers.



2. UNIVERSAL DIVIDING HEAD:

This type of dividing head is a very useful device for the purpose of indexing work. It essentially consists of a fairly robust body, enclosed in it is the worm drive, which consists of a worm wheel. The dividing head spindle carries a worm wheel.

The spindle carrying the worm, meshes with the worm wheel, carries a crank at its outer end. The index pin works inside the spring loaded plunger. This plunger can slide radically along a slot provided in the crank in order to adjust the pin position along a desired hole circle on the index plate. The index plate is also mounted on the some spindle as the crank, but on a sleeve such that the worm spindle, and hence the crank can move independent on the index plate. The sector arms provided on the index plate are usually of detachable type and can be set at a desired angle with one another in order to set a definite distance along a desired hole circle. The index plates are available in a set of two or three, with a number of hole circles usually on both sides on them. The spindle carrying the worm wheel is provided with a job carrier (driving device) and a centre at its front end. On the back side of the dividing head is provided a bracket, which carries a slot along its length. One or two studs, according to requirement, can be fitted in this slot and predetermined set of change gears can be mounted on them.

The universal dividing head performs the following operations:

1. It sets the work piece in a desire position in relation to the machining table.
2. After each cut, it rotates the job through a desired angle, thus indexes the periphery of the work.
3. It provides a continuous rotary motion on the during milling of helical grooves.
4. It, in conjunction with a tail stock, acts both as a holding as well as a supporting device for the work during the operation.

USING DIVIDING HEAD

The dividing head provides support to the job, holds it in position and rotates it through a desired angle after each cut is over. The index crank is rotated to provide the rotary motion to the job and the index plate enables this rotation to take place always through a desired angle. When the crank is rotated, the worm rotates which, in turn, rotates the worm wheel. Since this wheel is mounted directly on the spindle, the latter rotates along with the former. The job, being secured to the spindle, by means of a suitable holding device, also rotates as the spindle rotates. The angle, through which the job will rotate, for each revolution of the crank, depends up on the velocity ratio, between the worm and worm wheel. This ratio is usually 40 to 1 i.e. for 40 revolutions of the worm, or of the crank, the job will make one revolution. If the worm is single start, the worm wheel will have 40 teeth along its periphery. However, some dividing heads carry a different velocity ratio of these two and the same should be known before performing the actual indexing operation.

A set of change gears can be incorporated to connect the worm shaft and the spindle. These gears are mounted on the left hand side of the dividing head. The index plates, normally 2 or 3 in number are provided with a number of circles on each face. Each of these circles carries a definite number of holes on them. The standard brown and sharp index plates having the following circles:

No.1. 15, 16, 17, 18, 19, 20
No.2. 21, 23, 27, 29, 31, 33
No.3. 37, 39, 41, 43, 47, 49

Some German made dividing heads, which are commonly supplied with a set of 3 index plates carrying hole circles as follows: (Wider range)

Plate No.1
- One Side 13, 16, 18, 20, 23
- Other Side 15, 17, 19, 21, 24

Plate No.2
- One Side 27, 28, 31, 37, 41, 47
- Other Side 29, 33, 39, 43, 44, 49

Plate No.3
- One Side 18, 19, 20, 23, 29, 33, 39, 43, 49
- Other Side 15, 17, 19, 21, 27, 31, 37, 41, 47

For using the dividing head, first it is to be calculated as to how many full turns, the crank has to rotate through and how many holes on which circle it has to cross further in order to give the required rotation to the work. After that, the sector arms are opened out to accommodate as many holes on that circle, between them, as the crank has to move through for the part of its revolution. Before rotating the crank, the crank pin is withdrawn by pilling the plunger. It rotates independent of the index plate. In differential indexing, where the plate has also to rotate, the same is unlocked.

INDEXING METHODS

Indexing is dividing the job periphery in to a desired number of equal divisions. It is accomplished by a controlled movement of the crank such that the job rotates through a definite angle after each cut is over. The following methods of indexing are commonly used.

1. Direct Indexing
2. Plain or Simple Indexing
3. Compound Indexing
4. Differential Indexing
5. Angular Indexing

Direct Indexing: It is the simplest case of indexing in which a plain dividing head is used. The index plate is directly mounted on the spindle and rotated by hand. It can be used only when the number of divisions to be obtained is such that the number of slots on the periphery of the index plate is a multiple of the number of divisions. The indexing ratio is obtained by:

Required ratio = $\frac{N}{n}$ N = No. of slots on the periphery of index plate

n = No. of divisions required to be obtained

For example, if the circumference of the job has to be divided in to 6 equal divisions and the index plate has 24 slots, then the required ratio will be = $\frac{24}{6} = \frac{4}{1}$ i.e. the index plate will be required to move through 4 slots after each cut is over.

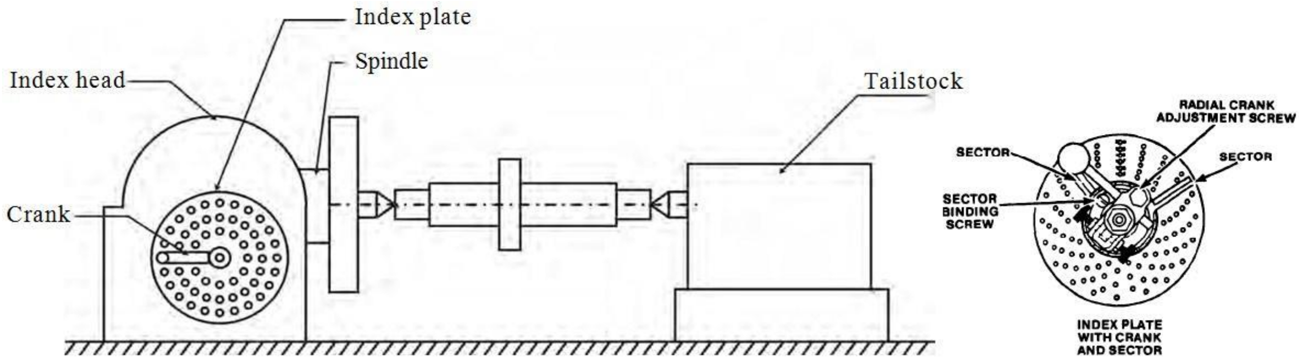
Alternatively, the plain indexing head can also be used for direct indexing. For this, the worm will have to be kept out of mesh with the worm wheel and the ratio obtained in the same way. For example suppose we have to divide the circumference of the job in to 10 equal divisions we select the 60 holes circles and calculate the movement of the crank pin as follows.

The required movement = $\frac{60}{10} = 6$ divisions on 60 holes circle.

2. Plain or Simple Indexing: This method of indexing is used when the direct method of indexing cannot be used for obtaining the required number of divisions on the work. For example: if the work required to be divided in to 22 equal divisions the direct indexing cannot be used, because 22 is not divisible in to any of the hole circles on the direct indexing plate. For such cases, simple indexing can easily be used.

For this, either a plain indexing head or a universal dividing head can be used. This method of indexing involves the use of the crank, worm, worm wheel and index plate. As already described, the worm wheel carries 40 teeth and the worm is single start. The worm wheel indirectly mounted on the spindle.

When the crank pin is pulled out wards and crank is rotated, the worm will rotate which, in turn will rotate the worm wheel, and hence the spindle and the work. Since the worm has single start thread and the worm wheel 40 teeth, with one turn of the crank (i.e. of the worm) the worm wheel will rotate through one pitch distance i.e. equal to $\frac{1}{40}$ of a revolution. Similarly 2 turns of crank will make the work to rotate through $\frac{2}{40}$ and 3 turns through $\frac{3}{40}$ of a revolution. Thus the crank will have to be rotated through 40 turns in order to rotate the work through one complete turn. The holes in the index plate serve to sub-divide the rotation of the index crank.



Index Head

For 2 divisions on the work, the crank will make $\frac{40}{2} = 20$ turns for each division.

For 4 divisions on the work, the crank will make $\frac{40}{4} = 10$ turns

For n divisions on the work, the crank will make $\frac{40}{\text{n}}$ turns

Let us consider that the work has to be divided in to 23 equal divisions,then the corresponding crank movement will be given by

Crank movement $= \frac{40}{23} = 1\ \frac{17}{23}$ turns.

Now, the whole number indicates, the number of full turns the crank has move through, and fraction represents the part of the turn that the crank has to make in addition to the above, in order to make the work to rotate through one required division i.e. $\frac{17}{23}$ of a revolution. In the fraction, the numerator denotes the number of holes to be moved and the denominator the number holes on the circle to be used. Thus for the above indexing, for each division on the job, the crank will make one complete revolution and will move further through 17 holes on the 23 holes circle.

To set the spacing on the index plate and avoid error and confusion in counting the holes every time, the sector arms should be used. These arms can be set, such that they will contain between them only as many holes on a particular circle as are required. This spacing can be maintained for as many operations as desired. For giving full turn to the crank, the pin can be withdrawn from the hole and the crank turned. For the remainder, the pin should be moved from one arm to the other and then engaged. After engaging the pin the arms can be moved further to set the spacing for the next operation.

Examples:

1. It is required to divide the periphery of a job in to 60 equal divisions. Find the crank movement?

   Required movement $=\frac{40}{60}=\frac{2}{3}\times\frac{6}{6}=\frac{12}{18}$ i.e. 12 holes on a 18 holes circle.

2. Required 35 divisions on a plate. Find the indexing movement

   Required movement $=\frac{40}{35}=\frac{8}{7}=1\frac{7}{7}$

   Now $\frac{1}{7}=\frac{1}{7}\times\frac{3}{3}=\frac{3}{21}$ Select a 21 holes circle

i.e. 1 full turn and 3 holes on a 21 holes circle.

In case of fractions, multiply the denominator by any such a number, that the result will give you one number or the other on any of the 3 plates. Multiply the numerator also by the same number.

3. Compound Indexing:

This method of indexing is used when the number of divisions required is outside the range that can be obtained by simple indexing. It involves the use of two separate simple indexing movements and is performed in two stages;

1. By turning the crank a definite amount in one direction in the same way as in simple indexing.
2. By turning the index plate and the crank both either in the same or reverse direction, thus adding further movement or subtracting from that obtained in the first stage.

Principle of Compound Indexing:

Let us consider that the crank is turned 3 holes on a 18 holes circle and the index plate and crank both turned 5 holes on 20 holes circle. On account of these two movements the worm will be turned through:

$$\frac{3}{18}+\frac{5}{20}=\frac{5}{12} \text{ of a revolution.}$$

Since 40 turns of the worm turn the work through 1 revolution.

Therefore $\frac{5}{12}$ turn of the worm, will turn the work through $\frac{5}{12}\times\frac{1}{40}$ revolution

i.e. $=\frac{1}{96}$ of a revolution.

This will enable 96 divisions on the work.

Similarly let us consider another case, where in the second operation the index plate and crank are rotated in a reverse direction to that adopted in the first operation. Suppose the crank is turned 5 holes on the 18 holes circle in one direction and then the index plate along with the crank turned 2 holes on 20 holes circle in a direction opposite to the first on account of these two movements the worm will be turned through:

$\frac{5}{18} - \frac{2}{20} = \frac{64}{360} = \frac{8}{45}$ of a revolution

Now the corresponding movement of the work will be $= \frac{8}{45} \times \frac{1}{40} = \frac{1}{225}$ of a revolution.

Procedure: In order to obtain the required number of divisions, through compound indexing method proceed as follows:

1. Factorize the number of divisions required.
2. Factorize the standard no. 40
3. Select for trial any two circles on the same plate and on its same side factorize their difference.
4. Factorize the number of holes of one circle.
5. Factorize the number of holes of the other circle.

After obtaining these factors place them as follows:

$$\frac{\text{Factors of divisions required} \times \text{Factors of difference of hole circles}}{\text{Factors 40} \times \text{Factors first circle } \times \text{Factors of second circle}}$$

First Check:

If suitable index circle have selected, then all the factors in the numerator will be can celled by those in the denominator. That is we will get unity in the numerator. If it does not happen, select another set of circles and make another attempt in the same way as above. Repeat it till unity is obtained in the numerator.

Now, suppose the above expression, after simplification, comes to the form $\frac{1}{X}$, where x may be any number. If a and b denote the numbers of holes on the two circles, then the required indexing movement is given by $\frac{X}{a} - \frac{X}{b}$ or $\frac{X}{b} - \frac{X}{a}$

The positive part of the two indicates the movement of the crank is one direction and the negative part denotes the movement of plate and crank in the opposite direction. It is always advisable to keep the backward motion as smaller of the two.

Second Check:

After finding the above two expressions, check that the algebraic sum of the two movements i.e. of the crank in one direction, and that of the crank and plate in the opposite direction, should be equal to $\frac{40}{N}$, where N is the number of divisions required.

$$\frac{X}{a} + \frac{X}{b} = \frac{40}{N}$$

Example: Compound indexing for 87 divisions.
Suppose we select circles of 29 and 33 holes.
Putting the relevant factors in the form of the above stated expression and applying the first check we get:

$$\frac{3 \times 29 \times 2 \times 2}{2 \times 2 \times 2 \times 5 \times 29 \times 3 \times 11} = \frac{1}{110}$$

i.e. we get unity in the numerator, indicating the circles selected are correct.
Therefore, the required indexing movement is given by

$$\frac{110}{29} - \frac{110}{33} = 3\frac{23}{29} - 3\frac{11}{33} \quad \text{Or} \quad \frac{110}{33} - \frac{110}{29} = 3\frac{11}{33} - 3\frac{23}{29}$$

Since there are 3 common complete turns in each case they cancel out leaving the required movement as: $\frac{23}{29} - \frac{11}{33}$ or $\frac{11}{33} - \frac{23}{29}$

Since we keep the forward motion of the crank as larger than the backward motion of the plate and crank path, we adopt the first expression for the required indexing movement.

i.e. the movement = $\frac{23}{29} - \frac{11}{33}$

The work will be indexed through $\frac{1}{87}$ of a revolution each time as the crank is moved forward 23 holes on 29 holes circle and the plate and crank backward 11 holes on 33 holes circle.

Now applying the Second Check $\frac{23}{29} - \frac{11}{33} = \frac{40}{87} = \frac{40}{N}$ confirm that the movements obtained are correct.

4 Differential indexing:

In principle it is not much different from compound indexing. It is also carried out in two stages. First the crank is moved in a certain direction. In the second operation that follows either some movement is added to the above crank movement or subtracted from the same. However, the said loss or gain in the movement is obtained by moving the plate by means of a train of gears, connecting the dividing head spindle to the worm spindle. The said motion is gained by rotating the index plate in the same direction as crank and it is lost by rotating the plate in the opposite direction to that of the crank. During differential indexing the index plate locking pin should be taken out to make the plate free to rotate.

The dividing heads are supplied with standard set of change gears. Change gears supplied with Brown &Sharp dividing heads are the following:

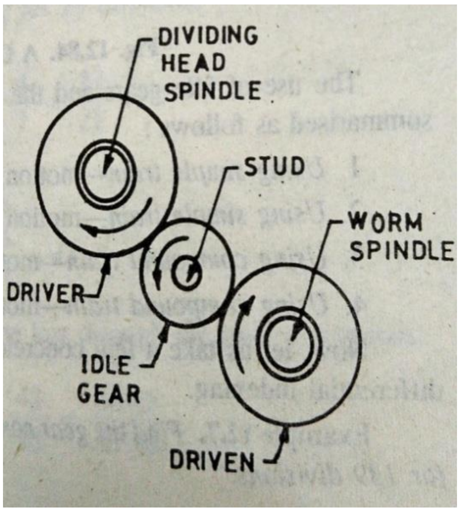
24 (2 No s) 28, 32, 40, 44, 48, 56, 64, 72, 86, 100

In addition to this, some dividing heads are provided with following set of gears

46, 47, 52, 58, 68, 76, 84

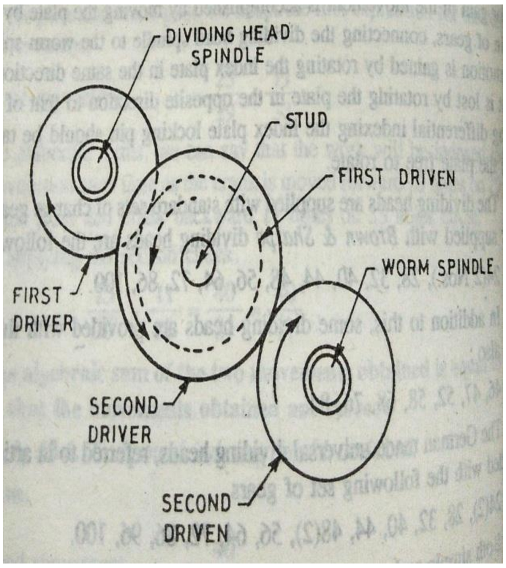
German made universal dividing heads are provided with following set of gears

24 (2 No s) 28, 32, 40, 44, 48(2), 56, 64, 72, 86, 96, 100



Both simple and compound gear train is used in differential indexing. In these gear trains, the first driver is always mounted on the main spindle of the dividing head, i.e. the same spindle on which is mounted the worm wheel inside and the job at the other end. The last driven is mounted on the worm spindle, which drives the index plate. The simple train consists of only one driver and one driven, connected together through one or two idle gears.

The compound train consists of two drivers and two driven wheels. The first driven and 2nd driver gears are mounted on a stud, incorporated between the dividing head spindle and the worm spindle. Idle gear may or may not be used. If it is used, it should be incorporated between the 2nd driver and 2nd driven. The motion in indexing is so transferred that, when the crank is rotated the worm wheel, and hence the spindle, is rotated in the usual way. This, in turn rotates, the first driver. The motion is transferred to the last driven gear. This through the worm spindle is ultimately transferred to the index plate. the direction of rotation of index plate depends upon the type of gear train employed and the number of idle gears used there in. the index plate is required to be rotated in the same direction as the crank if motion is to be gained and in reverse direction if the same is to be lost.



The use of idle gears and the consequent loss or gain of motion can be summarized as follows:

1. Using simple train---------- Motion is gained by using 1 idler.
2. Using simple train--------- Motion is lost by using 2 or no idler.
3. Using compound train----- Motion is gained by using no idler.
4. Using compound train-----Motion is lost by using 1 idler.

Example: Find the gear combination and indexing movement necessary for 139 divisions.

Let us select a number slightly greater or smaller then the given number, such that the selected number can be easily indexed through simple indexing.

Let us select the new number as 140

Simple indexing for 140 divisions= $\frac{40}{140} = \frac{2}{7} = \frac{6}{21}$

i.e. 60holes on 21 holes circle.

Now, if the index crank in turned $\frac{6}{21}$ of a revolution 139 times, it will make

$\frac{6}{21} \times 139 = 39\frac{15}{21}$ Revolutions.

Whereas, for complete one turn of the job it should make 40 complete revolutions. Obviously, the job would not be, thus indexed through exactly 139 equal divisions. The total movement done by the crank is short of the required 40 turns by

40-39$\frac{15}{21} = \frac{6}{21}$ of a revolution.

This fraction is to be gained by the movement of the plate. In order to gain the movement, the plate will have to be turned in the same direction as crank. Also, in order than the divisions are equal, this movement is to be gained gradually, such that certain amount of it is added equally to the crank movement in all the 139 movements of the latter, so as to make it complete 40 turns at the end of these movements. This will be done by using suitable gear train.

Now, the gear ratio=$\frac{6}{21} = \frac{2\times3}{3\times7} = \frac{32\times24}{48\times56} = \frac{\text{drivers}}{\text{driven}}$

i.e. First driver 32 teeth, First follower 48 teeth.

Second driver 24 teeth, Second follower 56 teeth.

5. Angular Indexing:

We have seen that 40 turns of the crank make the work rotate through one complete turn. That is 40 turns of the crank make the work to rotate through 360^0. Therefore for each one turn of the crank the work will rotate through$\frac{360}{40} = 9^0$

Now let us consider 18 holes circle.

If the crank is moved through 18 holes on 18 holes circles, i.e. one turn, it will make the work to turn through 9^0. If it is moved 9 holes i.e. half turn on this circle, the work will rotate through half the above angle i.e. $\frac{9}{2} = 4\frac{1}{2}^0$

Again it is moved 2 holes on this circle i.e. $\frac{2}{18}$ or $\frac{1}{9}$ of a turn,

The work will rotate through $\frac{9}{9} = 1^0$

1 turn of the crank will rotate the work through 9^0

$\frac{1}{9}$ turn through 1^0

$\frac{2}{9}$ turn through 2^0

$\frac{3}{9}$ turn through 3^0 and so on

Or we can say that crank movement=$\frac{\text{Angle required}}{9}$

Now the simple indexing method can be used for indexing when full, half, one third and two third degrees are involved

Example: 1. Index for 3^0-30^1

Crank movement $\frac{3\frac{1}{2}}{9} = \frac{7}{18}$ i.e. 7 holes on 18 holes circle.

2. Index for $31^0\,20^1$

Crank movement $\frac{31\frac{1}{3}}{9} = \frac{94}{3} \times \frac{1}{9} = \frac{94}{27} = 3\frac{13}{27}$

i.e. 3 full turns and 13 holes on 27 hole circle.

3. Index for 60^0

Crank movement =$\frac{60}{9} = 6\frac{6}{9}$ Now $\frac{6}{9} \times \frac{2}{2} = \frac{12}{18}$

Required movement= 6 full turns+12 holes on 18 holes circle.

LAPPING

It is an abrading process, used for improving the surface finish by reducing roughness, waviness and other irregularities on the surface. It is used on both heat treated and non-heat treated metal parts. It is used only where accuracy is vital consideration in addition to the surface finish. The basic purpose of lapping is to minimize the extremely minute irregularities left on the job surface after machining operation.

Lapping is basically used for removing minor surface imperfections, obtaining geometrically true surfaces, better dimensional accuracy and thus facilitates a very close fit between two contacting surfaces.

The material to be selected for making a lapping tool should be soft so that the abrasive grains can be easily embedded in its surface. In case a hard material is used for making the lap, the abrasive particles will quickly go out of their places. The commonly used materials are soft cast Iron, Copper, brass, lead and sometimes hard wood.

Abrasives: Natural as well as artificial are used for lapping. Aluminum oxide is preferred for lapping soft Ferrous and Non-Ferrous metals. Silicon-Carbide and natural corundum are used for hardened steel parts. Powdered garnet is used for lapping soft ferrous and non ferrous metals, emery for hardened steel components and diamond for extremely hard materials like cemented carbides.

Vehicle: It denotes the lubricant used to hold or retain the abrasive grains during the operation. It also controls the cutting action of the abrasive gains. The common vehicles used in lapping are vegetable oil or olive oil, lard oil, water soluble oil, mineral oil, kerosene mixed with a little machine oil, alcohol and heavy grease. For cleaning the laps, naphtha is commonly used. The vehicle should possess the following qualities:

1. It should be able to hold the abrasive particles uniformly during the operation.
2. Its viscosity should not be considerably affected by temperature changes.
3. It should not evaporate quickly.
4. It should be non-corrosive.
5. Its viscosity should suit the operating speeds.

Lapping allowance: Lapping operation is not meant for removing metal. Very negligible amount of material is removed by lapping. Smaller the amount of stock left, quicker will be the lapping process and higher dimensional accuracy obtained.

The recommended lapping allowances range is as follows:

1. General Lapping Work.	Allowance on surface	0.0075mm to 0.0125mm
	Allowance on dia or thickness	0.015mm to 0.05mm
2. For lapping the work which has a finish ground.	Allowance on surface	0.005mm
	Allowance on dia	0.01mm
Pressure and speed for Lapping.	For soft materials	0.07 to 0.2kg/cm^2
	For hard materials	0.7kg/cm^2

In rotary lapping the work and lap have a rotary motion relative to each other varies from 1.5m/sec to 4.0m/sec

Types of lapping operations

Lapping operations can be broadly classified in to two main groups.

1. Equalizing Lapping.
2. Form Lapping.

1. Equalizing Lapping: It is the operation of running two mating parts or shapes together with an abrasive between them. When two such surfaces run together in constant contact with the abrasive, their surface finish is improved and any deviation of shape is corrected. The results can be easily seen during seating of tapered valves in their seats or rotated together with these objectives.

2. Form Lapping: As it is clear from the name, it is not merely rubbing of surfaces together, but it is the shape of the lap that is responsible for finishing a corresponding work surface. Obviously, the lap used in the operation will be a form lap, containing the shape to be lapped.

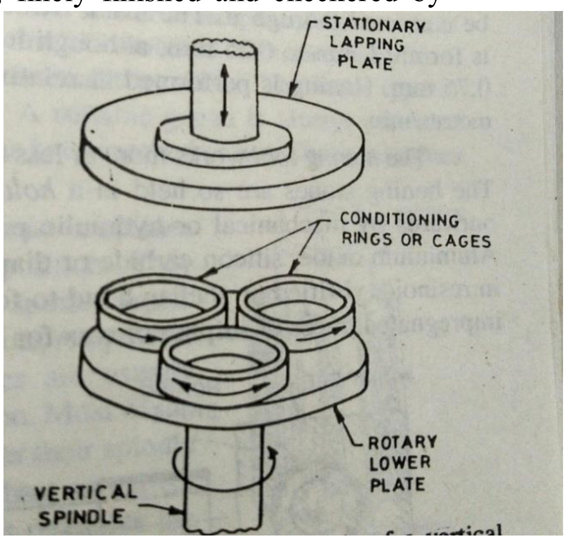
Lapping Methods and Machines

Lapping is done in the following two ways:

1. By Hand ______ Called Hand Lapping.
2. By Machines ______ Called Machine Lapping.

1. Hand Lapping:

In hand lapping, either the lap or the work piece is held by hand and motion of the other enables the rubbing of the two surfaces in contact. This method is widely used in lapping press work dies, moulding dies and moulds for casting, limit gauges etc. In some cases the lapping compound is placed between the two surfaces and the two are rubbed together by moving one of these by hand, the other remaining stationery. A few examples of this method are lapping of surface plates, engine valve and valve seat etc. whatever work may be method used, out of the above two it is necessary that the work and lap are not rigidly guided with regard to one another and that their relative movement is kept along an ever changing path, i.e. not repeated along the same path. Example: The bottom surface of a hardened steel piece being lapped on a cast Iron plate. The top surface of the plate is made perfectly plane, finely finished and checkered by providing cross grooves. These grooves help in collecting excess abrasive grains and removed chips.



Before commencing the operation the lapping compound is spread over the top surface of the plate. Grey cast Iron, which is porous and soft, is the material used for the plate. It is therefore, able to retain the abrasive grains (lapping medium). The work piece is placed over the lapping medium and rubbing over the same. The movement of the work piece has to be along an irregular path, not just to and fro. In this case the work piece is moved along a path taking a shape of number 8.

2. Machine Lapping:

Machine lapping is performed for obtaining a highly finished surface on many articles like races of ball and roller bearings, Gears, Crank shafts, machine bearings, pistons, pins and gauges, gauge blocks, various automobile engine parts and micrometer spindles etc. Many different types of machines are used in lapping. A typical vertical spindle machine consists of two bonded abrasive wheels in place of the above rotating wheels. Obviously, no loose abrasive is required in this case. In both the machines, the lower wheel rotates and the upper one does not, but floats over the work pieces. These two machines can be used only for circular and flat work.

Working Principle:

The work pieces are loaded on conditioning rings or cages on the rotary lower plate, which rotates about a vertical axis. At the same time, the conditioning rings also rotate along with the work pieces in their own positions. The combination of these two rotary motions provides a gyratory motion to the work pieces, due to which the entire surfaces of the two plates are covered. This results in an even wear of the plate surface and therefore, its flatness is maintained. The upper plate just provides a floating action and helps in maintaining parallelism. Most of the commonly used engineering materials can be lapped by this type of arrangement. In case of slender jobs, a work holder is incorporated between the two lap plates to keep the work pieces in proper alignment with the plates.

Some modern lapping machines are provided with vibratory motion instead of rotary motion, the lower plate carrying the abrasive paper fixed on its top surface. Work pieces are held over this paper by providing light pressure from the top plate. The lower table is vibrated and as a result, the work pieces flow on the emery paper for lapping.

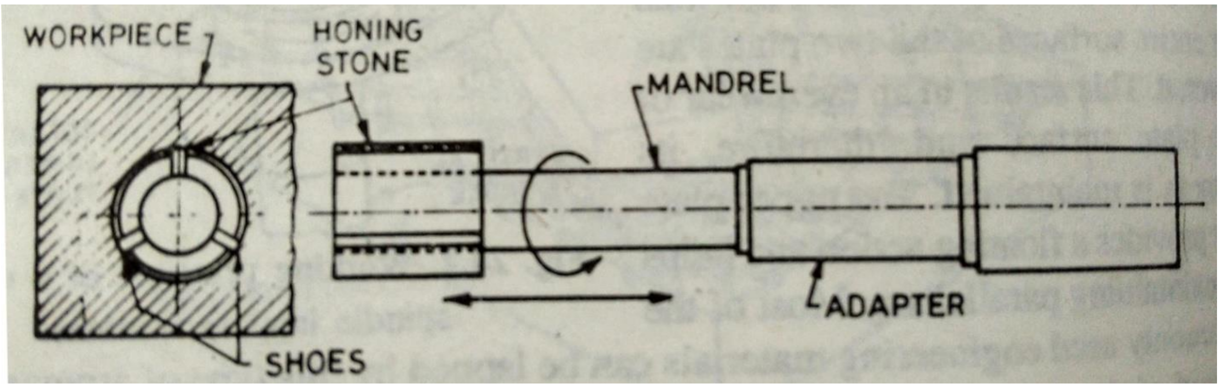
For lapping crank shafts and pins etc, an abrasive belt machine is commonly used. This machine is a horizontal spindle machine, of which the spindle carries the crank shaft. During the operation, the crank shaft gets a small reciprocating motion. This machine neither uses the embedded abrasive laps nor the bonded wheels. Instead of them, coated abrasive like paper or cloth care used.

A centre less grinding machine can be conveniently adopted to perform lapping operation for round objects. The bonded wheels will be sufficiently large so that the work piece is subjected to the abrasive action of the wheel for a longer period on each pass. Another special feature of these wheels will be that, they will have their grains of a much finer grit. Rest of the setting and operation will be quite similar to centre less grinding

HONING

It is also an abrading process, used for finishing previously machined surfaces. It is mostly used for finishing internal cylindrical surfaces such as drilled or bored holes. The tool used called a hone, is a bonded abrasive stone made in the form of a stick. Although honing enables the maximum stock removal out of all the surface finishing operations, still it is not primarily a metal removing operation. However this higher stock removing capacity enables the application of honing for correcting slight out of roundness or taper. Hole location cannot be corrected through it. The usual amount of stock left for removal by honing is from 0.1 to 0.25mm although it is capable of removing the stock up to 0.75mm. Honing is performed at relatively slow speeds in the range of 10 to 30 m/min.

Honing tool works more or less in the same way as an expanding reamer. The honing stones are so held in a holder or mandrel that they can be forced out wards by mechanical or hydraulic pressure against the surface of the bore. Aluminum oxide, Silicon Carbide, or diamond grains of suitable grit are bonded in resinoid, vitrified or shellac bond to form the honing stones, usually carrying, impregnated traces of sulphur or wax for longer tool life and better cutting action. Both internal cylindrical and flat surfaces can be honed. But the process of honing is largely applied to internal cylindrical surfaces only.



Hand Honing Process: Honing is a 'wet' process and it is necessary that a suitable coolant be used in ample quantity during the operation. In small parts, honing can be done by hand. In this, the hone is rotated and the work piece moved over rotating tool, back and forth by hand. The length of stone used is about half of that of the hole and the over travel at the end of the each stroke is about one- third of the stone length.

Machine Honing: The process of honing can be done on many general purpose machines also, such as lathes and drilling machines. Where the stationary type of machines do not suit the nature of work, a portable electric drill can be used for this purpose by fitting a hone is place of the drill, the reciprocating motion being given by hand. In production work, where honing is to be done on a large scale, such machines will fail to give satisfactory and economical results. In such cases, the use of regular honing machines only will give the desired results. These honing machines are made in various types and sizes. The most common classification of these is as follows:

1. Horizontal honing machines: These machines are mostly used for honing comparatively longer jobs, such as gun barrels. All such machines carry a horizontal spindle, on which is mounted the honing tool. On some machines the work piece is mounted on a table which reciprocates hydraulically to move the work to and fro on the hone, which rotates about its own axis and also simultaneously, oscillates a little. The oscillating motion of the hone may be controlled hydraulically or mechanically. In some machines the work is held in a horizontal position and rotated about its own axis. No reciprocating motion is given to it. Against this, the honing tool, which is mounted on a travelling head, is rotated and reciprocated to give the same result. The latter type of machine is used for extremely long jobs. A suitable gauge is always provided to indicate as to whether the correct size has been reached or not. These machines may carry single or double spindles.
2. Vertical honing machines: These machines hold the work as well as the tool in vertical positions. They are available in both single and multiple spindle types. Usually, the spindle heads and the tools reciprocate and not the work pieces. Suitable fixtures are used to hold the work pieces in position. Most of the modern machines carry a hydraulic drive for their spindle heads and the tools. These machines are best suited for shorter jobs. These machines resemble the drilling machines. In honing work, the vertical machines are more widely used than the horizontal ones.

Advantages of honing:

1. Rapid and economical removal of stock with minimum heat and distortion.
2. Generation of round and straight surfaces by correcting taper, out of roundness or shakiness caused by previous operation.
3. Development of any desirable surface finish.
4. Accurate control of size.
5. Distribution of cutting point over large contact area reduces heat generation during cutting.

Why straight and round bores are produced by honing:

1. Tool or fixture has a float which enables to apply equal pressure on all sides of the base regardless of vibration in machine. Tool is free to follow neutral axis bore.
2. Tool is expanded by wedging action of cone. Angle is shallow enough to be non-reversible. As tool is stroked in, the pressure will be maximum at high spots. If feed is positive controlled, any taper or out of roundness will be removed before stock removal from large sections.
3. Abrasive sticks have area contact with the surface and are rigid throughout the full length. They cannot follow bore but tend to straighten. These bridge on low spots and cut on high spots.
4. After irregularities have been leveled off, every section of the surface receives equal abrasive action. To accomplish this reciprocating or rotary motions are fixed at odd ratio, to one another. This assures that every part of the bore will be covered before any grit repeats its path of travel. Stick length is about half of the bore and stroke is such that $\frac{1}{2}$ to $\frac{1}{4}$ of stick length over shoots the bore at the end of stroke.

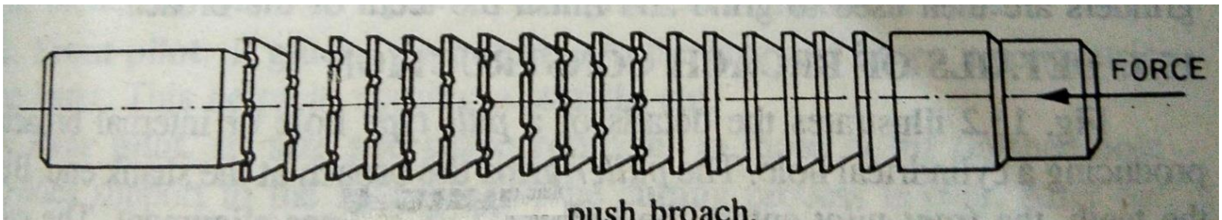
BROACHING MACHINES

Broaching is a machining operation in which a tool, having a series of cutting teeth, called broach, is either pulled or pushed by the broaching machine past the surface of a work piece. In doing so, each tooth of the tool takes a small cut through the metal surface. The surface to be cut may be external or internal. When the operation is performed on internal surface it is called **Internal or hole Broaching** and in case of external surface **External or surface Broaching.** Most of the cutting is done by the first and intermediate teeth, where as the last few teeth finish the surface to the required size.

Types of Broaches: There is large variety of broaches and they are classified.

1. According to the method of operation**:** Push, Pull or Stationary.
2. According to the kind of operations they perform**:** Internal and external.
3. According to their construction**:** Solid, built up, rotor cut, inserted tooth, over lapping tooth, progressive etc.
4. According their use**:** Single purpose or Combination.
5. According to the functions**:** Key way, spline, burnishing, roughing, sizing, serration, rifling, surface, spiral etc.

Push broaches are shorter in length than the pull broaches, of the same cross-section in order to ensure adequate stiffness to resist bending. Push broacher is used where a shorter length is to be broached and less material is to be removed. Where a considerable amount of metal is to be removed and a longer surface is to be broached a pull type broach, which carries more number of teeth and is longer, and hence removes more material is preferred. Internal broaches are generally made of solid construction, but where chances of wear are more and high accuracy is desired a shell type construction is always preferred, which consists of several replaceable shells mounted on a bar. They are known as built-up broaches. External or surface broaches are generally of built-up type having replaceable sections or teeth. The broaches used to produce single surface such as a round hole, are known as single purpose. Against this, many broaches, called combination broaches are designed to take two types of cuts simultaneously and produce two different surfaces or perform two different operations such as sizing and burnishing a hole or sizing a hole and cutting splines in it. Both the operations are done in a single pass of the tool. A burnishing broach is used for producing a highly finished and glazed surface. It is the tool (broach) which moves, while the work is stationary, but in certain cases the broach remains stationary, where as work pieces are moved past it as in continuous broaching machine. A broach made in single piece is known as solid broach.



push broach.

The internal broaches which are normally of solid type are commonly used for enlarging and sizing an existing hole and/or providing specific shapes to the existing holes. These holes in the components exist due to earlier operations on them, such as drilling, casting, forging, punching etc. Rotor cut broaches are used for heavy stock removal in castings and forgings.

Tool materials and Heat treatment:

For light work broaches made of high carbon steel are used. High speed steel is the most commonly used material for the manufacture of broaches and they give satisfactory performance in mass-production, and heavy duty work. They give fine surface finish and have long life. Broaches having their teeth tipped with sintered carbides used for hard materials and abrasive materials. Their use is mostly confined to mass production work in surface broaching.

Proper heat treatment and subsequent grinding are two very important aspects in manufacturing a broach. Long broaches are heated in vertical type of electric furnace, so that there is a uniform distribution of heat throughout the entire length of the tool and the distortion is minimum. This is followed by cooling in air under pressure. The broach is hung vertically during air cooling also in order to avoid war page. Short broaches are heat treated in horizontal furnaces. Specially designed grinders are used to grind and finish the teeth of the broach.

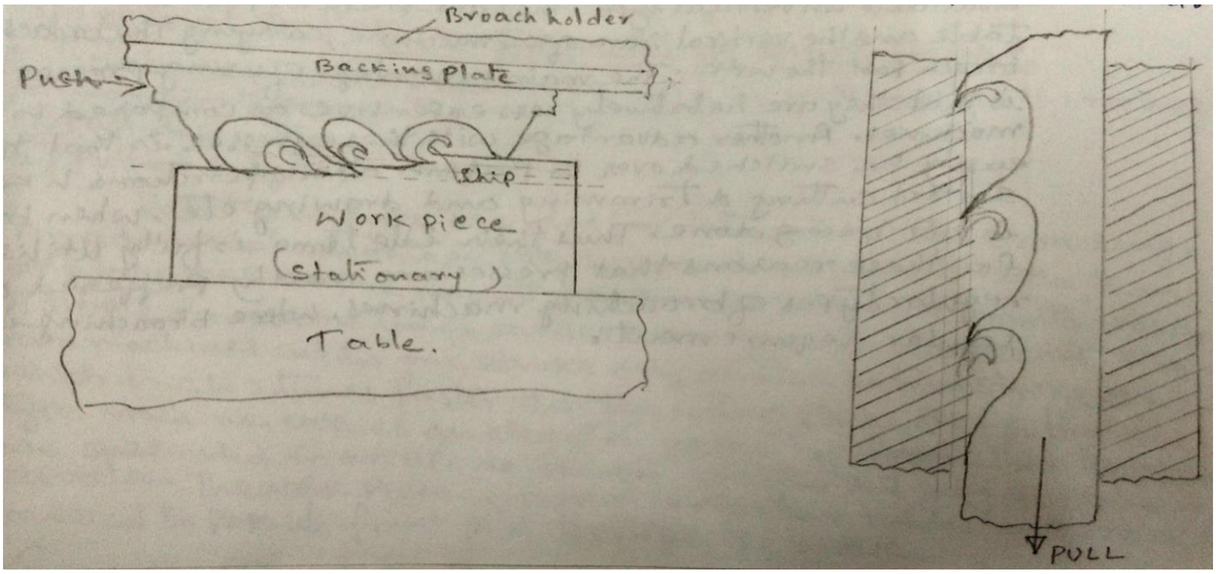
Broach Construction: The front pilot enters the hole to keep proper alignment. The cutting teeth follows the front pilot, gradually increase in size. The first set of cutting teeth, called roughing teeth, does most of the cutting. They are fallowed by semi-finished teeth, which remove comparatively less stock. The variation in their sizes will be smaller than the roughing teeth. They bring the size of the hole to the required size. The finishing teeth which follow after semi finish teeth do not practically remove any stock but they smooth finish the hole. When the first finishing teeth are worn out, those behind them start doing the sizing operation. The rear pilot supports the broach and keeps it aligned after the cut is over.

PRINCIPLE OF BROACHING:

The operation of broaching involves the use of a multi tooth cutter, called broach. The teeth of the broach are so designed that the height of the cutting edge of the following cutting tooth is slightly more, equal to the feed per tooth, than that of the preceding tooth. Thus when the broach is fed in a straight line, either, over an external surface or through an internal surface, the metal is cut in several successive layers by successive teeth of the broach. The thickness of each layer is same and is known as feed per tooth. The sum of thickness of all the layers taken together is called the depth of cut.

During the operation either the broaching fed past the stationary work piece or the work piece past a stationary broach, the former practice being more common. The surface produced carries an inverse profile to that of the broach teeth. A specific point regarding broaching is that out of all the basic machining processes, it is the only process in which the feed is in built in the tool (broach). This feed is equal to the chip the thickness.

A push type broach is fed past the stationary work on a horizontal broaching machine, to machine an external surface on the work piece. A pull type broach is fed in to the hallow work piece on a vertical pull-down type machine, to machine an internal surface of the work piece. In this case also, the work piece will remain stationary. Both the operations are performed in a single linear stroke of the broach. After end of the stroke in both the above operations, the broach is retraced to the original starting position, the finished part is replaced by a new work piece and the operation repeated as usual.



TYPES OF BROACHING MACHINES:

There are a number of different designs of broaching machines available in different sizes and capacities. A few of them like **arbor press** are manually operated and the rest all are operated by power. Manually operated machines are used normally where only a few pieces are required to be broached and the components are small in size. Where broaching is done on mass scale, a power driven machine is used.

The common types of broaching machines can be classified as follows**:**

1. According to the power employed---Manually operated or Power driven.
2. According to the direction of broach movement in cutting---Horizontal or Vertical
3. According to the method of cutting---Pull, Push or Continuous.
4. According to the condition of movement of the tool relative to the work---Moving or Stationary broach.
5. According to the type of drive---Mechanical or Hydraulic drive.
6. According to number of pull heads---Single or Multiple pull head.

Broaching Press: A small number of jobs can be easily broached on a manually operated arbor press. This is simplest and lightest of all the presses used in broaching work and is manually operated.

Modern power presses, used for broaching on mass scale, usually carry a hydraulic drive. Push type broaches are commonly used on these machines. Both internal as well as external broaching can be done, but internal broaching is more commonly performed on these machines. These machines are made in various different sizes, ranging in capacity from 250kg to 35 tons pressure. These machines are generally available in vertical type. The work piece is placed on the machine table and the vertical ram of the machine, carrying the broach, pushes the broach past the work. The main advantage of using presses for broaching is that they are relatively less expensive as compared to other broaching machines. Another advantage with these presses is that, they can easily be switched over to perform other operations like bending, swarf cutting or trimming and drawing etc, when broaching is not being done. Thus their idle time is fully utilized. It is for these reasons that presses are mostly preferred over other regular types of broaching machines, where broaching is not a regular requirement.

Horizontal Pull Type Broaching Machine:

All the modern horizontal pull type broaching machines carry a hydraulic drive for reasons of getting the required power and efficient drive. A pressure gauge always fitted which readily indicates the pull being applied on the tool. These machines are used both for internal as well as external broaching. Those used for hole or internal broaching carry a bed quite similar to that of a lathe and the broach moves like the tail stock on the bed ways. The other class which is used for external or surface broaching, carries the guide ways on a vertical surface, normal to the bed, along which the broach moves. Fixtures are invariably used on these machines. In addition to this, the cutting pressure or to say the pull, exerted on the broach further helps in clamping the work in position. The broach is pulled by a horizontal ram, which is driven by a hydraulic piston and cylinder mechanism incorporated in the body of the machine. The mouth or front part of the ram carries a hole to receive the shank of the broach puller. The shank of the broach is passed through initial opening of the job and connected to the broach puller or pulling head. The rear end of the broach is usually held in a supporting slide, which travels along with the broach during the operation, just like a travelling steady on a lathe. These machines are manufactured in both fully automatic and semi-automatic types. In both the type’s automatic stops and limit switches are provided to control the length of stroke of the ram.

Vertical Pull Type Broaching Machine: Vertical broaching machines, using the method of pull-broaching, are of two types:

1. Pull - Down Type.
2. Pull - Up Type.

Both these types are used for internal or hole broaching, an additional advantage with these machines is that more than one broache can be mounted and made to operate simultaneously. A single ram sometimes carries as many as four broaches. Single ram machines cut in one stroke only and the return stroke is idle, which is 2 to 3 times faster than the cutting stroke.

The Pull-Down type machine carries an elevator at the top from which the broaches are suspended in an upside position, the tail being gripped in the elevator. The work piece is mounted over the table and broach lowered to pass its front pilot through the work.

This pilot is gripped by the pulling head attached to the top of the ram, which is enclosed in the bed. The ram pulls the broach down through the work piece to produce the desired hole. After the cut is over the work piece is removed and the broach pushed up by the ram, so that the elevator again grips the rear end of the broach to take it back to the starting position. The work piece is removed and a fresh work piece loaded to start the next operation.

In pull-up type machine the ram is provided at the top, which carries the pulling heads at its bottom. The elevators are provided inside the bed to hold the broach in vertical position. The work piece is clamped to the underside of the table and the elevators raised to pass the front pilots of the broaches through the work piece and the table where they are gripped by the pulling head. The ram, then, starts its upward or cutting stroke and pulls-up broach through the work piece. After the end of the stroke the work piece falls down and is removed and the ram lowered. The rear ends of the broaches are gain gripped by the elevators and the formers is brought down to the starting position.

Duplex-Head Broaching Machines: these machines carry two rams instead of one. They are made in both horizontal type as well as vertical type. These machines give very fast rate of production as they provide a sort of continuous cutting in the sense that when one broach is providing the cutting action the second one is returning to the starting position and vice-versa. These machines use push method of broaching and are commonly used for external or surface broaching. Something happens in case of loading and unloading of the jobs that while one fixture is being unloaded and reloaded with fresh job the other is holding the other job in operation and vice-versa.

Continuous Broaching Machines: these machines are manufactured in both horizontal as well as vertical type. Horizontal machine mainly differs from other types in that the broach remains stationary while the work pieces move continuously past it to perform the cutting. The horizontal machine consists of two sprockets, one on each side of the machine, on which continuously travels an endless chain. A series of fixture are mounted on this chain to travel along with it. The broaches are rigidly held on the machine in horizontal position over the chain. Work pieces are loaded on the fixtures on one side of the machine and unloaded on the other side. The speed at which the parts can be broached depends upon how fast the loading of work pieces is done. The vertical type carries a number of platens on a continuous chain. Broach holders are mounted on these platens to carry the broach sections. The work is clamped on the horizontal table of the machine and the broach sections moved past the work by moving the chain.

Another useful type of continuous broaching machine is the **Rotary table Horizontal Continuous Broaching** machine. In this machine a rotary type of table continuously rotates about axis. The fixtures are mounted on this table. The broach is held rigidly on the broach holder above the table. The body of the broach also carries a curvature similar to that of the table. Work pieces are loaded in the fixtures. As the table rotates at a slow speed, the work pieces are fed past the stationary broach and the finished pieces unloaded, followed by loading the fixtures with fresh work pieces. Thus the cycle of loading, broaching, unloading and reloading continues without any break. These machines are very useful in mass production of identical broached components.

Machine Size: The size of the broaching machine is the length of stroke of ram in mm and the pressure applied on the broach in kgs or tons.

The other main specifications of the machine are:

1. Range of speeds and feeds.
2. Type of drive.
3. Power rating of electrical motors.

Methods of Broaching: Broaching methods can be classified as

1. Internal or Hole Broaching: In this, normally the work remains stationary and the broach is either pushed or pulled through the same to produce a hole of desired shape and size.

2. External or Surface Broaching: In this either the work or the broach is moved past the other to produce a groove or surface of desired shape and size on the external surface of the work.

3. Pull Broaching: Mostly adopted for internal broaching. In this, the work remains stationary and the broach is pulled through the same to produce the hole of desired shape and size.

4. Push Broaching: Adopted mostly for internal broaching of relatively lighter jobs. The work piece remains stationary and the broach is pushed through the same. However, it can be used for external broaching also.

5. Continuous Broaching: It is a method suitable and largely adopted for broaching of identical components on large scale. In this method, the broach remains stationary, while the work pieces move continuously past the same along a horizontal or circular path.

Broaching Speeds: Broaching operation uses lower cutting speeds. Selection of proper speed for broaching a particular component will be decided by the following factors:

1. Hardness of work piece material.
2. Length of broaching.
3. Type of material to be broached.
4. Rigidity of the component to be broached.
5. Economic considerations for the operation.

Broaching speeds for some common materials are

Carbon Steel --- 3 to 8m/min

Cast Iron --- 6 to 30 m/min

Copper Alloys --- 8 to 10 m/min

Free Machining Steel --- 10 to 12 m/min

Machining Time

In broaching operation the machining time depends on effective length of broach i.e. the length of tooth system of the broach. It is given by the following relation.

$$\text{Machining Time} = \frac{\text{Effective length of broach in meters}}{\text{Cutting speed in m/min}} = \frac{\text{Effective langth in mm}}{1000 \times \text{cutting speed in m/min}}$$

Broaching versus other Machining operations: Merits

1. Broaching is faster than other machining operations.
2. It enables a higher rate of production, more accuracy, and better finish than other operations.
3. Since each tooth of broach takes a small cut that too only once in one operation, it has longer life than other cutting tools.
4. Owing to the above reason, the tool cost per work piece is low.
5. A single tool (broach) performs both roughing and finishing operations.
6. Better surface finish is obtained because different teeth perform different operation.
7. Cutting fluid can be applied more easily and effectively than other operations.
8. Because of simplicity of machining cycle, it does not required highly skilled operator.
9. Interchangeable components can be produced at a much faster rate by broaching than any other operation.
10. A specific advantage in broaching is that the cutting force of the broach serves to clamp the work piece and hold it firmly in position.

Demerits:

1. It is a single purpose tool and can produce only one type of surface.
2. The initial cost of the tool is very high compared to other tools.
3. It is unsuitable for small quantity and are of variable sizes.
4. All the jobs in broaching will need fixtures and this will add to the cost.
5. The broaching machine is costly of all machine tools its existence will not be justified unless production required is very high.
6. Tool sharpening is difficult and expensive, needs separate sharpening machine.
7. All types of surfaces can’t be machined through broaching.
8. Very light and delicate jobs cannot be broached easily, as they can’t with stand the cutting force.
9. Surfaces which lie in separate planes can’t be machined in single setting.
10. Blind holes cannot be easily produced through broaching.

Broaching applications:

A wide variety of shapes, internal, external, regular, irregular, including complex contours can be produced through broaching. Several shapes which are difficult to be machined on the other machine tools can be easily machined through broaching.

Broaching applications include the machining of bearing caps, bearing bodies, cylinder blocks, connecting rods, cylinder heads, crank cases, rotors, toothed sprockets for chain drives, gears, turbine blades, sleeves, bushings and air craft engine parts etc.

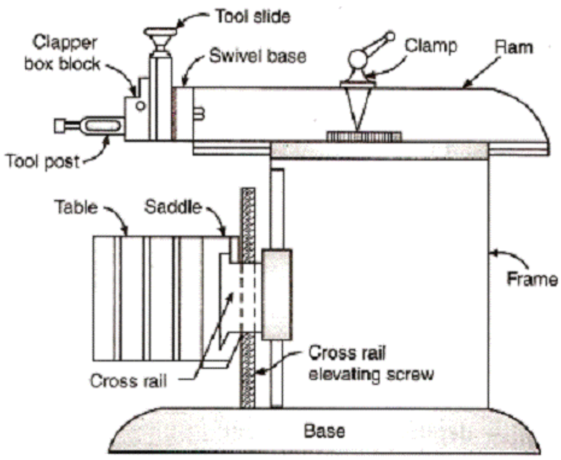
UNIT –V

CH - I

SHAPING,SLOTTING

WORKING PRINCIPLE:

The job is rigidly held in a vice or clamped on a machine table. The tool is held in tool post mounted on the ram of the machine. The ram reciprocates to and fro and in doing so, makes the tool to cut the material in the forward stroke. No cutting of material takes place, during the return stroke of the ram. Hence it is called idle stroke. In case of draw-cut shaper, the cutting takes place in the return stroke and forward stroke is idle stroke. The job is given an indexed feed in a direction normal to the line of action of the cutting tool.



PRINCIPAL PARTS:

1. Base: It is a heavy and robust cast iron body which acts as a support for all other parts of the machine, which are mounted over it.

2. Column: It is a box type cast Iron body, mounted on the base and acts as housing for the operating mechanism of the machine, and the electricals. It also acts as a support for other parts of the machine such as cross rail and ram, etc. On its top it carries a machined ways, in which ram reciprocates and vertical guide ways at its front.

3. Cross-rail: It is a heavy cast Iron construction, attached to the column at its front on the vertical guide ways. It carries two mechanisms, one for elevating the table and the other for cross traverse of the table.

4. Table: It is made of cast Iron and has a box type construction. It holds and supports the work during the operation and slides along the cross-rail to provide feed to the work. T-slots are provided on its top and sides for securing the work to it.

5. Ram: It is also an Iron casting, semi circular in shape and provided with a ribbed construction inside for rigidity and strength. It carries the tool head and travels in dove tail guide ways to provide a straight line motion to the tool. It carries the mechanism for adjustment of ram position inside it.

6. Tool head: It is the device to hold the tool. It can slide up and down and can be swung to a desired angle to set the tool at a desired position for the operation.

7. Vice: It is a job holding device and is mounted on the table. It holds and supports the work during the operation. Alternatively, the job can be directly clamped to the machine table.

SIZE AND SPECIFICATIONS

The size of the shaper is determined by the maximum length of cut or stroke it can make. A standard shaper is usually capable of holding and machining a cube of the same dimensions as the length of stroke. The length of stroke is always the principal dimension, but a number of other details are also required to specify a shaper fully. Complete specifications of a 300 mm stroke shaper are as follows.

1. Length of stroke	300 mm
2. Max. Horizontal travel of table	350 mm
3. Max. Vertical travel of table	365 mm
4. Max. Distance from table to ram	12 mm
5. Max. Vertical travel of tool slide	117 mm
6. Length and width to table top	300 × 250 mm
7. Length and depth of table side	241 × 317 mm
8. Power of Motor	2/2 HP OR 1.5/1.5kw
9. No. of ram cycles per minimum	6
10. Range of ram cycle per minimum	21 to 22 mm
11. Tool box takes tool of size	16 × 22 mm
12. Max. Vice opening	152 mm
13. Approximate Weight	700 kg
14. Floor space	1350 × 790 mm

CLASSIFICATION OF SHAPERS

Shapers are classified in many ways, i.e. according to length of stroke, type of driving mechanism, direction of travel of ram, the type of work they do, the type of design of table etc. The main classification is as follows:

1. Standard Shaper: It consists of a plain table, may or may not have the vertical supports at its front. In some machines there is a provision for the table to swivel around horizontal axis, parallel to ram. This enables machining of inclined flat surfaces. Material is cut in the forward stroke of the tool and the return stroke is idle. It is also known as plain shaper.

2. Draw-cut Shaper: it is similar to standard shaper, but is comparatively much heavier and the metal cutting operation takes place during the return stroke of the ram i.e. in moving towards the column. Its heavy construction enables heavier cuts with less vibration.

3. Horizontal Shaper: It is a very popular shaper in which the ram and tool reciprocates in horizontal plane. Normally used to machine flat surfaces.

4. Universal Shaper: It is a horizontal type shaper but its table can be swung about a horizontal axis parallel to ram ways. The top of this table can be tilted about another horizontal axis which is normal to the former axis. If a swivel vice is fitted to this table the work can be rotated about three possible axes. Machining of surfaces can be taken up in different planes and the machine is very useful for tool- room work.

5. Vertical Shaper: This shaper has its ram reciprocating in a vertical direction. The table is of circular, rotary type. The ram of vertical shaper can be adjusted 10 on either side of vertical, enabling machining of inclined surfaces also.

6. Geared Shaper: This classification is according to the type of driving mechanism. This type of shaper carries a rake under its arm which is driven by super gear (pinion). This has become obsolete.

7. Crank Shaper: These shapers carry a crank and slotted link mechanism for the ram movement. Large no. of shapers uses this mechanism.

8. Hydraulic Shaper: In this hydraulic pressure is used for driving the ram. It is more efficient as it enables constant speed and force from the start to the end of the cut.

9. Contour Shaper: In this a standard shaper is fitted with an additional tracer mechanism, a template and a follower is used to reproduce the contours of the template. This facilitates machining of those shapes which would have been impossible on any other type of shaper.

10. Travelling head Shaper: It is a specially designed shaper for machining heavy and large work pieces which can't be held on the table. Such jobs are loaded on the base of the shaper or on the floor and then machined. In these machines, the ram is so designed that, in addition to reciprocation for machining, it also gets a cross movement to provide necessary feed.

SHAPER OPERATIONS

Several different shapes of jobs can be produced on shapers. The basic operations done on a shaper can be broadly classified as

1. Horizontal cutting. 2. Vertical cutting 3. Angular cutting. 4. Irregular cutting

1. Horizontal Cutting: It is the most common operation on shaping machine. In this the work is fed in a horizontal direction under the reciprocating tool and the surface produced is horizontal and flat.

2. Vertical Cutting: The tool is fed down wards in vertical cutting. This type of tool feed is commonly used in cutting grooves, key-ways, tongues, parting off and squaring ends and shoulders.

3. Angular Cutting: The angular cutting is employed for machining inclined surfaces, beveled surfaces and dove- tails etc. In this down feed of the tool is used.

4. Irregular Cutting: If an irregular surface is to be machined, the shapes marked on the side of the job. The preferable procedure for such machining is to first rough machine the surface to about 15 mm above the marked shape. Then bevel the edges at about 45^0 by means of a file and machine off the beveled portion. Thus the job is machined up to the marked shape. For machining such surfaces a combination of vertical hand feed to the tool and horizontal power cross feed to the table is to be used.

MACHINING TIME:

$\text{Cutting speed (V1)} = \frac{\text{Length of cutting stroke(L)}}{\text{Time taken in cutting stroke}}$ (V_1 = average cutting speed m/min)

$\text{Cutting Time} = \frac{L}{V_1}\text{ min}$ $\text{Non Cutting Time} = \frac{L}{V_2}\text{ min}$ (V_2 = Average return speed m/min)

$\text{Total time per cycle} = \text{Cutting time} + \text{Idle time} = \frac{L}{V_1} + \frac{L}{V_2} = \frac{L}{V_1} + k \times \frac{L}{V_1}$

(Where k = Ratio of idle stroke time to cutting stroke time)

$\text{Total time} = \frac{L}{V_1} + k\frac{L}{V_1} = \frac{L(1+k)}{V_1}\text{ minutes}$

For shaping a work piece an allowance of about 5mm is left on either side of it

$$\text{Shaping Width B} = \text{Width of work piece} + 2 \times \text{allowance}$$

$\text{No. of Cycles required}(\eta) = \frac{\text{Shaping Width(B)}}{\text{Feed per cycle(f)}} = \frac{B}{f}$ (f = feed per cycle in mm)

Machining time = no. of cycle

Machining time = no. of cycles × Time required for each cycle

$$= \frac{B}{f} \times \frac{L(1+k)}{V_1} \quad = \frac{L \times B\,(1+k)}{f \times V_1}\ \text{min}$$

PLANING MACHINES

Planing is machining of large flat surfaces. These surfaces may be horizontal, vertical or inclined. The function of a planning machine is similar to that of a shaper except that the planer is basically designed to undertake machining of large and heavy jobs which are impracticable to be machined on shaper or milling machine etc. Planing machine is the most economical for machining large flat surfaces. Planing machine is differ from a shaper in that for machining, the work, loaded on the table, reciprocates past the stationery tool in a planer, where as in shaper the tool reciprocates past the stationery work.

WORKING PRINCIPLE:

It is almost a reverse case to that of a shaper. The work is rigidly held on the work table of the machine. The tool is held vertically in tool head mounted on the cross-rail. The work table, together with the job is made to reciprocate past the vertically head tool. The indexed feed, after each cut, is given to the tool during the idle stroke of the table.

PRINCIPAL PARTS:

1. Bed: It is a very large and heavy cast iron structure with cross ribs for additional strength and stiffness as it supports the whole structure of the machine over it. It is about two times longer than the table it carries over it. At its top it carries either v-ways or flat ways to support and guide the table. All the ways are straight, parallel and constantly lubricated with pressure lubrication at several points along the ways.

2. Table: it is made of Cast Iron with accurately machined top. It is a box type construction with ribs under it to make it strong to support heavy work over it. At its top, it carries longitudinal T-slots and holes to accommodate the clamping bolts and other devices to hold the work. Under the table, chip pockets are cast integral with it for collecting and removing the chips.

3. Housings or Columns: The columns are vertical members, situated on both sides in case of a double housing planer and on one side only in case of an open side planner. Inside them, they carry the different mechanisms for transmission of power to the upper parts of machine, from the main drive, viz. cross-rail elevating screws, vertical feed shaft and cross feed bar etc.

4. Cross-rail: It is a horizontal member of a heavy structure connecting the two vertical columns of the machine. It provides additional rigidity to the machine. By means of elevating screws it can be moved up and down along the ways on the columns. Clamps are provided to lock the cross-rail in any desired position along the columns. A suitable device is incorporated to ensure that the cross-rail is perfectly horizontal before clamping. The cross-rail is moved up or down uniformly on both ends, both the elevating screws are rotated simultaneously by horizontal shaft, mounted on the top of the machine through bevel gears.Ways are provided at the front of the cross-rail for the two vertical tool heads. Inside the rail are provided the feed rods for vertical power feed and cross feed to the tools. The rail is made sufficiently long, to project on both sides of columns, so that, one of the two tool heads can be pushed out to one end.This will enable other tool head to travel freely cross-wise from one end of the table to the other, covering entire width of the job.

5. Tool Heads: The planer tool heads, both in construction and operation resembles the shaper tool heads. Four tool heads can be fitted in a planer and any or all of them can be used at a time. Two tool heads can be fitted in vertical position on the cross-rail and the other two on the vertical columns. Each column carries one side tool head.

The method of mounting is similar for all the tool heads. First the saddles are mounted on the horizontal ways of the cross-rail (for vertical tool heads) and vertical ways of the columns (for side tool heads) these saddles further carry machined ways at their front, on which tool heads are mounted. All the four tool heads work independently, simultaneously.

The tools heads on the cross-rail can travel horizontally, along the rail. They can also be raised or lowered by moving cross-rail up or down. The tools can be fed down wards by rotating the down feed screw. Similarly the side tool heads can move up and down along the vertical column ways. Their tools can be fed horizontally in to the job or at desired inclination. A swivel plate incorporated between the slide and saddle. This enables the tool head swivel through an angle of 70^0 on either side from its normal position. Both hand feeds and power feeds can be used, but power feeds are commonly used.

6. Controls: Various controls for starting, operating and stopping the various mechanisms, automatic cutting off speed and regulation and similar other functions are provided with in quick approach of the operator of the machine.

SPECIFICATIONS:

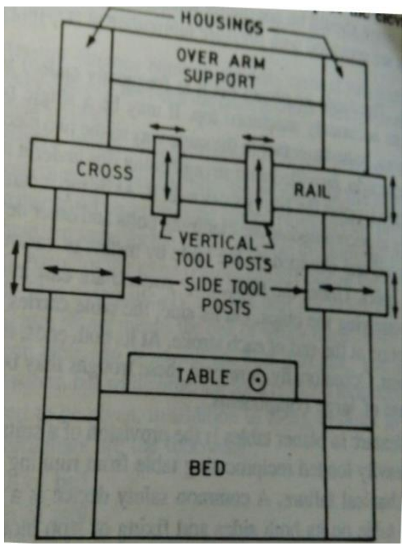
Planers are made in different sizes, the main specifications are

1. Horizontal distance between the two vertical columns or housings.
2. Vertical distance between the table top and the cross-rail when it is in top most position.
3. Maximum length of table travel or length of stroke.

TYPES OF PLANERS:

A large variety of planers of different designs and sizes are available and they are broadly classified in to the following types:

1. Standard or Double housing planer
2. Open side planer
3. Planer Miller
4. Plate planer



5. Pit planer
6. Divided table planer, and
7. Plano-Guillotine shearing machine.

1. STANDARD OR DOUBLE HOUSING PLANER:

This is most commonly used type of planer. It consists of two vertical housings or columns, one on each side of bed. The housings carry vertical machined and scraped ways. The cross rail is fitted between the two housings and carries one or two vertical tool heads. The work table is mounted over the bed. Side tool heads are fitted on the vertical housings.

These machines are heavy duty type and have very rigid construction. They use high cutting speeds but the size of the work is limited to width table i.e. the horizontal distance between the two columns. Extremely large and heavy casting, like machine beds, tables, plates, slides of columns, it is possible to hold a number of work pieces in a series over the bed length and machine them together. This will effect in saving machining time. Because of four tool heads a number of surfaces can be machined simultaneously. Because of high rigidity of machine, robust design of cutting tools, heavier cuts can be taken, which leads to quickes metal removal and reduced machining time and hence to economical machining.

2. OPEN SIDE PLANER:

This type of planer consists of only one housing, situated vertically on one side of the bed and the other side is left open without any obstruction. The cross-rail is of cantilever type and is wholly supported on the single column. Only three tool heads can be used maximum. The other features are same as double housing planer.

The main advantage of an open side planer is its adoptability for machining components which are much wider than could pass between the housings.

3. PLANER MILLER:

It is actually a combination of the two machines, and hence the name planer miller. It resembles a double housing planer but the conventional revolving cutters.

4. PLATE PLANER:

This is completely different from the conventional type both in construction and operation. The bed and the table of the plate planer are a fixed unit and the work is mounted on the table. The tool head is mounted on a movable carriage, which can travel longitudinally along the bed. The operator also stands on a flat form attached to the carriage and travels along it during machining. The work remains stationary while the tool moves to and fro. The tool holder can hold one or more tools at a time and can also be tilted for machining slant surfaces. It is a single purpose machine for a special work. Ex: machining edges of boiler plates, ships plates, for pipe lines and for welding.

5. PIT PLANER:

This machine is specially designed for machining long, heavy and tall work, that can't be machined on the conventional type of planers. The job is mounted either on stationary table or on the floor inside a pit. The machine is provided with two short vertical housing which carry cross-rail. One or two tool heads are mounted on the cross rail and two side tool posts on the housings. This whole unit travels along the horizontal ways to and fro and thus the tool moves past the work for machining the surface. The horizontal and inclined surfaces of the work piece are machined on these planers.

6. DIVIDED TABLE PLANER:

In this machine, the table is constructed in two or more parts which can be joined together to hold a very large work. Large part of total time, spent on machining a job, is spent in its proper setting because of the difficulty in handling the work due to its heavy weight. This machine with divided table is employed such that when the work on one table is being machined, the same is being simultaneously set up on the other table in readiness for replacing after the operation is over. Thus considerable setting time it saved.

7. PLANO-GUILLOTINE SHEARING MACHINE:

It is also a special purpose machine used for cutting and preparing ends of large plates. It is provided with a traversing cutter head which carries a rotary disc cutter instead of a single point tool. The standard cutter will always cut square with the surface. Other cutters can be fitted to cut to an angle. A swiveling type of head is also provided in order to produce angular cuts. The plate is sheared off in a single traverse of the cutter head. The machine, thus gives much higher output then the conventional planer.

DRIVING MECHANISMS:

Four different methods are employed for driving the table of a planer. They are as follows:

1. Crank drive: Similar to the one used for driving the ram of a shaper. It is however obsolete now.

2. Belt drive: In this the motor drives a counter shaft, which is turn, drives the main driving shaft through belts and a set of fast and loose pulleys. This shaft drives a pinion which meshes with a rack under the machine table.

3. Direct reversible drive: In this the reversible motor, through a set of reduction gears, drives the pinion which meshes with the rack provided under the machine table.

4. Hydraulic drive: it is quite similar to the one used for driving the ram of a shaper. More than one cylinder can be used for achieving different speeds.

What ever may be the methods of drive used for a planer table, it should essentially meet the following operating requirements:

i. It should be long lasting and its control should be easy.
ii. It should be capable of providing several quick and safe reversals of the table continuously without any chance of break down.
iii. It should in corporate a mechanism for faster return of the table, accurately at the same point in each stroke, without any stroke or vibrations. The return speed of the table is supposed to be 3 to 4
iv. It should provide a fairly wide range of variable speeds.
v. It should not unduly vary, after being set, during cutting.

vi. It should be possible to stop the running table suddenly. Whenever desired for any purpose, and restart it instantly.
vii. It should incorporate a mechanism for speed reduction.

CUTTING SPEED, FEED AND DEPTH OF CUT:

Frequent variations in cutting speeds are not needed and it will be considered on account of the kind of cutting tool and material to be machined. Planer is used for machining heavy jobs and obviously heavier cuts are used, with the result uses much slower speeds than most of other machines. Suitable cutting speed is selected depending upon tool material and the work. Planer usually employ a cutting speed of 6 to 15 m/min and return speed 30 m/min. a cutting speed of 25 m/min and a return speed of 45m/min is obtained on hydraulic planers. The feed and depth of cut depends upon the material of the work, required surface finish and rigidity of the machine.

OPERATIOINS DONE ON PLANER:

A planer performs the same operations as performed by a shaper, with the main difference that the work pieces handled on a planer are longer and heavier than those machined on a shaper and also the surfaces machined on a planer are much larger and wider than those produced on a shaper. The common operations performed on a planer are:

1. Machining horizontal flat surfaces.
2. Machining vertical flat surfaces.
3. Machining angular surfaces, including dove -tails.
4. Machining different types of slots and grooves.
5. Machining curved surfaces.
6. Machining along pre marked contours.

COMPARISION BETWEEN PLANER AND SHAPER

S.No	PLANER	SHAPER
1.	It is heavier, more rigid and costlier m/c.	Comparatively lighter and cheap m/c.
2.	It requires more floor area.	Less floor area.
3.	It is used for machining large flat surfaces horizontal. Vertical and inclined.	It is also used for the same purposes but for relatively smaller surfaces.
4.	Cutting takes place by reciprocating the work under the tool.	Cutting takes places by moving the cutting tool over the job.
5.	Indexed feed is given to tool during the idle stroke of the work table.	Indexed feed is given to the work during the idle stroke of the ram.
6.	Heavier cuts and coarse feed can be used.	Very heavy cuts and coarse feeds can't be used.
7.	Four tools can be used simultaneously facilitating a faster rate of production.	Only one tool can be used on a shaper.
8.	Because of its larger stroke length and table size, number of jobs can be held in series and machined in single setting.	This is not possible on a shaper.

9.	The tools used are longer, heavier and stronger.	Tools are smaller and lighter.
10.	The work is held on the machine table by means of fixtures and clamping devices.	The work is clamped directly on the table or held in a vice or chuck.

SLOTTING MACHINE

Its construction is similar to that of a vertical shaper. Its ram moves vertically and tool cuts driving down ward stroke only. Its main use is in cutting different types of slots in most economical way. Its other uses are machining irregular shapes, circular surfaces and other pre marked profiles both internal as well as external.

MAIN PARTS:

1. Base: It is a heavy cast Iron construction and acts as a support for the column, the driving mechanism ram, table and all other fittings. At its top it carries horizontally ways along which the table can be traversed.

2. Column: It is another heavy cast Iron body, which acts as a housing for the complete driving mechanism. At its front it carries vertical ways, along which the ram moves up and down.

3. Table: Usually circular table is provided on the top of the table are provided T-slots to clamp the work or facilitate the use of fixtures.

4. Ram: It moves in vertical direction, between the vertical guide ways provided in front of the column. At its bottom, it carries the tool post in which the tool is held. The cutting action takes place during the down ward movement of the ram.

SIZE AND SPECIFICATIONS:

The size of the slotting machine is generally given in terms of maximum length of stroke. The size of the job that can be machined will be less than this size by an amount equal to the sum of the top and bottom clearances of tool.

TYPES OF DRIVES:

Mainly three types of driving mechanisms are used in slotting machines for driving that ram.

1. Slotted disc mechanism.
2. Slotted link and gear mechanism, and
3. Hydraulic mechanism

1. The slotted disc mechanism: It is the simplest of all the methods commonly used for driving the ram of a slotting machine. The driving mechanism consists of, a pinion, a gear a slotted disc and crank. The disc carries a T-slot through which passes a crank pin. Its distance from the centre of the disc can be adjusted as desired.

The main driving pulley, situated at the rear side of the machine is driven by a motor through belts it in turn drives the pinion which drives the gear. The gear being on the same shaft as the disc and drives the disc. The crank and connecting rod mechanism converts the circular motion of the disc in to reciprocating motion of ram. The length of stroke of ram can be varied by shifting the crank pin towards or away from the centre of the disc. The starting and finishing positions of the ram stroke can be adjusted by means of hand lever for stroke adjustment. The fly wheel provided at the rear side, acts as a shock absorber at the end of the stroke.

2. Slotted link and Gear Mechanism: This mechanism is used in heavier type slotting machines. The mechanism consists of two driving wheels provided with a trunnion. These trunnions work inside the bushed bearings provided on the sides of the machine. Both the wheels carry an eccentric each. Three bolts are provided by means of which the eccentrics can be made loose or fast with the driving wheels. A slotted link of bell crank type is provided between the driving wheels. The crank pin forms the fulcrum. A die of usually of bronze works in the slot of the link. It is provided with a hardened steel bush, through which passes one of the three bolts. This bolt connects the two eccentrics and carries the above die, so that when eccentric revolve, along the driving wheels the die slides in the slot. Other end of the link is attached to the ram by means of connecting rod. The ram carries a shackle at its top to carry the end of the counter weight arm. The other end of the arm carries the counter weight and the same is provided about a point in its length somewhere on the top of the frame of the machine.

The mechanism works such that as the eccentric revolve the die slides inside the slot of the link and in doing so, it makes the link swing about the fulcrum, provided by the crank pin. With the result, the connecting rod, and hence the ram is alternatively pushed up and pushed down. This enables the reciprocating motion of the ram and the tool. The length of stroke is adjusted by varying the swing of the link. For this the both are made loose and the eccentrics rotated to adjust the throw, i.e. the position of die with respect to centre of rotation of the wheels. After the required adjustment is obtained the both are again tightened to make the mechanism ready again.

3. Hydraulic Mechanism: The hydraulic drive used in slotters is the same as shapers. The axis of the cylinder in this case will be in a vertical direction. Both constant pressure and constant volume type drives are prevalent.

TYPES OF SLOTTING MACHINES

Slotting machines are mainly three types.

1. Puncher Slotters
2. Production Slotters.
3. Tool room Slotters.

1. PUNCHER SLOTTERS: These are heavy duty machines. Usually such jobs are machined which are heavier and have been roughly machined to required shape through other operations like sawing, forging or stamping etc. The slotting machine to the required shape and size.

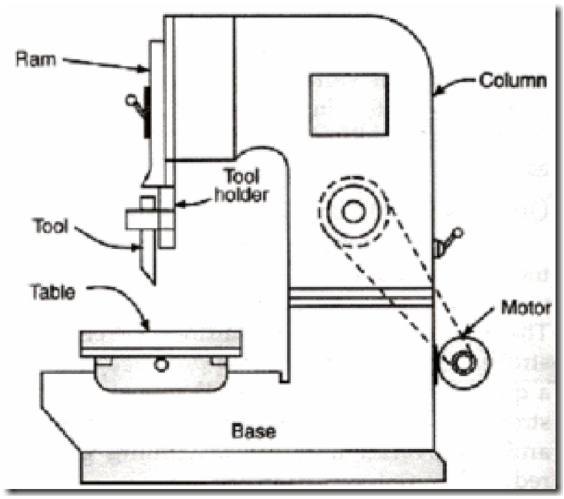
2. PRODUCTION SLOTTERS: This is a common category of slotters generally used for production work. It consists of a heavy cast base and heavy frame, made usually in two parts. The upper past may be stationary type or tilting type. In tilting type of frames a worm and worm wheel are provided at the rear side to enable the tilting of the frame. The tilting type frame enables machining of tapered surfaces, in addition to the normal machining operations performed with a stationary type of frame.

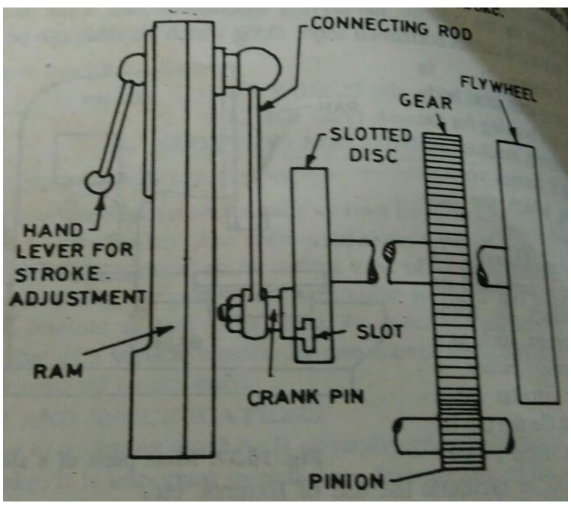
The drive of the ram is obtained by means of a slotted disc and connecting rod. The fly wheel is fitted to prevent shock at the end of the stroke. The ram carries V-slides with hardness ground faces. Two loose strips, fitted vertically in front of the frame, form guide ways for the ram. One of these is secured rigidly to the frame and the other carries adjusting screws to take up wear. The lower part of the frame is provided with horizontal ways. On this is fitted the cross slide, which can be given transverse motion by means of hand wheel. The table is mounted on the cross slide and can be given cross motion by means of a hand wheel. The table carries teeth along its periphery and can be rotated by means of worm meshing with these teeth.

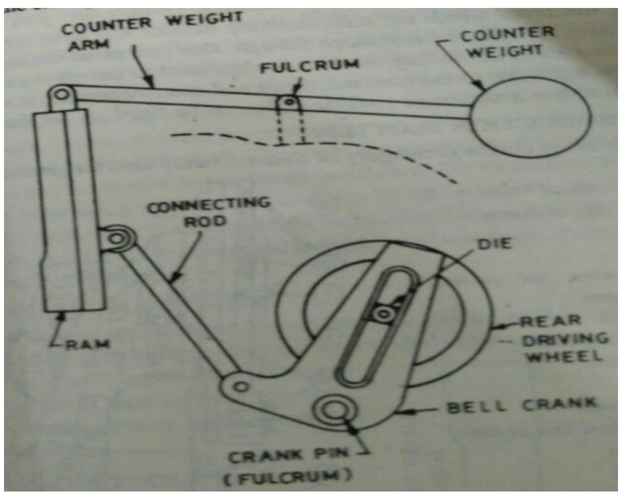
3. TOOL ROOM SLOTTERS: These slotting machines are of precision type and are used for very accurate machining. Usually tilting type frame is provided in these machines to enable machining at different angles. Slotted link type drive is commonly used. Rest of the construction is similar to that of production Slotter.

OPERATIONS:

Its main use is in cutting different types of slots and is most economical for this kind of work. Its other uses are machining irregular shapes, circular surfaces and other pre marked profiles both internal as well as external. Its construction is similar to that of a vertical shaper. Its ram moves vertically and tool cuts during down ward stroke only.







DRILLING

Drilling is an operation to produce holes in a solid metal by means of a revolving tool called drill. The drilling is followed by reaming for dimensional accuracy and fine surface finish by means of a multi-tooth revolving tool called reamer.

Boring is the operation for enlarging an existing hole previously produced through drill, cast, punched or by any other suitable operation.

The operations of drilling, boring and reaming can be performed both by hand feed as well as power feed on a large number of machines such as centre lathe, drilling machine, boring machine, turning mill(vertical lathe) Capstan and Turret Lathes, Automatic Lathes etc.

DRILL SIZE AND SPECIFICATIIONS:

According to the Indian standards the drills are specified by their diameters, series they belong to, the material they are made of and the IS number. These data are mainly based on the material for which the drill is to be normally used. They are made in 3 types:

1. Type-N → For normal low Carbon Steel.
2. Type-H → For hard materials.
3. Type -S → For soft and tough materials.

Example: A twist drill specified as "9.50 IS: 5101 HS" means a twist drill of 9.50mm dia. Confirming to IS: 5101 made of high speed steel unless otherwise mentioned in the tool designation the type should be taken as 'N' and the point angle as 118^0.

In metric sizes the drills are normally manufactured in diameters ranging from 0.2mm to 10mm.

TYPES OF DRILLING MACHINES:

Drilling machines are manufactured in various sizes and varieties to suit the different types of work. They are broadly classified as:

1. Portable drilling Machine.
2. Sensitive or Bench drill.
3. Upright drilling Machine (Single Spindle)
4. Upright drilling Machine (Turret Type)
5. Radial drilling Machine
6. Multiple spindles drilling Machine.
7. Deep hole drilling Machine
8. Gang drilling Machine.
9. Horizontal drilling Machine
10. Automatic drilling Machine.

1. PORTABLE DRILLING MACHINE:

It is a very small, compact and self-contained unit carrying a small electric motor inside it. It is very commonly used for drilling holes in such components that can't be transported to the shop due to their size or weight. On account of the high speeds available considerable time is saved. Another advantage is that the holes can be drilled at any desired inclination. Portable drills have a capacity to drill holes up to max. of 18mm dia.

2. SENSITIVE OR BENCH DRILL:

This type of drill machine is used for very light work. Its construction is very simple and so is the operation. No gears are used in the drive. It can be swung to any desired position. Vertical movement to the spindle is given by the feed handle through a rack and pinion arrangement. The max. dia. it can drill is 20mm dia steel.

3. UPRIGHT DRILLING MACHINE (SINGLE SPINDLE):

It is used for heavier work and has a back gearing arrangement. It differs from sensitive drill in its weight, rigidity, application of power feed and wide range of spindle speeds. The drilling capacity is up to 75mm in steel. The table can swung to any position with rotary movement. It enables any part of the surface to come under the tool without disturbing work.

4. UPRIGHT DRILLING MACHINE (TURRET TYPE):

It is a production drilling machine and is very useful when a series of different size holes are to be drilled repeatedly or number of different operations like drilling, reaming, counter boring, counter sinking, spot facing etc are to be performed in sequence repeatedly. The turret head which carries six, eight or ten different tool mounting positions is mounted on a ram. It can be easily indexed to bring the proper tool in operating position over the work and can be raised or lowered by moving the ram upwards or down wards. The required tools are mounted in sequence in the turret head so that they automatically come in operating position when the head is indexed. This type of machine eliminates tool changing time and a single machine can be used to perform no. of different operations one after the other.

5. RADIAL DRILLING MACHINE:

This machine is very useful because of its wider range of action. Its principal use is in drilling holes on such work which is difficult to be handled frequently. In this the tool is moved to the desired position instead of moving the work for drilling.

Based on the type and number of movements possible, the radial drill can be broadly grouped as:

i. Plain Radial drill: Three principal movements are possible in this type of machine. Viz. vertical movement of the arm along the column, horizontal sliding movement of the drilling head or spindle head along the arm and radial swinging of the arm in horizontal plane.

ii. Semi-Universal Radial drills: These machines in addition to the above three basic movements, carry provision for swinging of spindle head about horizontal axis which is normal to the arm. Thus the head, hence the spindle can be inclined to a suitable angle with its normal vertical position on either side, enabling drilling of holes at desired inclination with the normal vertical position.

iii. Universal Radial drills: in this machine, the arm itself can be rotates through a desired angle along horizontal axis. This is in addition to the four possible movements available on a semi-universal machine. Thus this machine is highly versatile and facilitates drilling at any desired inclination and location. It is normally provided with a geared drive.

6. MULTIPLE SPINDLES DRILLING MACHINE:

These machines are mostly used in production work and are so designed that several holes of different sizes can be drilled simultaneously increasing the production with sufficient accuracy. In these two or more spindles are driven from a common driving shaft through worm and worm gears or belts. Drill heads with a capacity to drive up to 50 spindles simultaneously are available. In these heads it is possible to adjust the spindles to several different positions to enable drilling of holes at any location within the area covered by the head.

7. DEEP HOLE DRILLING MACHINE:

Where very long holes of relatively smaller diameter are required to be drilled these machines are used, such as in rifle barrels and long spindles. These machines can be horizontal as well as vertical types, according to the requirements. These machines are provided with head stock and a carriage. The work is mounted between these two and the carriage carries the drill. On the head stock side, the work is supported on a spindle which also rotates the same as the drill is fed slowly.

In deep hole drilling operation, the work rotates at high speed, while the drill is fed in to the work at low speed and feed. Since the drill is quite long it is required to be supported, so is the case with the work piece, for which steady rests are used. Coolant is simultaneously fed to the cutting edges through the passages and it will cool the cutting edges and takes away the chips along with it. The drill is withdrawn each time it has cut through a length equal to its diameter. This helps in easy removal of the chips from the hole. Horizontal designs are used for longer jobs and vertical designs are used for relatively shorter jobs.

8. GANG DRILLING MACHINE:

It is a multiple spindle drilling machine and all the spindles are arranged in a row. These spindles are driven either separately or collectively. This machine is very useful when the nature of work is such that a number of operations like drilling, reaming, counter boring and tapping etc are to be performed in succession on it. The work moves from one spindle to the other, after each operation. The number of spindles depends upon the type of production. Four spindles are very common. One operator can perform all the operations.

9. HORIZONTAL DRILLING MACHINE:

All drilling machines, except one variety of deep hole drilling machines, are of vertical type. In these machines the spindle and the tool are in horizontal position and are mainly used for long jobs, such as columns pipes and barrels etc which are difficult to be drilled in vertical position. The horizontal drilling is also used for jobs of excessive weight and extraordinary large size jobs which can’t be handled easily. The operation of drilling performed by keeping the job stationery and moving the machine.

10. AUTOMATIC DRILLING MACHINE:

These are production machines arranged in series to perform a number of different operations in sequence at successive work stations. The work pieces, after completion of an operation at one station, are automatically transferred to the next station for another operation. The operation sequence, related cutting speeds, feeds, start and finish of the operation at each station etc are so arranged and synchronized that once the work piece is loaded at the first station, it automatically switches on to the next operation and unloaded.

Several different operations like drilling. boring, tapping, milling, honing etc can be performed on a job is succession on these machines.

OPERATIONS DONE ON DRILLING MACHINES

1. Drilling
2. Reaming
3. Boring
4. Counter boring
5. Counter sinking
6. Spot facing
7. Tapping

1. Drilling: It is the main operation done on drilling machine. It is the operation of producing a circular hole in a solid metal by means of a revolving tool called drill bit.

2. Reaming: It is the operation of finishing a hole to bring it to accurate size and have a fine surface finish. The operation is performed by means of a multi- tooth tool called reamer. The operation severs to produce a straight, smooth and accurate hole. The accuracy to be expected is within ±0.005mm.

3. Boring: It is an operation used for enlarging a hole to bring it to the required size and have a better finish. It involves the use of an adjustable cutting tool having a single cutting edge. It can be used for correcting the hole location and out of roundness, if any, as the tool can be adjusted to remove more metal from one side of the hole than the other. It is a slower process than reaming. The accuracy to be expected is within ±0.0125mm.

4. Counter Boring: The operation is used for enlarging only a limited portion of the hole, is called counter-boring. It can be performed by means of a double tool boring bar or a counter boring tool. In order to maintain alignment and true concentricity of the counter bored hole with the previously drilled hole, the counter boring tool is provided with a pilot at its bottom.

5. Counter Sinking: It is the operation used for enlarging the end of a hole to give it a conical shape for a short distance. This is done for providing a seat for the counter sunk heads of screws, so that the top face of screw matches with the main surface of work. The standard counter sunk carry included angle of 60^0, 82^0 or 90^0.

6. Spot facing: This operation is used for squaring and finishing the surface around and at the end of a hole, so that the same can provide a smooth and true seat to the underside of bolt heads or collars etc. This is usually done on castings or forgings. The hole may be spot faced below the rough or above it, i.e on the upper surface of the boss if the same is provided.

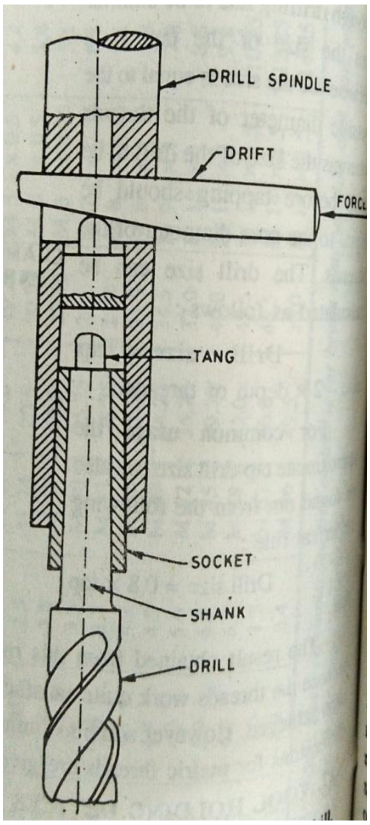
7. Tapping: It is the operation done for forming internal threads by means of a tapping tool. To perform this operation the machine should be equipped with a reversible motor or some other reversing mechanism. Drill size for taping = 0.08×tapping size. Drill size = tap size - 2×depth of thread.

TOOL HOLDING DEVICES:

Taper shank drills, of which the shank is sufficiently large, are directly fitted in the tapered hole of the spindle nose. The taper shank tools of which the shank is too small to fit the taper hole of the spindle are held in a socket. The shank of this socket has a standard taper to fit in to the taper hole of the spindle. Still the smaller taper shank drills or other tools are first fitted with a sleeve, which fits in to the socket and the complete assembly in the spindle. The socket as well as sleeve both carries a key slot each and a tang is provided at the end of the tapered hole and helps in providing a positive drive for the tool as the grip of taper alone is not sufficient. The drift helps in taking out the socket, sleeve or the tool by driving it in to the key slot. By doing so the drift presses against the top of the tang and because of the taper on the shank as well as the corresponding hole, the part or the tool is driven out. Straight shank drills are always held in a drill chuck.

Holding Parallel Shank Drills:

A drill chuck is the most useful device for holding the parallel shank drills and other small tools. Two types of chucks are commonly used.



1. Self centering three-jaw Chuck.
2. Quick change Chuck.

A drill chuck is capable of holding wide range of drill sizes and it is usually provided with radial fingers for this purpose. The chuck key is used for rotating the tool head body of the chuck. Inside the body, there are three radial fingers which carry teeth on their outer faces. These teeth mesh with three toothed blocks, mounted on ball bearings inside. For operating the chuck, the pilot of the key is inserted in the pilot hole so that the teeth of the gear, provided on the key, engage with the teeth provided on the body. As the key is rotated, the outer body rotates together with the toothed blocks inside. This forces the fingers to move out wards or in wards, depending on the direction of rotation of the key. This enables a firm gripping of the tool or its loosening respectively. While operating this chuck, the drill spindle has to be stopped and then only the key is fitted and rotated.

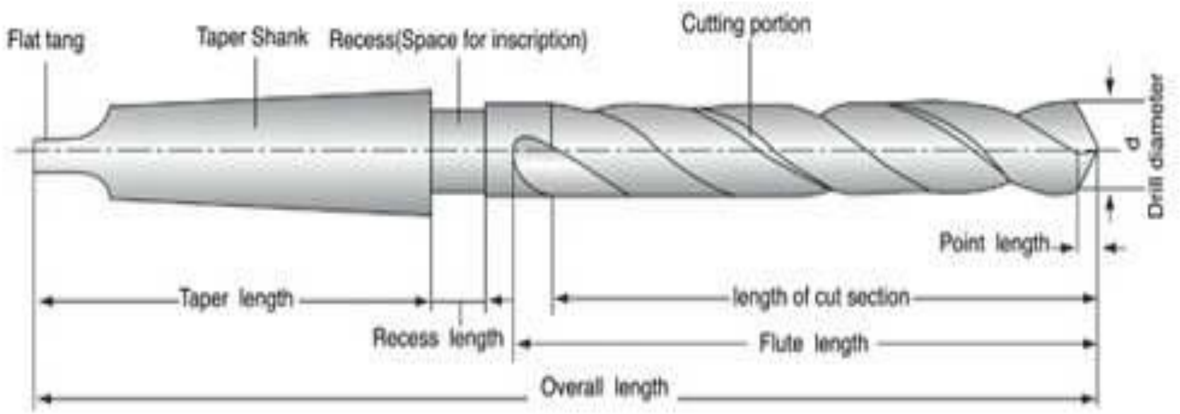
Quick change Chuck: It is mainly used in mass production work. The main advantage of this chuck is that the machine spindle is not required to be stopped, while changing the tool. Thus a number of tools can be held and replaced quickly, one after the other, without stopping the spindle. This type of requirement is always there, when a number of different operations like reaming, boring, spot facing etc are to be performed repeatedly on the same machine, such that a different tool is to be held for each operation.

A drill chuck is normally permanently fitted to the drill spindle on smaller and lighter type of drill machines. But on larger and heavier type of machines, the chucks carry standard taper shanks, which fit in to the corresponding tapered holes in the spindles.

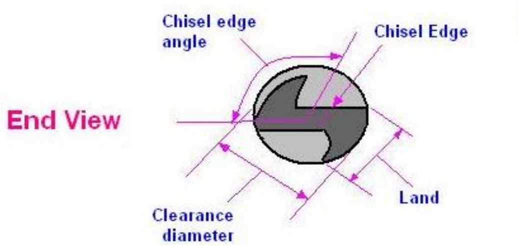
TWIST DRILLS

Twist drill is the most widely used tool in modern drilling practice. It consists of a cylindrical body carrying two spiral flutes cut on it. Twist drills are usually made of high speed steel. They are made in various sizes to suit the work and are provided with either tapered shank or parallel shank. Small drills say up to 12.7mm dia. are provided with parallel shank and larger sizes with tapered shank. Morse taper is commonly used for the tapered shank. Other types of shanks used on twist drills are bit shank and rachet shank, but they are not very common.

Twist drill consists of two main parts. Viz. a **shank**, which is gripped in the drill chuck or sleeve and the other the **body**, which forms the main cutting unit.



Tapered shank drills carry a tang at the end of the shank to ensure positive grip. The body consists of flutes, for removal of chips, the lips or cutting edges, the point or dead centre. The land or portion of full diameter which guides the drill in the hole and the body clearance or relief.



The drill should be so ground that the point is exactly in the centre i.e. the axis of the body and the lips are of equal angle and length. This will enable the production of a perfectly round, smooth, parallel and accurate hole of desired size and the drill will have better life. Unequal lips result in an over sized hole. This can be easily tested by drilling a small hole in mild steel. If the drill is correctly ground the spirals of chips that cut out will be exactly alike. If one is smaller than the other, or is broken it indicates an incorrect grinding. Alternatively, a drill grinding gauge can be used to test the same.

The advantages of using twist drills are:

1. The chips and cuttings of the metal are automatically driven out of the hole through the flutes.
2. Cutting edges are retained in good condition for a long time, thus avoiding the frequent re-grinding of the drill.
3. Heavier feeds and speeds can be used safely, resulting in a considerable saving of time.
4. For the same size and depth of the hole, they need less power in comparison to other forms of drills.

TWIST DRILL PARTS:

The twist drills are made to carry one of the following two types of spiral grooves on the body.

1. HIGH HELIX: They carry a helix angle of 35^0 to 40^0 and a heavy web. Their groove width is larger than that of the usual twist drills and therefore they enables easier and quicker disposal of chips. They are largely used for deep hole drilling especially in low tensile strength materials like Copper, Aluminum die casting alloys, Plastics, Wood etc. They are also known as **Fast spiral drills.**

2. LOW HELIX: They carry a small helix angle and are relatively more rigid. On account of their high rigidity, they are capable of taking higher torque and heavier feeds. They are widely used in general drilling work. They are also known as **Slow spiral drills**.

The detailed description of the different parts of a twist drill and their functions are as follows:

1. Body: It is that part of the drill which carries flutes and extends from dead centre up to the start of the neck.

2. Axis: The longitudinal centre line of the drill, along which the whole body, neck and shank of the drill are concentric, is called the axis of the drill.

3. Chisel edges or dead centre: The short edge formed at the extreme tip end of the drill, due to the inter section of the flanks, is called the chisel edge or dead centre. It coincides with axis of the drill. Some of the drills carry a screw type or spiral shaped chisel edge instead of a sharp edge type. This facilitates more accurate location of holes and lower axial thrust.

4. Shank: The portion of the drill beyond neck, which is gripped in the holding device (ex-Drill chuck, sleeve etc), is called Shank.

5. Point: The cone shaped surface at the end of the flutes, formed by grinding, and containing the dead centre, lips and flanks etc is known as point.

6. Lip or Cutting edge: It is the main cutting part of the drill and is formed by the inter section of each flank and face. There will be so many lips in a drill as the number of flutes and the faces. In a commonly used twist drill there are two lips, because it carries two flutes and two corresponding flanks. For correct drilling it is essential that both lips should be of equal length and be equally inclined with axis of the drill.
7. Body Clearance: A small reduction in the diameter of the body is provided on the drill adjacent to the land is called body clearance. It helps in reducing friction between the drill and the walls of the hole and thus helps in both metal cutting and increasing tool life.
8. Land or Margin: It is a narrow flat surface which runs all along the flutes of the drill on its leading edges. The diameter of the drill measured across its lands determines its correct size. The functions of the lands are to keep the drill aligned during the operation and produce the correct size hole.
9. Lip clearance: That part of the conical surface of point, which is ground to provide relief near the cutting edge, is called lip clearance.
10. Face: The curved surface of the flute near the lip is called face. The chips cut from the material, slide up wards along this surface.
11. Flutes: The helical grooves in the body of the drill are known as flutes. Commonly used drills carry two flutes, while special drills carry four. These flutes make the chips curl and provide passage for their exit. Cutting edges are formed on the point due to machining of these flutes and the cutting fluid reaches the cutting area through these flutes only.
12. Flank: It is the curved surface, on either side of the dead centre, which is confined between the cutting edge on its one side and the face of the other flutes on the other side.
13. Web: The central metal column of the drill body that separates the flutes from one another is known as web. Its thickness gradually increases from the tip side towards the shank side, where it is maximum. This will provide strength and rigidity to the drill.
14. Chisel edge corner: The point of inter section of the chisel edge and the lip is known as chisel edge corner.
15. Outer Corner: The extreme of the dead centre, where the face and flank intersect to form a corner is called outer corner.
16. Neck: The smaller diameter cylindrical portion, which separates the body and shank of a drill, is called neck. All necessary particulars of the drill are engraved on this portion.
17. Tang: The flat portion of rectangular cross-section provided at the end of the tapered shank is known as tang. This fits in to a matching slot in the holding device, such as socket, sleeve or spindle to provide a positive drive. Also for driving the drill out of the sleeve or spindle, the drift is applied over this part of the drill.
18. Heel: An edge is formed where the body clearance and the flute of the drill intersect. This edge is known as Heel.

DRILL DIMENSIONS:

The important dimensions of drill are:

1. Diameter: The linear measurement perpendicular to the axis and across the lands of a drill, at the outer corners.

2. Length of body: It is the length measured along the axis between the dead centre and start of neck of the drill.

3. Flute length: The length measured parallel to the axis between the dead centre and the point of termination of the flute near the neck.

4. Lip length: The distance between the chisel edge corner and the outer corner is called lip length.

5. Overall length: The distance measured along the axis between the dead centre and the extreme end of the tang is known as overall length. In the case of parallel shank drills, which carry no tang, it is the distance between dead centre and extreme end of shank measured along the axis of drill.

6. Depth of body clearance: The body diameter is slightly reduced either side and is measured along the radius of the drill, perpendicular to axis.

7. Core taper: It is the measure of the increase in web thickness or core thickness, starting from the minimum at the point end and to the maximum at the shank end of the drill.

8. Lead of helix: It is the axial distance measured between two corresponding points on a flute in its one complete turn.

IMPORTANT ANGLES OF A DRILL

Different angles are provided on a drill for efficient metal cutting. The main angles are:

1. Rake angle: It is also known as helix angle. It is the angle formed between a plane containing drill axis and the leading edge of the land. It can be positive, negative and zero value. For right hand flutes it is positive, for left hand flute it is negative and for parallel flutes it is zero. For most drills the rake angle varies from 0 to 48^0. However 16^0 to 32^0 is common for normal materials. Higher values are suitable for soft material and lower value for hard materials. Larger the value of this angle, lesser will be the torque required and vice-versa.

2. Point angle: It is also known as cutting angle. The most commonly used value for large variety of materials is 118^0. However it varies from 80^0 to 140^0 smaller cutting angle for brittle materials and larger for harder and tougher materials. It is the angle included between the two opposite lips of a drill measured in a plane containing the axis of the drill and both the lips.

3. Lip Clearance angle: The angle formed between the flank and a plane normal to the axis, measured at the periphery of the drill. Its value varies from 8^0 to 15^0 for most of the drills but 12^0 are most common. It enables easy entry of the drill.

4. Chisel edge angle: When the drill is viewed from its end, there appears to be an obtuse angle formed between the lip and chisel edge. This is called chisel edge angle. It determines the clearance on the cutting lip near the chisel edge. The greater this angle larger will be the clearance. Normally this angle varies between 120^0 to 135^0.

STRAIGHT FLUTE DRILLS:

Twist drill is not suitable for drilling holes in softer materials like brass as it will pull through the back of the metal. A straight fluted drill is proper tool for such work. The only disadvantage is chips clog in the flutes then in spiral flutes. Mainly used for drilling holes in sheet metal.

BORING MACHINES

The operation of a boring is enlargement of an already existing hole. This hole can be due to previous drilling, or produced in casting or forging. Small holes, particularly in small jobs the boring operation can easily done on centre lathe or capstan and turrets of medium size. For large and heavy jobs special boring machines are used, which make the operation easy and efficient. These machines are production machines for boring on a large scale.

Classification of Boring Machines:

Boring machines are manufactured in various different designs & sizes. They can be broadly classified in to the following three types.

1. Horizontal Boring Machines.
2. Vertical Boring Machine.
3. Jig Boring Machine.

The first two types are production machines used in general production work, the last one is a precision machine, used for precision boring operations, such as Jig Boring.

Horizontal Boring Machine:

Horizontal boring machines are of various types such as **Table type**, **Planer type, Floor type, and Multiple head type** etc each of these suitable for a certain range of operations, but of all these the table type or universal type is most versatile and commonly used. The spindle of this machine is capable of holding drills, and milling cutters as well to perform the operations of drilling and milling hence this machine is called horizontal boring, drilling and milling machine.

The principal parts of this type of machine are:

1. Two vertical columns, one on each end of the table.
2. A head stock which can be moved vertically, along the main column.
3. A horizontal spindle, suitably housed in the head stock, which can be rotated and fed forward and backward according to requirement.
4. A load bearing end support, for supporting the end of a long boring bar, which can be adjusted vertically along the end support column.
5. A horizontal table, mounted on a saddle that can be moved horizontally forward and backward and sideways by moving the saddle.
6. A heavy and strong bed, which carries the entire load of different parts, work piece and tooling over it.

Floor type Horizontal Boring Machine:

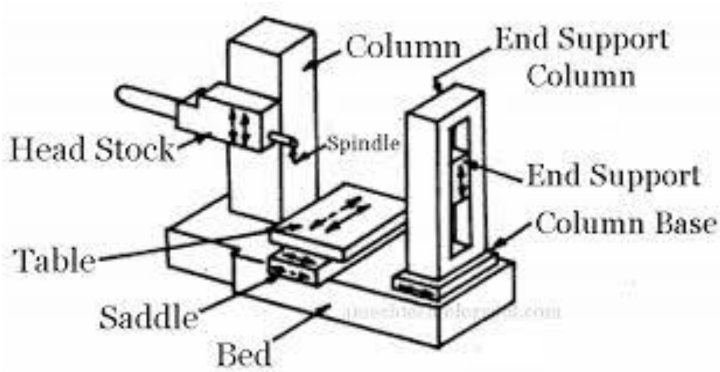
This machine is comparatively heavier type of horizontal boring machine. The operating and spindle supporting units are not mounted on a bed, as in the table type machine, but are carried on separate run ways, which facilitates the movement of these units, together with the spindle past the work. The work does not move at all, but is kept stationary at a platform floor plate. It is this relative movement of work with respect to the other units of the machine in which it differs from the table type machine. This type of the machine is very suitable for long and heavy jobs.

Planer type Horizontal Boring Machine:

This machine resembles in construction with the table type. The only difference in the construction and operation of the work supporting mechanism. In this a heavy cross-bed is incorporated between the spindle column and the end support column. This bed is mounted across the axis of the spindle and carries a table over it. On its two sides it carries two columns. The main column carrying the head stock, is rigidly fixed, whereas the end-support column can move towards or away from this bed along the horizontal ways provided on the top of the cross bed, at right angles to the former bed. The job is mounted on the table. In operation, it resembles a planner in that the tool is held between the two columns or mounted on the head stock only and the work, mounted on the table, moves past the tool. This type of machine is very suitable for long jobs.

Multiple Head type Horizontal Boring Machine:

It consists of two vertical columns mounted on the sides of a stationary bed. The columns are bridged by means of a cross-rail. As a maximum four head stock can be mounted on the machine, one each on the two vertical columns and two on the cross-rail. The head stock on the columns will have horizontal spindles and those on the cross-rail vertical spindles. In this way maximum four tools can be mounted simultaneously on this machine. The work is mounted on the table, which is supported and moved on the bed. This machine resembles a planer type milling machine. The head stocks can be swiveled to desired angles if angular cuts are required to be taken. Machining on more than one surface on a job is possible simultaneously as up to four tools can operate simultaneously on the job from different angles and at different locations.



Vertical Precision Boring Machine:

It is a production machine basically designed for boring holes in cylinder blocks and liners of automobile engines, fine boring of parts in Ferrous and non ferrous metals etc.

Constructional Features:

Column and Base: The vertical column is a cast Iron box type casting with stiffening ribs inside. The base is another massive cast Iron structure and carries guide ways at its top face, along which table traverse column and base are fastened together rigidly. Prismatic guide ways are provided on the front face of the column along which the spindle head moves up and down. Lead screw of the spindle head is located between the two vertical ways at the front face of the column.

Spindle Head: It traverses in vertical direction along the column ways. The spindle head housing carries inside it the v- belt drive for spindle and hand traverse mechanisms. According to the size of the hole to be bored, one of the three inter changeable spindles, provided with the machine is mounted on the spindle head. A screw is provided with the machine is mounted on the spindle head. A screw is provided on the tool holder face for adjustment of overhang of the boring tool. A special dial is provided to show precision adjustment of the tool up to 0.02mm.

Speed and feed gear box: It is mounted inside the column on the machine base. It transmits the motion from the electric motor to the shaft of the spindle drive and to the lead screw of the indle head. The gear box provides 6 spindle speeds and 4 feeds and also rapid traverse to the spindle.

Table: It is made in two parts. The lower part moves in cross direction along ways provided on the base and the upper one in longitudinal direction along the ways provided on the top of the lower part. During the operation the table can be locked by means of stops to prevent its movement in either direction.

Salient Features:

1. The machine is highly rigid and vibration proof, maintains its initial accuracy of performance over a long period of time.
2. The control of speed and feed gear box is conveniently grouped in an easy to reach place and is performed by means of three levers.
3. Most of the machine units are assembled in independent housings which facilitates easy repair.
4. The table being movable in two directions permits to bore several holes in a work piece at one setting.
5. The upper limit of the spindle speed, ample power of motor and rigidity of the machine permit the use of carbide cutting tools.
6. Precision antifriction spindle bearing ensure machine durability, accuracy and surface finish.

Vertical Boring Machines:
In this the work is held on a rotary table, rotates about a vertical axis, while the tool remains stationery, except for feeding. The table together with the work rotates in a horizontal plane. Thus if the table is considered to have replaced the chuck or face plate of a centre lathe, this machine can be considered as a vertical lathe with its bed working as a head stock mainly the following three types of boring machines in this category.

1. Standard Vertical boring mills.
2. Vertical Turret Lathes.
3. Vertical Precision Boring Machines.

Standard Vertical Boring Mills: It consists of a heavy Cast iron bed, which carries a circular table over it. On the sides of the bed are two vertical columns which are bridged together by means of a cross-rail. As a maximum four tool heads can be mounted on the machine one each on the two columns and two on the cross-rail. This number can also be reduced according to the requirements. Usually the tool heads carry the provision for being swiveled to a certain angle for taking angular cuts. The work is mounted on the table which rotates about its vertical axis. the rotating work is thus, fed against fixed tools, which results in circular cuts being taken on the job. The table is provided with T-slots for clamping the work.

Usually large symmetrical work pieces, such as cylindrical objects are bored on these machines. A few examples are the casings for steam turbines, tables for machine tools and pressure vessels. Vertical housing on the two sides of the table limits the size of the work. The maximum size of the work would be equal to dia. of the table and same will represent the size of the machine.

Vertical Turret Lathe: It has a special advantage that many tools can be simultaneously mounted on the turret head, and therefore, a large number of different operations can be performed in addition to boring a single setting of work. The table of the machine is of rotary type and carries adjustable jaws for clamping the work.

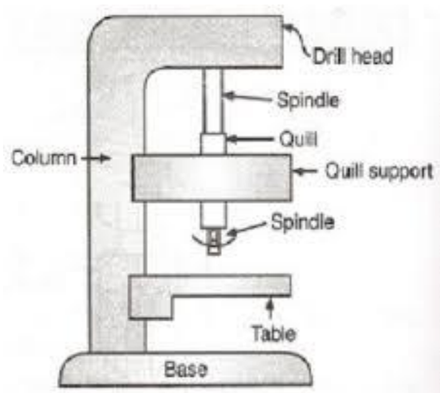
The rotary table rotates over the bed, about a vertical axis. The work piece is held over this table. Maximum two side tool posts can be mounted, one each on each column. These tool posts can be adjusted vertically and they can also move forward and backward. One or two vertical tool heads can be mounted on the cross-rail, which can be adjusted horizontally along the cross-rail. Each vertical tool head will carry a turret head enabling to mount a number of tools in sequence on it to enable different operations to be performed in a single setting of tools. The turret head can be indexed after each operation, to bring the proper tool in position for the next operation. The vertical tool head can also be moved, upwards and down wards, according to requirement.

Jig Boring Machine:

It is a specially designed machine tool used for precision location and production of holes, as are needed in Jigs, Fixtures templates, dies, gauges etc, such a high degree of accuracy is usually called for where the relative location of different holes on the same adjacent parts effects their operations.

In appearance and construction a Jig boring machine resembles very much to a vertical milling machine, but is comparatively more rigid and accurate than the latter (milling machine). It essentially consists of a heavy base and vertical column. The column at its top, carries the spindle head, which can slide up and down along the vertical guide ways provided at the front of the column. A saddle is mounted on the horizontal ways on the top of the base to give cross-feed to the work. The table is mounted over the saddle and the same can move to and fro at right angles to the movement of the saddle, along the guide ways provided on the saddle. The work is thus, given the longitudinal movement by moving the table, cross movement by moving the saddle and vertical adjustment of the tool to the work is made by moving the spindle head up and down. A quill is provided in the spindle head, and spindle moves inside it spindle RPM 30-1500.
Different Systems of Measurement: There is not much difference among the different types of jig boring machines, through, they seem to be so with respect to their designs and sizes. The specific difference, which is of importance, lies in the systems of measurements adopted in different Jig borers.

1. Precision Lead-Screw System: This system consists of a lead-screw, under the table for moving it, a graduated micro meter dial at its end and a compensating device for corrections of errors in the table movements. The compensating device consists of a profile cam fitted on the side of the table, a lever to follow the cam profile as the table moves and a link to transfer the variations in the cam to the vernier fitted on the dial of the lead screw. Another similar arrangement is used for cross movements of the saddle. The advantage of this system is that it is in closed in the machine and is not affected by the variations in room temperature. Also, it provides a rapid traverse, but has a disadvantage also in that it limits the size of the table and its travel. Another disadvantage is the accuracy of the lead screw is of the order of 0.005mm and if varies from one place of lead screw to another. The size of accurate lead screw is limited to 400mm.



2. End-Measurement System: The system used to the work accurately with end measures is the same as for other machines. The first step in it is to locate the work piece from two finished edges 90^0 a part, one placed to the right of the table and the other placed to the front of the table. With the help of the dial indicator in the spindle, the edges are made parallel to the table travel, and the work piece is clamped securely without distorting it. A microscope is then mounted in the spindle and the table moved so that the cross-hairs are exactly centered over the intersection of the two finished sections or any other zero point. Next the dimension at which hole is to be located is arranged by having suitable end measures for whole number and an inside micrometer for dimensional measurement and placing them together on the trough. The table is then moved till the built in dial indicator resting against the end standard and inside micrometer reads zero. In the similar manner, the dimension in other plane in set. Dial indicator on one side and adjustable stopper on the other side.

The traversing screws for the saddle and table have no connection with the measuring system, and back lash or wear in them has no effect on the accuracy of any setting.

The advantage is that it is very simple and easy to set up since the end measures are simple numbers. There is no particular limit to the size of the machine. The disadvantage of the system is that the end measures rest in an open trough and are therefore subject to dirt and temp. Variations due to surrounding temp and handling them by operator.

3. Scale and Microscope System: In this system, accurately graduated scales are in corporate in the machine to read the longitudinal movement of the table and the cross-traverse of the saddle. These measurements are read through a micro-scope. The main advantage of this system in that it carries no wearing parts and is free from dirt as it is enclosed in the machine. Care should be taken to keep it free from the temperature effect.

4. Electromagnetic System: This system consists of two master bars, attached one each to the underside of the table and the saddle. These bars carry a series of equal spaced projections, which are magnetized. The centre to centre distance between the adjacent projections in constant and the total accumulated error for the total length of the bar is 0.005mm. Just below the table, there is a precision micrometer screw having a micro meter dial at its end. A movable slide is connected to this screw and a magnetic head is fastened to the slide. This head is also connected to a meter which gives a zero reading, when the magnetic centre of a projection is just in front of the head. This is a very efficient system which enables a rapid traverse of table and saddle, except at the end of the setting, where a relative slower movement is needed.

5. Pickup Devices: An electro-magnetic system is used for accurate setting of longitudinal and cross co-ordinates automatically and for automatic stopping of them as they reach nearer the previously set traverses. Pickup for longitudinal co-ordinate on the saddle. The pickup device consists of a nut of 5mm pitch threads, a coil create an electric field and a screw of 5mm pitch threads. The coil moves along the screw with the nut and the indicator shows the exact position of the table or saddle for each 5mm travel. Automatic switching off of electric current just before reaching the end of preset travel is accomplished by means of an adjustable stop. The remaining setting is done by hand. Co-ordinates can be set with accuracy up to 0.001mm. Three dials are provided for reading the setting of the co-ordinates, one giving the whole numbers of millimeters, second reads up to 0.01mm and the third reads up to 0.001mm.

Many operations, other than boring, drilling and milling can be performed on all common types of boring machines. The allied operations are:

1. Facing— Machining of small un even surfaces to act as a seat for some other part. Boring bar can be effectively used for this operation.
2. Counter Boring— Enlargement of the hole to a certain depth only. Tools used for counter boring small holes need a pilot at the front end.
3. Counter Sinking— Providing a conical recess at the end of the hole, to make a seat for counter sunk head of a mating component like rivets and screws.
4. Trepanning— It is an operation done when a large hole is to be made in a this metal or a very deep and large hole is to be made in a solid work piece. A simple tool used on this sheets consists of a hallow body carrying the cutting edge with a prop at its centre for location. For making holes in solid body Carbide cutting tips are brazed to a hallow body and as the tool advanced a solid core is cut is accommodated in the bar.
5.

Description of Jig Boring Machine:

It is a high quality machine and carries an electromagnetic system of measurements. It is basically designed for drilling and boring holes in Jigs, Fixtures, templates, gauges, dies and other components of small and medium sizes, where a very accurate location of holes is needed. It can also be used for doing for light milling work. The machine is also equipped with plain rotary as well as inclined rotary tables, in addition to the rectangular, so that the holes can be drilled and bored along the circumference of the work and also at an inclination. It carries a guaranteed accuracy of centre to centre distance of 0.006mm.

This machine consists of the following main parts:

1. Bed: It is the main supporting member of the machine. It is made of Cast Iron and is highly rigid because of its box shaped construction having stiffening ribs. The column is mounted on it and at its top it carries guide ways for the saddle. Electricals for spindle drive and table feed drive are housed in it.

2. Column: It is a hollow vertical Cast Iron structure carrying vertical guide ways at its front for the vertical traverse of the spindle head. Counter weights for balancing the spindle head are housed inside it. It also carries the counter weight for balancing the spindle with the quill clamping device for spindle head and the belt drive for spindle.

3. Spindle head: It is mounted in front of the column. A rack and pinion mechanism, operated by a hand wheel is used to adjust its position vertically. It carries the quill, drive gearbox, and feed gearbox for the spindle. An indicator device is provided on it to measure the boring depth correctly. A separate dial is provided at its front to set the length of spindle travel. The feed gearbox provides 6 spindle feeds. A stop disengages a clutch at the end of previously set travel to disengage the spindle feed automatically.

4. Table and Saddle: The table and saddle are given longitudinal and transverse motions respectively by a separate electric motor inside the bed. They also carry the clamping and measurements reading mechanisms. Rapid traverse of the table and saddle is affected by clutch operated by an electro-magnet. Verniers are provided for setting the table by hand. The plain and inclined rotary tables are provided in addition to the rectangular table for boring holes the circumference of a job and at desired inclination respectively.

Boring Tools and Bars

The tools used in boring work are of mainly two types.

1. Rotating Type
2. Non-Rotating Type

Rotating type tool is used when it is in convenient to rotate the work on account of its shape or other reasons. Such tools are commonly used for boring work on drilling machines, centre lathes, boring machines and sometimes in milling machines. As against this when the work can be conveniently held in chuck, face plate or fixture i.e. it can be conveniently rotated, the non-rotating type tool is used. This type is generally used on Centre lathe, Capstan. Turret and Automatic lathes, Vertical lathes and Boring machines.

1. Forged Solid tools: They are generally forged out of tool steel and then ground to correct angles. They are made in pairs, consisting of a roughing and finishing tool. These tools are held either in slide rest, turret head or sometimes in tail stock. The work is held in a chuck or faces plate and revolved, the tool is fed in to the job by moving slide rest, turret slide, tail stock spindle as the case may be.

2. Boring Bars: There are many ways a boring bar can be held on lathe. The bar is held in the slide rest and the work in the chuck or face plate. The work will rotate and bar is fed in to it as the forged tool. Alternatively the bar can be held in tail stock or in turret head and fed as usual. In case through holes, when the shape of the job creates difficulty in rotating, the boring bar can be held between centers and job is clamped on the cross-slide. The bar rotates in its position, the feed in given by moving the carriage, the depth of cut can be varied by projection of the boring bit adjustment.

3. Boring tools with inserted teeth: These tools consist of a round blank, fitted with a shank for holding. The blank carries a number of slots along its periphery in which various tool bits can be inserted. The advantage with such tools is that after the bits are worn out, they can be replaced by new ones, the blank and shank remaining the same.

GRINDING MACHINE

Grinding is a process of removing material by the abrasive action of a revolving wheel on the surface of a work piece, in order to bring it to the required shape and size. Grinding is similar to other machining operations since the material is removed in the form of very small chips, similar to those obtained in other machining operations. The wheel used for performing the grinding operation is known as “Grinding Wheel”. It consists of sharp crystals, called abrasives, held together by a binding material or bond .It may be a single piece type or several segments joined together. In most of the cases, it is a finishing operation and a very small amount of material is removed from the surface during the operation

ABRASIVES: It is the material of the grinding wheel, which does cutting action. These are extremely hard materials, consisting of very small particles, called grains, which carry a number of sharp cutting edges and corners. They are two types. 1). Natural 2). Artificial

Natural Abrasives: They are obtained directly from mines. The common natural abrasives are sand stone, emery, corundum, Quartz and diamond. All the natural abrasives, except diamond are now obsolete. Sand stone is used only for sharpening wood working tools. All other natural abrasives are almost replaced by artificial abrasives. Diamond, still retains its place even in modern grinding processes. It is largely used for dressing grinding wheels and for grinding hard materials.

Artificial Abrasives: They are manufactured under controlled conditions in closed electric furnaces to avoid impurities and to achieve necessary temperature for the chemical reaction to take place. The main artificial abrasives are:

1. Silicon Carbide (Sic): It is made from Silicon dioxide, coke, sawdust and salt. These constituents are mixed together and piled up around carbon electrical conductor of a resistance type electric furnace. A heavy current is switched on and temperature of about 2600^0C generated. The mass, under the action of intense heat, fuses. The outer shell is removed and the Silicon Carbide Crystals are broken in to grains.

2. Aluminum Oxide: This abrasive is very hard and tough grains having sharp cutting edges. It is obtained by fusing impure Aluminum Oxide (Bauxite) in an electric arc furnace. Dry bauxite is mixed with ground coke and Iron chips. This mixture is heated in the furnace with a heavy current. It is then crushed and the powdered grains are formed are screened through standard meshes. These grains are not as hard as Silicon Carbide but less brittle preferred for grinding metals of high tensile strength like hardened tool steel components.

3. Artificial Diamonds: The diamonds produced through artificial means are quite comparable to the natural diamonds in their grinding characteristics and give normally better results than the natural diamonds.

Advantages and uses of artificial abrasives

The manufactured or artificial abrasives superseded the natural abrasives for the following reasons:

1. The controlled conditions in the electric furnace enable uniformity in the product.
2. The quantity of production and supply can easily be varied according to the demands.
3. They have largely abolished the dependence on natural means to meet the growing demand in the modern manufacturing processes.

The selection of a particular abrasive is governed by many factors, like hardness, toughness and other properties of work material.

BOND MATERIALS:

In order to give an effective and continuous cutting action, it is necessary that the grains of abrasive material should be held firmly together to form a series of cutting edges. The material used for holding them is known as bond. The principal bonds are:

1. Vitrified
2. Silicate
3. Oxychloride
4. Resinoid
5. Shellac
6. Rubber

1. Vitrified bond: It is a clay bond, reddish brown color. The base material is “**Felspar”** which is fusible clay. Proper proportions of Felspar, refractories and flux mixed thoroughly with abrasive grains to form a paste. The paste is placed is moulds to get the shape of a wheel and air dried. The wheels become enough hard are fed in to kiln at 1260^0C and allowed to remain there for few days. This process is known as fusing and it provides uniform distribution of bond through and the wheel. After this, the wheels are trimmed to the required size. For obtaining very hard and close grained wheels, the paste after being place in the moulds, is pressed under hydraulic pressure.

Advantages:

1. It is made porous and enables quicker metal removes.
2. It is not affected by water, oil, acids, temperature or climatic conditions.
3. The bond itself is very hard and acts as an abrasive.
4. On account of excessive heat in the kiln the impurities are burnt and only bond and abrasive left.
5. The structure of the wheel is uniform due to wet mixing of different constituents.

Disadvantages:

1. The process of manufacture is very slow.
2. Cracks may develop in large size wheels during fusing.
3. Wheels over 750mm dia can’t be easily produced.
4. Proper control during fusing becomes difficult.
5. High temperature in kiln tends to make the abrasive grains weak.

2. Silicate bond: It s base material is Silicate of soda. The process of mixing, moulding, packing or ramming, drying etc are done in the same way as vitrified bond, but the oven carries a temperature of about 260^0C only. The application of lower temperature results in high tensile strength. As usual, the paste mixture after moulding is subjected to hydraulic pressure if hard and close grained wheels are needed. They are light grey in color. These wheels are used where a cool cutting action with less wear is needed as in grinding the edges of the heat treated steel cutting tools. The cool cutting action is due to the bond releases the abrasive grains more quickly than vitrified bond.

Advantages:

1. It is more rapid process than vitrified bond.
2. Because of the moderate temperature in kiln, there is no tendency to weaken the grains.
3. Fusing is better controlled, results in more reliable bond.
4. When wet grinding is performed, the soda acts as a lubricant.
5. Large wheels up to 1500mm dia can be easily produced.
6. The cutting action of the wheel is smoother and cooler.
7. Because of low fusing temperature the wheel can be moulded on Iron backs, which is not possible in case of vitrified bond.

Disadvantages:

1. Extra hard wheels cannot be produced with this bond.
2. Harder grades of this bond do not provide a free cutting action.

3. Oxychloride bond: It is a mixture of Oxide and Chloride of Magnesium and setting takes place in cold state. The process of wheel manufacture is similar to the above two, but no heating and subsequent cooling is required on account of the cold setting property. Ageing is necessary so that the bonded wheel gets adequate hardness. This bond provided a cool cutting action, but grinding is usually done dry as it is very susceptible to the action of conventional coolants and therefore, the full use of the cutting capability of the wheel cannot be taken.

4. Resinoid bond: It is a synthetic organic compound, which is enough strong and flexible. It provides a sharp cutting action and enables a high rate of stock removal at high speeds. Mainly used for cutting bar stocks, fine grinding of cams, precision grinding of rolls etc.

These wheels are manufactured from a mixture of abrasive grains, synthetic resins and some compounds. This mixture is filled in moulds and then fed in to the furnace for heating. A constant temperature of about 2000°c is maintained in the furnace. Due to heat, the resin sets and binds the abrasive grains together. The shape and size of the bonded wheels will depend upon the shape and size of the mould.

5. Shellac bond: These wheels are produced by mixing the bond and the abrasive grain in a steam heated mixer, followed by moulding under pressure in steam heated moulds. These wheels are cool cutting and are vastly used on hardened tool steel and thin sections. They also help in producing high surface finish, as is normally required on components like cam shafts. They can run safely in water but use of oil or caustic soda should be avoided.

6. Rubber bond: It is composed of fairly hard vulcanized rubber. The common manufacturing process consists of passing of rubber and sulphur through the mixing rolls and adding the abrasive grains slowly as the above two constituents pass through the rolls. Adding of abrasive grains continues till the required proportion is achieved. The mixture is then passed through another set of rolls to obtain the required thickness. The wheels are then cut and placed in preheated moulds and vulcanized under pressure. These wheels are quite strong, close grained and can be made in very thin sections. They are mainly used where a very high class surface finish with close dimensional accuracy is required. During the operation water can be safely used as a coolant, but caustic soda and oil should not be used as caustic soda will disintegrates the bond and the oil will softens it.

Symbols used for representing the type of bond.

Vitrified ______ V
Silicate ______ S
Oxychloride ______ O
Resinoid ______ B
Shellac ______ E
Rubber ______ R

SELECTION OF GRINDING WHEELS

Selection of proper grinding wheel is a vital necessity to obtain the best results in grinding work. A wheel may be required to perform various different functions like quick removal of stock material, give a high grade surface finish, maintain close dimensional tolerances and a single wheel will fail to meet all the requirements. It is necessary therefore, that proper grain size, bond, grade, strength, shape and size of the wheel should be selected to meet the specific requirements of a job. The factors up on which the above selection will depend are as follows:

1. Properties of the material to be machined i.e. its hardness, toughness, strength etc.
2. Quality of surface finish required.
3. Grinding allowance provided on the work piece i.e. the amount of the stock material to be removed.
4. Dimensional accuracy required.
5. Method of grinding i.e. wet or dry.
6. Rigidity, size and type of machine.
7. Relative sizes of wheel and job.
8. Type of grinding to be done.
9. Speed and feed of the wheel.

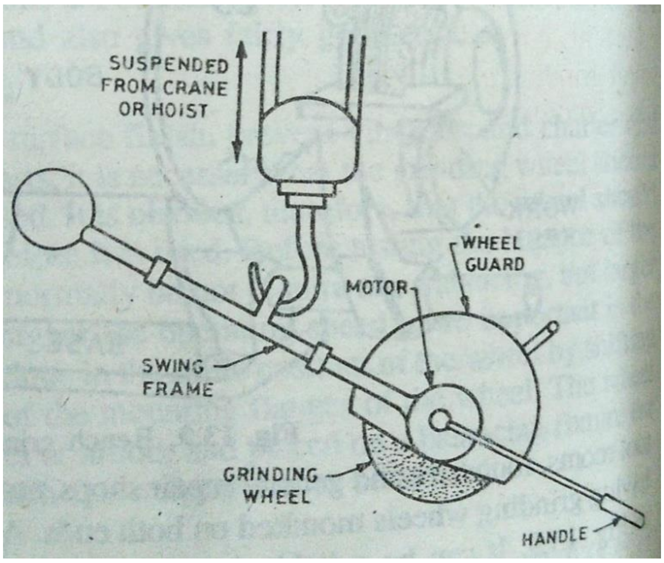
TYPES OF GRINDING MACHINES

Different types of grinding machines have been designed and are being used. Some of these are for roughing work, some for precision work and some for special purpose i.e. to perform a specific type of operation only. There are many varieties of grinding machines; the most commonly used types can be classified as:

1. Roughing or non precision grinders.
2. Precision grinders.

1. Roughing or non Precision grinders: The main purpose of these grinders is to remove more stock than can be removed by other types of grinders. The quality of surface finish is of secondary importance are as follows:

1. Bench, pedestal or floor grinders.
2. Swing frame grinders.
3. Portable and flexible shaft grinders.
4. Belt grinders.



1. Bench, pedestal or floor grinders: These grinders are commonly used for grinding various materials and cutting tools in tool rooms, foundries and general repair shops etc. They carry horizontal spindle, having grinding wheels mounted on both ends. It can be suitably bolted on a bench.

The floor stand or pedestal grinder is bench grinder of above type mounted on a steel stand or pedestal of suitable height. The horizontal spindle carrying the grinding wheels is normally an extension on both sides of the armature shaft of the motor. These grinders can also be used for polishing by replacing the grinding wheels by polishing wheels.

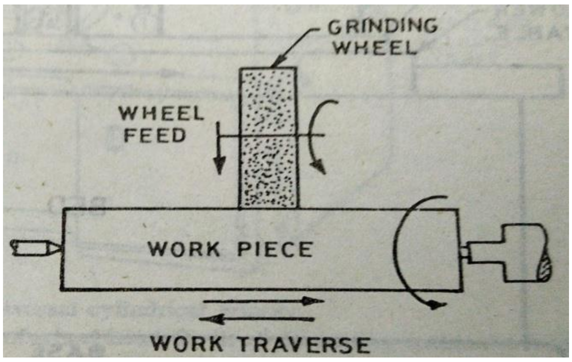
2. Swing frame grinders: It consists of a 2 to 4 meters long horizontal frame, freely suspended at its centre. The frame carries a grinding wheel at its one end and motor at the other. The motor drives the grinding wheel by means of a belt. In operation, the motor is started to revolve the wheel and the frame swung by the operator about its point of suspension (centre point) to cover up the desired grinding area.

3. Portable and flexible shaft grinders: These grinders resemble very much with the portable electric drills, both in construction, as well as operation, with only difference that the spindle carrying the drill chuck is replaced by a spindle on which a small grinding wheel is mounted. A safety guard is also provided over the wheel. These grinders are vastly used in finishing casting, forgings, welded joints in structural work, removing burrs and sharp edges.

Flexible shaft grinders consist of a flexible shaft driven by an electric motor. The shaft carries a chuck or collet at its end to receive small grinding tools, mounted wheels and points and small grinding discs. The electric motor is mounted on a fixed stand.

4. Belt grinders: These machines are designed to use an endless abrasive belt for grinding instead of a regular type of grinding wheel. The belt runs round the pulleys or rollers and the work is fed against the revolving the abrasive coated belt. One of the rollers (driver) revolves at high speed. A heavy metal plate called platen is so incorporated that the smooth under side of the belt runs in contact with the same. This platen may carry the shape conforming to the shape of an object or may be flat as required. The work piece is fed manually on to the open abrasive side of the belt and pressed against the platen to perform the grinding operation. With proper selection of proper grade and grit size, this process can be used both for rough and finish grinding. Machines are available in different varieties like wet-belt, dry-belt, combination machines etc.

CYLINDRICAL GRINDERS



The principle of cylindrical grinding involves holding the work piece rigidly on centers in a chuck or in a suitable holding fixture, rotating it about its axis and feeding a fast revolving grinding wheel against the work. If the work surface to be ground is longer than the face width of the grinding wheel, the work is traversed past the wheel or the wheel past the work. Traversing of wheel or work is done either by hydraulic or mechanical power or by hand. Feed is given to the work or the wheel at the end of each traversing movement. In case the width of wheel face is more or equal to the length of the work surface to be ground, the wheel may be fed in with no traversing movement of it or that of the work. This is known as "**Plunge Grinding**". The simplest and commonly used type of cylindrical grinder is a tool post grinder used on lathes. When wheels of large diameters are used, they can be mounted directly on the motor shaft. For mounting small wheels an auxiliary shaft is provided, which runs at a relatively much higher speed than the motor. Both external and internal cylindrical grinding can be done on lathe by this equipment.

Cylindrical grinding machines are mainly of the following three types:

1. Plain Cylindrical Grinders.
2. Universal Cylindrical Grinders.
3. Centre less Grinders.

1. PLAIN CYLINDRICAL GRINDERS: On these grinders, the work piece is usually held between two centers. One of these centers is in the head stock and the other in the tail stock. In operation, the rotating work is traversed across the face of the rotating grinding wheel. At the end of each traverse, the wheel is fed in to the work by an amount equal to the depth of cut. While mounting the work between centers, the head stock centre is not disturbed. It is the tail stock centre which is moved in or out, manually or hydraulically, to insert and hold the work. Tail stock and head stock both can be moved along the table to suit the work. The table is usually made in two parts. The upper table carries the tail stock, head stock and the work piece and can be swiveled in horizontal plane, to a maximum of 10^0 on either side along the circular ways provided on the lower table. This enables the grinding of tapered surfaces. The lower table is mounted over horizontal guide ways to provide longitudinal traverse to the upper table, and hence the work. The table movements can be both by hand as well as power. Hydraulic table drives are usually preferred.

The wheel head is usually mounted on horizontal cross ways on the bed and travels along these to feed the wheel to the work. This movement is known as in feed. The wheel and work are so adjusted that the grinding force is directed downwards to ensure proper stability.

UNIVERSAL CYLINDRICAL GRINDERS: A universal cylindrical grinder carries all the parts and movements of a plain cylindrical and in addition, carries the following advantageous features:

1. The head stock can be made to carry a live or dead spindle, as desired, the former (live centre) being needed, when the work is held in a chuck.
2. The head stock can itself be swiveled in a horizontal plane.
3. Its wheel head can be raised or lowered and can also be swiveled to $\pm 90^0$ to grind tapered surface having large taper angles.

All these factors contribute towards the greater versatility of these grinders. All the modern universal type cylindrical grinders carry hydraulic drive for wheel head approach and feed, table traverse and elimination of back lash in the feed screw nut. Most of the modern universal grinders are provided with necessary extra equipment like work rest to support slender work, wheel truing device, arbor for balancing the wheel, internal grinding spindle and three jaw self centering chuck etc.

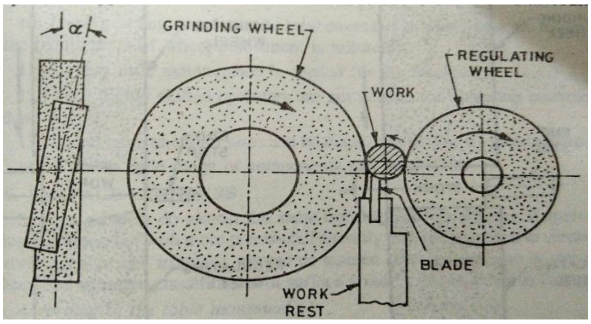
3. CENTRELESS GRINDERS: These grinders are also a type of cylindrical grinders only, but the principle of centre less grinding differs from centre type grinding in that the work, instead of being mounted between centers, is supported by a combination of a grinding wheel, a regulating wheel and a work rest blade. The relative movements of the work piece and two wheels, the principle of centre less grinding is used for both the external as well as internal grinding. Many hallow cylindrical and tapered work pieces, like bushes, pistons, valves tubes and balls etc, which either do not or cannot have centers, are best ground on centre less grinders.

It carries a heavy base and two wheel heads, one carrying the grinding wheel (larger one) and the other regulating wheel (smaller one). The work piece rests on the blade of the work rest between these two wheels. Each head carries a separate wheel truing mechanism for the wheel it carries. Housing is provided on one side of the machine body to house the main driving motor. There are two control panels on the front. The left hand panel carries controls for speed adjustments of the two truing mechanisms and the in feed grinding mechanism. The right hand panel carries controls for hydraulic mechanism speed adjustment of regulating wheel, automatic working cycle switch, start and stop switches etc.

In operation, grinding operation is performed by the grinding wheel only while the function of the regulating wheel is to provide the required support to the work piece while it is pushed away by the cutting pressure of the grinding wheel. At the same time, required support from bottom is provided by the work rest as the work piece, while rotating rests on the blade of the work rest. The regulating wheel essentially carries rubber bond and helps in the rotation of the work piece due to friction. The directions of rotation of the two wheels are the same. The common methods used feeding the work is:

1. Through feed 2. In feed 3. End feed

1. Through feed Grinding: In this method of centre less grinding, the work piece is supported and revolved as described above but is simultaneously given an axial movement also by the regulating wheel and guides so as to pass between the wheels. For this, the axis of the regulating wheel is inclined at 2° to 10° with the vertical. The amount of the stock to be removed determines as to how many times a work piece has to pass between the wheels. This method is used for straight cylindrical objects.



The actual feed (f) can be determined by the following relationship:

$$\mathbf{f = \pi d n \sin\alpha}$$

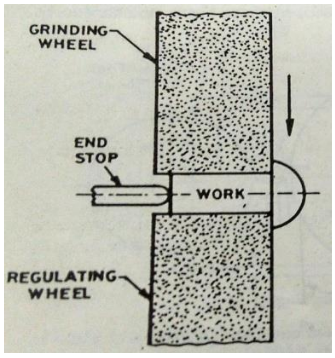
Where f = feed in mm/min

d = dia. of regulating wheel in mm

n = Revolutions/min

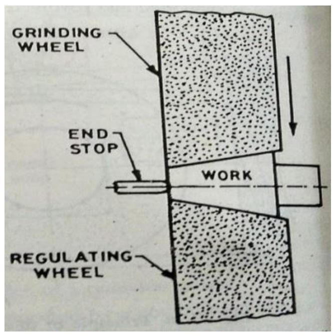
α = Angle of inclination of regulating wheel

2. In feed Grinding: Both regulating wheel and grinding wheel are more in width than the work length to be ground. Axis of the regulating wheel is inclined about half a degree from the horizontal. This method is used for grinding shouldered or formed components.



Before the operation, the regulating wheel is drawn away to accommodate the work piece. After placing the work piece on the blade of the work rest, the regulating wheel is again pushed in to press against the work. In this operation, the work rest does not carry guides. Instead, it is made to have an end stop at the rear end.

3. End feed Grinding: This method, in a way, a sort of form grinding. It is because both the wheels i.e. the grinding wheel and regulating wheel, and dressed to contain the required shape or form. The work is fed longitudinally from the side of the wheels. As it advances between the revolving wheels, its surface is ground till its farther end touches the end stop. This method can be used for grinding of both spherical and tapered surfaces, but it suits best to the grinding of short tapered surfaces.



Advantages of centre less Grinding:

1. Need for centering and use of fixtures etc is totally avoided.
2. It can be applied equally to both external and internal grinding.
3. Once a set up has been made, it is a faster method than centre type grinding
4. In feed method also no chucking of work is needed and idle time is negligible.
5. Since there is no end thrust, there is no any spring action or distortions in long work pieces.
6. The work is rigidity supported during the operation, heavy cuts can be taken, rapid & economical.
7. Making and making of centre holes totally eliminated and smaller grinding allowance, less time.
8. Large grinding wheels are used and errors due to wheel wear are reduced.
9. Very little maintenance is needed for the machine.
10. Very high skilled operators are not needed.
11. Direct adjustment for sizes can be made, resulting in high accuracy.
12. A fairly wide range of components can be ground.

SURFACE GRINDERS:

Surface grinders do almost the same operation as the planers, shapers or milling machines, but with more precision. Primarily they are intended to machine flat surfaces, although irregular, curved or tapered surfaces can also be ground on them. The common classification of surface grinders can be made as follows:

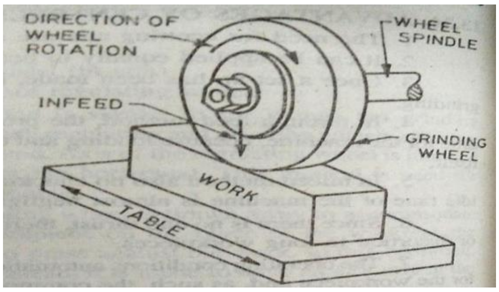
1. According to the table movement:
a) Reciprocating Table Type. b) Rotary Table Type

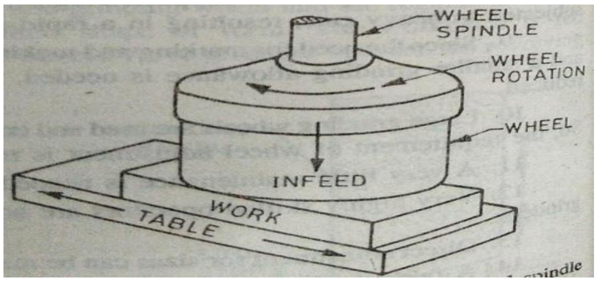
2. According to the direction of wheel spindles:
a) Vertical Spindle Type. b) Horizontal Spindle Type.

3. Special type and single purpose machines.
a) Face Grinders. b) Way Grinders. c) Wet Belt Grinders.

Reciprocating table type Surface Grinders:

A reciprocating table type surface grinder may have a horizontal spindle of the grinding wheel, or a vertical spindle of the same. The horizontal spindle carries a straight wheel and the vertical spindle a cup type wheel. Hydraulic drives are commonly used in all such grinders. Cutting is done on the periphery of the straight wheel, in case of horizontal type and on the revolving edge of the cup wheel on vertical spindle machines. The horizontal spindles are widely used in tool rooms. The work piece is held on a magnetic chuck on these machines. They are vastly used for grinding flat surfaces. The machine size is designated by the dimensions of the working area of the table.

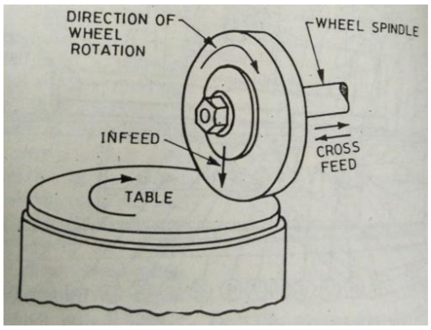




The longitudinal feed to the work is given by reciprocating the table. Forgiving cross feed, there are two methods. One is to mount the table on a saddle and give the cross feed by moving the saddle. Alternatively, the cross feed can be given by moving the wheel head in and out. In feed is provided by lowering the wheel head along the column.

In case of vertical spindle reciprocating table grinders the table along with work piece, reciprocates under the wheel. The wheel covers all or a major portion of the width of the job. Cross feed to the work can be given by moving the saddle. A manual or power feed can be used to feed the wheel head vertically. An individual motor drive is provided to rotate the wheel.

Rotary table Surface Grinders:



Rotary table surface grinders are also made in two types. i.e. either having horizontal wheel spindle or a vertical wheel spindle. A circular shaped magnetic chuck is mounted on the circular table to hold the jobs. The work pieces are normally arranged in a circle, concentric with the round chuck. If it is a single piece, it can be mounted centrally on the chuck. The table is made to rotate under the revolving wheel, both rotating in opposite directions.

The vertical feed to the wheel is given by moving the wheel head along a column and the cross feed by the horizontal movement of the wheel spindle. A straight wheel is used on these machines, which cuts on its periphery. Some machines carry the provision to raise or lower the table also and also to incline the same.

A cup wheel has to be used on these machines. Vertical feed to the wheel is given by moving the wheel head. The work pieces are mounted on the round chuck in same way as in the horizontal spindle type. The table rotates in a direction opposite to that of the wheel and brings the work pieces one after the other under the rotating wheel. The table is mounted on a slide, so as to give cross feed. Some rotary table surface grinders are provided with two tables instead of one, so that, while the work pieces are being ground on one table, the other table can be used for loading the fresh batch of work pieces.

OTHER TYPES OF SURFACE GRINDERS

1. Face Grinder: It is similar in operation to a horizontal spindle reciprocating table surface grinder, but differs in that a vertical flat surface is ground instead of a horizontal one. The cutting is done on the face of the wheel and not on the periphery. Cup ring or segmental type wheels are used, which are mounted on a horizontal spindle and fed on to the vertical surface of the work piece, mounted on the reciprocating table. This type of the machine is used for large and heavy work pieces.

2. Way Grinder: It is a single purpose machine used for grinding the bed ways of different machines. It is a very large and heavy duty machine carrying a vertical spindle. Cup, ring or segmental type wheels are used on this machine. The wheel spindle can be tilted to a desired angle to grind inclined the work past the rotating wheel.

3. Wet Belt Grinders: These machines carry a vertical platen, which supports an endless abrasive belt revolving in a vertical direction. The table moves to feed the work against the belt and the table oscillates across the belt to effect desired grinding. The abrasive used on the belt carries the resinoid bond. This type of machine is specially used in grinding low fusion point materials as a large amount of heat generated is absorbed by the coolant, which is used in ample quantity.

TOOL AND CUTTER GRINDING MACHINES

These machines are primarily intended for tool room work for grinding cylindrical and tapered multi tooth cutting tools, like milling cutters, hobs, drills, reamers, taps, broaches, gear shaper cutters etc.

They are also capable of doing light cylindrical, surface and internal grinding operations. They are made in various different designs. The most versatile and widely used form is a universal tool and cutter grinder.

It carries a work head and tail stock on an upper table, which is mounted on a lower table on which the upper table can be swiveled to grind the tapered tools. The saddle travels in cross direction. The saddle and table travels are controlled by hand. The wheel head is rigidly mounted on an elevating column and consists of a housing carrying a wheel spindle, which runs in two bearings. Both ends of the spindle are tapered to receive the clamping sleeves, carrying the grinding wheels. The wheel heads can be swiveled about a vertical axis together with the column and its driving motor. These grinders largely owe their high versatility to the large number of attachments they carry. A few main of these are:

1. Universal work head.
2. Wheel dressing device.
3. External cylindrical grinding attachment.
4. Swiveling vice.
5. Internal grinding attachment.
6. Core drill grinding attachment.
7. Tap grinding attachment.
8. Face milling cutter grinding attachment.
9. Long reamer grinding attachment.
10. Form cutters grinding attachment.
11. Universal tooth rest.
12. . Gear shaper cutters grinding attachment.
13. Hob grinding attachment.
14. Twist drill grinding attachment.

Other tool grinders include the profile or contour grinder and moonset tool and cutter grinder. The former is used to reproduce a template form on a flat or round cutter. The latter is mainly used in grinding spiral fluted cutters and twist drills. Carbide tool grinder is used for grinding various angles on single point tools, mainly carbide tipped tools.

SPECIAL TYPES OF GRINDING MACHINES:

These machines are designed to do some specialized operations. Some common types of these machines are the following:

1. Roll Grinders.
2. Cam shaft Grinders.
3. Disc Grinders.
4. Crank shaft Grinders.
5. Piston Grinders.
6. Thread Grinders.
7. Tool post Grinders.

1. Roll Grinders: These are very heavy duty types of plain cylindrical grinders. They carry all the features of plain cylindrical grinder, but are made relatively heavier and more rigid. Normally roll grinders do not carry any provision for grinding the tapered work, but some carry, a set over type tail stock, similar to that used on a lathe, in order to deal with such type of work. The main use of these grinders is in grinding various types of heavy cylinders, like hydraulic rams, turbine shafts and rolls used in various industries like paper mills, steel mills, textile mills, printing presses, rubber industries and flour mills etc.

The specific equipment of these machines includes the journal rests and a cambering device. The journal rests are used to receive the previously turned journals of the rolls and support the rotating rolls on them during the operation. The cambering device is a special attachment used for crowning or cambering the rolls at the centre. The term crowning has similar meaning here also as applied to the pulleys. It means, increasing the size of the roll at its centre as compared to the dimensions at the ends. A reverse of it is called cambering. Rolls used in cold working of metals are crowned, as they are likely to be subjected to heavy forces. Against this, the rolls which work on hot metal are cambered as they are likely to expand more at the centre than the ends during hot working. The above features in the rolls neutralize the bad effects of cold and hot working and enables the products to have a uniform thickness. A common type of cambering and crowing attachment involves the use of a cam which works in conjunction with the table traverse to direct the grinding wheel in or out to produce the desired curvature at the centre.

2. Cam Shaft Grinders: It is a special type of cylindrical grinder. In this, the work piece is mounted between the centers. A separate base is provided, which carries the tail stock and head stock and the complete unit can oscillate about a centre below the work piece. A template, which is a small facsimile of the cam shaft, is mounted on the head stock. It rotates along with the cam shaft to be ground and actuates a hardened steel roller, which makes the whole unit to oscillate in and out to produce the desired shape. The work revolves very slowly. All such machines are made automatic.

3. Disc Grinders: The operation of disc grinding is used for large scale grinding of flat surfaces. A surface grinder does the same work, with more close dimensional tolerances, but a disc grinder does it more rapidly. The abrasive discs used in disc grinding are fairly large in size and less in thickness as compared to the standard grinding wheels. As such they are backed by steel plates to with stand the grinding pressure. The main reason for faster a grinding is that the discs present more abrasive area to the work than the wheels.

The main types of disc grinders are the single and double spindle. Single spindle grinders are used for off-hand grinding and double spindle for grinding both sides of the work simultaneously. The size of the machine is designated by the diameter of the disc it uses. Some machines carry horizontal spindles and some others vertical spindles.

4. Crank Shaft Grinder: These machines are basically cylindrical grinders, involving the principle of plunge cut grinding, for grinding of crank shafts for different types of automobiles and air craft engines, compressors etc. With large scale increase in the use of automobiles, engines, pumps etc. the use of these machines has also considerably increased in the country.

Main parts of a crank shaft grinder:

The machine consists of the following principal units:

1. Bed
2. Table
3. Hydraulic system
4. wheel head
5. wheel head spindle cross feed and axial movement mechanisms
6. table hand traverse mechanisms
7. head stock
8. tail stock
9. coolant system and
10. Electricals

5. Piston Grinders: A majority of pistons used in I.C. Engines are not of true cylindrical shape. Most of these pistons carry slightly elliptical outer surface. At times, the outer surface may be slightly tapered also. The grinders used in grinding of these pistons, therefore, carry suitable mechanism to automatically regulate and synchronize the inward and out ward movements of the revolving piston and the cutter feed in such a way that the required type of outer surface is ground on the piston together with taper, if desired.

6. Thread Grinders: Thread grinding is basically, a generating process, in which the desired thread profile is generated on a solid cylindrical object through grinding. The machines used in this process operate on the principle of cylindrical grinders. These machines carry a lead screw which is connected to the head stock, in the same way as in a centre lathe, in order to establish a definite ratio between the speed of rotation of the work and the longitudinal traverse of the grinding wheel. Thus the grinding wheel, which is given the shape of thread profile on its face, follows the desired helix path similar to a single point thread cutting tool on a lathe. The helix angle is provided to the grinding wheel by tilting its spindle to the required angle.

If the thread length is small, a better and quicker alternative to the above method is plunge cut grinding. In this, the cylindrical grinding wheel chosen should have its face wider than the length of the threads. The desired thread profile is provided on its periphery and, after mounting, the spindle is tilted to contain the required helix angle. The work piece is revolved as usual and the shape of revolving grinding wheel is fed straight across the work axis. There is no need for longitudinal traverse of wheel spindle in this case, because the entire thread length is covered by the wheel face.

7. Tool Post Grinder: It consists of a bracket, which is mounted on the cross-slide, a grinding wheel and a separate motor. The grinding wheel is driven by a separate motor. The job is held in a chuck or between the centers and the rotating grinding wheel is fed against the job. The attachments may be for external or internal grinding. Some tool post grinders carry provisions such that the same attachments with a little change can be used for internal as well as external grinding.