AIRCRAFT PRODUCTION TECHNOLOGY (R22A2105)

COURSE FILE

II B. Tech I Semester

(2024-25)

Prepared By

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MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

Affiliated to JNTU, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified)
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MALLA REDDY COLLEGE OF ENGINEERING AND TECHNOLOGY

II Year B.Tech. ANE- I Sem **L/T/P/C**
3/-/-/3

(R22A2105) Aircraft Production Technology

Objectives:

1. Students gain the knowledge of different casting and welding processes involved in manufacturing
2. Acquire knowledge of Conventional and unconventional processes.
3. Able to know the importance and applications of Sheet metal in Aircraft Industry
4. Students acquire knowledge of Material processing and property improvements techniques
5. Students gain the importance of DT and NDT in Aircraft Industry

UNIT – I Casting and Welding Techniques:

Various molding process employed in aircraft industry, Types of patterns, Casting Process involved in Sand casting, die-casting, centrifugal casting, investment casting and shell molding. Working Principles and equipment used with emerging trends in arc welding, gas welding, resistance welding, Laser welding, Soldering and brazing techniques.

UNIT – II Machining and Forming:

Classification of machining processes, Types of chips, working principles (with schematic diagram only), types-lathe, shaper, milling machines, grinding (designation of grinding wheel), drilling m/c, CNC machining (overview of G-Codes, M-Codes). Sheet metal operations- shearing, punching, super plastic forming and diffusion bonding. Bending, Automation in bend forming and different operations in bending like stretch forming, spinning, drawing etc.

UNIT – III Unconventional Machining:

Principles of working and applications of abrasive jet machining, ultrasonic machining, electron beam, EDM, EBM, and plasma arc machining, Water jet machining, Ion beam machining.

UNIT – IV Heat Treatment and Surface Finishing:

Heat treatment of Aluminum alloys, titanium alloys, steels, case hardening. Corrosion prevention, protective treatment for aluminum alloys, steels, anodizing of titanium alloys, organic coating, and thermal spray coatings.

UNIT – V Jigs & Fixtures:

Jigs, fixtures, stages of assembly, types and equipment for riveted joints, bolted joints (only). Aircraft Tooling Concepts. - types of tools used in A/C industry.

NDT and Other Inspection Techniques: comparison of NDT & DT, process involved in Dye Penetrate Test, X-ray, and magnetic particle and ultrasonic testing.

Text Books:

1. "Manufacturing Engineering and Technology" by Kalpajikau - Addison Wesley.
2. "Aircraft production techniques' Keshu S.C, Ganapathy K.K, Interline Publishing House, Bangalore-1993.

Reference Books:

1. "Production technology" - R.K. Jain - Khanna Publishers - 2002.
2. "Production technology" - O.P.Khanna and lal. M.Dhanpat rai publications - New delhi - 1997.

Outcomes:

1. The student can correlate the various methods of manufacturing employed for different materials.
2. Students acquire of various processes involved in Sheet metal for aircraft production
3. Gain knowledge of Machining and correlate various applications to aircraft industry
4. Gain a knowledge and importance of heat treatment and surface finish in aircraft manufacturing
5. Able to gain knowledge in differentiating and applying DT and NDT in Aircraft Industry

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II B. Tech I Semester Examination
AIRCRAFT PRODUCTION TECHNOLOGY

Time: 3 hours **MODEL PAPER-I** **Marks: 60**

UNIT-I

1. Explain the steps and procedure involved in shell molding. Also discuss the advantages and disadvantages of shell molding.
2. (a) Explain about the types of cylinders and hoses used in gas welding with a tabular column for each and required figures.
   (b) Explain the process involved and types of flames in gas welding.

UNIT-II

3. Explain about any one type of drilling m/c in detail. And discuss about the twist drill nomenclature
4. Explain in detail about the various types of sheet metal operations with one example for each.

UNIT-III

5. Explain the AJM machining process; electrode used its advantages and disadvantages.

(or)

6. Explain the EDM machining process its advantages and disadvantages.

UNIT-IV

7. (a) Explain the requirement and advantage of heat treatment & surface finishing.
   (b) Discuss the process of anodizing of titanium alloys

(or)

8. Explain the terms with neat sketches
   a. Organic coating b. Honing c. Polishing & Buffing

UNIT-V

9. Explain about the process of liquid penetrate testing and it types with neat sketches and required equations.

(or)

10. Explain about the types and uses of jigs and fixtures employed in aircraft assembly.

II B. Tech I Semester Examination
AIRCRAFT PRODUCTION TECHNOLOGY
MODEL PAPER-II

Time: 3 hours **Marks: 60**

UNIT-I

1. Explain the steps and procedure involved in die casting. Also discuss the advantages and disadvantages of die casting.

(or)

2. Explain the types and process involved in resistance welding with neat sketches.

UNIT-II

3. Explain about any one type of milling machine and the procedure of milling (up & down) in detail.

(or)

4. Explain the terms with neat sketch
   a. Bending b. Super plastic forming
   c. deep drawing d. Louvering [2 ,3, 2, 3]

UNIT-III

5. Explain the laser machining process; electrode used its advantages and disadvantages.

(or)

6. Explain the ECM machining process its advantages and disadvantages.

UNIT-IV

7. a) Explain the requirement and advantage of heat treatment & surface finishing.
   (b) Discuss the process of heat treatment of aluminum alloys

(or)

8. Draw and explain about iron carbon diagram its compositions and variations in percentage effects.

UNIT-V

9. Explain the various types of project related tools used in aircraft assembly.

(or)

10. Explain about the process of magnetic particle testing and it types with neat sketches and required equations.

II B. Tech I Semester Examination
AIRCRAFT PRODUCTION TECHNOLOGY
MODEL PAPER-III

Time: 3 hours **Marks: 60**

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1) Explain the principle of Electronic Beam welding with neat sketch.

(OR)

2) Explain about gas welding in details with neat sketch.

3) Explain about quick return mechanism in shaper machine

(OR)

4) Explain about radial milling machine with neat sketch

5) Explain about USM in detail with the help of neat sketch

(OR)

6) Explain why the mechanical properties of work piece materials are not significant in most of the NTMM

7) Discuss the alloying elements which improves strength of pure titanium

(OR)

8) Discuss the process of anodizing of aluminum alloys

9) Explain different mechanical clamping system used in fixtures

(OR)

10) How is metal inspected by ultrasonic testing and x-rays

II B. Tech I Semester Examination
AIRCRAFT PRODUCTION TECHNOLOGY

MODEL PAPER-IV

Time: 3 hours **Marks: 60**

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1) Explain the soldering and brazing techniques

(OR)

2) Explain about die-casing in detail with neat sketch

3) Describe "Metal Spinning" write its product applications, differentiate between cold and hot Metal spinning.

(OR)

4) Explain the roll and importance of CNC machine in the field of aircraft industry

5) Explain about EDM in detail with the help of neat sketch

(OR)

6) Explain about EBM & PAM in detail with the help of neat sketch

7) Explain how aluminum alloys classified when used for aircraft application

(OR)

8). Explain the initial stresses and the stress alleviation procedures in manufacturing

9) How is metal inspected by ultrasonic testing and x-rays

(OR)

10) Explain the various types of rivets that are used in an aircraft industry justify your answer with Respect to the loads and atmospheric affects over an aircraft.

II B. Tech I Semester Examination
AIRCRAFT PRODUCTION TECHNOLOGY
MODEL PAPER-V

Time: 3 hours Varks: 60

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1) Explain in detail about Centrifugal casting with neat sketch.

(OR)

2) Explain about Investment casting in detail with neat sketch

3) What are the various methods of bending, describe each with neat sketch

(OR)

4) Compare "Metal spinning" with deep drawing

5. Explain about ECM in detail with the help of neat sketch

(OR)

6. List the principle advantages of
   A) Arc welding over gas welding
   B) Gas welding over arc welding

7) A) why the cleaning of a joint is important before welding?
   B) Explain about welding techniques

(OR)

8) Explain about sand casting in detail

9) Explain the tooling docks/tooling bars method in jig alignments

(OR)

10) what are advantages of using jigs and fixture in aircraft manufacturing

UNIT-1

Casting and Welding Techniques

1. Various molding process

Injection Molding:

The pellets or granules are fed into the heated cylinder, and the melts forced into the mold either by a hydraulic plunger or by the rotating screw system of an extruder. As in plastic extrusion, the barrel (cylinder) is heated externally to promote melting of the polymer. In injection-molding machines, however, a far greater portion of the heat transferred to the polymer is due to frictional heating. Modern machines are of the reciprocating or plasticating screw type with the sequence of operations. As the pressure builds up at the mold entrance, the rotating screw begins to move backwards under pressure to a predetermined distance. This movement controls the volume of material to be injected. The screw then stops rotating and is pushed forward hydraulically, forcing the molten plastic into the mold cavity.

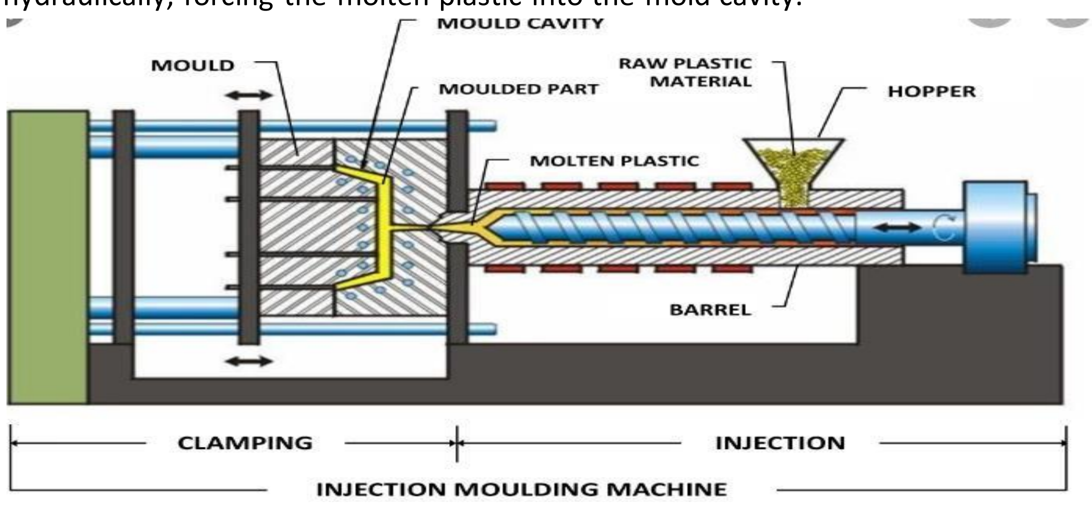


Figure: injection molding

The pressures developed usually range from 70 to 200 MPa. Products include cups, containers, housings, tool handles, knobs, toys, plumbing fixtures, telephone receivers, and electrical and communication-equipment components. For thermoplastics, the molds are kept relatively cool at about 90°C. Thermoset parts are molded in heated molds at about 200°C, where polymerization and cross-linking take place. After the part has cooled sufficiently (for thermoplastics) or cured (for thermosets), the molds are opened and ejectors are used to remove the part from the mold. The molds are then closed, and the process is repeated automatically. Elastomers also are injection molded into discrete products by these processes. Because the material is molten when injected into the mold, complex shapes with good dimensional accuracy can be obtained. However, because of uneven cooling of the part in the mold, residual stresses develop. Molds with moving and unscrewing mandrels also are used in injection molding, as they allow the molding of parts having multiple cavities or internal and external threaded features. To accommodate part design, molds may have several components including runners (such as those used in metal-casting dies), cores, cavities, cooling channels, inserts, knockout pins, and ejectors.

There are three basic types of molds:

I. Cold-runner, two-plate mold: This design is the simplest and most common.

2. Cold-runner, three-plate mold: The runner system is separated from the part when the mold is opened.

3. Hot-runner mold also called runner less mold: The molten plastic is kept hot in a heated runner plate.

Injection-molding machines are usually horizontal, Vertical machines are used for making small, close-tolerance parts and for insert molding. The clamping force on the dies generally is supplied by hydraulic means, although electrical means (which weigh less and are quieter than hydraulic machines) also are used. Modern machines are equipped with microprocessors in a control panel and monitor all aspects of the operation. Injection-molding machines are rated according to the capacity of the mold and the clamping force. In most machines, this force ranges from 0.9 to 2.2 MN. The largest machine in operation has a capacity of 45 MN, and it can produce parts weighing 25 kg. The cost of a 1-MN machine ranges from about $60,000 to about $90,000 and of a 2.7-MN machine from about $85,000 to about $140,000.

Reaction-injection Molding: In the reaction-injection molding (RIM) process, a monomer and two or more reactive fluids are forced at high speed into a mixing chamber at a pressure of 10 to 20 MPa and then into the mold cavity. Chemical reactions take place rapidly in the mold, and the polymer solidifies. Typical polymers are polyurethane, nylon, and epoxy. Cycle times may range up to about 10 minutes, depending on the materials, part size, and shape. Major applications of this process include automotive parts (such as bumpers and fenders, steering wheels, and instrument panels), thermal insulation for refrigerators and freezers, water skis, and stiffeners for structural components. Parts made may range up to about 50 kg. Reinforcing fibers (such as glass or graphite) also may be used to improve the product's strength and stiffness. Depending on the number of parts to be made and the part quality required, molds can be made of common materials, such as steel or aluminum.

Blow Molding:

Blow molding is a modified extrusion- and injection-molding process. In extrusion blow molding, a tube or preform (usually oriented so that it is vertical) is first extruded. It is then clamped into a mold with a cavity much larger than the tube diameter and blown outward to fill the mold cavity. Depending on the material, the blow ratio may be as high as 7:1. Blowing usually is done with a hot air blast at a pressure ranging from 350 to 700 kPa. Drums with a volume as large as 2000 liters can be made by this process. Typical die materials are steel, aluminum, and beryllium copper. In some operations, the extrusion is continuous and the molds move with the tubing. The molds close around the tubing, sealing off one end, breaking the long tube into individual sections, and moving away as air is injected into the tubular piece. The part is then cooled and ejected from the mold. Corrugated-plastic pipe and tubing are made by continuous blow molding in which the pipe or tubing is extruded horizontally and blown into moving molds. In injection blow molding, a short tubular piece (parison) is injection molded into cool dies. (Parisons may be made and stored for later use.) The dies then open, and the parison is transferred to a blow-molding die by an indexing mechanism. Hot air is injected into the parison, expanding it to the walls of the mold cavity. Typical products made are plastic beverage bottles (typically made of polyethylene or polyetheretherketone , PEEK) and small, hollow containers. A related process is stretch blow molding, in which the parison is expanded and elongated simultaneously, subjecting the polymer to biaxial stretching and thus enhancing its properties. Multilayer blow molding involves the use of coextruded tubes or parisons and thus permits the production of a multilayer structure. A typical example of such a product is plastic packaging for food and beverages, having such characteristics as odor and permeation barrier, taste and aroma protection, scuff resistance, the capability of being printed, and the ability to be filled with hot fluids. Other applications of this process are for containers in the cosmetics and the pharmaceutical industries.

Rotational Molding:

Most thermoplastics and some thermosets can be formed into large, hollow parts by rotational molding. In this process, a thin-walled metal mold is made in two pieces (split-female mold) and is designed to be rotated about two perpendicular axes. For each part cycle, a premeasured quantity of powdered plastic material is placed inside the warm mold. (The powder is obtained from a polymerization process that precipitates a powder from a liquid.) Then the mold is heated (usually in a large oven) and is rotated continuously about the two principal axes. This action tumbles the powder against the mold, where the heat fuses the powder without melting it. For thermosetting parts, a chemical agent is added to the powder; cross-linking occurs after the part is formed in the mold. The machines are highly automated, with parts moved by an indexing mechanism similar to that. A large variety of parts are made by rotational molding, such as storage tanks of various sizes, trash cans, boat hulls, buckets, housings, large hollow toys, carrying cases, and footballs. Various metallic or plastic inserts or components also may be molded integrally into the parts made by this process. In addition to powders, liquid polymers (plastisols) can be used in rotational molding PVC plastisols being the most common material. In this operation (called slush molding or slush casting), the mold is heated and rotated simultaneously. Due to the tumbling action, the polymer is forced against the inside walls of the mold, where it melts and coats the mold walls. The part is cooled while it is sti ll rotating and removed by opening the mold. Parts made are typically thin-walled products, such as boots and toys.

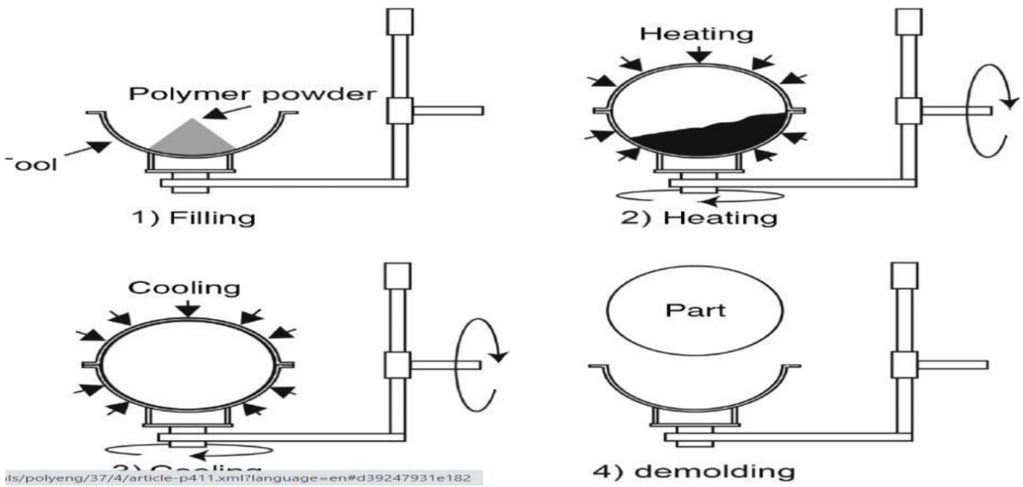


Figure: rotational molding

Thermoforming:

Thermoforming is a process for forming thermoplastic sheets or films over a mold through the application of heat and pressure. In this process, a sheet is (a) clamped and heated to the sag point usually by radiant heating, and (b) forced against the mold surfaces through the application of a vacuum or air pressure. The sheets used in thermoforming are available as a coiled strip or as lengths and widths of various sizes. They also are available filled with various materials for making parts with specific applications. The mold is generally at room temperature; thus, the shape produced becomes set upon contact with the mold. Because of the low strength of the materials formed, the pressure difference caused by a vacuum usually is sufficient for forming. However, thicker and more complex parts require air pressure, which may range from about 100 to 2000 kPa, depending on the type of material and thickness of the sheet. Mechanical means, such as the use of plugs, also may be employed to help form the parts.

Compression Molding:

In compression molding, a preshaped charge of material, premeasured volume of powder, or viscous mixture of liquid-resin and filler material is placed directly into a heated mold cavity that typically is around 200°C but can be much higher. Forming is done under pressure from a plug or from the upper half of the die, thus, the process is somewhat similar to closed-die forging of metals. Pressures range from about 10 to 150 MPa. There is a flash formed, which subsequently is removed by trimming or by some other means. Typical parts made are dishes, handles, container caps, fittings, electrical and electronic components, washing-machine agitators, and housings. Fiber-reinforced parts with chopped fibers also are formed exclusively by this process. Compression molding is used mainly with thermosetting plastics, with the original material being in a partially polymerized state. However, thermoplastics and elastomers are also processed by compression molding. Curing times range from about 0.5 to 5 minutes, depending on the material and on part thickness and shape. The thicker the material, the longer it will take to cure.

Three types of compression molds are available:

° Flash type: for shallow or flat parts

° Positive type: for high-density parts

° Semipositive type: for quality production.

Undercuts in parts are not recommended; however, dies can be designed to open sideways to allow removal of the molded part. In general, the complexity of parts produced is less than that from injection molding, but the dimensional control is better. Surface areas of compression-molded parts may range up to about 2.5 ml. Because of their relative simplicity, dies for compression molding generally are less costly than those used in injection molding. They typically are made of tool steels and may be chrome plated or polished for an improved surface finish of the molded product.

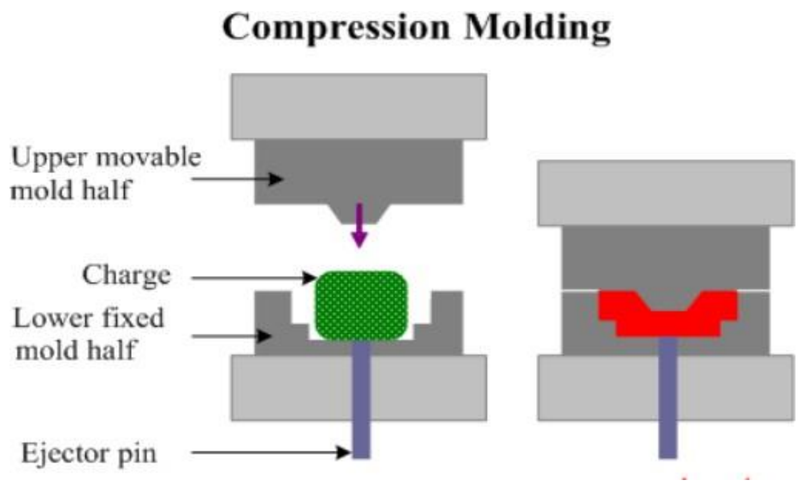


Figure: compression molding

Transfer Molding:

Transfer molding represents a further development of compression molding. The uncured thermosetting resin is placed in a heated transfer pot or chamber and after the material is heated, it is injected into heated closed molds. Depending on the type of machine used, a ram, plunger, or rotating-screw feeder forces the material to flow through the narrow channels into the mold cavity at pressures up to 300 MPa. This viscous flow generates considerable heat, which raises the temperature of the material and homogenizes it. Curing takes place by cross - linking. Because the resin is in a molten state as it enters the molds, the complexity of the parts and the dimensional control approach those of injection molding.

Typical parts made by transfer molding are electrical connectors and electronic components, rubber and silicone parts, and the encapsulation of microelectronic devices. The process is suitable particularly for intricate shapes with varying wall thicknesses. The molds tend to be more expensive than those for compression molding, and some excess material is left in the channels of the mold during filling, which is later removed.

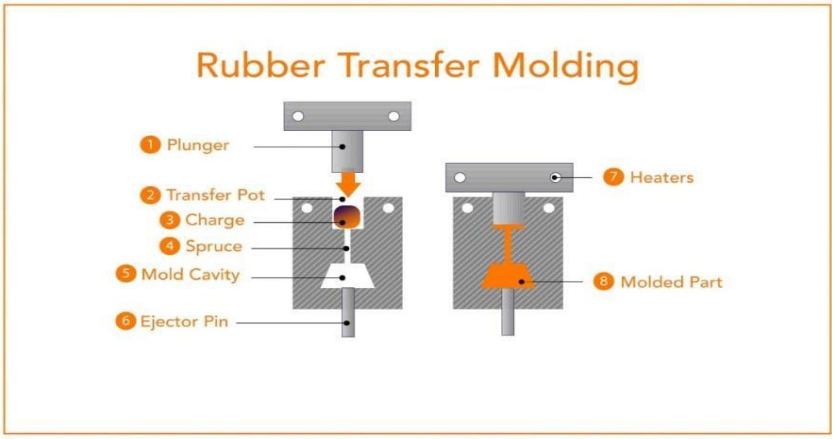


Figure: transfer molding

2. Pattern:

- In casting, a pattern is a replica of the object to be cast, used to prepare the cavity into which molten material will be poured during the casting process.
- Patterns used in sand casting may be made of wood, metal, plastics or other materials.

Expendable molds, which typically are made of sand, plaster, ceramics, and similar materials and generally are mixed with various binders (bonding agents) for improved properties. A typical sand mold consists of 90% sand, 7% clay, and 3% Water. These materials are refractories (that is, they are capable of withstanding the high temperatures of molten metals). After the casting has solidified, the mold is broken up to remove the casting. The mold is produced from a pattern; in some processes, such as sand and shell casting, the mold is expendable, but the pattern is reused to produce several molds. Such processes are referred to as expendable-mold, permanent-pattern casting processes. On the other hand, investment casting consumes a pattern for each mold produced; it is an example of an expendable-mold, expendable pattern process.

Permanent molds, which are made of metals that maintain their strength at high temperatures. As the name implies, they are used repeatedly and are designed in such a Way that the casting can be removed easily and the mold used for the next casting. Metal molds are better heat conductors than expendable nonmetallic molds hence, the solidifying casting is subjected to a higher rate of cooling, which in turn affects the microstructure and grain size Within the casting.

Composite molds, which are made of two or more different materials (such as sand, graphite, and metal) combining the advantages of each material. These molds have a permanent and an expendable portion and are used in various casting processes to improve mold strength, control the cooling rates, and optimize the overall economics of the casting process.

3. Casting process

Casting:

Some thermoplastics (such as nylons and acrylics) and thermosetting plastics (epoxies, phenolics, polyurethanes, and polyester) can be cast into a variety of shapes using either rigid or flexible molds. Compared with other methods of processing plastics, casting is a slow, but simple and inexpensive, process. However, the polymer must have sufficiently low viscosity in order to flow easily into the mold. Typical parts cast are gears (especially nylon), bearings, wheels, thick sheets, lenses, and components requiring resistance to abrasive wear. In the basic conventional casting of thermoplastics, a mixture of monomer, catalyst, and various additives (activators) is heated to above its melting point, Tm, and poured into the mold. The part is formed after polymerization takes place at ambient pressure. Degassing may be necessary for product integrity. Intricate shapes can be produced using flexible molds, which are then peeled off (in a manner similar to using rubber gloves) and reused. As with metals, thermoplastics may be cast continuously, with the polymer carried over continuous stainless-steel belts and polymerized by external heat.

Sand Casting:

The traditional method of casting metals is in sand molds and has been used for millennia. Sand casting is still the most prevalent form of casting; in the United States alone, about 15 million tons of metal are cast by this method each year. Typical applications of sand casting include machine bases, large turbine impellers, propellers, plumbing fixtures, and a wide variety of other products and components.

sand casting consists of (a) placing a pattern (having the shape of the desired casting) in sand to make an imprint, (b) incorporating a gating system, (c) removing the pattern and filling the mold cavity with molten metal, (d) allowing the metal to cool until it solidifies, (e) breaking away the sand mold, and (f) removing the casting

Sands:

Most sand-casting operations use silica sand (SiO_2) as the mold material. Sand is inexpensive and is suitable as a mold material because of its high-temperature characteristics and high melting point. There are two general types of sand: naturally bonded (bank sand) and synthetic (lake sand). Because its composition can be controlled more accurately, synthetic sand is preferred by most foundries. For proper functioning, mold sand must be clean and preferably new. Several factors are important in the selection of sand for molds, and certain tradeoffs with respect to properties are involved. Sand having fine, round grains can be packed closely and, thus, forms a smooth mold surface. Although fine-grained sand enhances mold strength, the fine grains also lower mold permeability (where fluids and gases penetrate through pores). Good permeability of molds and cores allows gases and steam evolved during the casting to escape easily. The mold also should have good collapsibility to allow the casting to shrink while cooling and, thus, to avoid defects in the casting, such as hot tearing and cracking.

Types of Sand Molds:

Sand molds are characterized by the types of sand that comprise them and by the methods used to produce them. There are three basic types of sand molds: green-sand, cold-box, and no-bake molds. The most common mold material is green molding sand, which is a mixture of sand, clay, and water. The term “green” refers to the fact that the sand in the mold is moist or damp while the metal is being poured into it. Green-sand molding is the least expensive method of makingmolds, and the sand is recycled easily for subsequent reuse. In the skin-dried method, the mold surfaces are dried, either by storing the mold in air or by drying it with torches. Because of their higher strength, these molds generally are used for large castings. In the cold-box mold process, various organic and inorganic binders are blended into the sand to bond the grains chemically for greater strength. These molds are more dimensionally accurate than green-sand molds, but are more expensive. ln the no-bake mold process, a synthetic liquid resin is mixed with the sand and the mixture hardens at room temperature. Because the bonding of the mold in this and in the cold-box process takes place without heat, they are called cold-setting processes. Sand molds can be oven dried (baked) prior to pouring the moltenmetal; they are then stronger than green-sand molds and impart better dimensional accuracy and surface finish to the casting. However, this method has the drawbacks that (a) distortion of the mold is greater, (b) the castings are more susceptible to hot tearing because of the lower collapsibility of the mold, and (c) the production rate is lower because of the considerable drying time required.

The major features of molds in sand casting are as follows:

I. The flask, which supports the mold itself. Two-piece molds consist of a cope on top and a drag on the bottom; the seam between them is the parting line. When more than two pieces are used in a sand mold, the additional parts are called cbeeks.

2. A pouring basin or pouring cup, into which the molten metal is poured.

3. A sprue, through which the molten metal flows downward.

4. The runner system, which has channels that carry the molten metal from the sprue to the mold cavity. Gates are the inlets into the mold cavity.

5. Risers, which supply additional molten metal to the casting as it shrinks during solidification. Two types of risers-a blind riser and an open riser.
Cores, which are inserts made from sand. They are placed in the mold to form hollow regions or otherwise define the interior surface of the casting. Cores also are used on the outside of the casting to form features such as lettering on the surface or deep external pockets.

7. Vents, which are placed in molds to carry off gases produced when the molten metal comes into contact with the sand in the mold and the core. Vents also exhaust air from the mold cavity as the molten metal flows into the mold.

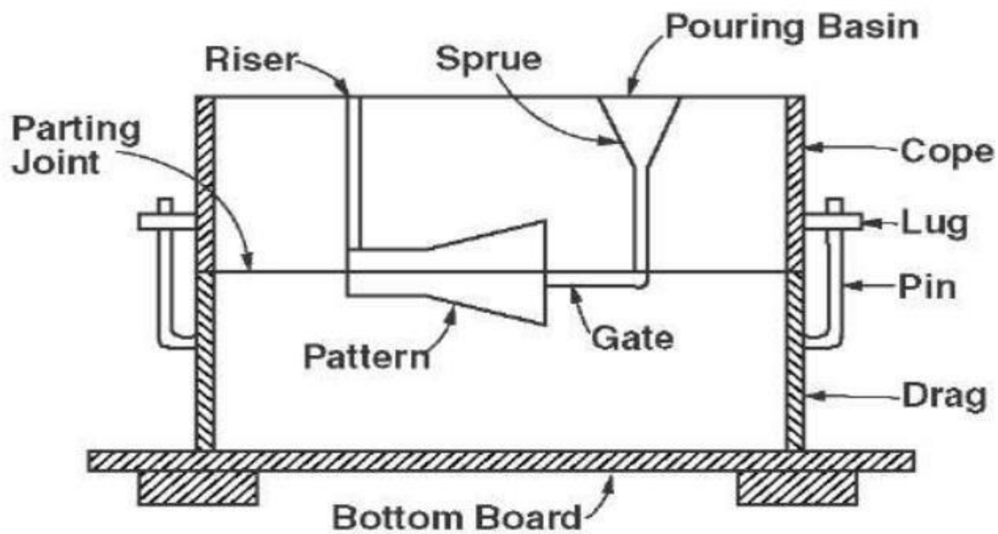


Figure: sand casting

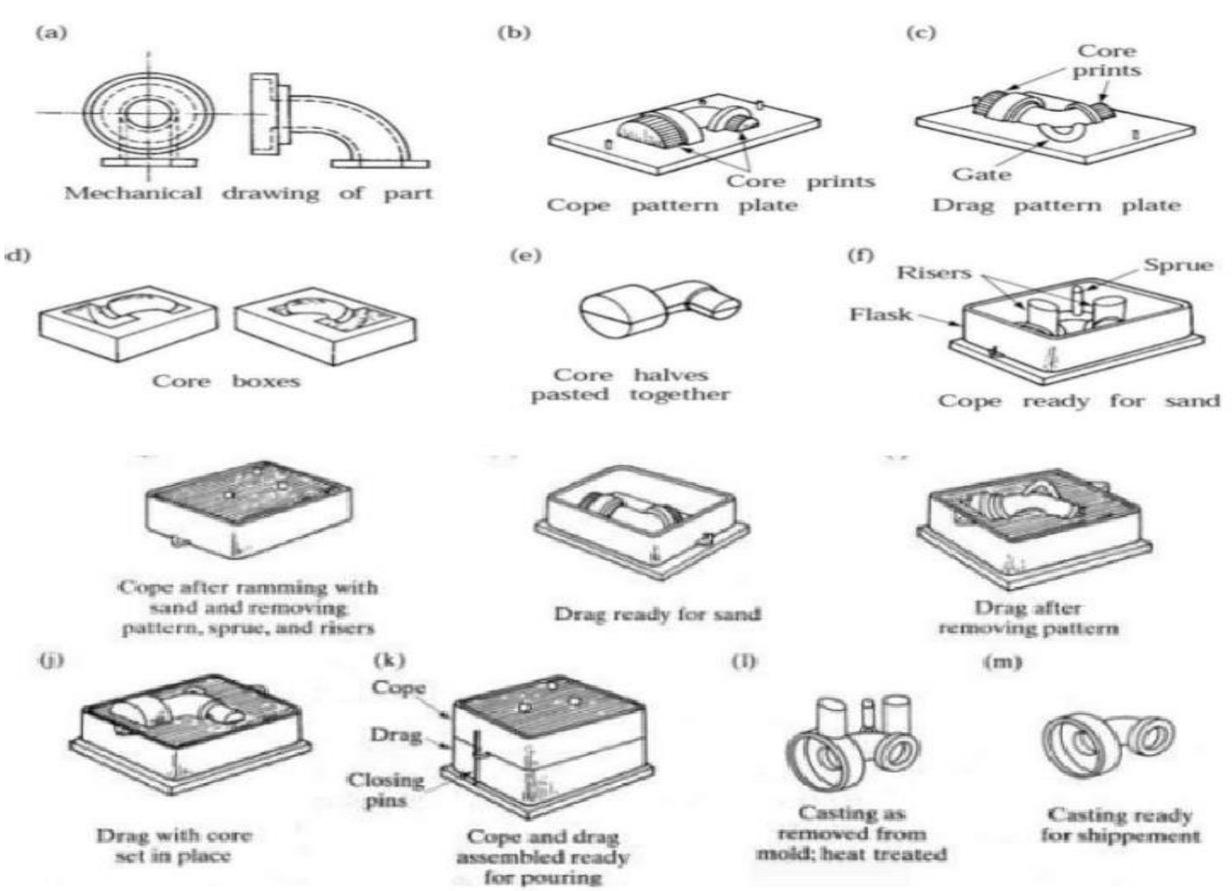
Sand-molding Machines:

The oldest known method of molding, which is still used for simple castings, is to compact the sand by hand hammering (tamping) or ramming it around the pattern. For most operations, however, the sand mixture is compacted around the pattern by molding machines. These machines eliminate arduous labor, offer high-quality casting by improving the application and distribution of forces, manipulate the mold in a carefully controlled manner, and increase production rate. In vertical flaskless molding, the halves of the pattern form a vertical chamber wall against which sand is blown and compacted. Then the mold halves are packed horizontally, with the parting line oriented vertically, and moved along a pouring conveyor. This operation is simple and eliminates the need to handle flasks, allowing for very high production rates, particularly when other aspects of the operation (such as coring and pouring) are automated.

Sand slingers fill the flask uniformly with sand under a high-pressure stream; they are used to fill large flasks and are operated typically by machine. An impeller in the machine throws sand from its blades (or cups) at such high speeds that the machine not only places the sand, but also rams it appropriately. In impact molding, the sand is compacted by a controlled explosion or instantaneous release of compressed gases. This method produces molds with uniform strength and good permeability. In vacuum molding (also known as the V process), the pattern is covered tightly with a thin sheet of plastic. A flask is placed over the coated pattern and is filled with dry, binderless sand. A second sheet of plastic then is placed on top of the sand, a vacuum action compacts the sand, and the pattern can then be withdrawn. Both halves of the mold are made in this manner and subsequently assembled. During pouring, the mold remains under vacuum, but the casting cavity does not. When the metal has solidified, the vacuum is turned off and the sand falls away, releasing the casting. Vacuum molding produces castings with high-quality surface detail and dimensional accuracy; it is suited especially well for large, relatively flat (plane) castings.

The Sand-casting Operation:

After the mold has been shaped and the cores have been placed in position, the two halves (cope and drag) are closed, clamped, and weighted down to prevent the separation of the mold sections under the pressure exerted when the molten metal is poured into the mold cavity. After solidification, the casting is shaken out of its mold, and the sand and oxide layers adhering to the casting are removed by vibration (using a shaker) or by sand blasting. Castings also are cleaned by blasting with steel shot or grit. The risers and gates are cut off by oxyfuel-gas cutting, sawing, shearing, or abrasive wheels; or they are trimmed in dies. Gates and risers on steel castings also may be removed with air carbon-arc cutting or torches. Castings may be cleaned further by electrochemical means or by pickling with chemicals to remove surface oxides. The casting subsequently may be heat treated to improve certain properties required for its intended use; heat-treatment is particularly important for steel castings. Finishing operations may involve machining, straightening, or forging with dies (sizing) to obtain final dimensions. Inspection is an important final step and is carried out to ensure that the casting meets all design and quality-control requirements.



Rammed-graphite Molding:

In this process, rammed graphite is used to make molds for casting reactive metals, such as titanium and zirconium. Sand cannot be used because these metals react vigorously with silica. The molds are packed like sand molds, air dried, baked at 175°C, fired at 870°C, and then stored under controlled humidity and temperature. The casting procedures are similar to those for sand molds.

Applications:

- All most any metal cast
- No limit to size
- Shape or weight
- Low tooling cost

Limitations:

- Some finishing required

- Somewhat coarse finish
- Wide tolerances

Shell Molding:

Shell molding was first developed in the 19405 and has grown significantly because it can produce many types of castings with close dimensional tolerances and a good surface finish at low cost. Shell-molding applications include small mechanical parts requiring high precision, such as gear housings, cylinder heads, and connecting rods. The process also is used widely in producing high-precision molding cores. In this process, a mounted pattern made of a ferrous metal or aluminum is

(a) Heated to a range of 175° to 37O°C,

(b) Coated with a parting agent (such as silicone), and

(C) Clamped to a box or chamber. The box contains fine sand, mixed with 2.5 to 4% of a thermosetting resin binder (such as phenol-formaldehyde) that coats the sand particles.

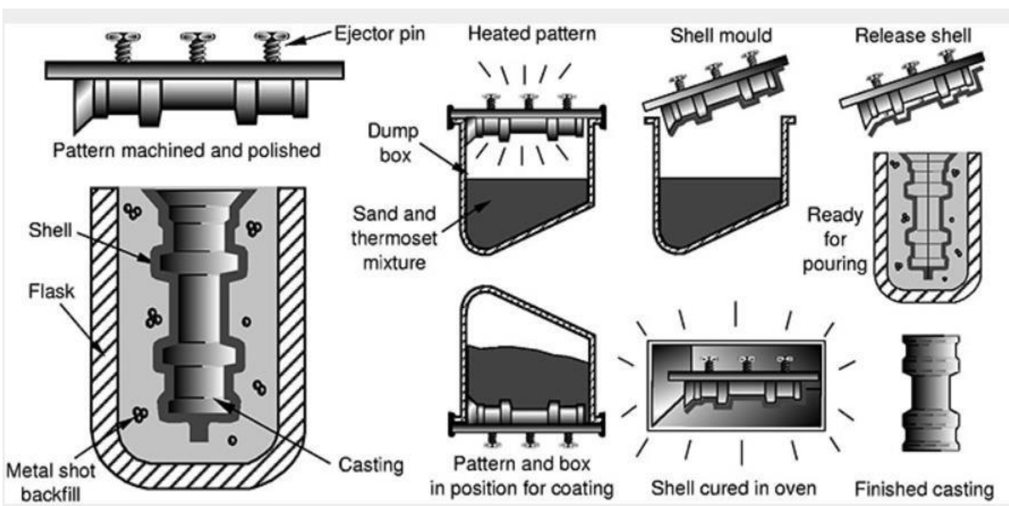


Figure: shell molding

Either the box is rotated upside down or the sand mixture is blown over the pattern, allowing it to form a coating. The assembly is then placed in an oven for a short period of time to complete the curing of the resin. In most shell-molding machines, the oven consists of a metal box with gas-fired burners that swing over the shell mold to cure it. The shell hardens around the pattern and is removed from the pattern using built-in ejector pins. Two half-shells are made in this manner and are bonded or clamped together to form a mold. The thickness of the shell can be determined accurately by controlling the time that the pattern is in contact With the mold. In this way, the shell can be formed with the required strength and rigidity to hold the Weight of the molten liquid. The shells are light and thin-usually 5 to 10 mm-and consequently, their thermal characteristics are different from those for thicker molds. Shell sand has much lower permeability than the sand used for green-sand molding, because a sand of much smaller grain size is used for shell molding. The decomposition often shell-sand binder also produces a high volume of gas. Consequently, unless the molds are vented properly, trapped air and gas can cause serious problems in the shell molding of ferrous castings. The high quality of the finished casting can reduce cleaning, machining, and other finishing costs significantly. Complex shapes can be produced with less labor, and the process can be automated fairly easily.

Sodium silicate process

- The mold material in the sodium silicate process is a mixture of sand and 1.5% to 6% sodium silicate as binder.
- The mixture is packed around the pattern and hardened by blowing carbon dioxide gas through it.
- Cores made through this process reduce the tendency for parts to tear because of their compliance at elevated temperature.

Rammed graphite process

- In this process rammed graphite is used to make molds for casting reactive metals such as titanium and zirconium.
- Sand can not be used because these metals react vigorously with silica.

Applications:

- Good dimensional accuracy
- And surface finish
- High production rate

Limitations:

- Part size limited
- Expensive patterns and equipment required

Investment Casting:

The investment-casting process, also called the lost-wax process, was first used during the period from 4000 to 3000 B.C. Typical parts made are components for office equipment, as well as mechanical components such as gears, cams, valves, and ratchets. Parts up to 1.5 m in diameter and weighing as much as 1140 kg have been cast successfully by this process. The sequence involved in investment casting is shown in Fig. The pattern is made of wax, or of a plastic such as polystyrene, by molding or rapid prototyping techniques. The pattern is then dipped into a slurry of refractory material such as very fine silica and binders, including water, ethyl silicate, and acids. After this initial coating has dried, the pattern is coated repeatedly to increase its thickness for better strength. Note that the initial coating can use smaller particles to develop a better surface finish in the casting; subsequent layers use larger particles and are intended to build coating thickness quickly. The term investment derives from the fact that the pattern is invested (surrounded) with the refractory material. Wax patterns require careful handling because they are not strong enough to withstand the forces encountered during mold making; however, unlike plastic patterns, wax can be recovered and reused. The one-piece mold is dried in air and heated to a temperature of 90° to 175 °C. It is held in an inverted position for a few hours to melt out the wax. The mold is then fired to 650° to 105 0°C for about four hours (depending on the metal to be cast) to drive off the water of crystallization (chemically combined water) and to burn off any residual wax. After the metal has been poured and has solidified, the mold is broken up and the casting is removed. A number of patterns can be joined to make one mold, called a tree, significantly increasing the production rate. For small parts, the tree can be inserted into a permeable flask and filled with a liquid slurry investment. The investment then is placed into a chamber and evacuated (to remove the air bubbles in it) until the mold solidifies. The flask usually is placed in a vacuum-casting machine, so that molten metal is drawn into the permeable mold and onto the part, producing fine detail. Although the mold materials and labor involved make the lost-wax process costly, it is suitable for casting high-melting-point alloys with good surface finish and close dimensional tolerances; few or no finishing operations, which otherwise would add significantly to the total cost of the casting, are required. The process is capable of producing intricate shapes, with parts weighing from 1 g to 35 kg, from a wide variety of ferrous and nonferrous metals and alloys . Recent advances include the casting of titanium aircraft-engine and structural airframe components with wall thicknesses on the order of 1.5 mm, thus competing with previously used sheet-metal structures.

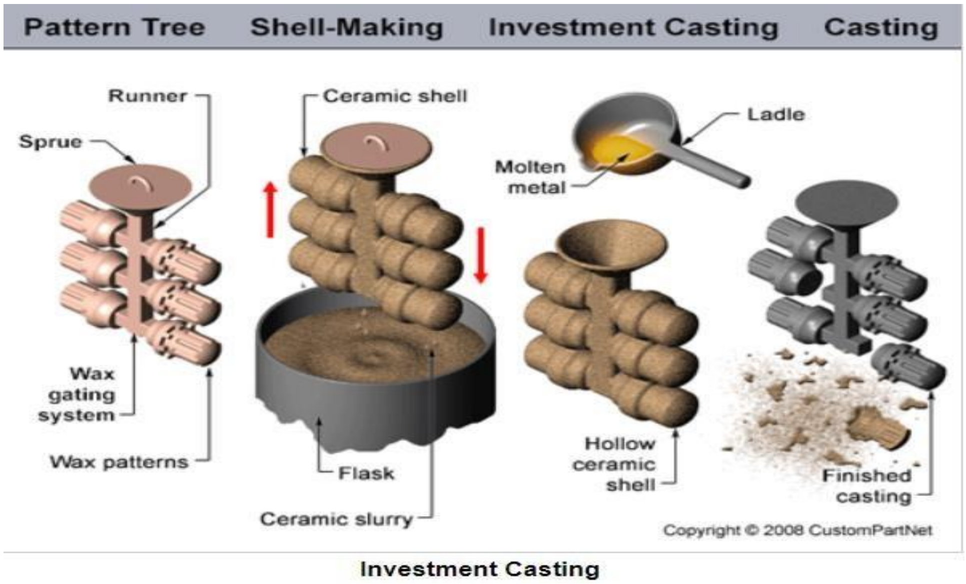


Figure: investment casting

Ceramic-shell Investment Casting:

A variation of the investment-casting process is ceramic-shell casting. It uses the same type of wax or plastic pattern, which is dipped first in ethyl silicate gel and subsequently into a fluidized bed of fine-grained fused silica or zircon flour. The pattern is then dipped into coarser grained silica to build up additional coatings and develop a proper thickness so that the pattern can withstand the thermal shock due to pouring. The rest of the procedure is similar to investment casting. The process is economical and is used extensively for the precision casting of steels and high-temperature alloys. The sequence of operations involved in making a turbine disk by this method is shown in Fig. If ceramic cores are used in the casting, they are removed by leaching with caustic solutions under high pressure and temperature. The molten metal may be poured in a vacuum to extract evolved gases and reduce oxidation, thus improving the casting quality. To further reduce microporosity, the castings made by this (as well as other processes) are subjected to hot isostatic pressing. Aluminum castings, for example, are subjected to a gas pressure up to 100 MPa at 500°C.

Applications:

- Intricate shapes
- Exellent surface finish
- And accuracy
- Almost any metal cast

Limitations:

- Part size limited
- Expensive patterns, molds, labor.

Die Casting

The die-casting process, developed in the early 1900s, is a further example of permanent-mold casting. The European term for this process is pressure die casting and should not be confused with pressure casting described in Section 11.4.4. Typical parts made by die casting are housings, business-machine and appliance components, hand-tool components, and toys. The weight of most castings ranges from less than 90 g to about 25 kg. Equipment costs, particularly the cost of dies, are somewhat high, but labor costs are generally low, because the process is semi- or fully automated. Die casting is economical for large production runs. In the die-casting process, molten metal is forced into the die cavity at pressures ranging from 0.7 to 700 MPa.

There are two basic types of die-casting machines: hot-chamber and cold-chamber machines.

The hot-chamber process involves the use of a piston, which forces a certain volume of metal into the die cavity through a gooseneck and nozzle. Pressures range up to 35 MPa, with an average of about 15 MPa. The metal is held under pressure until it solidifies in the die. To improve die life and to aid in rapid metal cooling (thereby reducing cycle time) dies usually are cooled by circulating water or oil through various passageways in the die block. Low-melting-point alloys (such as zinc, magnesium, tin, and lead) commonly are cast using this process. Cycle times usually range from 200 to 300 shots (individual injections) per hour for zinc, although very small components, such as zipper teeth, can be cast at rates of 18,000 shots per hour.

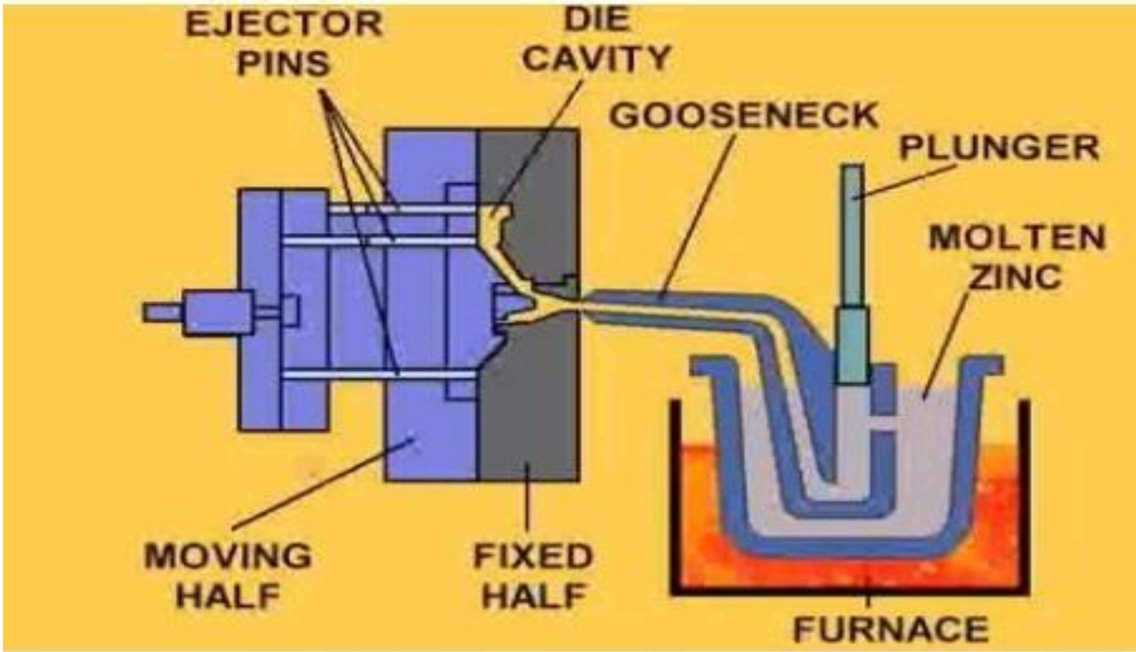


Figure: hot chamber process

In the **cold-chamber process**, molten metal is poured into the injection cylinder (shot chamber). The chamber is not heated-hence the term cold chamber. The metal is forced into the die cavity at pressures usually ranging from 20 to 70 MPa, although they may be as high as 150 MPa. The machines may be horizontal (as in the figure)-or vertical, in which case the shot chamber is vertical. High-melting-point alloys of aluminum, magnesium, and copper normally are cast using this method, although other metals (including ferrous metals) also can be cast. Molten-metal temperatures start at about 600°C for aluminum and some magnesium alloys, and increase considerably for copper based and iron-based alloys.

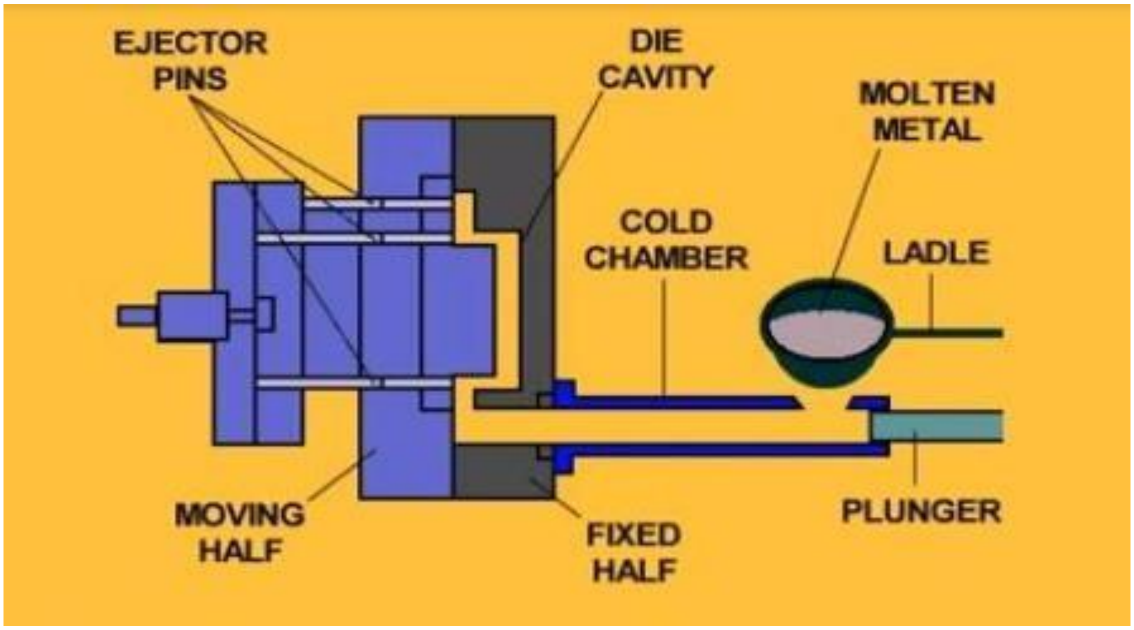


Figure: cold chamber process

Process Capabilities and Machine Selection

Die casting has the capability for rapid production of strong, high-quality parts with complex shapes, especially with aluminum, brass, magnesium, and zinc. It also produces good dimensional accuracy and surface details, so that parts require little or no subsequent machining or finishing operations (net-shape forming). Because of the high pressures involved, walls as thin as 0.38 mm are produced, which are thinner than those obtained by other casting methods. However, ejector marks remain, as may small amounts of flash (thin material squeezed out between the dies) at the die parting line.

Note the intricate shape and fine surface detail. In the fabrication of certain parts, die casting can compete favorably with other manufacturing methods (such as sheet-metal stamping and forging) or other casting processes. In addition, because the molten metal chills rapidly at the die walls, the casting has a fine-grained, hard skin with high strength. Consequently, the strength-to-weight ratio of die-cast parts increases with decreasing wall thickness. With a good surface finish and dimensional accuracy, die casting can produce smooth surfaces for bearings that otherwise normally would be machined. Components such as pins, shafts, and threaded fasteners can be die cast integrally. Called insert molding, this process is similar to placing wooden sticks in popsicles prior to freezing. For good interfacial strength, insert surfaces may be knurled, grooved, or splined. Steel, brass, and bronze inserts are used commonly in die-casting alloys. In selecting insert materials, the possibility of galvanic corrosion should be taken into account. To avoid this potential problem, the insert can be insulated, plated, or surface treated. Because of the high pressures involved, dies for die casting have a tendency to part unless clamped together tightly. Die-casting machines are thus rated according to the clamping force that can be exerted to keep the dies closed. The capacities of commercially available machines range from about 23 to 2700 metric tons. Other factors involved in the selection of die-casting machines are die size, piston stroke, shot pressure, and cost. Die-casting dies may be single cavity, multiple cavity (with several identical cavities), combination cavity (with several different cavities), or unit dies (simple, small dies that can be combined in two or more units in a master holding die). Typically, the ratio of die weight to part weight is 1000 to 1; thus, the die for a casting weighing 2 kg would weigh about 2000 kg. The dies usually are made of hot-work die steels or mold steels. Die wear increases with the temperature of the molten metal. Heat checking of can be a problem. When die materials are selected and maintained properly, dies may last more than a half million shots before any significant die wear takes place.

Applications:

- Excellent dimensional accuracy
- And surface finish
- High production rate

Limitations:

- Die cost is high
- Part size limited
- Usually limited to non ferrous metals
- Long lead time

Centrifugal Casting

As its name implies, the centrifugal-casting process utilizes inertial forces (caused by rotation) to distribute the molten metal into the mold cavities-a method that was first suggested in the early 1800s.

There are three types of centrifugal casting: true centrifugal casting, semicentrifugal casting, and centrifuging.

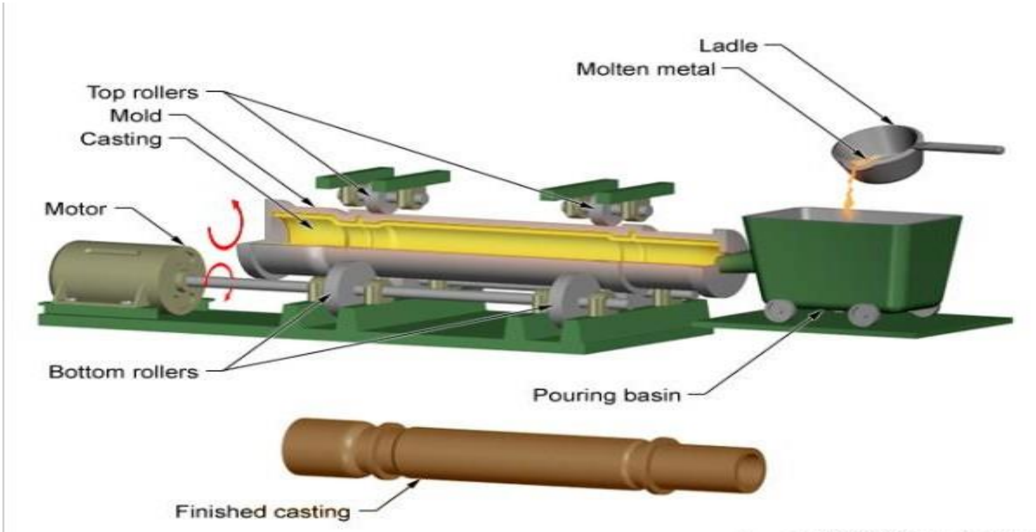


Figure : centrifugal casting

True Centrifugal Casting

In true centrifugal casting, hollow cylindrical parts (such as pipes, gun barrels, bushings, engine -cylinder liners, bearing rings with or without flanges, and street lampposts) are produced by the technique shown in Fig. In this process, molten metal is poured into a rotating mold. The axis of rotation is usually horizontal, but can be vertical for short workpieces. Molds are made of steel, iron, or graphite and may be coated with a refractory lining to increase mold life. The mold surfaces can be shaped so that pipes with various external designs can be cast. The inner surface of the casting remains cylindrical, because the molten metal is dis tributed uniformly by the centrifugal forces. However, because of density differences, lighter elements (such as dross, impurities, and pieces of the refractory lining) tend to collect on the inner surface of the casting. Consequently, the properties of the casting can vary throughout its thickness. Cylindrical parts ranging from 13 mm to 3 m in diameter and 16 m long can be cast centrifugally with wall thicknesses ranging from 6 to 125 mm. The pressure generated by the centrifugal force is high (as much as 150 g); such high pressure is necessary for casting thick-walled parts. Castings with good quality, dimensional accuracy, and external surface detail are produced by this process.

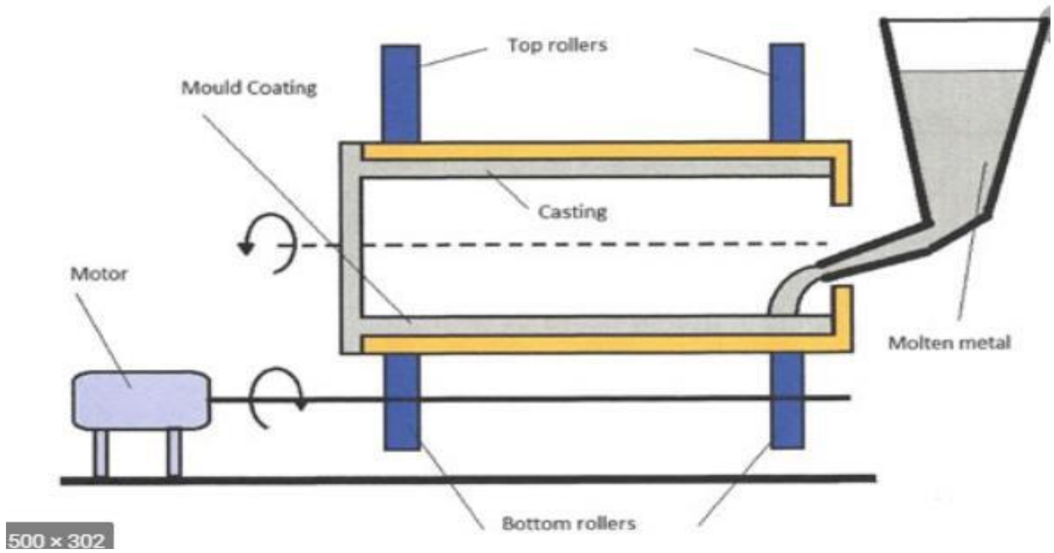


Figure: true centrifugal casting

Semicentrifugal Casting

An example of semicentrifugal casting is shown in Fig. This method is used to cast parts with rotational symmetry, such as a wheel with spokes.

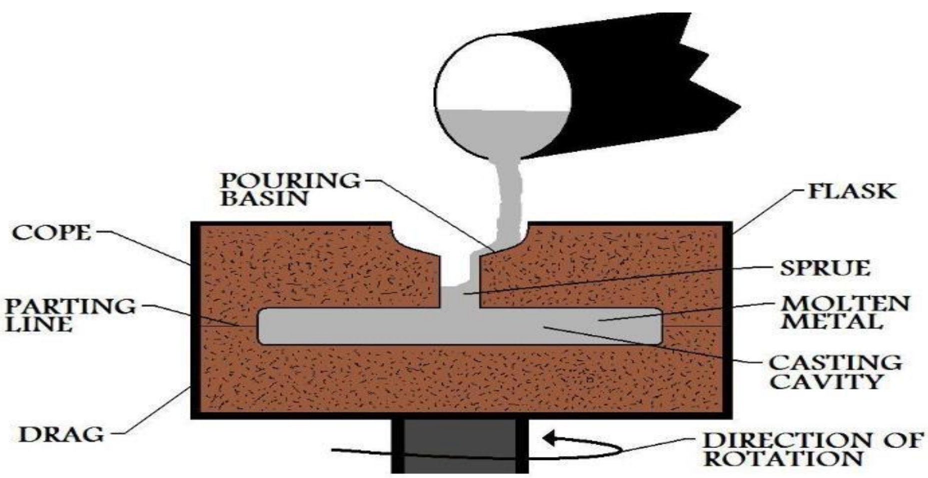


Figure: semicentrifugal casting

Centrifuging

In centrifuging (also called centrifuge casting), mold cavities of any shape are placed at a certain distance from the axis of rotation. The molten metal is poured from the center and is forced into the mold by centrifugal forces. The properties of the castings can vary by distance from the axis of rotation, as in true centrifugal casting.

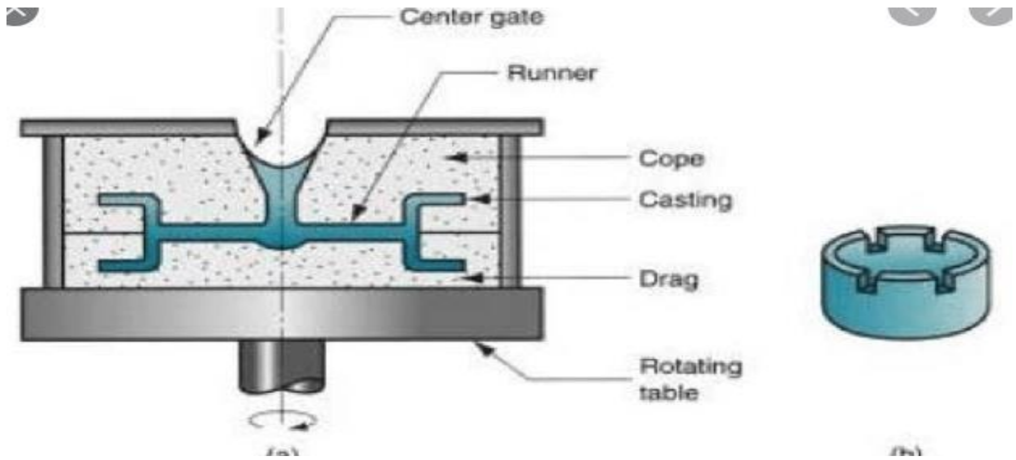


Figure: centrifuging casting

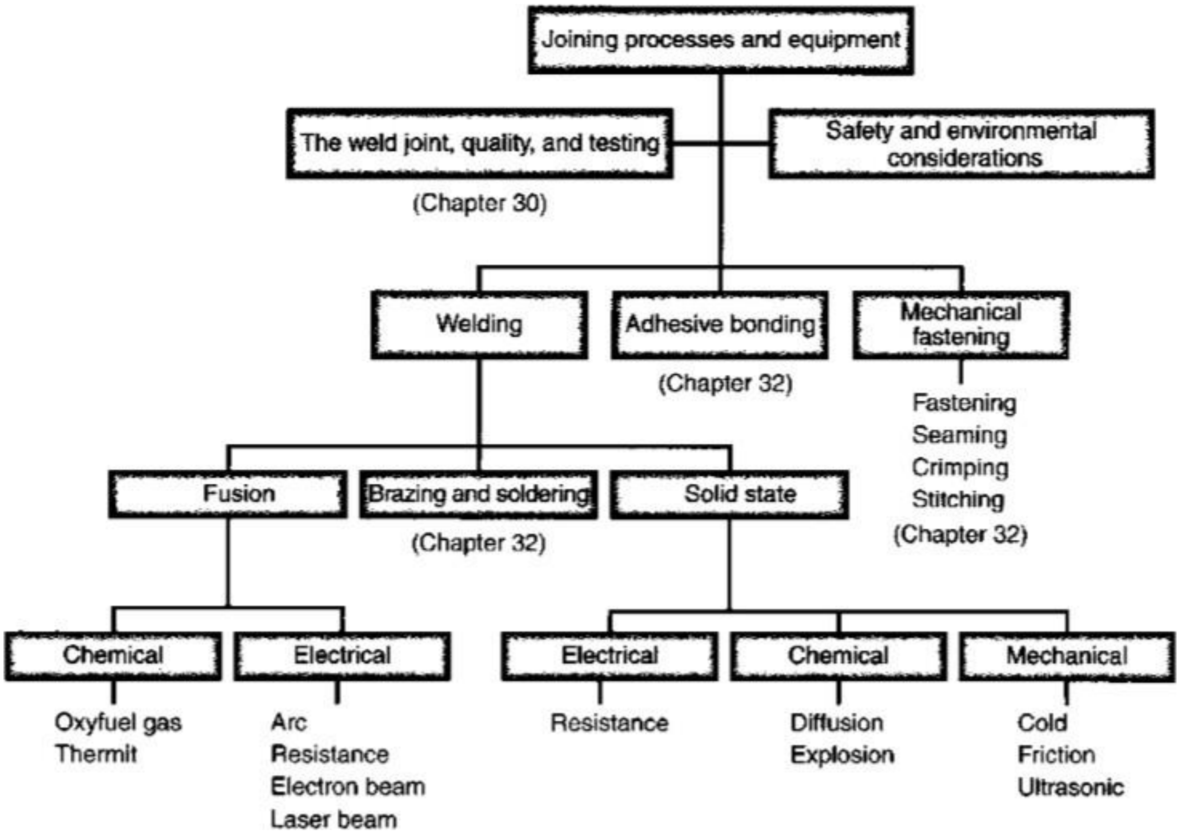
Applications:

- Large cylindrical parts with good quality
- High production rate

Limitations:

- Equipment is expensive
- Part shape limited

4. Welding process:



Oxyfuel-gas Welding:

- Oxyfuel-gas welding (OFW) is a general term used to describe any welding process that uses a fuel gas combined with oxygen to produce a flame. The flame is the source of the heat that is used to melt the metals at the joint. The most common gas welding process uses acetylene.The process is known as oxyacetylene-gas welding (OAW) and is typically used for structural metal fabrication and repair work**.** The heat is generated in accordance with a pair of chemical reactions. The primary combustion process, which occurs in the inner core of the flame

$$C_2H_2 + O_2 \rightarrow 2CO + H_2 + \text{Heat.}$$

This reaction dissociates the acetylene into carbon monoxide and hydrogen and produces about one-third of the total heat generated in the flame**.**

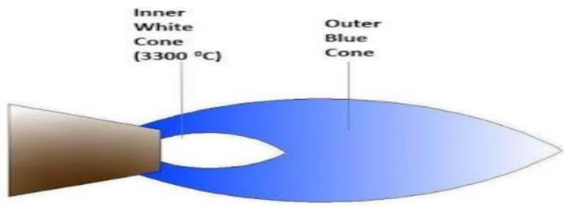
The secondary combustion process is

$$2CO + H_2 + 1.5O_2 \rightarrow 2CO_2 + H_2O + \text{Heat.}$$

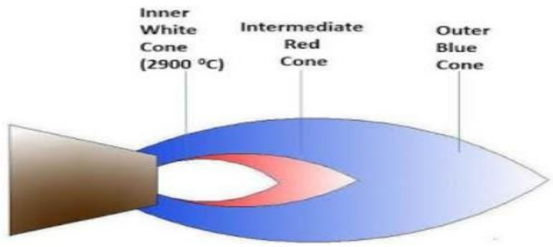
This reaction consists of the further burning of both the hydrogen and the carbon monoxide and produces about two-thirds of the total heat. Note that the reaction also produces water vapor. The temperatures developed in the flame can reach 3300°C.

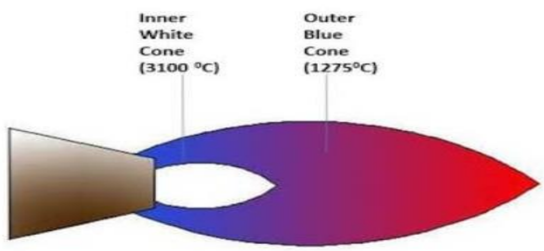
Flame Types: The proportion of acetylene and oxygen in the gas mixture is an important factor in oxyfuel-gas welding. At a ratio of 1:1 (i.e., when there is no excess oxygen), the flame is considered to be neutral.With a greater oxygen supply, the flame can be harmful (especially for steels), because it oxidizes the metal. For this reason, a flame with excess oxygen is known as an oxidizing flame. Only in the welding of copper and copper-based alloys is an oxidizing flame desirable, because in those cases, a thin protective layer of slag (compounds of oxides) forms over the molten metal. If the oxygen is insufficient for full combustion, the flame is known as a reducing, or carburizing, flame (a flame having excess acetylene). The temperature of a reducing flame is lower; hence, such a flame is suitable for applications requiring low heat, such as brazing, soldering, and flame-hardening operations. Other fuel gases (such as hydrogen and methylacetylene propadiene) also can be used in oxyfuel-gas welding. However, the temperatures developed by these gases are lower than those produced by acetylene. Hence, they are used for welding (a) metals with low melting points (such as lead) and (b) parts that are thin and small. The flame with pure hydrogen gas is colorless; therefore, it is difficult to adjust the flame by eyesight.

Filler Metals: Filler metals are used to supply additional metal to the weld zone during welding. They are available as filler rods or wire and may be bare or coated with flux. The purpose of the flux is to retard oxidation of the surfaces of the parts being welded by generating a gaseous shield around the weld zone. The flux also helps to dissolve and remove oxides and other substances from the weld zone, thus contributing to the formation of a stronger joint. The slag developed (compounds of oxides, fluxes, and electrode-coating materials) protects the molten puddle of metal against oxidation as it cools.

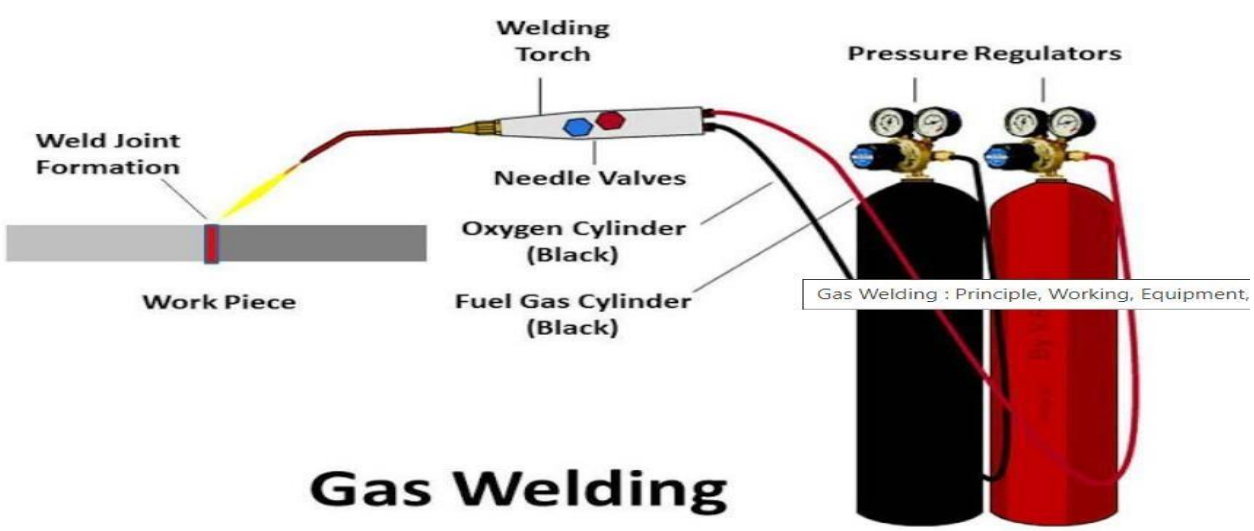


Oxidizing Flame





Natural Flame



Welding Practice and Equipment: Oxyfuel-gas welding can be used with most ferrous and nonferrous metals for almost any workpiece thickness, but the relatively low heat input limits the process to thicknesses of less than 6 mm _ Small joints made by this process may consist of a single-weld bead. Deep-V groove joints are made in multiple passes. Cleaning the surface of each weld bead prior to depositing a second layer is important for joint strength and in avoiding defects. Wire brushes (hand or power) may be used for this purpose. The equipment for oxyfuel-gas welding consists basically of a welding torch connected by hoses to high-pressure gas cylinders and equipped with pressure gages and regulators. The use of safety equipment (such as goggles with shaded lenses, face shields, gloves, and protective clothing) is essential. Proper connection of the hoses to the cylinders is an important factor in safety. Oxygen and acetylene cylinders have different threads, so the hoses cannot be connected to the wrong cylinders. The low equipment cost is an attractive feature of oxyfuel-gas welding. Although it can be mechanized, this operation is essentially manual and, hence, slow. However, it has the advantages of being portable, versatile, and economical for simple and low-quantity work.

Pressure-gas Welding: In this method, the welding of two components starts with the heating of the interface by means of a torch using (typically) an oxyacetylene-gas mixture. After the interface begins to melt, the torch is withdrawn. A force is applied to press the two components together and is maintained until the interface solidifies. Note the formation of a flash due to the upsetting of the joined ends of the two components.

Applications:

- It is used to join thin metal plates.
- It can used to join both ferrous and non-ferrous metals.
- Gas welding mostly used in fabrication of sheet metal.
- It is widely used in **automobile** and aircraft industries.

Advantages:

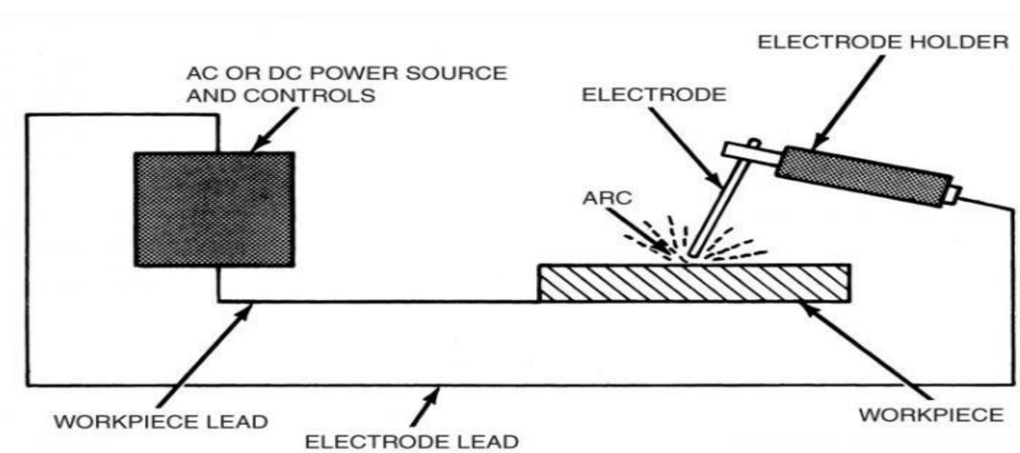
- It is easy to operate and dose not required high skill operator.
- Equipment cost is low compare to other welding processes like **MIG**, **TIG** etc.
- It can be used at site.
- Equipment’s are more portable than other type of welding.
- It can also be used as gas cutting.

Disadvantages:

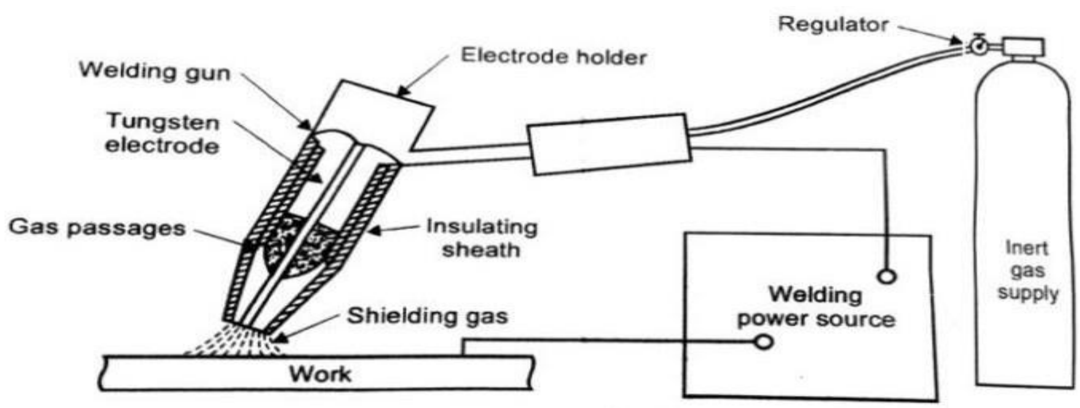
- It provides low surface finish. This process needs a finishing operation after welding.

- Gas welding have large heat affected zone which can cause change in mechanical properties of parent material.
- Higher safety issue due to naked flame of high temperature.
- It is Suitable only for soft and thin sheets.
- Slow metal joining rate.
- No shielding area which causes more **welding defects**

Arc-welding Processes: **Nonconsumable Electrode In arc welding**, developed in the mid- 1800s, the heat required is obtained from electrical energy. The process involves either a consumable or a nonconsumable electrode. An AC or a DC power supply produces an arc between the tip of the electrode and the workpiece to be welded. The arc generates temperatures of about 30,000°C, which are much higher than those developed in oxyfuel-gas welding. In nonconsurnable-electrode welding processes, the electrode is typically a tungsten electrode. Because of the high temperatures involved, an externally supplied shielding gas is necessary to prevent oxidation of the weld zone. Typically, direct current is used, and its polarity (the direction of current flow) is important. The selection of current levels depends on such factors as the type of electrode, metals to be welded, and depth and width of the weld zone. In straight polarity-also known as direct-current electrode negative (DCEN)- the workpiece is positive (anode), and the electrode is negative (cathode). DCEN generally produces welds that are narrow and deep. In reverse polarity-also known as direct-current electrode positive (DCEP)-the workpiece is negative and the electrode is positive. Weld penetration is less, and the weld zone is shallower and wider. Hence, DCEP is preferred for sheet metals and for joints with very wide gaps. ln the AC current method, the arc pulsates rapidly. This method is suitable for welding thick sections and for using large-diameter electrodes at maximum currents.



Gas Tungsten-arc Welding: In gas tungsten-are welding (GTAW), formerly known as TIG (for "tungsten inert gas") welding, the filler metal is supplied from a filler wire. Because the tungsten electrode is not consumed in this operation, a constant and stable arc gap is maintained at a constant current level. The filler metals are similar to the metals to be welded, and flux is not used. The shielding gas is usually argon or helium (or a mixture of the two). Welding with GTAW may be done without filler metals-for example, in the welding of close-fit joints. Depending on the metals to be welded, the power supply is either DC at 200 A or AC at 500 A. In general, AC is preferred for aluminum and magnesium, because the cleaning action of AC removes oxides and improves weld quality. Thorium or zirconium may be used in the tungsten electrodes to improve their electron emission characteristics. The power supply ranges from 8 to 20 kW Contamination of the tungsten electrode by the molten metal can be a significant problem, particularly in critical applications, because it can cause discontinuities in the weld. Therefore, contact of the electrode with the molten-metal pool should be avoided. The GTAW process is used for a wide variety of applications and metals, particularly aluminum, magnesium, titanium, and the refractory metals. It is especially suitable for thin metals. The cost of the inert gas makes this process more expensive than SMAW but provides welds of very high quality and surface finish. GTAW is used in a variety of critical applications with a wide range of workpiece thicknesses and shapes. The equipment is portable.



gas tungsten arc welding diagram

Advantages of gas tungsten arc welding:

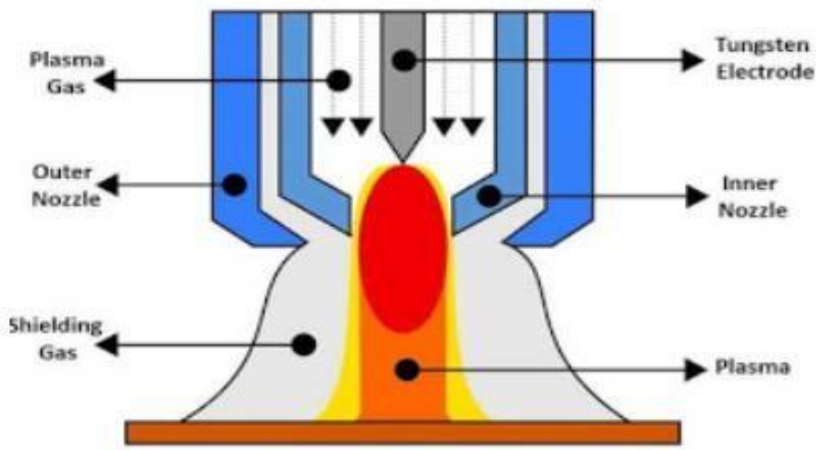
- All position of metal will be welded
- The weld is equal to base metal in composition
- The finished weld surfaces not require cleaning process because of flux is not used.
- Smoke or fumes not presented to obscure vision

- The heat is concentrated in the small area, so distortion of base metal is minimal
- The metal is not transferred across the arc, so no splatter is provided.
- Thus produce high quality weld on non-ferrous metal.

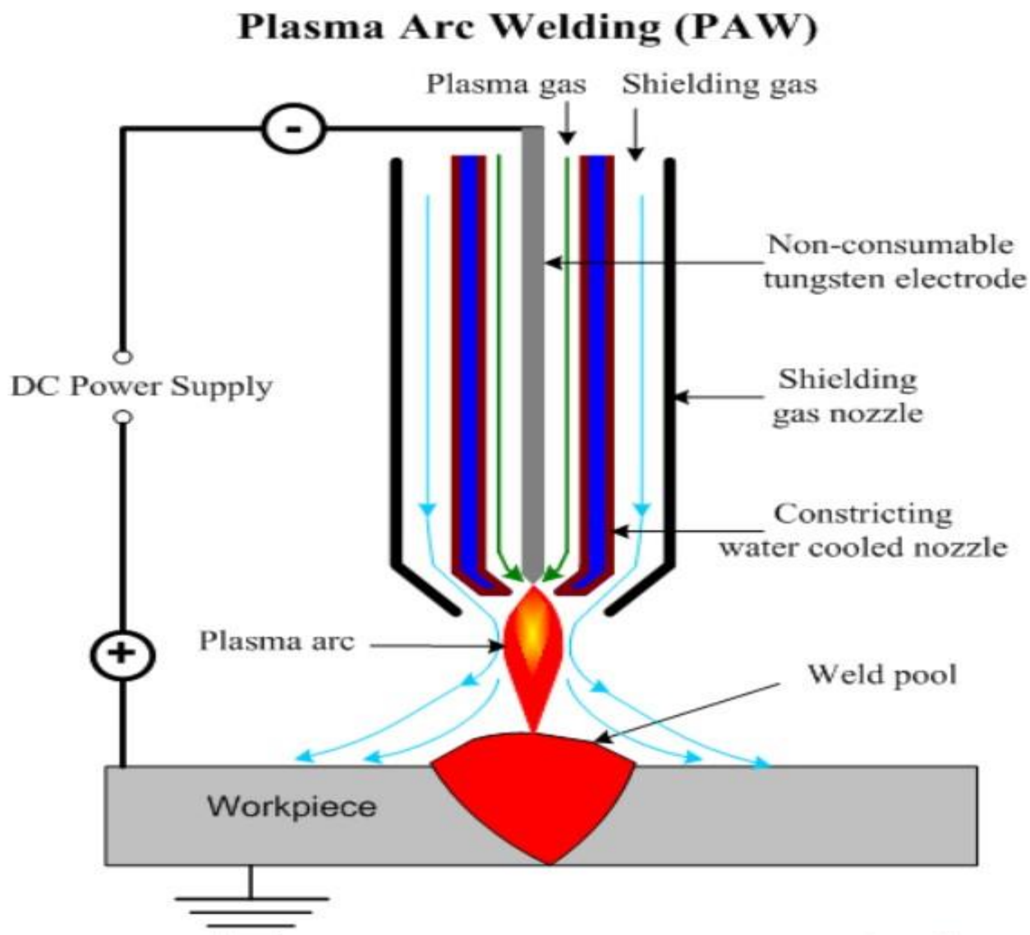
Application of gas tungsten arc welding:

- It is general to common welding process of aluminum. The gas tungsten arc welding used to weld for following materials.
- Copper base alloys
- Nickel base alloys
- Low alloy steel
- Dissimilar metal like as copper
- Titanium and its alloy
- Hard falling
- Magnesium alloy
- It is suitable for thin sheet 0.5 to 3 mm thickness produce weld with excellent quality and surface finish.
- It is used for pressure vessels, pipes, and heat exchanger where tight less is important.

Plasma-arc Welding: In plasma-arc welding (PAW), developed in the 1960s, a concentrated plasma arc is produced and directed towards the weld area. The arc is stable and reaches temperatures as high as 33,000°C. A plasma is an ionized hot gas composed of nearly equal numbers of electrons and ions. The plasma is initiated between the tungsten electrode and the orifice by a low-current pilot arc. What makes plasma-arc welding unlike other processes is that the plasma arc is concentrated because it is forced through a relatively small orifice. Operating currents usually are below 100 A, but they can be higher for special applications. When a filler metal is used, it is fed into the arc, as is done in GTAW. Arc and weld-zone shielding is supplied by means of an outer-shielding ring and the use of gases such as argon, helium, or mixtures. There are two methods of plasma-arc welding: ° In the transferred-arc method, the workpiece being welded is part of the electrical circuit. The arc transfers from the electrode to the workpiecehence the term transferred. ° In the nontransferred method, the arc occurs between the electrode and the nozzle, and the heat is carried to the workpiece by the plasma gas. This thermal-transfer mechanism is similar to that for an oxyfuel flame. Compared with other arc-welding processes, plasma-arc welding has better arc stability, less thermal distortion, and higher energy concentration, thus permitting deeper and narrower welds. In addition, higher welding speeds, from 120 to 1000 mm/min, can be achieved. A variety of metals can be welded with part thicknesses generally less than 6 mm. The high heat concentration can penetrate completely through the joint (known as the keyhole technique), with thicknesses as much as 20 mm for some titanium and aluminum alloys. In the keyhole technique, the force of the plasma arc displaces the molten metal and produces a hole at the leading edge of the weld pool. Plasma-arc welding (rather than the GTAW process) often is used for butt and lap joints because of its higher energy concentration, better arc stability, and higher welding speeds. Proper training and skill are essential for operators who use this equipment. Safety considerations include protection against glare, spatter, and noise from the plasma arc.



Principle of Plasma Arc Welding



Application:

- This welding is used in marine and aerospace industries.
- It is used to weld pipes and tubes of stainless steel or titanium.
- It is mostly used in electronic industries.
- It is used to repair tools, die and mold.
- It is used to welding or coating on **turbine** blade.

Advantages:

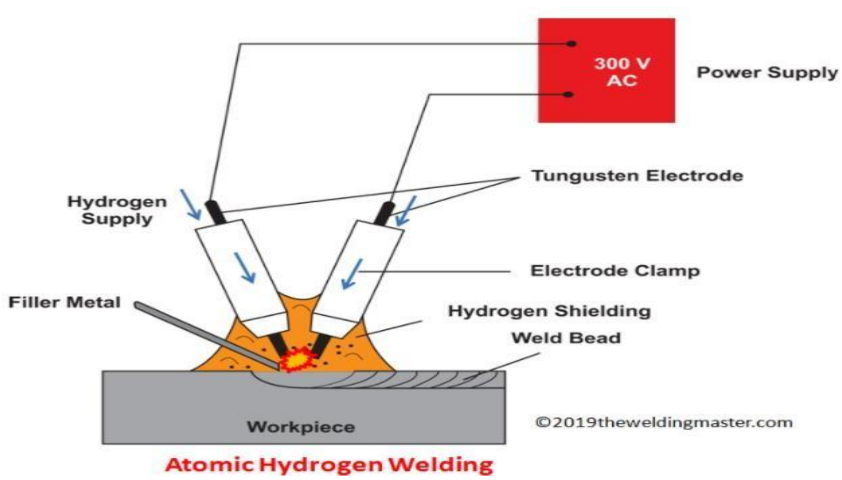
- High welding speed.
- High energy available for welding. It can be easily used to weld hard and thick work pieces.

- The distance between tool and work piece does not effects the arc formation.
- Low power consumption for same size weld.
- More stable arc produced by PAW method.
- High intense arc or high penetration rate.
- It can work at low amperage.

Disadvantages:

- Higher equipment cost.
- Noisy operation.
- More radiation.
- High skill labor required.
- High maintenance cost.

Atomic-hydrogen Welding: In atomic-hydrogen welding (AHW), an arc is generated between two tungsten electrodes in a shielding atmosphere of hydrogen gas. The arc is maintained independently of the workpiece or parts being welded. The hydrogen gas normally is diatomic (HZ), but where the temperatures are over 6,000°C near the arc, the hydrogen breaks down into its atomic form, simultaneously absorbing a large amount of heat from the arc. When the hydrogen strikes the cold surface of the workpieces to be joined, it recombines into its diatomic form and rapidly releases the stored heat. The energy in AHW can be varied easily by changing the distance between the arc stream and the workpiece surface. This process is being replaced by shielded metal-arc welding, mainly because of the availability of inexpensive inert gases.



Advantages:

- AHW produces very less distortion. The less distortion is due to the very intense flame. This intense flame produced can be concentrated at a particular joint.
- Atomic Hydrogen welding gives you a faster welding process. A faster welding process is always beneficial for welders and it also saves time.
- In the AHW process, there is no requirement of the flux separately. Hydrogen gas works as a shielding gas and prevents the oxidation of metals as well as of the tungsten electrode.
- In some welding processes, the workpiece is the part of the electric circuit and due to these situations like striking the arc and maintaining the arc column arises. But, as the workpiece is not part of the electric circuit in the AHW, there are no such problems during the entire process.

Disadvantages:

- For carrying out the atomic hydrogen welding process, a skilled labor supply is required. Without skilled labor, this process cannot be implemented efficiently. So, a talented and experienced labor work is a must.
- The cost of this welding process is slightly higher than that of the other welding processes. So, you must require a minimum capital to do the AWH.
- AHW is limited to only flat positions. For other positions, this welding process is not suitable.
- Required precautions should be taken as hydrogen is involved in this process. Hydrogen is a highly inflammable gas.

Applications:

- Atomic hydrogen welding is used in the applications where we require fast welding. This welding process is mainly used for stainless steel and some special alloys.
- It can also be used for almost all the ferrous as well as non-ferrous metals.
- It is an ideal process for welding thin as well as thick sheets of metals with diameters in the range of 2 to 10 mm.

Arc-welding Processes: Consumable Electrode:

There are several consumable-electrode arc-welding processes.

Shielded Metal-arc Welding:

Shielded metal-arc welding (SMAW) is one of the oldest, simplest, and most versatile joining processes. About 50% of all industrial and maintenance welding currently is performed by this process. The electric arc is generated by touching the tip of a coated electrode against the workpiece and withdrawing it quickly to a distance sufficient to maintain the arc. The electrodes are in the shapes of thin, long rods (hence, this process also is known as stick welding) that are held manually. The heat generated melts a portion of the electrode tip, its coating, and the base metal in the immediate arc area. The molten metal consists of a mixture of the base metal (the workpiece), the electrode metal, and substances from the coating on the electrode; this mixture forms the weld when it solidifies. The electrode coating deoxidizes the weld area and provides a shielding gas to protect it from oxygen in the environment. A bare section at the end of the electrode is clamped to one terminal of the power source, while the other terminal is connected to the workpiece being welded. The current, which may be DC or AC, usually ranges from 50 to 300 A. For sheet-metal welding, DC is preferred because of the steady arc it produces. Power requirements generally are less than 10 kW. The SMAW process has the advantages of being relatively simple, versatile, and requiring a smaller variety of electrodes. The equipment consists of a power supply, cables, and an electrode holder. The SMAW process commonly is used in general construction, shipbuilding, pipelines, and maintenance work. It is especially useful for work in remote areas where a portable fuel-powered generator can be used as the power supply. SMAW is best suited for workpiece thicknesses of 3 to 19 mm, although this range can be extended easily by skilled operators using multiple-pass techniques. The multiple-pass approach requires that the slag be removed after each weld bead. Unless removed completely, the solidified slag can cause severe corrosion of the weld area and lead to failure of the weld, but it also prevents the fusion of weld layers and, therefore, compromises the weld strength. Before another weld is applied, the slag should be removed completely-for example, by wire brushing or weld chipping. Consequently, both labor costs and material costs are high.

Submerged-arc Welding:

In submerged-arc welding (SAW), the weld arc is shielded by a granular flux consisting of lime, silica, manganese oxide, calcium fluoride, and other compounds. The flux is fed into the weld zone from a hopper by gravity flow through a nozzle. The thick layer of flux completely covers the molten metal. It prevents spatter and sparks and suppresses the intense ultraviolet radiation and fumes characteristic of the SMAW process. The flux also acts as a thermal insulator by promoting deep penetration of heat into the workpiece. The unused flux can be recovered (using a recovery tube), treated, and reused. The consumable electrode is a coil of bare round wire 1.5 to 10 mm in diameter; it is fed automatically through a tube (welding gun). Electric currents typically range from 300 to 2000 A. The power supplies usually are connected to standard single- or three-phase power lines with a primary rating up to 440 V Because the flux is gravity fed, the SAW process is limited largely to welds in a flat or horizontal position having a backup piece. Circular welds can be made on pipes and cylinders-provided that they are rotated during welding. the unfused flux can be recovered, treated, and reused. SAW is automated and is used to weld a variety of carbon and alloy steel and stainless-steel sheets or plates at speeds as high as 5 m/min. The quality of the Weld is very high-With good toughness, ductility, and uniformity of properties. The SAW process provides very high welding productivity, depositing 4 to 10 times the amount of Weld metal per hour as the SMAW process. Typical applications include thick-plate Welding for shipbuilding and for pressure vessels.

Gas Metal-arc Welding:

In gas metal-arc welding (GMAW), developed in the 19505 and formerly called metal inert-gas (MIG) welding, the Weld area is shielded by an effectively inert atmosphere of argon, helium, carbon dioxide, or various other gas mixtures. The consumable bare Wire is fed automatically through a nozzle into the Weld arc by a Wire-feed drive motor. In addition to using inert shielding gases, deoxidizers usually are present in the electrode metal itself in order to prevent oxidation of the molten-weld puddle. Multiple-weld layers can be deposited at the joint. Metal can be transferred by three methods in the GMAW process: l. in spray transfer, small, molten metal droplets from the electrode is transferred to the Weld area at a rate of several hundred droplets per second. The transfer is spatter free and very stable. High DC currents and voltages and large-diameter electrodes are used with argon or an argon-rich gas mixture as the shielding gas. The average current required in this process can be reduced with the use of a pulsed arc, which superimposes high-amplitude pulses onto a low, steady current. The process can be used in all welding positions. In globular transfer, carbon-dioxide-rich gases are utilized, and globules are propelled by the forces of the electric-arc transfer of the metal, resulting in considerable spatter. High Welding currents are used, making it possible for greater Weld penetration and higher welding speed than are achieved in spray transfer. Heavier sections commonly are joined by this method. 2. In short circuiting, the metal is transferred in individual droplets (more than 50 per second) as the electrode tip touches the molten Weld metal and short circuits. Low currents and voltages are utilized with carbon-dioxide-rich gases and electrodes made of small-diameter Wire. The power required is about 2 kW 3. The temperatures generated in GMAW are relatively low; consequently, this method is suitable only for thin sheets and sections of less than 6 mm; otherwise incomplete fusion may occur. The operation, which is easy to perform, is commonly used for welding ferrous metals in thin sections. Pulsed-arc systems are used for thin ferrous and nonferrous metals. The GMAW process is suitable for welding most ferrous and nonferrous metals and is used extensively in the metal-fabrication industry. Because of the relatively simple nature of the process, the training of operators is easy. The process is versatile, rapid, and economical, and welding productivity is double that of the SMAW process. The GMAW process can be automated easily and lends itself readily to robotics and to flexible manufacturing systems.

Flux-cored Arc Welding:

The flux-cored arc welding (FCAW) process is similar to gas metal-arc Welding, except that the electrode is tubular in shape and is filled with flux (hence the term flux-cored). Cored electrodes produce a more stable arc, improve weld contour, and produce better mechanical properties of the weld metal. The flux in these electrodes is much more flexible than the brittle coating used on SMAW electrodes, so the tubular electrode can be provided in long coiled lengths. The electrodes are usually 0.5 to 4 mm in diameter, and the power required is about 20 kW. Self shielded cored electrodes also are available. They do not require any external shielding gas, because they contain emissive fluxes that shield the weld area against the surrounding atmosphere. Small-diameter electrodes have made the welding of thinner materials not only possible, but often preferable. Also, small-diameter electrodes make it relatively easy to weld parts in different positions and the flux chemistry permits the welding of many metals. The FCAW process combines the versatility of SMAW with the continuous and automatic electrode-feeding feature of GMAW The process is economical and versatile, so it is used for welding a variety of joints, mainly on steels, stainless steels, and nickel alloys. The higher weld-metal deposition rate of the FCAW process (compared with that of GMAW) has led to its use in the joining of sections of all thicknesses. The use of tubular electrodes with very small diameters has extended the use of this process to work pieces of smaller section size. A major advantage of FCAW is the ease with which specific weld-metal chemistries can be developed. By adding alloying elements to the flux core, virtually any alloy composition can be produced. The process is easy to automate and is readily adaptable to flexible manufacturing systems and robotics.

Electrogas Welding:

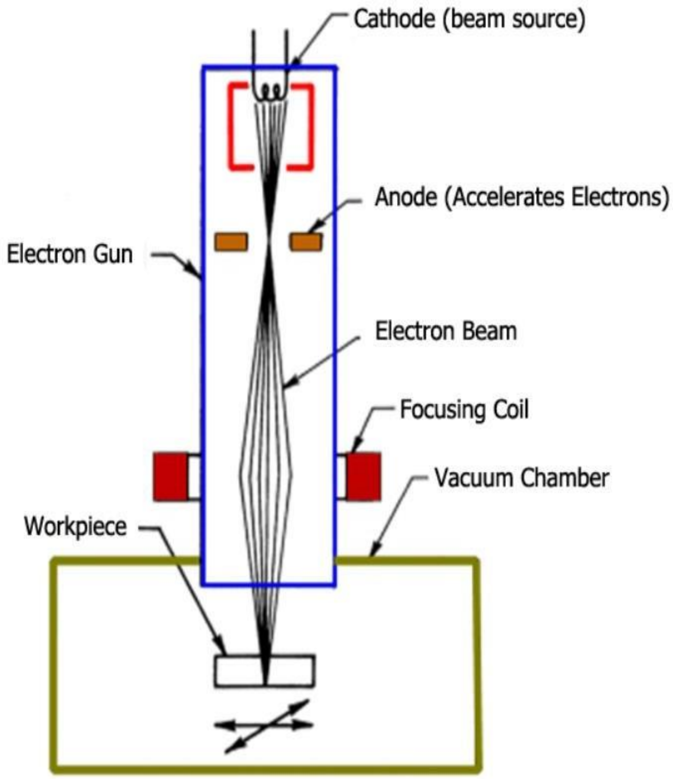
Electrogas welding (EGW) is used primarily for welding the edges of sections vertically and in one pass with the pieces placed edge to edge (butt joint). It is classified as a machine-welding process, because it requires special equipment. The weld metal is deposited into a weld cavity between the two pieces to be joined. The space is enclosed by two water-cooled copper dams (shoes) to prevent the molten slag from running off; mechanical drives move the shoes upward. Circumferential welds (such as those on pipes) also are possible, with the work piece rotating.

Single or multiple electrodes are fed through a conduit, and a continuous arc is maintained by flux-cored electrodes at up to 750 A or solid electrodes at 400 A. Power requirements are about 20 kW Shielding is done by means of an inert gas, such as carbon dioxide, argon, or helium- depending on the type of material being Welded. The gas may be provided either from an external source, from a flux-cored electrode, or from both. The equipment for electrogas Welding is reliable and training for operators is relatively simple. Weld thickness ranges from 12 to 75 mm on steels, titanium, and aluminum alloys. Typical applications are in the construction of bridges, pressure vessels, thick-Walled and large-diameter pipes, storage tanks, and ships.

Electroslag Welding:

Electroslag welding (ESW) and its applications are similar to electrogas welding. The main difference is that the arc is started between the electrode tip and the bottom of the part to be vvelded. Flux is added, which then melts by the heat of the arc. After the molten slag reaches the tip of the electrode, the arc is extinguished. Heat is produced continuously by the electrical resistance of the molten slag. Because the arc is extinguished, ESW is not strictly an arc-welding process. Single or multiple solid as Well as flux-cored electrodes may be used. The guide may be nonconsumable (conventional method) or consumable. Electroslag Welding is capable of Welding plates with thicknesses ranging from 50 mm to more than 900 mm, and Welding is done in one pass. The current required is about 600 A at 40 to 50 \L although higher currents are used for thick plates. The travel speed of the weld is in the range from 12 to 36 mm/min. Weld quality is good. This process is used for large structural-steel sections, such as heavy machinery, bridges, oil rigs, ships, and nuclear-reactor vessels.

5. Electron-beam Welding: In electron-beam welding (EBW), developed in the 1960s, heat is generated by highvelocity narrow-beam electrons. The kinetic energy of the electrons is converted into heat as they strike the workpiece. The process requires special equipment to focus the beam on the workpiece, typically in a vacuum. The higher the vacuum, the more the beam penetrates, and the greater is the depth-to-width ratio; thus, the methods are called EBW-HV (for “high vacuum”) and EBW-MV (for “medium vacuum”); some materials also may also be welded by EBW-NV (for “no vacuum”). Almost any metal can be welded by EBW, and workpiece thicknesses can range from foil to plate. Capacities of electron guns range up to 100 kW. The intense energy also is capable of producing holes in the workpiece (see keyhole technique) generally; no shielding gas, flux, or filler metal is required. The EBW processes has the capability of making high-quality welds that are almost parallel sided, are deep and narrow, and have small heat-affected zones. Depth-to-width ratios range between 10 and 30. The sizes of welds made by EBW are much smaller than those of welds made by conventional proces ses. With the use of automation and servo controls, parameters can be controlled accurately at welding speeds as high as 12 m/min. Almost any metal can be butt or lap welded with this process at thicknesses up to 150 mm. Distortion and shrinkage in the weld area are minimal. The weld quality is good and of very high purity. Typical applications include the welding of aircraft, missile, nuclear, and electronic components, as well as gears and shafts for the automotive industry. Electron-beam welding equipment generates X-rays; hence, proper monitoring and periodic maintenance are essential.



Advantages of electron beam welding process:

- High speed weld
- Low heat input
- Cooling rate high
- Low distortion of work piece
- Welded part cleaned to gather
- The high accelerated electron hit require for tremendous penetration.
- The heat affect zone small compare to other weld process.

Limitation of electron beam welding process:

- Usually in this process take place with vacuum so the weld provide in vacuum chamber.
- Equipment is more expensive compare to conventional weld.
- The air removed from vacuum chamber so the pump is required.
- The safety measures must place on welding.

electron beam welding applications in industrial:

- Titanium alloy and aluminum alloy can be welded.
- Diamonds can be welded
- 150 mm thickness plate can be weld

6. Laser-beam Welding:

Laser-beam welding (LBW) utilizes a high-power laser beam as the source of heat, to produce a fusion weld. Because the beam can be focused onto a very small area, it has high energy density and deep-penetrating capability. The beam can be directed, shaped, and focused precisely on the workpiece. Consequently, this process is suitable particularly for welding deep and narrow joints with depth-to-width ratios typically ranging from 4 to 10. Laser-beam welding has become extremely popular and is used in most industries. In the automotive industry, welding transmission components are the most widespread application. Among numerous other applications is the welding of thin parts for electronic components. The laser beam may be pulsed (in milliseconds) with power levels up to 100 kW for applications such as the spot welding of thin materials. Continuous multi-kW laser systems are used for deep welds on thick sections. Laser-beam welding produces welds of good quality with minimum shrinkage or distortion. Comparison of the sizes of weld beads: (a) laser-beam or electron-beam welding and (b) tungsten have good strength and generally are ductile and free of arc welding. Source: Courtesy of American Welding Society.

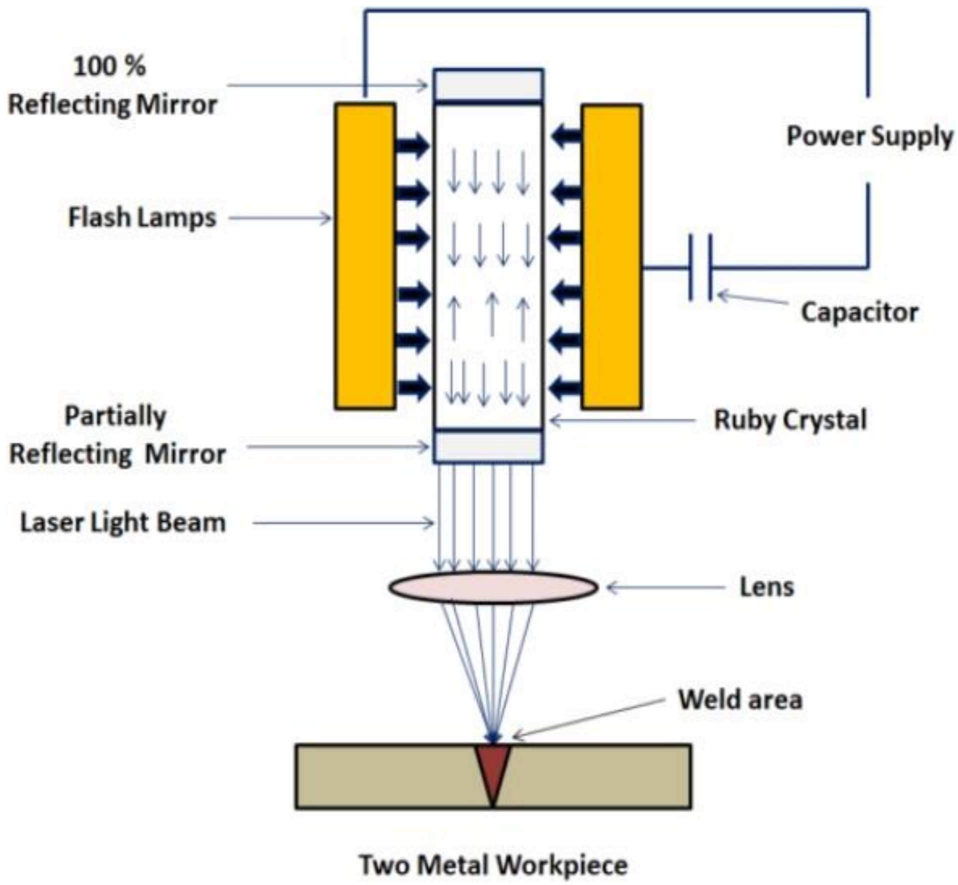
Porosity: The process can be automated to be used on a variety of materials with thicknesses up to 25 mm; it is particularly effective on thin workpieces. Tailor-welded sheet-metal blanks are joined principally by laser-beam welding using robotics for precise control of the beam path. Typical metals and alloys welded include aluminum, titanium, ferrous metals, copper, superalloys, and the refractory metals. Welding speeds range from 2.5 m/min to as high as 80 m/min for thin metals. Because of the nature of the process, welding can be done in otherwise inaccessible locations. As in other and similar automated welding systems, the operator skill required is minimal. Safety is particularly important in laser-beam welding due to the extreme hazards to the eye as well as the skin; solid-state (YAG) lasers also are dangerous.

The major advantages of LBW over EBW are the following:

° A vacuum is not required, and the beam can be transmitted through air.

° Laser beams can be shaped, manipulated, and focused optically (by means of fiber optics), so the process can be automated easily. ° The beams do not generate X-rays.

° The quality of the weld is better than in EBW; the weld has less tendency toward incomplete fusion, spatter, and porosity; and there is less distortion.



Advantages:

- It produces high weld quality.
- LBW can be easily automated with robotic machinery for large volume production.
- No electrode is required.

- No tool wears because it is a non-contact process.
- The time taken for welding thick section is reduced.
- It is capable of welding in those areas which are not easily accessible.
- It has the ability to weld metals with dissimilar physical properties.
- It can be weld through air and no vacuum is required.
- X-Ray shielding is not required as it does not produce any X-Rays.
- It can be focused on small areas for welding. This is because of its narrower beam of high energy.
- A wide variety of materials can be welded by using laser beam welding.
- It produces a weld of aspect ratio (i.e. depth to width ratio) of 10:1.

Disadvantages

- The initial cost is high. The equipment used in LBW has a high cost.
- High maintenance cost.
- Due to the rapid rate of cooling, cracks may be produced in some metals.
- High skilled labor is required to operate LBW.
- The welding thickness is limited to 19 mm.
- The energy conversion efficiency in LBW is very low. It is usually below 10 %.

Application

- The laser beam welding is dominant in the automotive industry. It is used in the area where large volume production is required.

ELECTRICAL DISCHARGE MACHINING (EDM):

- Electrical discharge machining (EDM) is one of the most widely used non-traditional machining processes. The main attraction of EDM over traditional machining processes such as metal cutting using different tools and grinding is that this technique utilises thermoelectric process to erode undesired materials from the workpiece by a series of discrete electrical sparks between the workpiece and the electrode. The traditional machining processes rely on harder tool or abrasive material to remove the softer material whereas non-traditional machining processes such as EDM uses electrical spark or thermal energy to erode unwanted material in order to create desired shape. So, the hardness of the material is no longer a dominating factor for EDM process. A schematic of an EDM process is shown in Figure, where the tool and the workpiece are immersed in a dielectric fluid.

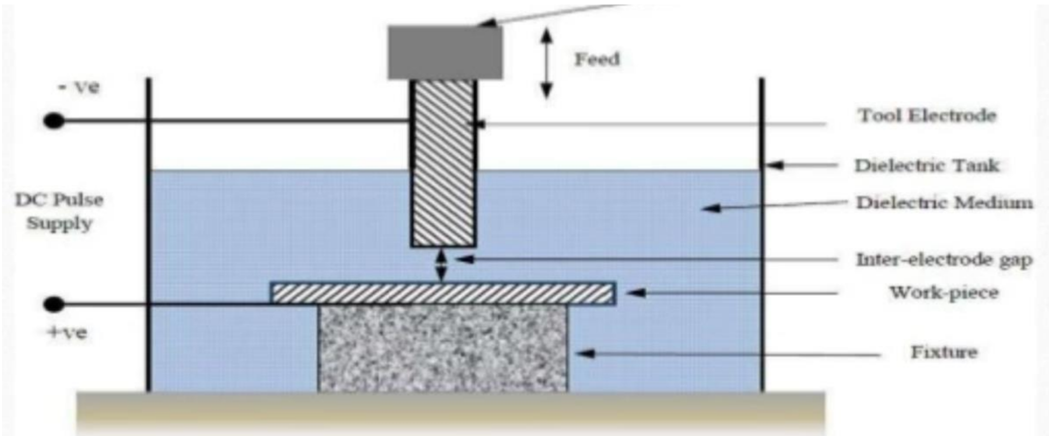
- 

Fig.: Schematic of an Electric Discharge Machining (EDM)

- EDM removes material by discharging an electrical current, normally stored in a capacitor bank, across a small gap between the tool (cathode) and the workpiece (anode) typically in the order of 50 volts/10amps.

Application of EDM

- The EDM process has the ability to machine hard, difficult-to-machine materials. Parts with complex, precise and irregular shapes for forging, press tools, extrusion dies, difficult internal shapes for aerospace and medical applications can be made by EDM process.

Working principle of EDM

At the beginning of EDM operation, a high voltage is applied across the narrow gap between the electrode and the workpiece. This high voltage induces an electric field in the insulating dielectric that is present in narrow gap between electrode and workpiece. This cause conducting particles suspended in the dielectric to concentrate at the points of strongest electrical field. When the potential difference between the electrode and the workpiece is sufficiently high, the dielectric breaks down and a transient spark discharges through the dielectric fluid, removing small amount of material from the workpiece surface. The volume of the material removed per spark discharge is typically in the range of 10-6 to 10-6 mm3.

The material removal rate, MRR, in EDM is calculated by the following foumula: MRR = 40 I / Tm 1.23 (cm3 /min) Where, I is the current amp, Tm is the melting temperature of workpiece in ^{0}C

Advantages of EDM

- The main advantages of DM are:
- By this process, materials of any hardness can be machined;
- No burrs are left in machined surface;
- One of the main advantages of this process is that thin and fragile/brittle components
- can be machined without distortion; Complex internal shapes can be machined

Limitations of EDM

- The main limitations of this process are: This process can only be employed in electrically conductive materials;
- Material removal rate is low and the process overall is slow compared to conventional
- machining processes; Unwanted erosion and over cutting of material can occur;
- Rough surface finish when at high rates of material removal.

7. Resistance Welding:

The category of resistance welding (RW) covers a number of processes in which the heat required for welding is produced by means of electrical resistance across the two components to be joined. These processes have major advantages, such as not requiring consumable electrodes, shielding gases, or flux. The heat generated in resistance welding is given by the general expression

$$H = I^2Rt,$$

where H = Heat generated in joules (watt-seconds)

I = Current (in amperes)

R = Resistance (in ohms)

t = Time of current flow (in seconds)

Equation is often modified so that it represents the actual heat energy available in the weld by including a factor K, which denotes the energy losses through conduction and radiation. The equation then becomes

$$H = I^2RtK,$$

Where the value of K is less than unity

The total resistance is the sum of the following properties

a. Resistances of the electrodes;

b. Electrode-workpiece contact resistance;

c. Resistances of the individual parts to be welded;

d. Contact resistance between the two workpieces to be joined (faying surfaces).

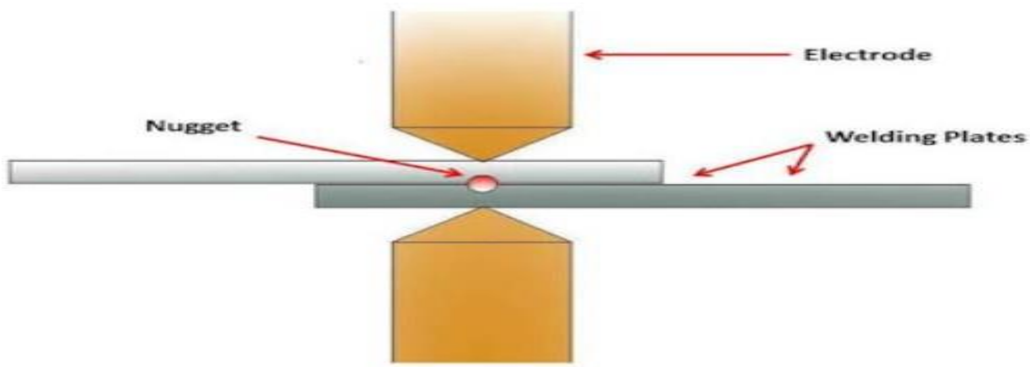
The actual temperature rise at the joint depends on the specific heat and the thermal conductivity of the metals to be joined. For example, metals such as aluminum and copper have high thermal conductivity, so they require high heat concentrations. Similar or dissimilar metals can be joined by resistance welding. The magnitude of the current in resistance-welding operations may be as high as 100,000 A, but the voltage is typically only 0.5 to 10 V.

The strength of the bond depends on surface roughness and on the cleanliness of the mating surfaces. Oil films, paint, and thick oxide layers should therefore be removed before welding. The presence of uniform, thin layers of oxide and of other contaminants is not as critical. Developed in the early 1900s, resistance-welding processes require specialized machinery. Much of it is now operated by programmable computer control. Generally, the machinery is not portable, and the process is suitable primarily for use in manufacturing plants and machine shops. The operator skill required is minimal, particularly with modern machinery.

Resistance Spot Welding:

In resistance spot welding (RSW), the tips of two opposing solid, cylindrical electrodes touch a lap joint of two sheet metals, and resistance heating produces a spot weld. In order to obtain a strong bond in the weld nugget, pressure is applied until the current is turned off and the weld has solidified. Accurate control and timing of the alternating electric current and of the pressure are essential in resistance welding. In the automotive industry, for example, the number of cycles ranges up to about 30 at a frequency of 60 Hz. The weld nugget is generally 6 to 10 mm in diameter. The surface of the spot weld has a slightly discolored indentation. Currents range from 3000 to 40,000 A. The current level depends on the materials being welded and on their thicknesses. For example, the current is typically 10,000 A for steels and

13,000 A for aluminum. Electrodes generally are made of copper alloys and must have sufficient electrical conductivity and hot strength to maintain their shape. Spot welding is the simplest and most commonly used resistance~welding process. Welding may be performed by means of single (most common) or multiple pairs of electrodes (as many as a hundred or more), and the required pressure is supplied through mechanical or pneumatic means. Rocker-arm-type spot-welding machines normally are used for smaller parts; press-type machines are used for larger workpieces. The shape and surface condition of the electrode tip and the accessibility of the site are important factors in spot welding. A variety of electrode shapes are used to spot-weld areas those are difficult to reach. Spot welding is used widely for fabricating sheet-metal parts. Examples range from attaching handles to stainless-steel cookware to spot-welding mufflers and large sheet-metal structures. Modern spot-welding equipment is computer controlled for optimum timing of current and pressure; its spot-welding guns are manipulated by programmable robots. Automobile bodies can have as many as 10,000 spot welds; they are welded at high rates with the use of multiple electrodes.

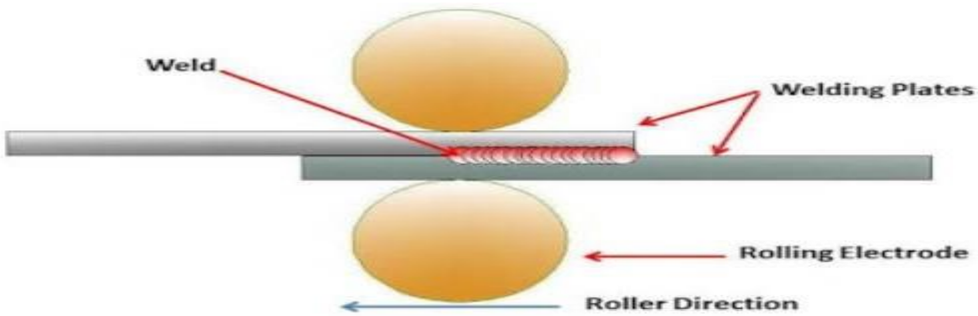


Spot Welding

Because they are easy to perform and are inexpensive, tension-shear tests are commonly used in fabricating facilities. The cross-tension and twist tests are capable of revealing flaws, cracks, and porosity in the Weld area. The peel test is commonly used for thin sheets. After the joint has been bent and peeled, the shape and size of the torn-out weld nugget are evaluated.

Resistance Seam Welding:

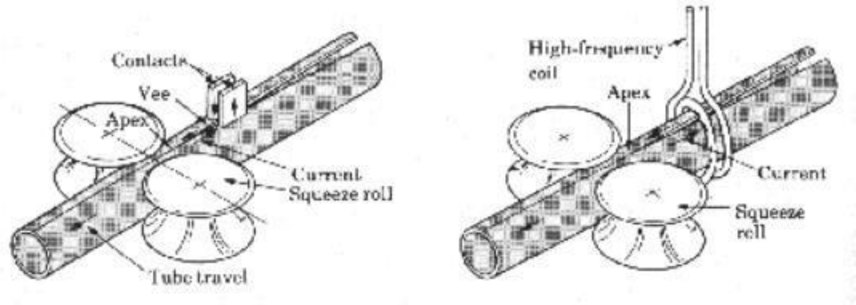
Resistance seam welding (RSEW) is a modification of spot welding wherein the electrodes are replaced by rotating wheels or rollers .Using a continuous AC power supply, the electrically conducting rollers produce a spot weld whenever the current reaches a sufficiently high level in the AC cycle. With a high enough frequency or slow enough traverse speed, these spot welds actually overlap into a continuous seam and produce a joint that is liquid tight and gastight. In roll spot welding, current to the rollers is applied only intermittently, resulting in a series of spot welds at specified intervals along the length of the seam. In mash seam welding, the overlapping welds are about one to two times the sheet thickness, and the welded seam thickness is only about 90% of the original sheet thickness. This process is also used in producing tailor welded sheet-metal blanks, which can be made by laser welding as well. The RSEW process is used to make the longitudinal (side) seam of cans (for household products) mufflers, gasoline tanks, and other containers. The typical welding speed is 1.5 m/min for thin sheets.



Seam Welding

High-frequency Resistance Welding:

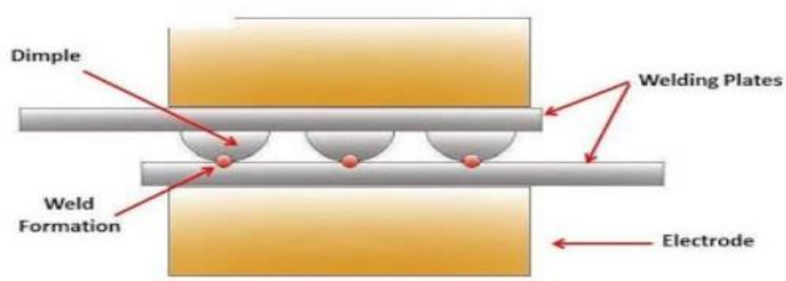
High-frequency resistance welding (HFRW) is similar to seam welding, except that high-frequency current (up to 450 kHz) is employed. A typical application is the production of butt-welded tubing or pipe where the current is conducted through two sliding contacts to the edges of roll-formed tubes. The heated edges then are pressed together by passing the tube through a pair of squeeze rolls. Any flash formed is then trimmed off. Structural sections (such as I-beams) can be fabricated by HFRW by welding the webs and flanges made from long, flat pieces. Spiral pipe and tubing, finned tubes for heat exchangers, and wheel rims also may be made by this technique. In another method, called high-frequency induction welding (HFIW), the roll-formed tube is subjected to high-frequency induction heating.



- Similar to seam welding except a high frequency current is used (up to 450kHz)
- Typical application is in roll-forming of tubes

Resistance Projection Welding:

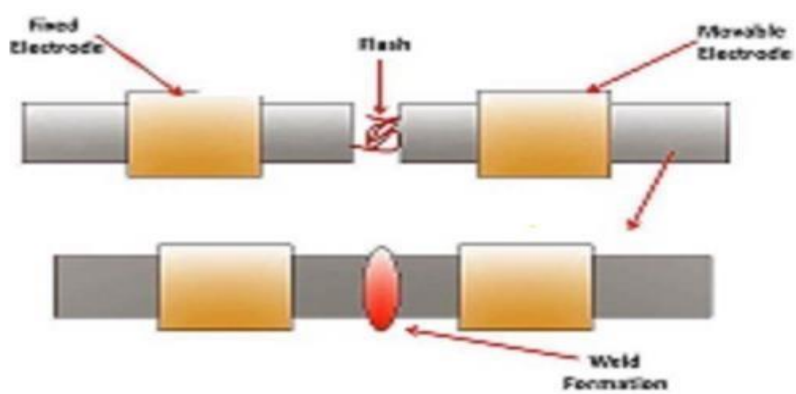
In resistance projection welding (RPW), high electrical resistance at the joint is developed by embossing one or more projections on one of the surfaces to be welded. The projections may be round or oval for design or strength purposes. High localized temperatures are generated at the projections, which are in contact with the flat mating part. The electrodes (typically made of copper-based alloys) are large and flat, and water cooled to keep their temperature low. Weld nuggets similar to those in spot welding are formed as the electrodes exert pressure to soften and compress the projections. Spot-welding equipment can be used for resistance projection welding by modifying the electrodes. Although the embossing of the workpieces adds expense, the process produces a number of welds in one pass, extends electrode life, and is capable of welding metals of different thicknesses, such as a sheet welded over a plate. Nuts and bolts can be welded to sheets and plates by this process, with projections that are produced by machining or forging. joining a network of rods and wires (such as the ones making up metal baskets, grills, oven racks, and shopping carts) also is considered resistance projection welding, because of the many small contact areas between crossing wires (grids).



Projection Welding

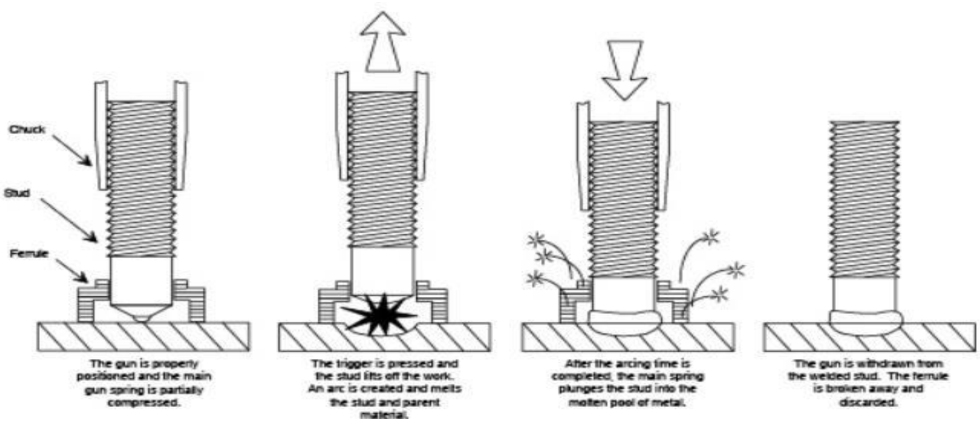
Flash Welding:

In flash welding (FW), also called flash butt welding, heat is generated very rapidly from the arc as the ends of the two members begin to make contact and develop an electrical resistance at the joint. After the proper temperature is reached and the interface begins to soften, an axial force is applied at a controlled rate and a weld is formed by plastic deformation of the joint. The mechanism is called hot upsetting, and the term upset welding (UW) also is used for this process. Some molten metal is expelled from the joint as a shower of sparks during the process - hence the name flash welding. Because of the presence of an arc, the process can also be classified as arc welding. impurities and contaminants are squeezed out during this operation; therefore, the quality of the weld is good. However, a significant amount of material may be burned off during the welding process. The joint may be machined later to improve its appearance. The machines for flash welding usually are automated and large and have a variety of power supplies ranging from 10 to 1500 kVA. The flash-welding process is suitable for end-to-end or edge-to-edge joining of sheets of similar or dissimilar metals 0.2 to 25 mm thick and for end-joining bars 1 to 75 mm in diameter. Thinner sections have a tendency to buckle under the axial force applied during welding. Rings made by forming processes also can be flash butt welded. In addition, the process is used to repair broken band-saw blades with the use of fixtures that are mounted on the band-saw frame. The flash-welding process can be automated for reproducible welding operations. Typical applications are the joining of pipe and of tubular shapes for metal furniture and windows. The process is also used for welding the ends of sheets or coils of wire in continuously operating rolling mills and in the feeding of wire-drawing equipment. Once the appropriate process parameters are established, the required operator skill is minimal. Some design guidelines for mating surfaces in flash welding are shown in Fig. Note the importance of uniform cross sections at the joint.



Stud Welding:

Stud welding (SW) is also called stud are welding and is similar to flash welding. The stud (which may be a small part or, more commonly, a threaded rod, hanger, or handle) serves as one of the electrodes while being joined to another component, which is usually a flat plate. Polarity for aluminum is usually direct-current electrode positive (DCEP), and for steel it is direct-current electrode negative (DCEN). In order to concentrate the heat generated, prevent oxidation, and retain the molten metal in the weld zone, a disposable ceramic ring (ferrule) is placed around the joint. The equipment for stud welding can be automated with various controls for arcing and for applying pressure. Portable stud-welding equipment also is available. Typical applications of stud welding include automobile bodies, electrical panels, and shipbuilding; the process is also used in building construction. In capacitor-discharge stud welding, a DC arc is produced from a capacitor bank. No ferrule or flux is required, because the welding time is very short-on the order of 1 to 6 milliseconds. The choice between this process and stud arc welding depends on such factors as the types of metals to be joined, the workpiece thickness and cross section, the stud diameter, and the shape of the joint.



Percussion Welding:

The resistance-welding processes already described usually employ an electrical transformer to meet the power requirements. Alternatively, the electrical energy for welding may be stored in a capacitor. Percussion welding (PEW) utilizes this technique, in which the power is discharged within 1 to 10 milliseconds to develop localized high heat at the joint. The process is useful where heating of the components adjacent to the joint is to be avoided, as in electronic assemblies and electrical wires.

Applications:

- Resistance welding is widely used in automotive industries.

- Projection welding is widely used in production of nut and bolt.
- Seam welding is used to produce leak prove joint required in small tanks, **boilers** etc.
- Flash welding is used to welding pipes and tubes.

Advantages:

- It can weld thin (0.1 mm) as well as thick (20mm) metals.
- High welding speed.
- Easily automated.
- Both similar and dissimilar metals can be weld.
- The process is simple and fully automated so does not required high skilled labor.
- High production rate.
- It is environment friendly process.
- It does not require any filler metal, flux and shielding gases.

Disadvantages:

- High equipment cost.
- The thickness of work piece is limited due to current requirement.
- It is less efficient for high conductive materials.
- High electric power required.
- Weld joints have low tensile and fatigue strength.

8. Brazing and Soldering:

The two joining processes-brazing and solderingthat require lower temperatures than those used for fusion welding. Filler metals are placed in or supplied to the joint and are melted by an external source of heat; upon solidification, a strong joint is obtained. Brazing and soldering are distinguished arbitrarily by temperature. Temperatures for soldering are lower than those for brazing, and the strength of a soldered joint is much lower.

Brazing:

Brazing is a joining process in which a #Her metal is placed between the faying surfaces to be joined (or at their periphery) and the temperature is raised sufficiently to melt the filler metal, but not the components (the base metal)-as would be the case in fusion welding. Thus, brazing is a liquid-solid-state bonding process. Upon cooling and solidification of the filler metal, a strong joint is obtained. Filler metals used for brazing typically melt above 450°C, which is below the melting point (solidus temperature) of the metals to be joined. Brazing is derived from the word brass, an archaic word meaning "to harden," and the process was first used as far back as 3000 to 2000 B.C. In a typical brazing operation, a filler (braze) metal wire is placed along the periphery of the components to be joined, Heat is then applied by various external means, melting the braze metal and, by capillary action, filling the closely fitting space (joint clearance) at the interfaces. In braze welding, filler metal (typically brass) is deposited at the joint by a technique similar to oxyfuel-gas welding the major difference is that the base metal does not melt. The main application of braze welding is in repair work, typically on parts made of cast steels and irons. Because of the wider gaps between the components being welded (as in oxyfuel-gas welding), more braze metal is used than in conventional brazing. In general, dissimilar metals can be assembled with good joint strength. Intricate, lightweight shapes can be joined rapidly and with little distortion.

Filler Metals:

Several filler metals (braze metals) are available with a range of brazing temperatures. Note that, unlike those for other welding operations, filler metals for brazing generally have a composition that is significantly different from those of the metals to be joined. They are available in a variety of shapes, such as wire, rod, ring, shim stock, and filings. The selection of the type of filler metal and its composition are important in order to avoid enibrittlement of the joint by (a) grain-boundary penetration of liquid metal (b) the formation of brittle interinetallic compounds at the joint and (c) galvanic corrosion in the joint. Because of diffusion between the filler metal and the base metal, the mechanical and metallurgical properties of a joint can change as a result of subsequent processing or during the service life of a brazed part. For example, when titanium is brazed with pure tin as the filler metal, it is possible for the tin to diffuse completely into the titanium base metal when it is subjected to subsequent aging or to heat treatment. Consequently, the joint no longer exists.

Fluxes:

The use of a flux is essential in brazing; a flux prevents oxidation and removes oxide films. Brazing fluxes generally are made of borax, boric acid, borates, fluorides, and chlorides. Wetting agents may be added to improve both the wetting characteristics of the molten filler metal and the capillary action. It is essential that the surfaces to be brazed be clean and free from rust, oil, and other contaminants in order (a) for proper wetting and spreading of the molten filler metal in the joint and (b) to develop maximum bond strength. Sand blasting also may be used to improve the surface finish of the faying surfaces for brazing. Because they are corrosive, fluxes must be removed after brazing, usually by washing with hot water.

Brazed joint Strength: The strength of the brazed joint depends on (a) joint clearance, (b) joint area, and (c) the nature of the bond at the interfaces between the components and the filler metal. joint clearances typically range from 0.025 to 0.2 mm. The smaller the gap, the higher is the shear strength of the joint. The shear strength of brazed joints can reach 800 MPa by using brazing alloys containing silver (silver solder). Note that there is an optimum gap for achieving maximum tensile strength of the joint. Because clearances are very small, roughness of the mating surfaces becomes important. The surfaces to be brazed must be cleaned chemically or mechanically to ensure full capillary action; thus, the use of a flux is also important.

Brazing Methods:

The heating methods used in brazing identify the various processes.

Torch Brazing: The heat source in torch brazing (TB) is oxyfuel gas with a carburizing flame. Brazing is performed by first heating the joint with the torch and then depositing the brazing rod or wire in the joint. Suitable part thicknesses are typically in the range from 0.25 to 6 mm. Torch brazing is difficult to control and requires skilled labor; however, it can be automated as a production process by using multiple torches. Torch brazing can also be used for repair work.

Furnace Brazing: The parts in furnace brazing (PB) are first cleaned and preloaded then with the assembly brazing metal is placed in appropriate configuration where it is heated uniformly. Furnaces may be either batch type, for complex shapes, or continuous f;,j j type, for high production runs-especially for small parts with simple joint designs. Vacuum furnaces or neu- \ tral atmospheres are used for metals that react with the environment. Skilled labor is not required, and complex shapes can be brazed because the Whole assembly is heated uniformly in the furnace.

Induction Brazing: The source of heat in induction brazing (IB) is induction heating by high-frequency AC current. Parts are preloaded with filler metal and are placed near the induction coils for rapid heating. Unless a protective (neutral) atmosphere is utilized, fluxes generally are used. Part thicknesses usually are less than 3 mm. Induction brazing is particularly suitable for brazing parts continuously.

Resistance Brazing: In resistance brazing (RB), the source of heat is the electrical resistance of the components to be brazed. Electrodes are utilized in this method, as they are in resistance welding. Parts typically with thicknesses of 0.1 to 12 mm either are preloaded with filler metal or supplied externally with the metal during brazing. As in induction brazing, the process is rapid, heating zones can be confined to very small areas, and the process can be automated to produce reliable and uniform quality.

Dip Brazing: Dip brazing (DB) is carried out by dipping the assemblies to be brazed into either a molten filler-metal bath or a molten salt bath at a temperature just above the melting point of the filler metal. Thus, all component surfaces are coated with the filler metal. Consequently, dip brazing in metal baths is typically used for small parts (such as sheet, wire, and fittings), usually less than 5 mm in thickness or diameter. Molten salt baths, which also act as fluxes, are used for complex assemblies of various thicknesses. Depending on the size of the parts and the bath size, as many as 1000 joints can be made at one time by dip brazing.

Infrared Brazing: The heat source in infrared brazing (IRB) is a high-intensity quartz lamp. The process is particularly suitable for brazing very thin components, usually less than 1 mm thick, including honeycomb structures. The radiant energy is focused on the joint, and brazing can be carried out in a vacuum. Microwave heating also can be used.

Diffusion Brazing: Diffusion brazing (DFB) is carried out in a furnace where, with proper control of temperature and time, the filler metal diffuses into the faying surfaces of the components to be joined. The brazing time required may range from 30 minutes to 24 hours. This process is used for strong lap or butt joints and for difficult joining operations. Because the rate of diffusion at the interface does not depend on the thickness of the components, part thicknesses may range from foil to as much as 50 mm. High-energy Beams. For specialized and high-precision applications and with high-temperature metals and alloys, electron-beam or laser-beam heating may be used.

Braze Welding: The joint in braze welding is prepared as it is in fusion welding, While an oxyacetylene torch with an oxidizing flame is used, filler metal is deposited at the joint (hence the term welding) rather than drawn in by capillary action. As a result, considerably more filler metal is used than in brazing. However, temperatures in braze welding generally are lower than in fusion welding, and thus part distortion is minimal. The use of a flux is essential in this process. The principal use of braze welding is for maintenance and repair work, such as work on ferrous castings and steel components, although the process can be automated for mass production.

Soldering:

In soldering, the filler metal (called solder) melts at a relatively low temperature. As in brazing, the solder fills the joint by capillary action between closely fitting or closely placed components. Two important characteristics of solders are low surface tension and high wetting capability.

Heat sources for soldering are usually soldering irons, torches, or ovens. The word “solder” is derived from the Latin solidare, meaning “to make solid.” Soldering with copper-gold and tin-lead alloys was first practiced as far back as 4000 to 3000 B.C.

Types of Solders and Fluxes Solders melt at a temperature that is the eutectic point of the solder alloy. Solders traditionally have been tin-lead alloys in various proportions. For example, a solder of 61.9% Sn-38.1% Pb composition melts at 188°C, whereas tin melts at 232°C and lead at 327°C. For special applications and higher joint strength (especially at elevated temperatures), other solder compositions are tin-zinc, lead-silver, cadmium-silver, and zinc-aluminum alloys. Because of the toxicity of lead and its adverse effects on the environment, lead-free solders are being developed continuously and are coming into wider use. Among the various candidate materials are silver, indium, and bismuth eutectic alloys incombination with tin. Three typical compositions are 96.5% Sn-3.5% Ag, 42% Sn-58% Bi, and 48% Sn-52% In. However, none of these combinations are suitable for every soldering application. Fluxes are used in soldering and for the same purposes as they are in welding and brazing.

Types of Solders and Their Applications

Tin–lead	General purpose
Tin–zinc	Aluminum
Lead–silver	Strength at higher than room temperature
Cadmium–silver	Strength at high temperatures
Zinc–aluminum	Aluminum, corrosion resistance
Tin–silver	Electronics
Tin–bismuth	Electronics

Fluxes for soldering are generally of two types: I. Inorganic acids or salts, such as zinc-ammonium-chloride solutions, which clean the surface rapidly. To avoid corrosion, the flux residues should be removed after soldering by washing the joint thoroughly with water. 2. Noncorrosive resin-based fluxes, used typically in electrical applications.

Solderability: Solderability may be defined in a manner similar to weldability. Special fluxes have been developed to improve the solderability of metals and alloys. As a general guide, ° Copper, silver, and gold are easy to solder ° Iron and nickel are more difficult to solder ° Aluminum and stainless steels are difficult to solder because of their thin, strong oxide films ° Steels, cast irons, titanium, and magnesium, as well as ceramics and graphite, can be soldered by first plating them with suitable metallic elements to induce interfacial bonding. This method is similar to that used for joining carbides and ceramics. A common example of the method is tinplate, which is steel sheet coated with tin, thus making it very easy to solder. Tinplate is a common material used in making cans for food.

Soldering Techniques: The following soldering techniques are somewhat similar to brazing methods: a. Torch soldering (TS). b. Furnace soldering (FS). c. Iron soldering (INS) (with the use of a soldering iron). d. Induction soldering (IS). e. Resistance soldering (RS). f. Dip soldering (DS). g. Infrared soldering (IRS). Other soldering techniques, for special applications, are: h. Ultrasonic solderin in which a transducer subjects the molten solder to ultrasonic cavitation. This action removes the oxide films from the surfaces to be joined and thus eliminates the need for a flux-hence the term fluxless soldering). i. Reflow (paste) soldering (RS). j. Wave soldering (WS).

The last two techniques are widely used for bonding and packaging in surfacemount technology, Because they are significantly different from other soldering methods, they are described next in greater detail.

Reflow Soldering: Solder pastes are solder-metal particles held together by flux, binding, and wetting agents. The pastes are semisolid in consistency, have high viscosity, and thus are capable of maintaining their shape for relatively long periods.

The paste is placed directly onto the joint, or on flat objects for finer detail, and it can be applied via a screening or stenciling process, Stenciling is commonly used during the attachment of electrical components to printed circuit boards. An additional benefit of reflow soldering is that the surface tension of the paste helps keep surface-mount packages aligned on their pads; this feature improves the reliability of the solder joints. Once the paste has been placed and the joint assembled, it is heated in a furnace and soldering takes place. In reflovv soldering, the product is heated in a controlled manner, so that the following sequence of events occurs: I. Solvents present in the paste are evaporated. 2. The flux in the paste is activated, and fluxing action occurs. 3. The components are preheated carefully. 4. The solder particles are melted, and they Wet the joint. 5. The assembly is cooled at a low rate to prevent thermal shock and fracture of the solder joint.

Although this process appears to be straightforward, there are several process variables for each stage, and good control over temperatures and exposures must be maintained at each stage in order to ensure proper joint strength.

Wave Soldering: Wave soldering is a common technique for attaching circuit components to their boards. To understand the principle of wave soldering, it is important to note that molten solder does not wet all surfaces. The solder will not stick to most polymer surfaces, and it is easy to remove while molten. Also, as can be observed with a simple handheld soldering iron, the solder wets metal surfaces and forms a good bond only when the metal is preheated to a certain temperature. Thus, wave soldering requires separate fluxing and preheating operations before it can be completed. A typical wave-soldering operation is illustrated in Fig. A standing laminar wave of molten solder is generated by a pump. Preheated and prefluxed circuit boards are then conveyed over the wave. The solder wets the exposed metal surfaces, but it does not remain attached to the polymer package for the integrated circuits, and it does not adhere to the polymer-coated circuit boards. An air knife (basically a high-velocity jet of hot air) blows excess solder away from the joint to prevent bridging between adjacent leads. When surface-mount packages are to be wave soldered, they must be bonded adhesively to the circuit board before soldering can commence. Bonding usually is accomplished by (1) screening or stenciling epoxy onto the boards, (2) placing the components in their proper locations, (3) curing the epoxy, (4) inverting the board, and (5) performing wave soldering.

Soldering Applications and Design Guidelines:

Soldering is used extensively in the electronics industry. Note, however, that because soldering temperatures are relatively low, a soldered joint has very limited utility at elevated temperatures. Moreover, since solders generally do not have much strength, the process cannot be used for load-bearing (structural) members.]oint strength can be improved significantly by mechanical interlocking of the joint. Soldering can be used to join various metals of different thicknesses. Copper and precious metals such as silver and gold are easy to solder. Aluminum and stain less steels are difficult to solder because of their strong, thin oxide film. However, these and other metals can be soldered with the aid of special fluxes that modify sur faces. Although manual operations require skill and are time consuming, soldering speeds can be high with the use of automated equipment.

UNIT - II

Maching and Forming

Metal cutting is the predominant processes employed for manufacture of the majority of the parts of an aircraft. These processes produce required shape in the work piece by removal of metal from selected areas to define depths. Machining processes commonly used in aircraft industry employing conventional machines. Conventional machining, one of the most important material removal methods, is a collection of material-working processes in which power-driven machine tools, such as lathes, milling machines, and drill presses are used with a sharp cutting tool to mechanically cut the material to achieve the desired geometry. Machining is a part of the manufacture of almost all metal products. It is not uncommon for other materials to be machined. A person who specializes in machining is called a machinist. Machining is also a hobby. A room, building, or company where machining is done is called a machine shop.

Machining operations

There are many kinds of machining operations, each of which is capable of generating a certain part geometry and surface texture. The three principal machining processes are classified as turning, drilling, milling, planning, broaching, sawing.

LATHES

Lathe is the oldest machine tool invented. The principle form of surface produced in a lathe is the cylindrical surface. This is achieved by rotating the work piece while the single point cutting tool removes the material by traversing direction parallel to the axis of rotation called turning. Although we have number of modern machine tools, still the lathe maintains its existence as an indispensable machine. It still proves to be vital necessity in all modern tool rooms, repair shops and training workshops.

Principle:

The lathe can be defined as a machine tool which holds the work between two rigid supports, called centers, or in a chuck or face plate while work revolves. The chuck or the face plate is mounted on the projected end of the machine spindle. The cutting tool is rigidly held and supported in a tool post and fed against the revolving work. While the work revolves about its own axis the tool is made to move either parallel to or at an inclination with axis to cut the desired material. In doing so it produces cylindrical surfaces, if it is fed parallel to the axis. Or will produce a tapered surface if fed at an inclination.

Lathes can be classified as:

- Bench lathe
- Central lathe
- Speed lathe
- Engine lathe
- Tool room lathe
- Capstan and turret lathe
- Special purpose lathes
- Automatic lathe

Some smaller ones are bench mounted and semi-portable. The larger lathes are floor mounted and may require special transportation if they must be moved. Field and maintenance shops generally use a lathe that can be adapted to many operations and that is not too large to be moved from one work site to another. The engine lathe is ideally suited for this purpose. A trained operator can accomplish more machining jobs with the engine lathe than with any other machine tool.

Turret lathes and special purpose lathes are usually used in production or job shops for mass production or specialized parts, while basic engine lathes are usually used for any type of lathe work.

Lathe carries the following main parts:

- Bed
- Head Stock
- Tail Stock
- Carriage
- Feed Mechanism
- Legs

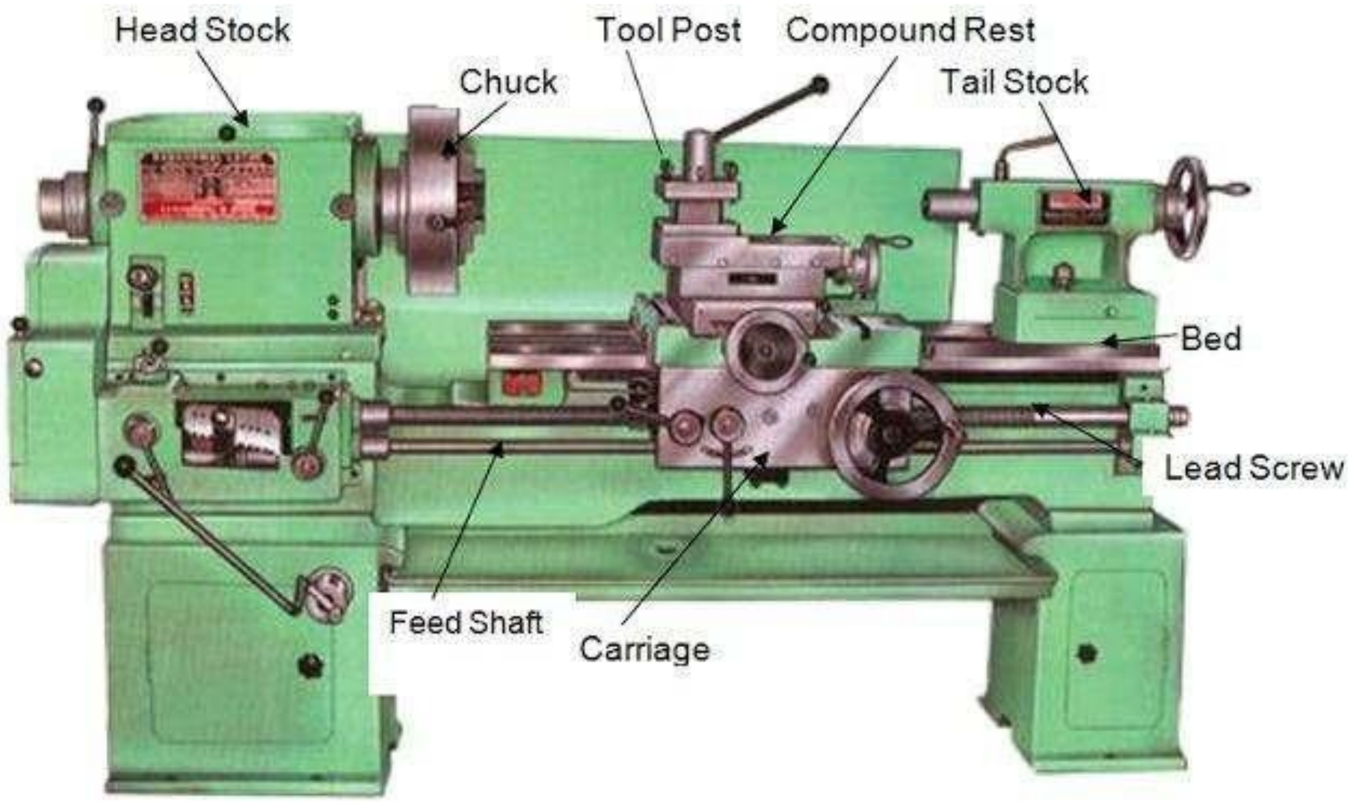


FIGURE- Parts of Lathe

Bed

The bed acts as the base on which the different fixed and operating parts of the lathe are mounted. This facilitates the correct relative location of the fixed parts and at the same time provides for a well guided and controlled movement of the operating parts (carriage). Also it has to with-stand various forces exerted by the cutting tool during the operation. They are generally made as single piece casting or semi-steel (i.e. toughened cast iron), with the addition of small quantity of steel scrap to the cast iron during melting; the material Cast iron facilitates easy sliding action.

An important point to be noted is that an accurate location proper leveling of the bed, during installation and afterwards plays an important role. Even strong beds are observed to be distorted if they are placed on unleveled flooring.

Head Stock

The head stock is that part of the lathe which serves as housing for the power source, power transmission, driving pulleys the gear box, provides bearing for the spindle and keeps the latter in alignment with the bed. It is towards the left most ends on the bed and is fixed to it.

It consists of:

- Cone pulley
- Back gears and back gear lever
- Main spindle or head stock spindle
- Live center
- Feed reverse lever

The back-geared head stock consists of a casing accommodation the main spindle, the three or four step-cone-pulley and the back gears. The internal mechanism of this type of headstock is shown in the figure. In this a step cone pulley is mounted on the main spindle, which carries a spur gear G1 at its one end and a pinion P1 at the other. Gear G1 is firmly keyed to the spindle so that it can never revolve free of the same. The spindle carries a sleeve over it which is a loose fit. The cone pulley is firmly secured to this sleeve. This arrangement forces the pinion P1 to revolve with the cone pulley under all conditions. A spring knob K engages the gear G1 with the cone pulley. The cone pulley is driven by means of a belt, through a countershaft, by an electric motor as shown in figure. This enables 4 speeds of the spindle.

Use of back gears:

The back gears are used for effecting reduction in spindle speeds, thereby facilitating a wider range of speeds. The back gears are mounted on an eccentric shaft which is operated by means of a hand lever known as back gear engaging lever (L). The back gear consists of a spur gear G2 (opposite to P1) and a pinion P2 (opposite to G1). When speed reduction is required, the knob is pulled out to make the cone pulley free of gear G1 and hence spindle. The back gears are put into mesh with the spindle gears by pulling in the eccentric shaft. Now, the sequence of transmission of motion and power is such that the cone pulley is driven by the motor through belt. With the result, the pinion P1 revolves. This being in mesh with gear G2, transfers the motion to latter which in turn, revolves the eccentric shaft and hence pinion P2. This further being in mesh with gear G1, transmits the motion to the latter and hence to the spindle.

Speed ratios: Now the countershaft is the driving shaft and lathe spindle is the driven shaft.

Spindle speed = Counter speed x Dia of the step on counter shaft

Spindle: The spindle of the lathe is in the form of a hollow shaft and revolves in two bearings fixed one each at the front and rear ends of the head stock. The inside hole runs through the entire length of the spindle and at the front end it is made tapered to accommodate the live centers. Also at the front end the outside surface of the spindle is made threaded to receive the job holding devices such as chuck, face plate or driving plate.

Live center:
It is the center support which is fitted into the tapered inside portion of the spindle nose while using a driver plate. No such center is used if work is held in a chuck. It acts as a bearing support for the work during the operation. It is usually softer than the dead center fitted in tail stock, for the reason that there are no chances of wear occurring on its surface as it always revolves along the work piece. It is only due to its revolving with the work that the name livecenter is given to it.

Feed reversal lever:
This is fitted on the left hand side of the head stock and has three positions. Central – it disengages and feed to the carriage is given by hand.

Top & Bottom – it engages to give power feed to the carriage but one allows carriage to move left to right and the other in reverse direction.
This is mostly used for left and right hand threads. It should not be operated when spindle is moving.

Tail Stock:
It also called as puppet head or loose head stock fitted on the bed on the right side of the lathe. It is capable of sliding along the bed maintaining its alignment with the head stock. And its main function is to provide bearing and support to the job which is being worked between the centers.

Carriage:
This serves the purpose of supporting, guiding and feeding the tool against the job during the operation on the lathe. It consists various parts like –

Saddle:
Which slides along the bed ways and supports the cross slide.

Cross slide:
Mounted on the top of the saddle and moves in the direction perpendicular to the main spindle. This can be moved by hand or power.

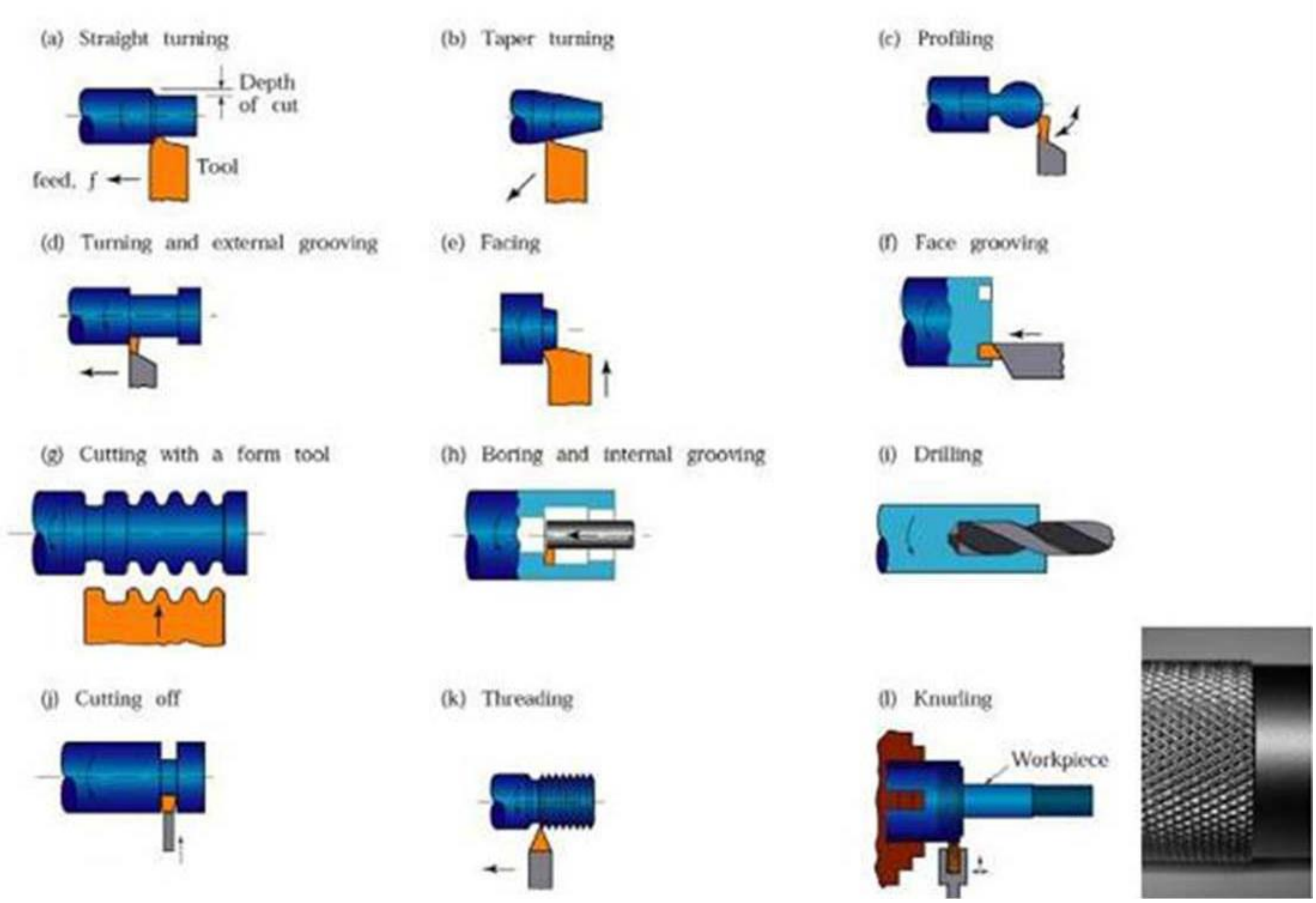
Compound rest:
This is called as tool rest, on cross slide and carries graduated circular base swivel plate to swivel tool rest to any angle, which is moved by a compound rest feed screw.
Tool post: Holds the tool

Feed Mechanism:
Provides power feed to the carriage.

Legs:
They are the supports which take the entire load of the machine over them.

TURNING OPERATIONS
The turning processes are typically carried out on a lathe, considered to be the oldest machine tools, and can be of four different types such as straight turning, taper turning, profiling or external grooving. Those types of turning processes can produce various shapes of materials such as straight, conical, curved, or grooved work piece. In general, turning uses simple single-point cutting tools. Each group of work piece materials

has an optimum set of tools angles which have been developed through the years.



1) **Turning** is a machining process of generating external surfaces of revolution on a rotating work piece employing a traversing cutting tool. Or the process whereby a Centre lathes is used to produce "solids of revolution". It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not.

A. **Straight Turning**: The work is turned straight when it is made to rotate about the lathe axis, and the tool is fed parallel to the lathe axis.

B. **Taper Turning**: To produce a conical surface by gradual reduction in diameter from the cylindrical work piece.

2) **Eccentric Turning**: If cylindrical workpiece has two separate axis of rotation one being out of center to the other, the workpiece is known as eccentric turning.

3) **Facing** is part of the turning process.

Facing is the operation of machining the ends of piece of work to produce flat surface with the axis. It involves moving the cutting tool across the face (or end) of the work piece and is performed by the operation of the cross-slide. The feed is in the perpendicular direction of the axis of revolution. It is frequently the first operation performed in the production of the work piece, and often the last- hence the phrase "ending up".

4) **Knurling** is a manufacturing process, typically conducted on a lathe, whereby a visually-attractive diamond-shaped (crisscross) pattern is cut or rolled into metal. This pattern allows hands or fingers to get a

better grip on the knurled object than would be provided by the originally-smooth metal surface. Occasionally, the knurled pattern is a series of straight ridges or a helix of "straight" ridges rather than the more-usual crisscross pattern.

Knurling tool having requisite serrations is forced on to the work piece, thus forming the top layer as shown in the figure.

5) **Parting or grooving**: In this a flat nosed tool plunge cuts the work piece with a feed in direction perpendicular to the axis of rotation.

6) **Drilling**: Making cylindrical holes in work piece by using a twist drill in the tailstock. Even same operation is used for Boring, counter boring, Reaming, counter sinking. This operation is limited to holes through the axis of rotation of the work piece and from any of the ends.

7) **Thread cutting**: Helical groove on a cylindrical or conical surface can be done by feeding the tool longitudinally when job is revolved between the centers, by operating the lead screw.

8) **Milling**: Milling is the operation of removing metal by feeding the work against a rotating cutter having multiple cutting edges.

9) **Grinding**: Grinding is the operation of removing metal in the form of multiple minute chips by feeding the work against the rotating grinding wheel.

10) **Grooving**: Is the processes of reducing diameter of a work piece over a narrow surface.

11) **Spinning**: Spinning is the process of forming a thin sheet of metal piece by revolving the job at high speed and pressing it against a former attached to the head stock spindle.

12) **Forming**: Forming is the process of turning of a convex, concave or of any irregular shape.

TURNING FORCES

The forces acting on a cutting in turning are important in the design of machine tools. The machine tool and its components must be able to withstand these forces without causing significant deflections, vibrations, or chatter during the operation. There are three principal forces during a turning process: cutting force, thrust force and radial force.

•The cutting force acts downward on the tool tip allowing deflection of the work piece upward. It supplies the energy required for the cutting operation.

•The thrust force acts in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. This force tends to push the tool away from the chuck.

•The radial force acts in the radial direction and tends to push the tool away from the work piece.

MATERIAL REMOVAL RATE

The material removal rate (MRR) in turning is the volume of material removed per unit time in mm3/min. For each revolution of the work piece, a ring-shaped layer of material is removed.

$$\mathbf{MRR = pi \times D_{avg} \times d \times f \times N}$$

Where

D_{avg}: Average diameter

N: Rotational speed of the work piece

F: Feed

D: Depth of cut

Drilling is the process of using a drill bit in a drill to produce cylindrical holes in solid materials.

Drilling operations are operations in which holes are produced or refined by bringing a rotating cutter with cutting edges at the lower extremity into contact with the work piece. Drilling operations are done primarily in drill presses but not uncommon on the lathes or mills. The tool is fed in a direction parallel to its axis of rotation into the work part to form the round hole.

Drilling in metal

Under normal usage, swarf is carried up and away from the tip of the drill bit by the fluting. The continued production of chips from the cutting edges produces more chips which continue the movement of the chips outwards from the hole. This continues until the chips pack too tightly, either because of deeper than normal holes or insufficient backing off (removing the drill slightly or totally from the hole while drilling). Lubricants and coolants (i.e. cutting fluid) are sometimes used to ease this problem and to prolong the tools life by cooling and lubricating the tip and chip flow. Coolant is introduced via holes through the drill shank (see gun drill).

Straight fluting is used for copper or brass, as this exhibits less tendency to "dig in" or grab the material. If a helical drill (twist drill) is used then the same effect can be achieved by stoning a small flat parallel with the axis of the drill bit.

For heavy feeds and comparatively deep holes oil-hole drills can be used, with a lubricant pumped to the drill head through a small hole in the bit and flowing out along the fluting. A conventional drill press arrangement can be used in oil-hole drilling, but it is more commonly seen in automatic drilling machinery in which it is the work piece that rotates rather than the drill bit.

Drilling in wood

Wood being softer than most metals, drilling in wood is considerably easier and faster than drilling in metal. Cutting fluids are not used or needed. The main issue in drilling wood is assuring clean entry and exit holes and preventing burning. Avoiding burning is a question of using sharp bits and the appropriate cutting speed. Drill bits can tear out chips of wood around the top and bottom of the hole and this is undesirable in fine woodworking applications.

Drilling machine construction

In order to carry out the drilling operation, the motions required are the rotation of the drill while it is fed linearly into the work piece. Drilling machines come in a variety of shapes and sizes.

Drill press:

A typical drill press is shown in. The cutting tool in this case is the spindle either with the help of the drill chuck for small size drills that are straight shank type or by means of the spindle taper. The spindle is located inside a quill, which can reciprocate by means of manual

Operation or by means of power feed. The work piece is normally placed on the table and clamped using a suitable work holding device. These are relatively simple and less expensive in operation. However, these are not suitable for mass production.

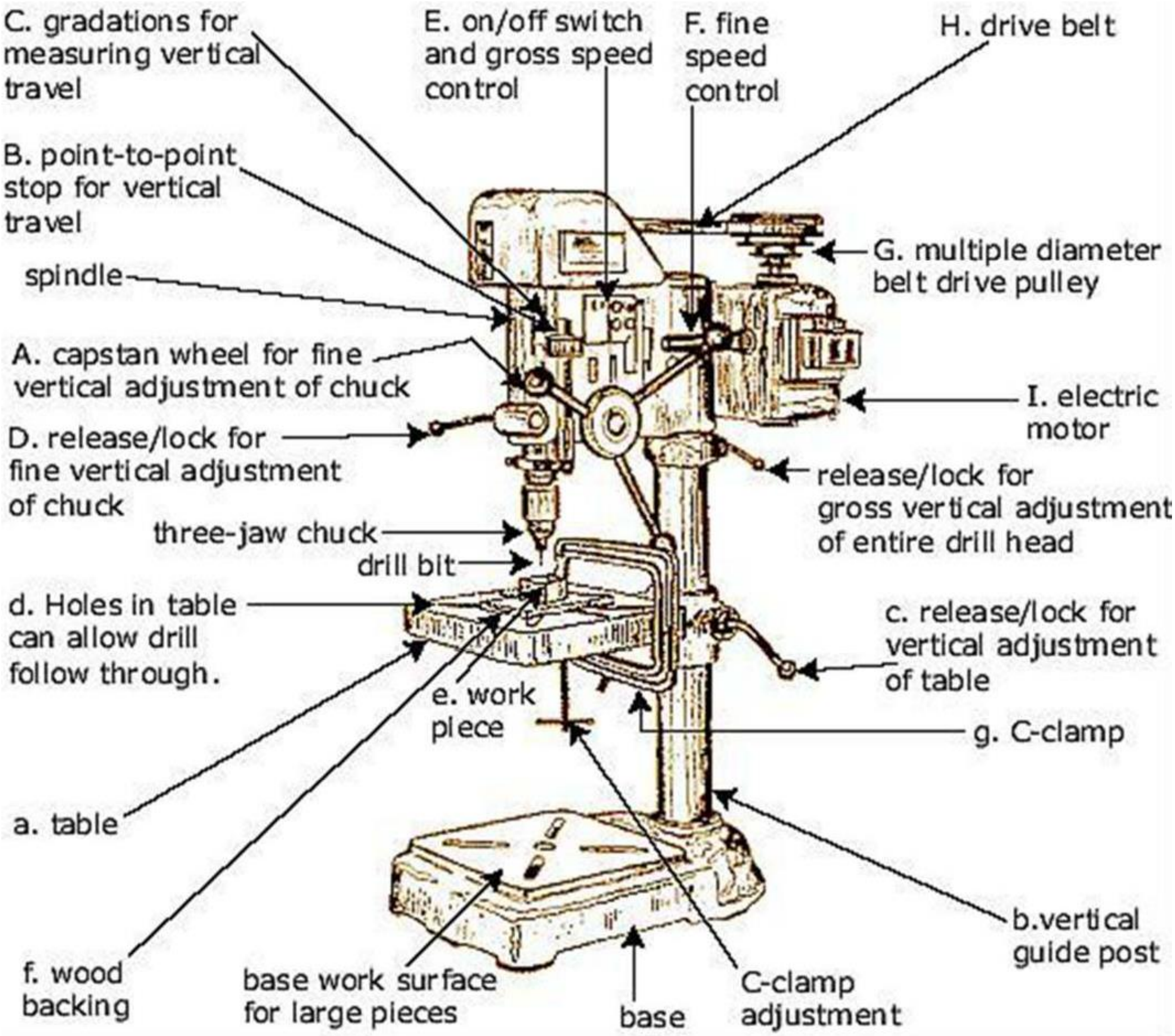
Redial drilling: The redial drilling machine is more versatile than the drill press as described earlier. The schematic diagram of a radials drilling machine showing the principal parts and motions is shown in. the drill head can move along the radial arm to any position while the radial arm itself can rotate on the column, thus allowing for reaching any position in the radial range of machine. They are more convenient for large work piece which cannot be moved easily because of their weight, such that the drill head itself is moved to the actual location on the work piece, before carrying the drilling operations. In addition to the twist drills other hole making tools are also used.

Multiple spindle drilling: For production operations a large number of operations are carried out simultaneously which can be done through the multiple-spindle drilling machines. In the drilling heads of these machines more than one drill can be located with each of them getting the power from the same spindle motor. The use of these machines becomes more economical for large volume production of identical parts. These machines are capable of producing a large number of holes in a short time. Some machines have a fixed number of spindles in fixed locations while the others have the number fixed but their locations can be changed to suit the work piece geometry. The latter type areore versatile.

Gang drilling: Gang drilling machines are the equivalent of the progressive action type multiple spindle lathes. These consist of a number of spindles (often equal to four) laid out in parallel. Each of the spindle can have different drills or other hole making operation tools foxed in sequence. The work piece will move from one station to the other, with each completing the designated hole making operation. These are used for volume production with the work piece located in a jig with a reasonable size to allow the operator to move the part with the jig to the next station, generally on a roller conveyor.

Work holding: Work holding in drilling machines is similar to milling. Most of the small components are held in vices for drilling in job shops. However, for production operations, it is not only necessary to locate and clamp the work piece properly, but also to locate and guide the drill. Hence jigs are used to serve this function.

Main parts of drill press are:
Base: The base is that portion of the machine on which the vertical column is mounted. In a belt driven machine the counter shaft consisting of a fast and loose pulley and the cone pulley is fitted to the base of the machine. The top of the base in round column drilling machine is accurately machined and has T-slots on it so that large work piece may be set.
Column: The column is the vertical component of the machine, which supports the table and the head containing the driving mechanism. The column should be sufficiently rigid so that it can take up the entire cutting pressure of the drill. The column may be made of box section or round column. The box type is more rigid. In some of the round column machines rack teeth are cut on the column for vertical movement of the ram and the table. In box column type machines, the front face of the column is accurately machined to form guide ways for the movement of the table.
Table: The table is mounted on the column and is provided with T slots for clamping the work directly on its face. The table may be round or rectangular in shape. For centering the work below the spindle, the table may have three types of adjustments: vertical, radial about the column and circular adjustment about its own axis. After the required adjustment has been made the table and the arm are clamped in position.
Head: The drill head is mounted on the top of the column and houses the driving and feeding mechanism for the spindle. In some of the machines the drill may be adjusted up or down forAccommodating different heights of work in addition to the table adjustment. In lighter machines, the driving motor is mounted at the rear end of the head counterbalancing the weight of the drill spindle.



Hole making operations:

Introduction; machining round holes in metal stock is one of the most common operations in the manufacturing industry. It is estimated that of all the machining operations carried out, there are about 20% hole making operations. Literally no work piece leaves the machine shop without having a hole made in it. The various types of holes are shown in.

The types of hole making operations performed on the holes are:

i. Drilling
ii. Boring
iii. Reaming
iv. Counter sinking
v. Counter boring
vi. Tapping

A large variety of drills are development in addition to the standard twist drill as detailed above for specific applications.

Oils hole drills: These drills are most useful for deep hole drilling. These are provided with two internal holes extending through the length of the drill through which the cutting fluid can be pumped under pressure. This keeps the cutting edge cool while flushing away the chips as well.
Step drills: A variety of step drills are development to suit for combination machining of operations such as multiple hole drilling, counter boring and counter sinking.
Core drills: These are special holes meant for enlarging already existing holes such as those in castings. These are either of the three-flute or four-flute type. The four flute type is used for enlarging the drilled holes while the three-flute type is used for punched or cored holes. The three-flute type keeps the chatter to minimum due to the fact that the cutting lips are not diametrically opposite.
Shell core drill: these are similar to the core drills, but do not have a normal shank for the purpose of holding and are for the large diameters. This needs it be mounted using a stub arbor similar to the shell end mills with the help of the central hole present.
Spade drills: Spade drills are used to make smaller diameter holes with low cutting speeds and high feed rates. These have long supporting bars with the cutting blade attached at the end. These are less expensive since the support structure can be made more rigid using ordinary steel with no spiral flutes. Spade drill are also used to machine small conical shapes for subsequent drilling or making a bevel (similar to counter sinking) on the existing holes to facilitate the subsequent tapping and assembling operations.
Carbide tipped drills: Most of the drills are made of high speed steel. However, for machining hard material as well as for large volume production, tungsten carbide tipped drills are available as shown in. the tungsten carbide tips of suitable geometry are clamped to the end of the tool to act as the cutting edges. As explained earlier in coatings provide a better alternative in improving the cutting tool life. This is more so in the case of a high speed steel drill. The titanium nitride (Tin) coating on the drills improves the drill tool life on an average by two to ten times while drilling steel.

Terminology of twist drill:
Twist drill is made out of high speed steel. They may be parallel shank or tapered shank.
Body: It is the part of the drill which carries flutes and extends from the dead center up to almost the start of the neck. This part is always relieved.
Axis: The longitudinal center line of the drill along which the whole body, neck and shank are concentric.
Chisel edge or dead center: The short edge formed at extreme tip end of the drill, due to intersection of the flanks.
Shank: The portion of drill beyond neck which is gripped in the holding device.
Point: The cone shaped surface at the end of the flutes, formed by grinding, and containing the dead center, lips and flanks, etc.

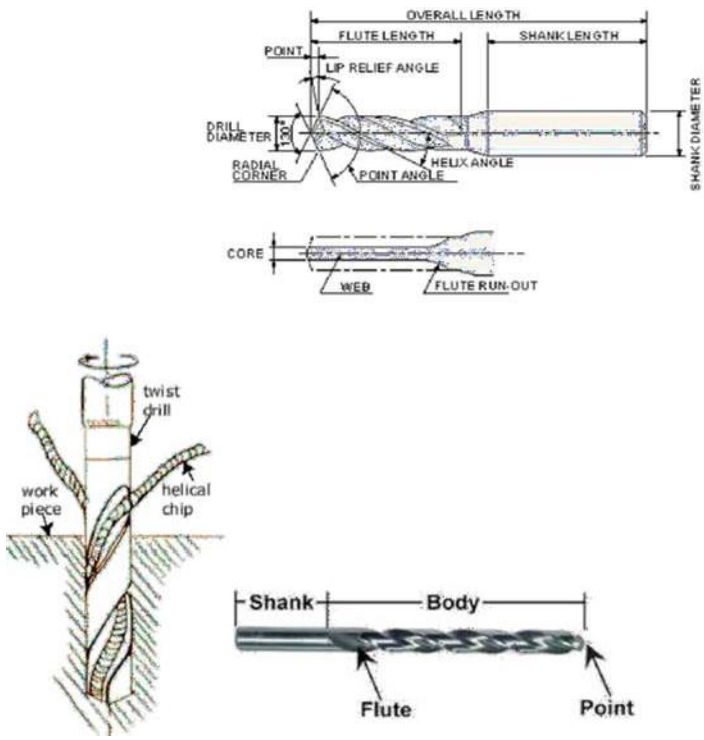


FIGURE – TWIST DRILL

Lip or cutting edge: it is the main cutting part formed by the intersection of each flank and face. Body clearance: A small reduction in the diameter of the body adjacent to the land.

Land or margin: Narrow flat surface which runs all along the flutes of the drill on its leading edge. Lip clearance: the part of the conical surface of point, which is ground to relief near the cutting edge.

Face: the curved surface of the flute near the lip is called face. The chips cut the material slide upward along the surface

Flutes: the helical grooves in the body of the drill are known as flutes. Commonly used drills carry two flutes, while special drills may carry four. These flutes make the chips curl and provide passage for their exit. Also, 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.

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 flute on the other side.

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 shank side, where it is maximum.
It is this part of the drill which is largely responsible for providing strength and rigidity to the drill.

Chisel Edge Corner: The point of intersection of the chisel edge and the lip is known as chisel edge corner.

Outer Corner: That extreme of the dead Centre, where the face and flank intersect to form a corner, is called outer corner

Neck: the smaller diameter cylindrical portion which separates the body and shank

Tang: the flat portion of rectangular cross-section provided at the end of the tapered shank, which fits into the sleeve or spindle.
Heel: an edge formed where the body clearance and flute intersect.

Rake angle: also called as helix angle formed between plane containing the drill axis and the leading edge of land.

Positive for left hand flute Negative for right hand flute Zero for parallel flute

Drilling Time Estimation

$$V = \pi D N / 1000$$

Where
V= Cutting speed (surface), m/min
D= Diameter of the twist drill, mm
N= rotational speed of the drill, rev/min.

Material Removal Rate (MRR)

$$MRR = \pi D2 f / N 4$$

MILLING PROCESS

A milling machine is a machine tool used for the shaping of metal and other solid materials. Its basic form is that of a rotating cutter which rotates about the spindle axis (similar to a drill), and a table to which the work piece is affixed. The cutter and work piece move relative to each other, generating a tool path along which material is removed. The movement is precisely controlled, usually with slides and leadscrews or analogous technology. Often the movement is achieved by moving the table while the cutter rotates in one place, but regardless of how the parts of the machine slide; the result that matters is the relative motion between cutter and work piece. Milling machines may be operated manually or by CNC (computer numerical control).

Milling machines can perform a vast number of operations, some of them with quite complex tool paths, such as slot cutting, planning, drilling; die sinking, rebating, routing, etc.

Cutting fluid is often pumped to the cutting site to cool and lubricate the cut, and to sluice away the resulting swarf.

Types of milling machines: To satisfy various requirements they come in different shapes and sizes. In view to large material removal rates milling machines come with a very rigid spindle and large power. They can be broadly classified as –

Knee and column type milling machines Fixed bed type milling machines

Planer type milling machines Production milling machines
Special purpose milling machines

Further they are classified as

Knee and column type milling machines: These are general purpose machines and have single spindle only. They are so called because their two main structural elements – a column shaped frame and a knee shaped projection. Where the work table is supported on the knee and which can slide in vertical direction along the vertical column. These machines depending upon the spindle position are classified as:

1. Hand milling machine

2. Plain or horizontal milling machine
3. Vertical milling machines
4. Universal milling machine
5. Omniversal milling machines

Fixed bed type or manufacturing type milling machines: These machines, in comparison to the column type are more sturdy and rigid, heavier in weight and larger in size. They are not suitable for tool room work. Most these are either automatic or semi-automatic in operation. They may carry either single spindle or multiple spindles. They perform operations like slot cutting, grooving, gang milling and facing. Also they facilitate machining of various jobs together, called multiple piece milling. They are classified as:

1. Plain milling machine (having single horizontal spindle)
2. Duplex head milling machine (having double horizontal spindles)
3. Triplex head milling machines (having two horizontal and 1 vertical spindles)
4. Rise and fall milling machine (for profile milling)

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 a robust and massive construction like a planer.

Production milling machines:

They are also manufacturing machines but don‘t have fixed bed. They are classified as:

1. Rotary type or continuous type
2. Drum type
3. Tracer controlled

Special purpose milling machines:

These machines are designed to perform a specific type of operation only. They include:

1. Thread milling machine
2. Profile milling machine
3. Gear milling machine
4. Cam milling machine
5. Planetary milling machine
6. Double end milling machine
7. Skin milling machine
8. Spar milling machine

From all types of milling machines knee type milling machines are used commonly in tool rooms and machine shops. The principal parts of all knee type are similar although the movements of the moving parts differ they are:

1. **Base**: It is a heavy casting provided at the bottom of the machine. It is accurately machined on both the top and bottom surfaces. It actually acts as load bearing member for all parts. Column of the machine is secured to it. Also it carries the screw jack which supports and moves the knee. In addition it serves as a reservoir for the coolant.

2. **Column**: It is a very prominent part of milling machine and is produced with enough care. To this, are fitted all various parts and controls. On the front face vertical parallel ways are made in which the knee

slides up and down. And its rear end carries the enclosed motor drive. Top of the column carries a dovetail 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 or in other words the distance between the cutter and the job mounted on the table. The adjustment is provided by operating elevating jack, provided below the knee, means of hand or application of power feed.

4. Saddle: It is the intermediate part between the knee and the table and acts as support to the table. It can be adjusted along the ways provided on the top surface of the knee, to provide cross feed to the table. As it carries horizontal ways, along this moves the table during longitudinal traverse.

5. Table: it acts as a support for the work. Work piece is mounted on it either directly or held in a driving head. It is made of cast iron, accurately machined on the top surface. It carries T- slots to accommodate the clamping bolts for fixing the work or securing the fixtures. Cross feed is provided by moving the saddle and vertical feed is given by raising or lowering the knee. Both hand and power feed can be employed for this purpose.

6. Over arm: it is a heavy support provided on the top of the 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 support to the projection arbor by accommodating its free end in the yoke.

MILING CUTTERS

There are a large variety of milling cutters available to suit specific requirements. The versatility of the milling machine is contributed to a great extent by the variety of milling cutters that are available.

Milling cutters are classified into various types based on a variety of methods.
1) Based on constructions:
(A) Solid
(b) Inserted tooth type

2) Based on mounting:
(a) Arbor mounted
(b) Shank mounted
(c) Nose mounted

3) Based on rotation:
(a)Right hand rotation (counter clockwise)
(b)Left hand rotation (clockwise)

4) Based on helix:
(a)Right hand helix
(B) left hand helix

Milling cutters are generally made of high speed steel or cemented carbides. The cemented carbide cutters can be of a brazed tip variety or with index able tips. The index able variety is more common since it is normally less expensive to replace the worn out cutting edges than to regrind them.
Plain milling cutters:

These are also called slab milling cutters and are basically cylindrical with the cutting teeth on the periphery as shown. These are generally used for machining flat surface.

Side and face milling cutters:

These have the cutting edges not only on the face like the slab milling cutters, but also on both the sides. As a result, these cutters become more versatile since they can be used for side milling as well-as for slot milling.

Staggered tooth side milling cutters are a variation where the teeth are arranged in an alternate helix pattern. This type is generally used for milling deep slots, since the staggering of teeth provides for greater chip space.

Sitting saw:

The other common form of milling cutters in the arbor mounted category is the slitting saw. This is very similar to a saw blade in appearance as well as function. Most of these have teeth around the circumference while some have side teeth as well. The thickness of these cutters is generally very small and is used for cutting off operations or for deep slots.

Special form cutters:

In addition to the general type of milling cutters described above, there are a large number of special form milling cutters available which are used for machining specific profiles. Angular milling cutters are made in single or double angle cutters for milling any angle such as 30, 45 or 600. Form relieved cutters are made of various shapes such as circular, corner rounding, convex or concave shapes.

T-slot milling cutters are used for milling T-slots such as those in the milling machine table. The central slot is to be milled first using an end mill before using the T-slot milling cutter. Woodruff key seat milling cutters are used for milling as the name suggests woodruff key seats.

Some other special form cutters are dovetail milling cutters and gear milling cutters.

End mills:

These are shank mounted as shown and are generally used in vertical axis milling machines. They are used for milling slots, key ways and pockets where other type of milling cutters cannot be used. A depth of cut of an almost half the diameter can be taken with the end mills.

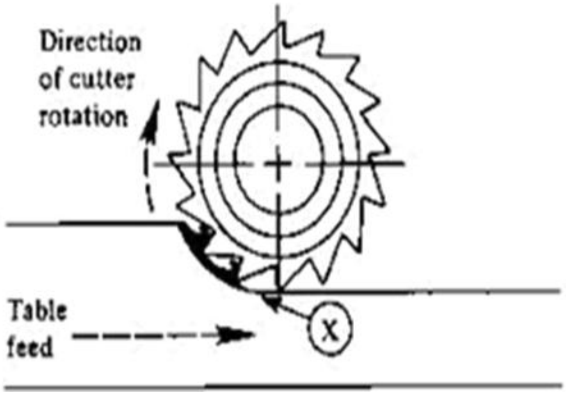
The end mills have the cutting edge running through the length of the cutting portion as well as on the face radically up to a certain length. The helix angle of the cutting edge promotes smooth and efficient cutting even at high cutting speeds and feed rates. High cutting speeds are generally recommended for this type of milling cutters.

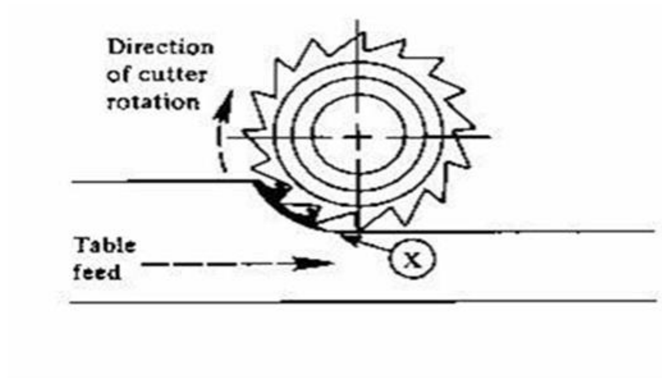
Up and down milling:

Based on the directions of the movement of the milling cutter and the feeding direction of the work piece, there are two possible types of milling:

(i) Up milling (conventional milling)

(j) Down milling (climb milling)





Up milling:
In up milling the cutting tool rotates in the opposite direction to the table movement. In the conventional or up milling, the chip starts as zero thickness and gradually increases to the maximum size as shown. This tends to lift the work piece from the table. There is a possibility that the cutting tool will rub the work piece before starting the removal. However, this process is inherently safe.
The initial rubbing of the cutting edge during the start of the cut in up milling tends to dull the cutting edge and consequently have a lower tool life. Also since the cutter tends to cut and slide alternatively, the surface generated is left with the machining marks.

Down milling (climb milling)
In down milling the cutting tool rotates in the same directions as that of the table movement. In climb or down milling, the chip starts as maximum thickness and goes to zero thickness gradually as shown. This is suitable for obtaining fine finish on the work piece. The cutting force acts downwards and as such keeps the work piece firmly in the work holding device. This is good for thin and frail work pieces. In this case the cutting force direction as well as the lead screw motion being in the same direction, there is a possibility that the backlash present in the table lead screw will interfere with the actual motion of the table making it jerky. Sometimes the work may be pulled into the cutter, which may result in a broken milling cutter or damaged work piece. This may sometimes be dangerous to the machine tool as well. The chip starts with maximum thickness and this gives a large force, which will have to be taken care of by a rigid lead screw for table feeding.

In down milling, though the cut starts with a full chip thickness, it gradually reduces to zero. This helps in eliminating the feed marks present in the case of up milling and consequently a better surface finish. Climb milling also allows greater feeds per tooth and longer cutting life between regrinds than conventional milling.

Advantages:

1. Suited to machine thin and hard-to-hold parts since the work piece is forced against the table or holding device by the cutter.
2. Work need not be clamped as tightly.
3. Consistent parallelism and size can be maintained, particularly on thin parts.
4. It can be used where breakouts at the edge of the workpeice cannot be tolerated.

5. It requires up to 20% less power to cut by this method.
6. It can be used when cutting off stock or when milling deep, thin slots.

Disadvantages:-

1. It can be used unless the machine has a backlash eliminator and the table jibs have been tightened.
2. It cannot be used for machining castings or hot rolled steel, since the hard outer scale will damage the cutter.

Dividing head:

A dividing head is one of the most important attachments of the milling machine and is almost indispensable. A typical construction of the dividing head is shown. The main spindle of the dividing head drives the work piece by means of a 3- jaw universal chuck or a dog and live center similar to a lathe.

The index plate of a dividing head consists of a number of holes with a crank and pin. The index crank drives the spindle and the live center through a worm gear, which generally has 40 teeth as shown. As a result, a full rotation of the work piece is produced by 40 full revolutions of the index crank. Further indexing is made possible by having the index plates with equi-spaced holes around various circles. This would aloe for indexing the periphery of the work piece to any convenient number of divisions.

Simple or plain indexing:-

Plain indexing is the name given to the indexing method which is carried out using any of the indexing plates in conjunction with the worm. With this it is possible to obtain relatively simple divisions. To understand this procedure let us assume that a gear is to be divided equally into 20 divisions. Since 40 revolutions of the index crank produces one full revolution of the work piece, we need to rotate the index crank for two full turns for cutting each tooth of the gear.

Let us assume that we want six equal divisions to be made. The rotation of the index crank=40/6=6*2/3=turns.

This means that the index crank should be rotated for six full turns followed by two thirds of a rotation. The fraction of a rotation required is to be obtained with the help of the index plates as given above. This can be done as follows using any of the Brown & Sharpe plates.

Compound Indexing:

Using the simple indexing method a majority of the indexing jobs can be completed. However when the available capacity of the index plates is not sufficient to do a given indexing job, the compound indexing method can be used. In order to obtain more complex indexing the following method is used. First, the crank is moved in the usual fashion in the forward direction. Then a further motion is added or subtracted by rotating the index plate after locking the plate with the plunger. This is termed as compound indexing.

For example, if the indexing is done by moving the crank by 5 holes in the 20 hole circle and then the index plate together with the crank is indexed back by a hole with the locking plunger registering in a 15 hole circle as shown. Then this is compound indexing.

The total indexing done is then

5/20-1/15=11/60

i.e. 19holes in a 60 hole circle. Unfortunately the 60 hole circle is not available in the brown and Sharpe range of index plates. Similarly it is possible to have the two motions in the same direction as

5/20+1/15=19/60

i.e., 19 holes in a 60 hole circle.

Therefore by following this method any other indexing can also be done.

Angular Indexing:
Sometimes it is desirable to carry out indexing using the actual angles rather than equal numbers along the periphery. Here, angular indexing would be useful. The producer remains the same as in the previous cases. Except that the angle will have to be first converted to equivalent divisions. Since 40 revolutions of the crank equals to a full rotation of the work piece, which means 3600, one revolution of the crank is equivalent to 90.

Differential Indexing:
Though compound index is a convenient way to get any indexing required, it is fairly cumbersome to use in practice. Hence differential indexing is used for that purpose which is an automatic way to carry out the compound index method. The arrangement for differential indexing is shown.
In differential indexing, the index plate is made free to rotate. A gear is connected to the back end of the dividing head spindle while another gear is mounted on a shaft and connected to the shaft of the index plate through bevel gear as shown. When the index crank is rotated, the motion is through the intermediate gearing as explained above, the index plate will also start rotating. If the chosen indexing is less than the required one, then the index plate will have to be moved in the same direction as the movement of the crank to add the additional motion. If the chosen indexing is more, then the plate should move in the opposite direction to subtract the additional motion.
The direction of the movement of the index plate depends upon the gear train employed. If an idle gear is added between the spindle gear and the shaft gear in case of a simple gear train, then the index plate will move in the same direction to that of the indexing crank movement. In the case of a compound gear train an idler is used when the index plate is to move in the opposite direction. The procedure of calculation is explained with the following example.
The change gear set available is 24, 24, 28, 32, 40, 44, 48, 56, 64, 72, 86 and 100.

Shaping Machine:
Shaper is a versatile machine which is primarily intended for producing flat surfaces. These flat surfaces may be horizontal, vertical or inclined. This machine involves the use of a single point tool held in a properly designed tool box mounted on a reciprocating ram. The main significance of this machine lies in:
- It has Greater flexibility.
- Ease in work holding
- Quick adjustment of the work
- Tools used have relatively simple design.

Principle:
The job is held in a device like vice or clamped directly on the machine table. The tool is held in the tool post mounted on the ram. This 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 termed as idle stroke.

There are different types of shaping machine

1. Standard shaper
2. Draw-cut shaper
3. Horizontal shaper
4. Vertical shaper
5. Geared shaper

6. Crank shaper
7. Hydraulic shaper
8. Contour shaper
9. Traveling head shaper
10. Universal shaper

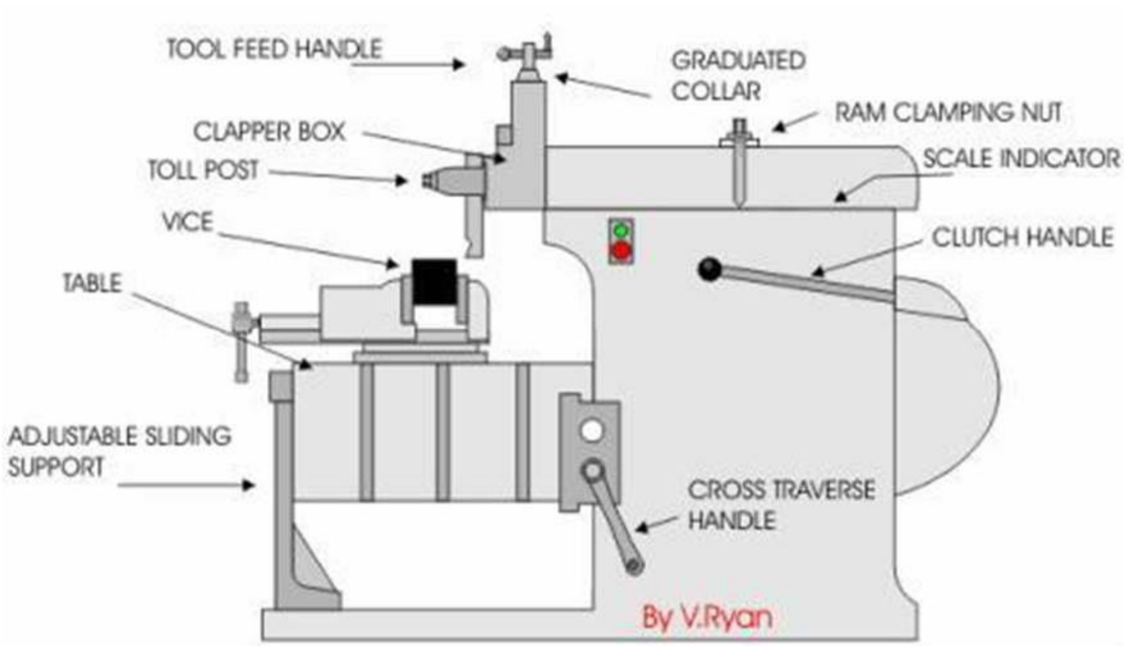


Figure: Shaping machine

Main parts of shaper:

Base:

It is a heavy robust cast iron body which acts as a support for all the other parts of the machine which are mounted over it.

Column:

It is a box type cast iron body, mounted on the base and acts as housing for operating mechanism of the machine and the electrical. It also acts as a support for other parts such as cross rail, ram, etc.

Cross-rail:

It is a heavy cast iron construction, attached to the column at its front vertical guide ways. It carries two mechanisms- one for elevating the table & second for cross traverse of the table.

It carries accurately machined and scraped horizontal guide ways at its front. An apron to which is bolted the machine table, slides along these ways to provide cross traverse to the table and hence the job. The apron is moved by rotating a lead screw provided inside the cross rail. Up and down vertical motion to the table is provided by means of a vertical lead screw which is operated by rotating a table traverse screw. The table carries T-slot on its top side faces for clamping the work or a vice is provided. Automatic feed is provided by means of an eccentric driven ratchet and pawl operated mechanism. For the drive, an electric motor, fitted at the back of the machine, is used from which the drive is transferred to gear box through V-belts. Quick return motion of the ram is controlled by an eccentric pin sliding in rocker arm.

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.

Ram:

It is also a cast iron casting, semicircular in shape and provided with ribbon construction inside for rigidity and strength. It carries the tool head and travels in dove tail guide ways to provide straight line motion to the tool. It carries the mechanism for adjustment of ram position inside it.

Tool Head:

It is the device in which tool is held. It can slide up and down and swung to a desired direction or angle to set the tool at a desired position for the operation.

Vice:

It is the job holding device and is mounted on the table. It holds and supports the work during operation.

Types of operations performed on shaper

- Machining Horizontal surfaces Machining Vertical surfaces
- Machining angular surfaces and machining irregular surfaces
- Machining Splines or Cutting gears
- Cutting slots, grooves and keyway

GRINDING OPERATION

Grinding is the processes of removing material by the abrasive action of a revolving wheel on the surface of a work piece in order to bring it to required shape and size. The wheel used for performing the grinding operation is known as grinding wheel. It consists of sharp crystals called abrasives, held together by a bond material. The wheel may be a single piece or solid type composed of several segments of abrasive blocks joined together. It is basically a finishing operation used to remove a very small amount of material. This is used for the following purposes:

1. Machining materials which are too hard for other materials such as tool and die steels and hardened steel materials.

2.For close dimensional accuracy of 0.3 to 0.5 Zm

3. High degree of surface finish or smoothness Ra = 0.15 to 1.25 Zm

Grinding wheel designation and selection:

Grinding wheels are produced by mixing the appropriate grain size of the abrasive with the required bond and pressed into the shape. The characteristics depend upon following parameters:

- Abrasive material used
- Bonding material used
- Grade
- Grain

Abrasive material:

These are hard materials with adequate toughness. They are classified as:

1. Natural abrasives: they are obtained directly from mines like stone, emery, corundum and diamond. Except diamond others are not used now as they have impurities.

2. Artificial abrasives: they are manufactured under controlled conditions in closed electric furnace to avoid impurities and achieve necessary temperature for chemical reaction to take place. Examples are:

(a) Silicon carbide:

Silicon dioxide is mixed with coke, saw dust, salt and piled up around a carbon electric conductor of

resistance type furnace. A heavy current is switched on and
A temperature of about 2600C is generated to form silicon carbide.
$SiO_2 + 3C = SiC + 2CO$
Where silicon combines with coke to form silicon carbide and salt vaporizes to form carbides with the metallic impurities present and removes them. The saw dust burns and provides porosity to the mass for escaping gases.

(b) Carborundum, crystolon and electrolon.

(c) Aluminum oxide (Al_2O_3):
Bauxite is fused in to the furnace and current is passed where aluminum oxide block is formed along with iron scraps acts as flux to collect impurities. Common trade names are Aloxite and borolon.

(d)Artificial diamonds: artificially manufactured
Bond materials: To have 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 edge. The material used to for holding the grains together with the wheel is called as bonds. They are different types like

OVirtified_V‘: Clay mixed with fluxes like feldspar which hardens to a glass like substance on firing to a temperature of 1250C.this has good strength, rigid, and porous and not affected by fluids. But is brittle and is sensitive to impacts and also called as ceramic bond.

OSilicate_S‘: This is NaSio sodium silicate or water glass and hardened when heated. It is not strong as _V‘ and used at less generation of heat. It is affected by dampness and less sensitive to shocks.

ORubber_R‘: Of all this is the flexible bond and is made up of natural or synthetic rubber. The strength is developed by vulcanization. This has high strength and is less porous. This is affected by dampness and alkaline solutions. It is generally used for cutting off wheels, regulating wheels in Centre less grinding and for polishing.

OResiniod _B‘: These are thermosetting plastics such as phenol formaldehyde. This has good strength and is more elastic than _V‘. It is not heat and chemical resistant. Used for rough grinding, parting off and high speed grinding and for fine finishing of roll grinding.

OShellac_S‘: This is relatively less used bond. Generally used for getting a very high surface finish. Typical applications are rolls, cutlery, and cam shaft finishing‘s.

Grain size:
The term grain or grit denotes the approximate size of the abrasive particles and givesan idea of the coarseness or fineness of the grinding wheel. Compared to a normal cutting tool, the abrasives used in grinding wheel are relatively small. The size of an abrasive grain more generally called grit is identified by a number which is based on the sieve size used. These vary coarse size of 6 or 8 to a super fine size of 500 or 600. The sieve number is specified in terms of the number of openings per square inch. Thus larger the grain number finer is the grain size.
The surface finish generated depends upon the grain size used as shown. Fine grains take a very small depth of cut and hence provide a better surface finish. Also fine grains generate les heat and are good for faster material removal. Though each grain cuts less, there are more grains per unit surface area of the wheel in case of fine grain size. Fine grains are also used for making from grinding wheels.

Grade: It is number representing the number of meshes per inch of the screen through whichgrains of crushed abrasives are passed for grading. The coarser grit wheels are used for grinding soft and ductile materials whereas hard and brittle materials are grinded by soft grit wheels. This designates the force holding the grains. The grade of the wheel depends on the kind of bond, structure and amount of abrasive grains. Greater the bond content and a strong bond results in a harder grinding wheel.

Soft wheels are generally used for hard materials and hard wheel for soft materials.

Different wheel grades are represented by alphabets from A to Z, A being the softest and Z the hardest.

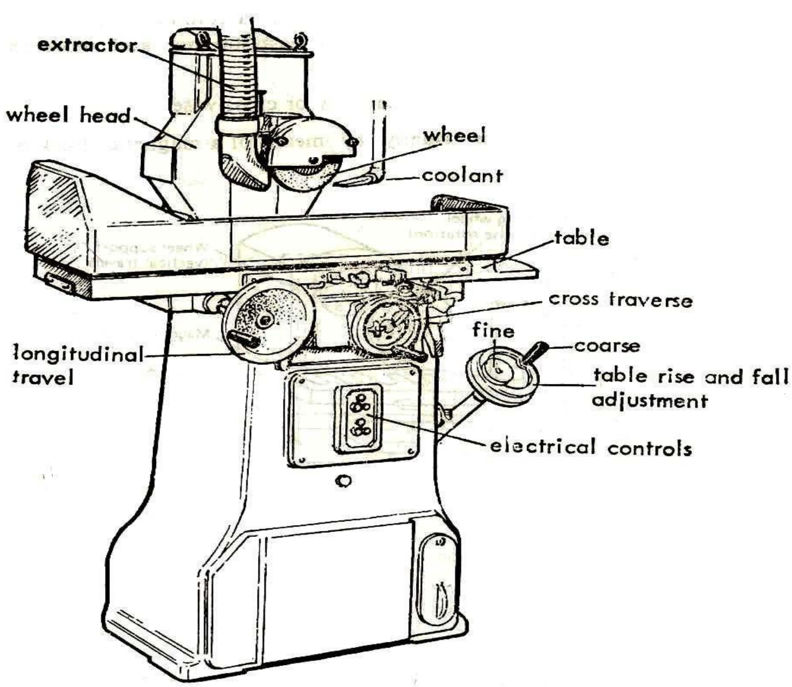
Soft	A B C D E F G H
Medium	I J K L M N O P
Hard	Q R S T U V W X Y Z

Structure: This term denotes the spacing between the abrasive grains, or in other words thedensity. It is also called as the hardness of the grinding wheel. The proportion of the bond in certain volume of the wheel effects the structure. A higher proportion will render an open structure and a lower proportion will lead to closer structure. If two wheels of same grit and grade are used on same material, one having an open structure and the other close structure, the former will be found to cut faster and more freely in comparison to the latter and also will have more life as compared to it.

Types of grinding machines:

There are three types of grinding machines

1. Cylindrical grinding machine
2. Surface grinding machine
3. Centre less grinding machine

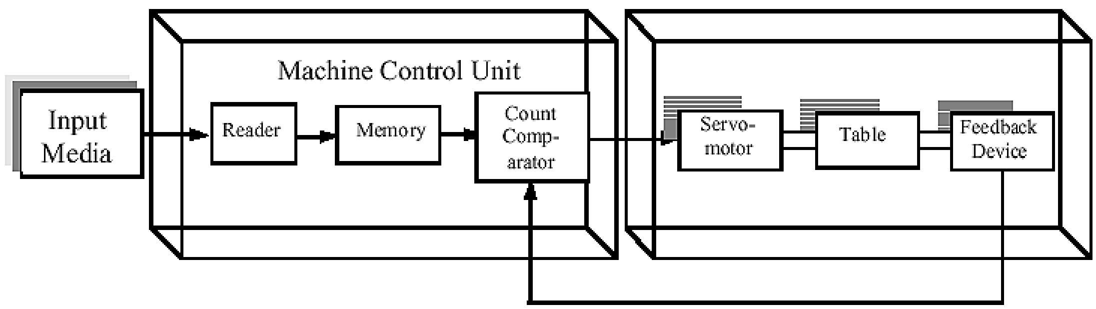


Grinding is the process of removing metal by the application of abrasives which are bonded to form a rotating wheel. When the moving abrasive particles contact the workpiece, they act as tiny cutting tools, each particle cutting a tiny chip from the work piece. It is a common error to believe that grinding abrasive wheels remove material by a rubbing action; actually, the process is as much a cutting action as drilling, milling, and lathe turning.

The grinding machine supports and rotates the grinding abrasive wheel and often supports and positions the work piece in proper relation to the wheel.

The grinding machine is used for roughing and finishing flat, cylindrical, and conical surfaces; finishing internal cylinders or bores; forming and sharpening cutting tools; snagging or removing rough projections from castings and stampings; and cleaning, polishing, and buffing surfaces. Once strictly a finishing machine, modem production grinding machines are used for complete roughing and finishing of certain classes of work.

CNC MACHINING



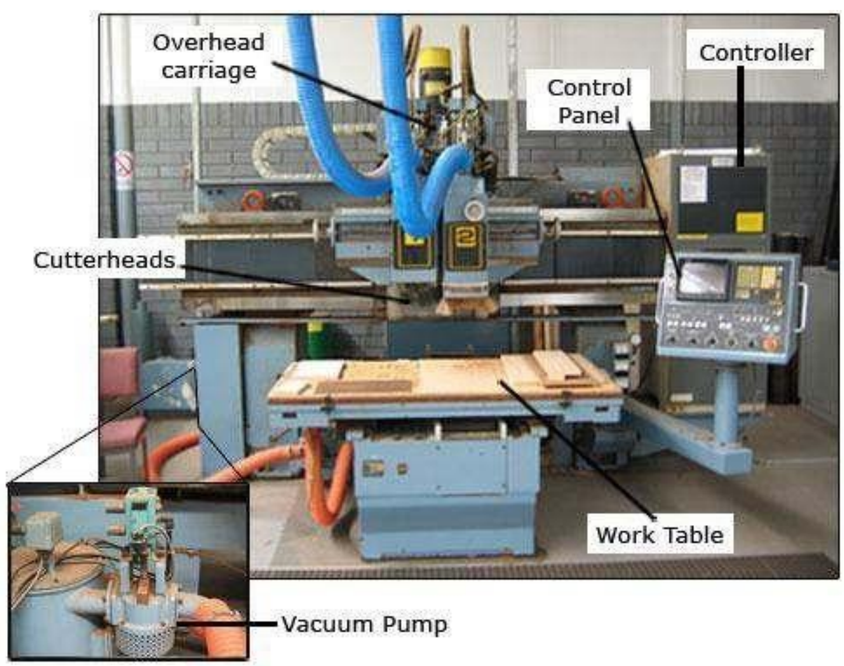


FIGURE – CNC Machine and process

BASIC PRINCIPLES OF CNC OPERATION
The basic principles of CNC operation include the following:

- Tooling
- Function keys
- Operational keys
- Movements
- Vacuum pump.

Tooling
Tooling consists of vertical mounted tooling that can operate independently or in conjunction with each other under computer or manual control and move laterally across the machine axis.

Function keys
The computer numerical control consists of address/data/programming function keys.

Operational keys
The operator control panel consists of operational keys to start the machine cycle in memory, manual or tape mode.

Movements
The machine consists of three lateral axial movements which operate in conjunction with each other, or independently. These consist of:

- X axis, horizontal longitudinal head carriage movement (usually left/right).
- Y axis, horizontal, lateral table movement (usually front/back at 90° to X axis).
- Z axis, vertical lateral cutting head movement (up/down).
- Further axes can define head tilt, helicoidally revolution, etc.

Vacuum pump
The work piece is held in place by suction from a vacuum pump located at the side of the machine.

SHEET METAL OPERATIONS

Sheet Metal Classification

There are 3 major classes of processes of sheet metal working.

Cutting:

Cutting is the use of shearing forces to remove material from a work piece. Technically not a metal forming process, but of extreme industrial importance.

Bending:

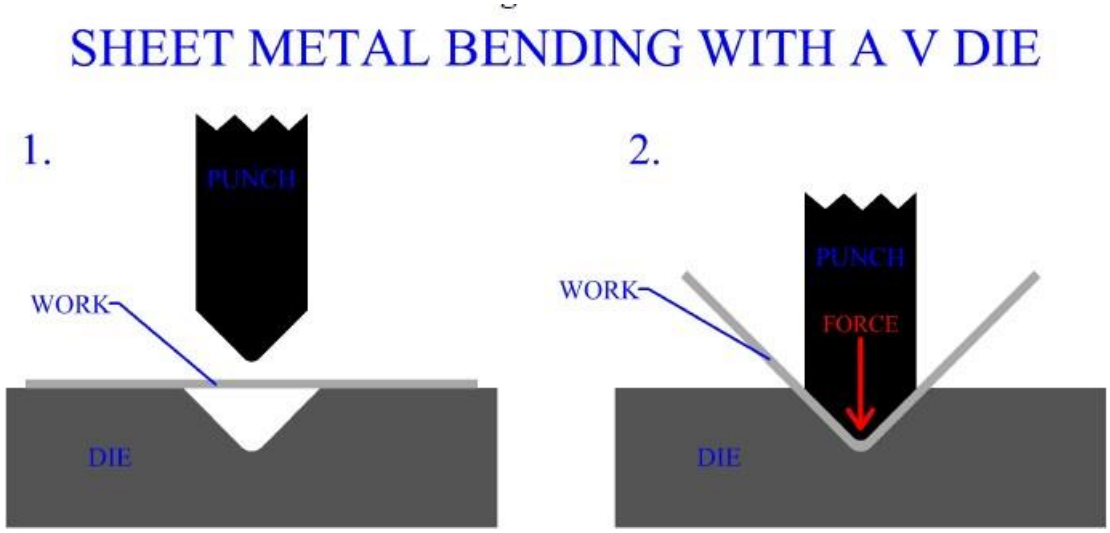
Bending is the forming of a sheet metal work about an axis.

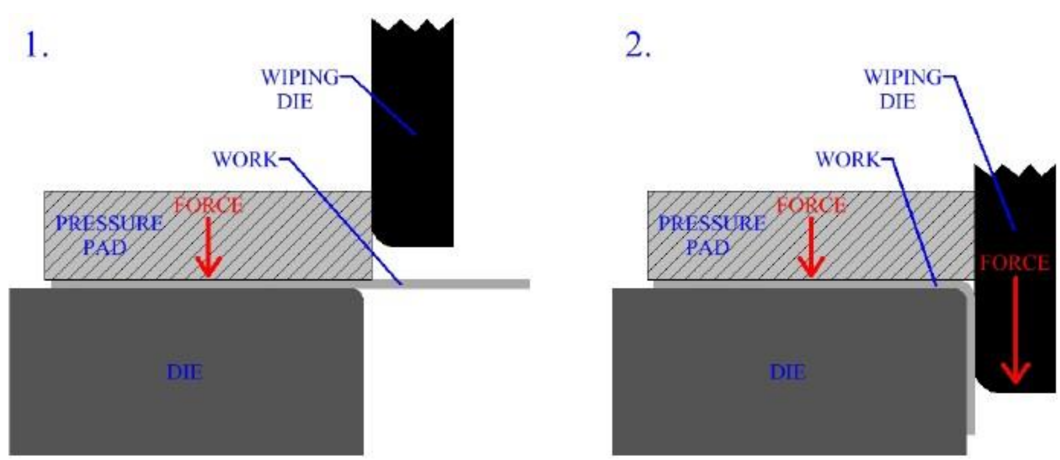
Deep Drawing:

Deep drawing is the forming of a cup or box with a flat base and Straight walls, from a sheet metal blank.

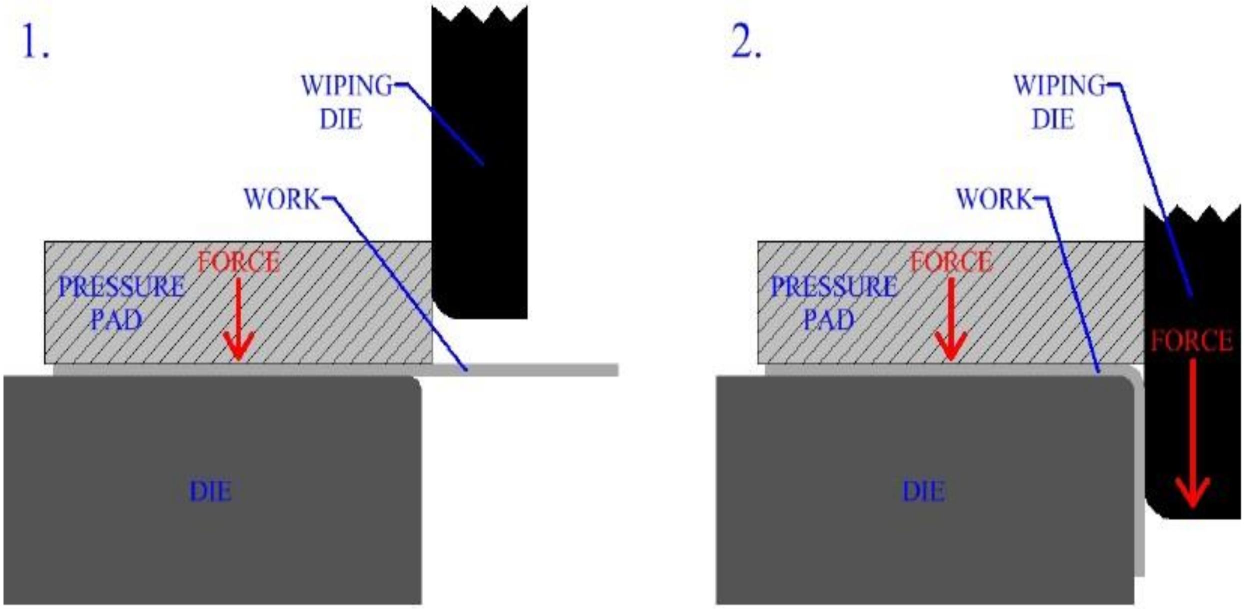
Other Processes:

Other sheet metal working processes such as ironing, spinning, Rubber forming and high energy rate forming are also discussed in latter sections.

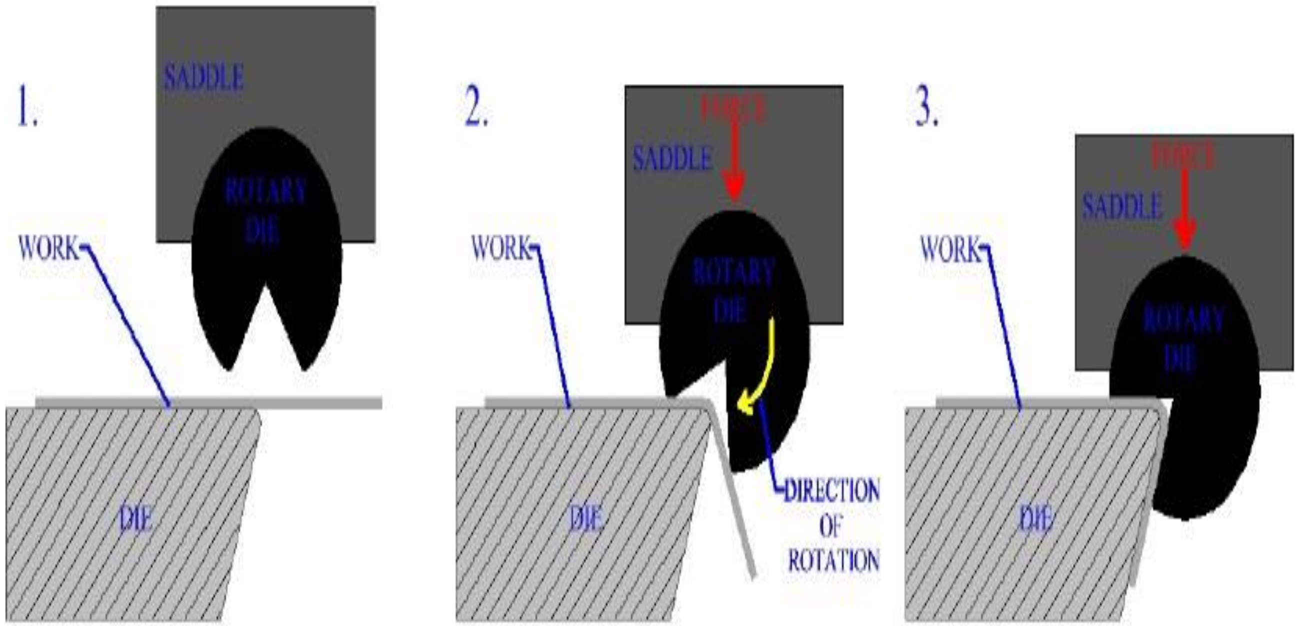




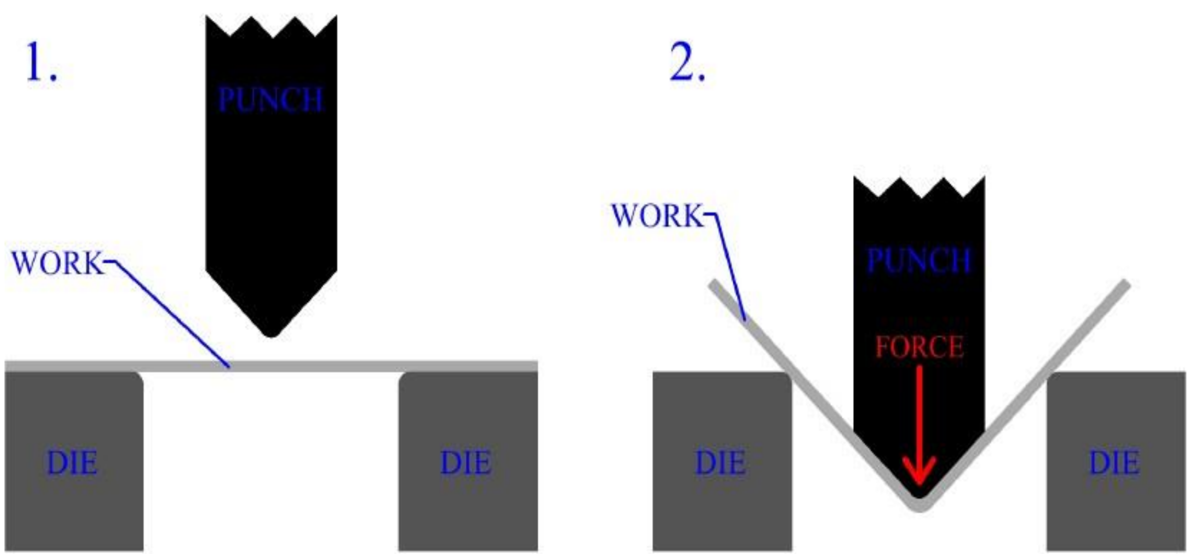
EDGE BENDING WITH WIPING DIE



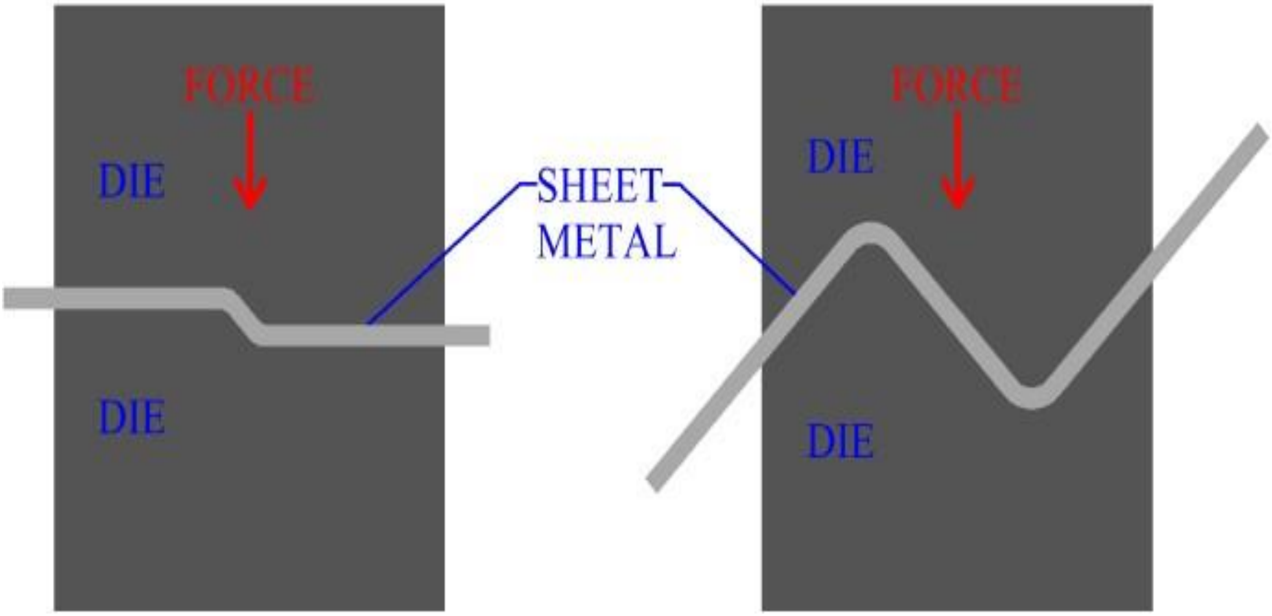
ROTARY BENDING OF SHEET METAL



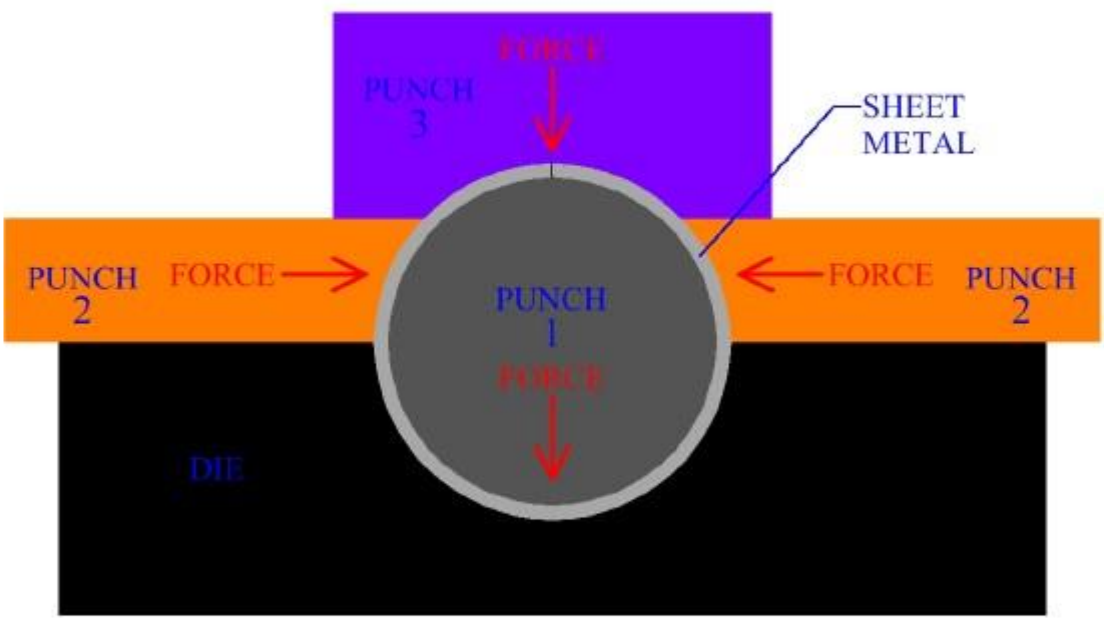
AIR BENDING



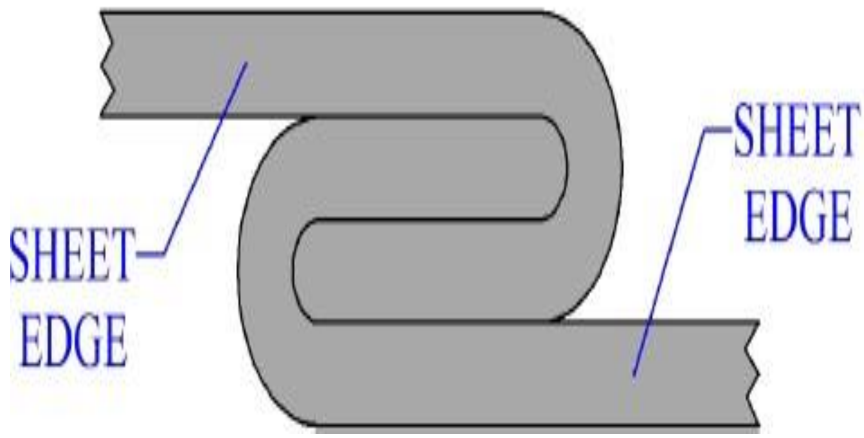
OFFSET BENDING SHEET METAL



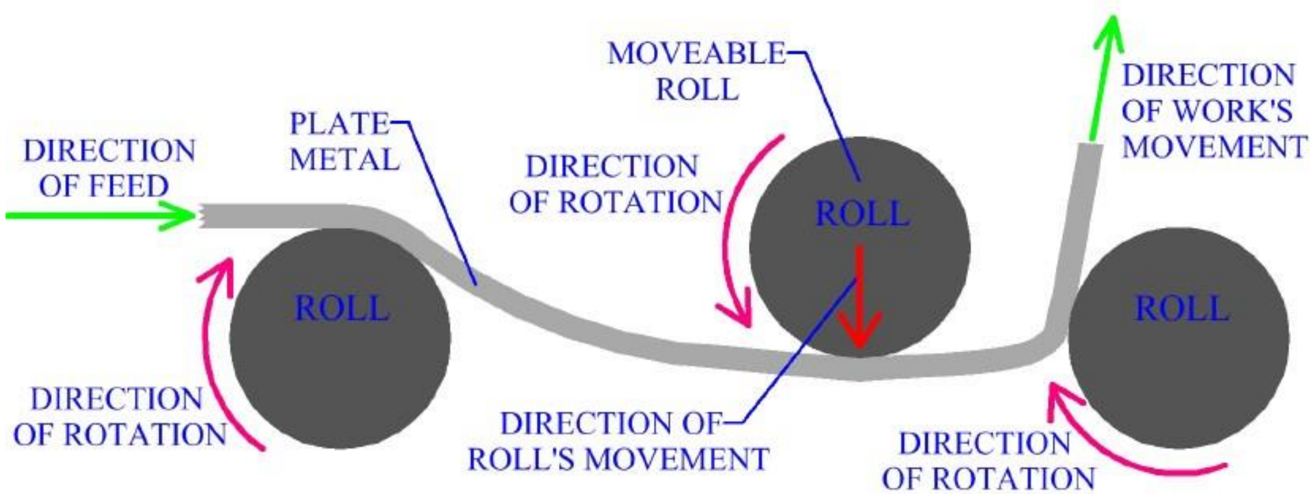
FORMING A HOLLOW TUBE



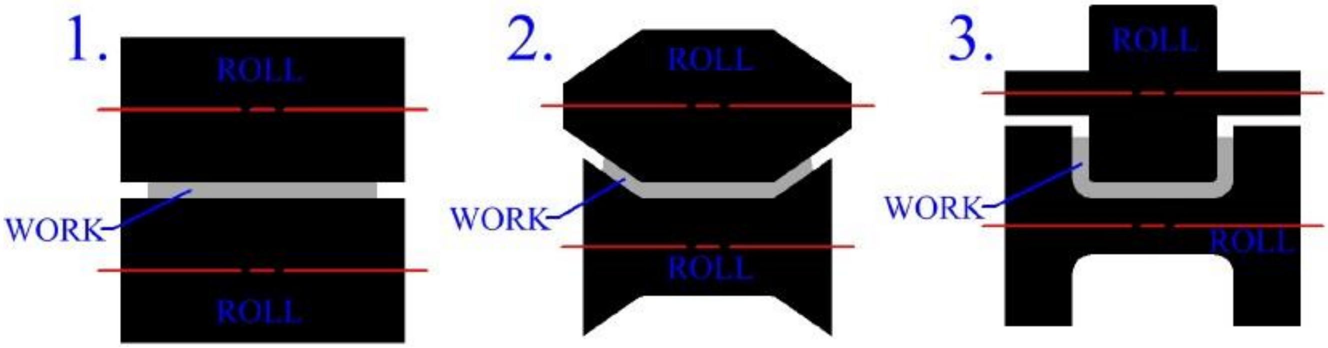
SEAMING OF SHEET METAL



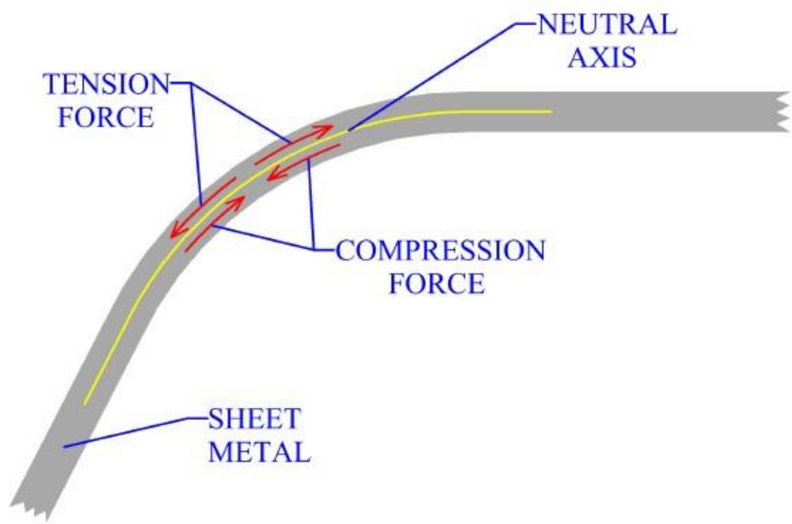
ROLL BENDING



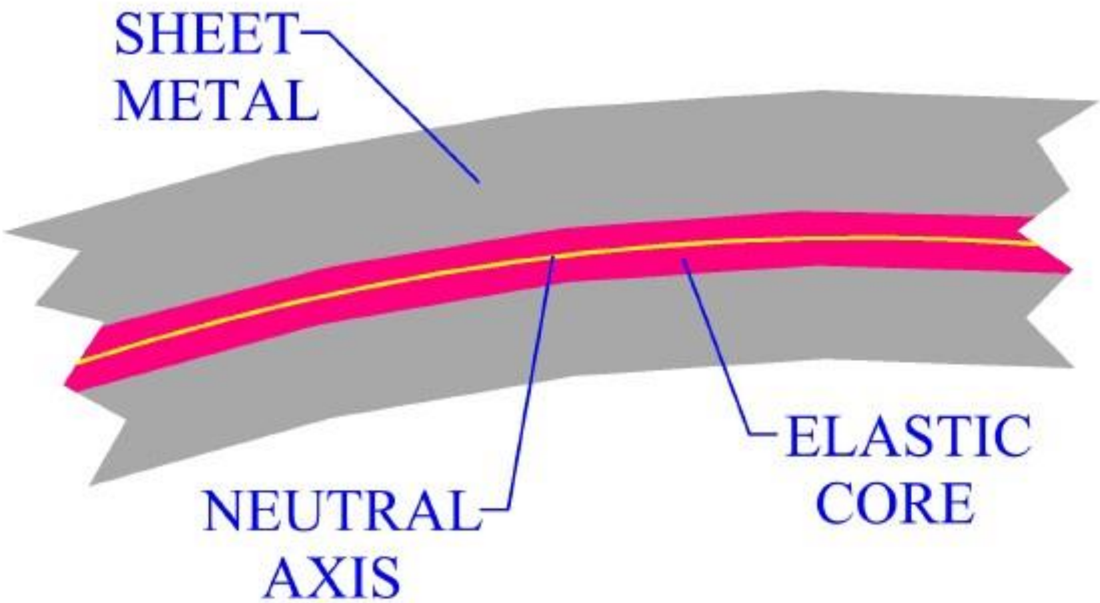
ROLL FORMING SHEET METAL



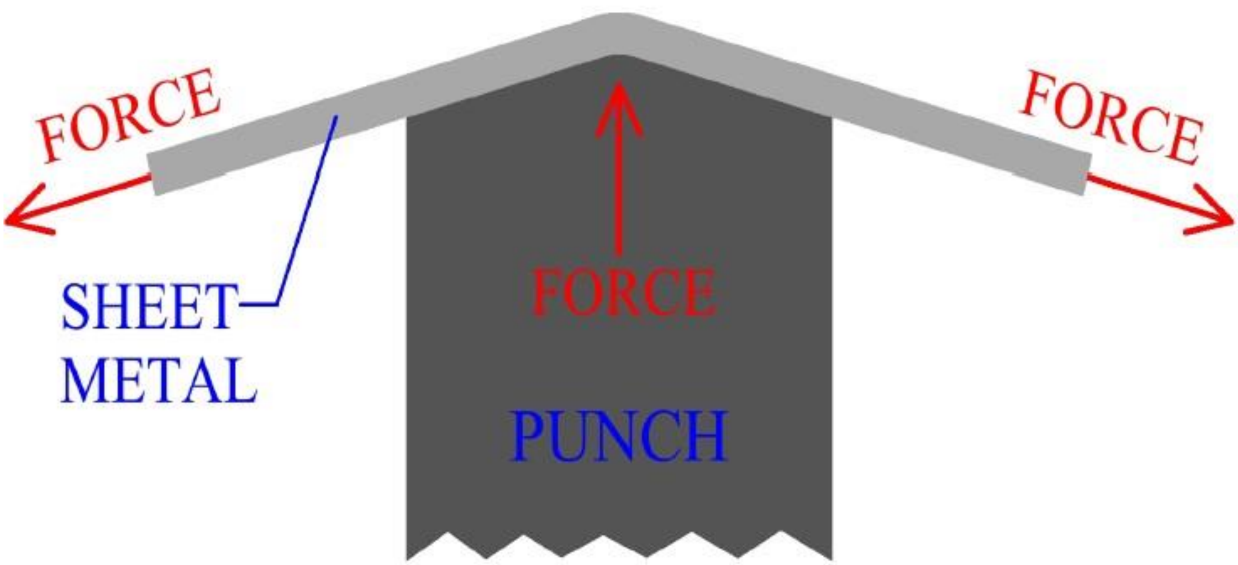
FORCE DISTRIBUTION DURING BENDING



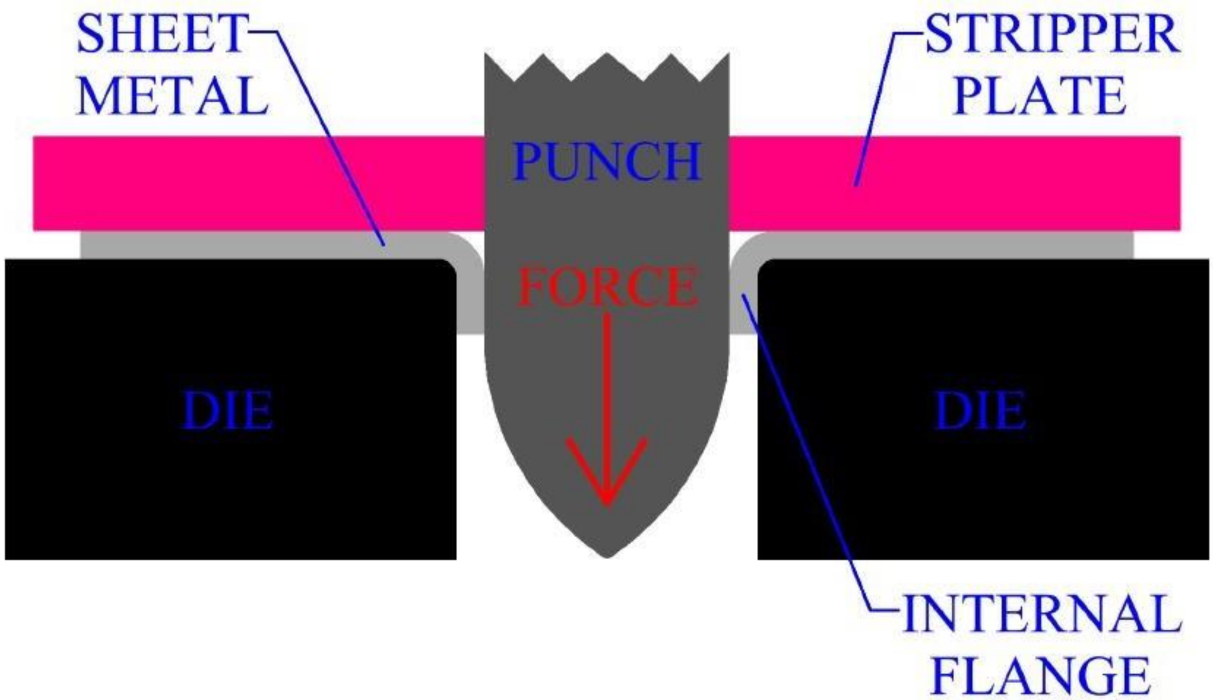
ELASTIC CORE DURING BENDING



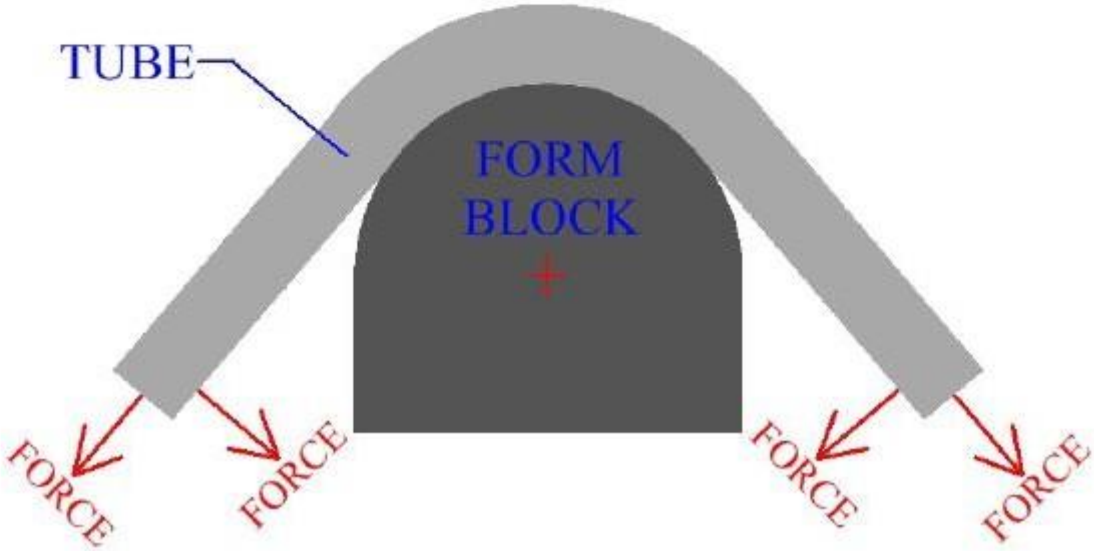
STRETCH FORMING



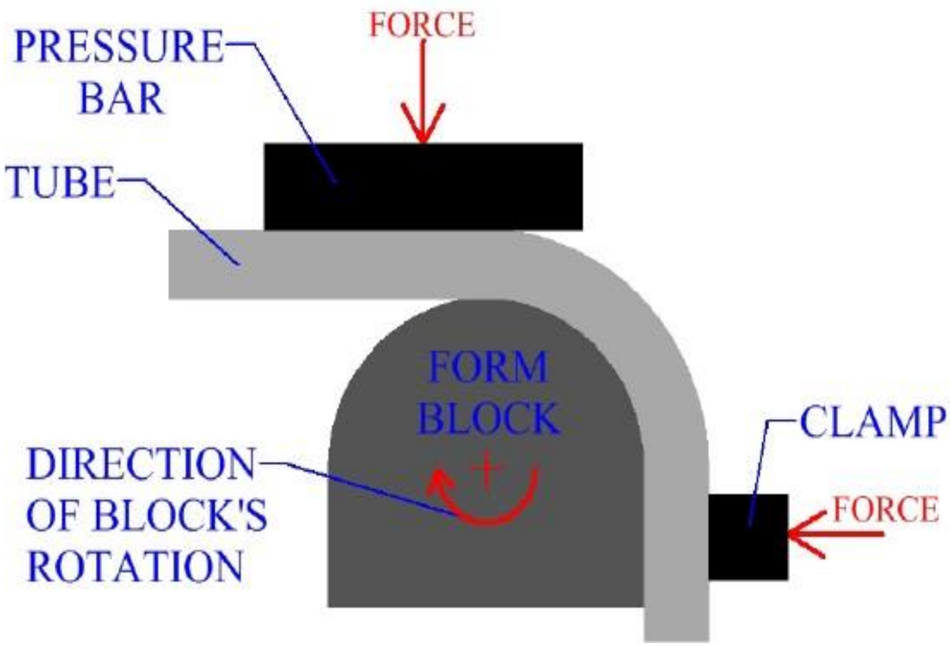
PIERCING


SHEET METAL
STRIPPER PLATE
PUNCH
FORCE
DIE
DIE
INTERNAL FLANGE

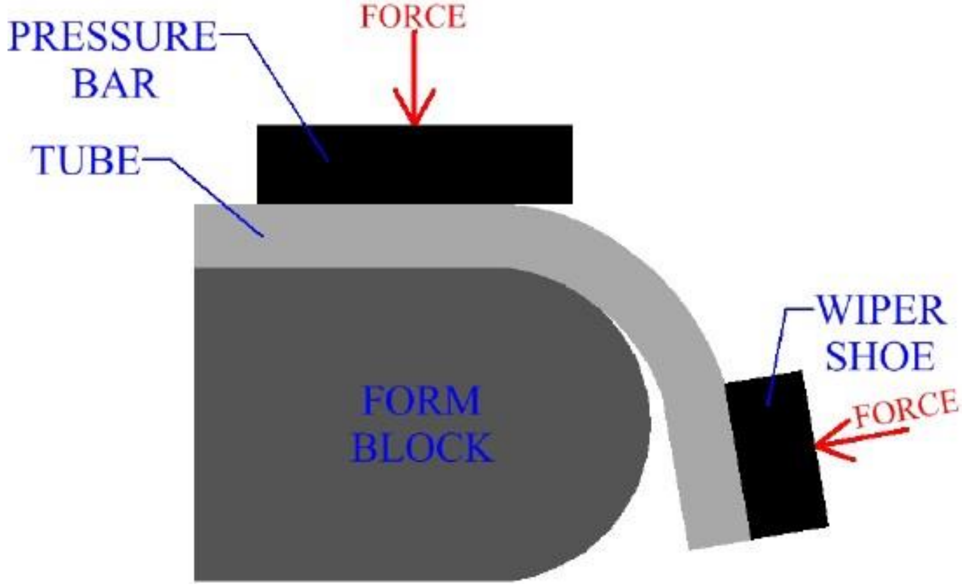
STRETCH BENDING



DRAW BENDING



COMPRESSION BENDING



UNIT- III

Unconventional Machining

Conventional machining processes utilize the ability of the cutting tool to stress the material beyond the yield point to start the material removal processes so they require harder cutting tool than the work piece.

Development of newer methods has always been the endeavor of engineering personnel and scientist. The main idea behind such endeavors have generally been the economic considerations, replacement of exciting manufacturing methods by more efficient and quicker ones, achievement of higher accuracies and quality of surface finish, adaptability of cheaper materials in place of costlier ones and developing methods of machining such materials which cannot be easily machined through conventional methods, etc. of all these reasons, the last one has contributed considerably to the post-war development in machining methods, particularly because of the use of a large number of hard to machine materials in the modern industry. A few of such materials are tungsten, hardened and stainless steel, tantalum, Inconel, uranium, beryllium and some high-strength steel alloys. The increasing utility of such materials in the modern industry has forced the research engineers to develop newer machining methods, so as to have full advantage of these costly materials.

The use of such hard to machine materials is quite common in aircraft industries, space research equipment, nuclear power plants, missile technology, sophisticated armament, etc. To meet the needs of such industries, whereas on one hand newer materials have been developed at the same time newer machining methods have evolved called as Unconventional or Non-traditional Machining methods.

Classification of Unconventional or Non-traditional Machining methods:

They are broadly classified on the basis of the following criteria:

Type of energy used:

Mechanical, chemical, electro-chemical or electro-thermal

Media for energy transfer

High velocity particles, physical contact, reactive atmosphere, electrolyte, hot gases, electrons, radiation.

Mechanism of metal removal:

Erosion, shear, chemical ablation, ionic dissolution, vaporization, spark, erosion.

Source of energy:

Pneumatic, hydraulic, mechanical, corrosive agent, high current, high voltage, ionized gases.

Thermal and electro thermal methods are:

- EDM
- LBM
- PAM
- EBM
- IBM

Chemical and Electro Chemical Are

- ECM
- ECG
- ECH
- ECD

Mechanical Are

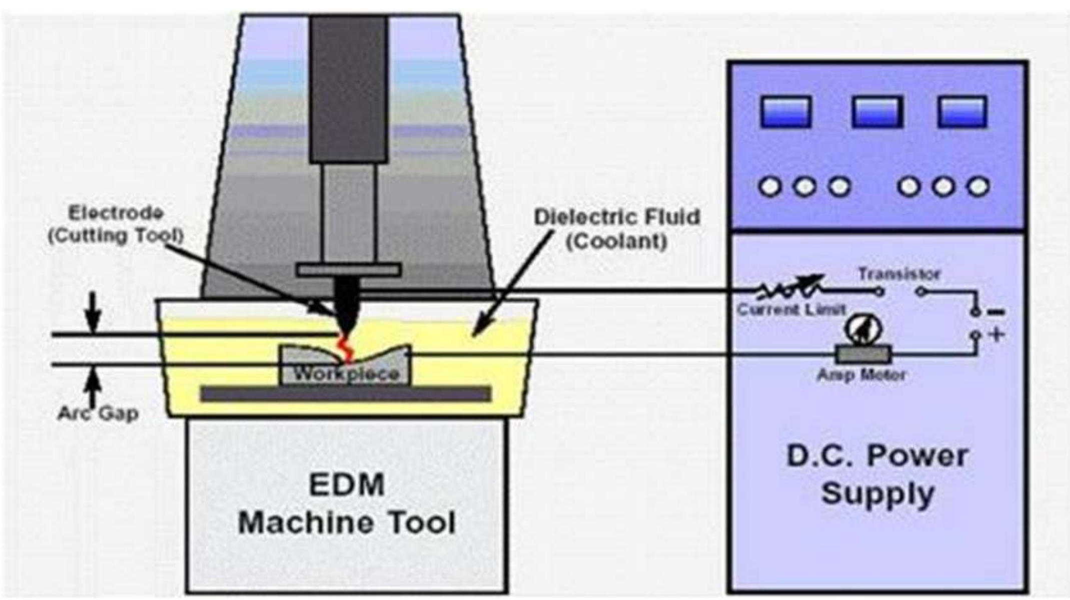
- USM
- AJM
- WJM

Electrical Discharge Machining:

It is also known as spark-over-initiated discharge machining or spark erosion machining or simply spark machining. It is probably the versatile of all methods. The metal removal takes place due to erosion caused by the electric spark. These processes may be used for machining any material, irrespective of its hardness, which is an electric conductor. The rate of metal removal and the resulting surface can be controlled by proper variation in the energy and the duration of spark discharge. A liquid dielectric is used, in some cases gaseous dielectrics are also used.

Setup:

- The main elements of this setup include
- Power supply
- Dielectric medium Work piece
- Tool servo control
- Speed reduction gear box
- Rack and pinion mechanism or any other mechanism Electric circuit to generate discharge
-



Both tool and work piece are connected to the D.C Electric supply source. As shown in figure the work piece is connected to the positive terminal and the tool to the negative terminal of the power supply. Consequently, the work piece becomes Anode and tool cathode

Principle:

The principle involved in the process is that the work piece and the electrode are separated by a gap, called spark gap. This gap is filled up by a dielectric, which breaks down when a proper voltage is applied between these two. The spark usually varies from 0.0005 to 0.05 mm. when a circuit voltage of 50v to 450v is applied, electrons start flowing from cathode to anode, due to the electrostatic field, and the gap is ionized. The consequent drop in resistance and discharge of electric energy results in an electrical breakdown. The electric spark so caused directly impinges on the surface of the work piece. It takes only a micro-second to complete the cycle and the spark discharges hit the anode with considerable force and velocity, resulting in the development of a very high temperature (around 10,000°C) on the spot hit by the discharges. This forces the metal to melt, and a portion of it may be vaporized even. These vaporized are melted particles are thrown into the gap by electrostatic and electromagnetic forces, from where they are driven away by the flowing liquid dielectric. The maximum effect of the arc impingement is on the elevated spots on the work surface. So they are first to get removed. It is because they are nearest to the tool tip.

The gap control is affected through a servo system. This system correctly locates the tool in relation to the work piece surface and maintains constant gap throughout the operation and senses changes in gap conditions, if any. Also it immediately corrects the deviations caused due to these changes. The servo system used may be electrical or hydraulic.

Remember that erosion takes place on both tool and piece, but tool is eroded less because of its tip subjected to compressive forces due to electric and magnetic fields, resulting smaller erosion.

And other important point to be noted is that unlike conventional method the machining speed cannot be increased by simply using multiple tools because it is confined to particular spot. If more tools are used separate servomechanisms are required.

Dielectric fluid:

Dielectric fluid called as a spark conductor, coolant and also flushing medium. The requirements are as follows:

a. It should have sufficient and stable dielectric strength to serve as an insulating between the tool and work till the breakdown voltage is reached.

b. It should de-ionize rapidly after the spark discharge has taken place.

c. It should have low viscosity and good wetting capacity to provide an efficient cooling mechanism and remove the swarf particles from the machining gap.

d. It should be chemically neutral so as to attack the electrode, work piece, the table or the tank.

e. Its flash point should be high so that there no fire hazards.

f. It should not emit any toxic vapors or unpleasant odurs.

g. It should be economical and easily available.

Examples: Hydrocarbon fluids, silicone-based oils and de-ionized water. Kerosene and water with glycol are also used.
Electrodes:
In the EDM process the shape of the electrode is impressed on the work piece in its complimentary form and as such the shape and accuracy of the electrode plays a very important role in the final accuracy of the work piece machined.

The electrode material should have the following characteristics serve as a good tool.

- It should be a good conductor of electricity and heat.
- It should be easily Machin able to any shape at reasonable cost
- It should produce efficient material removal rates from work pieces. It should resist the deformation during erosion process.
- It should exhibit low electrode wear rates. It should be available in a variety shapes.

Process Characteristics:
The metal removal rates in EDM depend upon the following parameters:

1. Current in spark
2. Frequency of the discharge
3. Electrode material
4. Work piece
5. Dielectric flushing condition

Advantages:
•There is no physical contact between the tool and the work piece and hence no cutting forces
•Enable high accuracy on tools and dies, because they can be machined in _as hard‘ condition.
•Even highly delicate section and week materials can be machined without any fear of distortion because there is no direct contact between the tool and the Work piece.
•Irrespective of its hardness or strength, any material, which is an electrical conductor, can be machined.
•Any shape that can be imparted to the tool can be reproduced on the work
•Fine holes can be easily drilled.
•It is a quicker process. Even harder materials can be machined at a much faster rate than conventional machining.

Disadvantages:
This process has some distinct disadvantages as well, such as capacity to machine small Work pieces only, unsuitability for machining of electrical non-conductors, thermal distortion, inability to produce sharp corners etc.

Applications:

•There is no physical contact between the work and the tool hence no cutting forces act on the work. Even fragile pieces can be machined.

•Any complex shapes required in dies can be easily produced with required degree of accuracy and finish.

•Process not affected by the work piece hardness.

•High aspect ratio surfaces can be machined.

•Process is mostly automated. With very little operator skill.

•Even spark are produced there is no thermal damage of the material.

ELECTRON BEAM MACHINING

Definition:

It is a process of machining materials with the use of a high velocity beam of electrons. The work piece is held in a vacuum chamber and the electron beam focused on to it magnetically. As the electrons strike the work piece, their kinetic energy is converted into heat. This concentrated heat raises the temperature of work piece materials and vaporizes a small amount of it, resulting in removal of metal from the work piece. The reason for using a vacuum chamber is that, if otherwise, the beam electrons will collide with gas molecules and will scatter.

The main elements of Electron Beam Machining setup are shown in.

The setup is enclosed in a vacuum chamber, which carries vacuum of the order of 10-5 mm of mercury. This chamber carries a door, through which the work piece is placed over the table. The door is than closed and sealed.

The Electron gun:

Which is mainly responsible for emission of electrons, consists of three main parts

1. A tungsten filament (acts as cathode)
2. The grid cup
3. and the anode.
4. Electromagnetic lens
5. Deflector coil

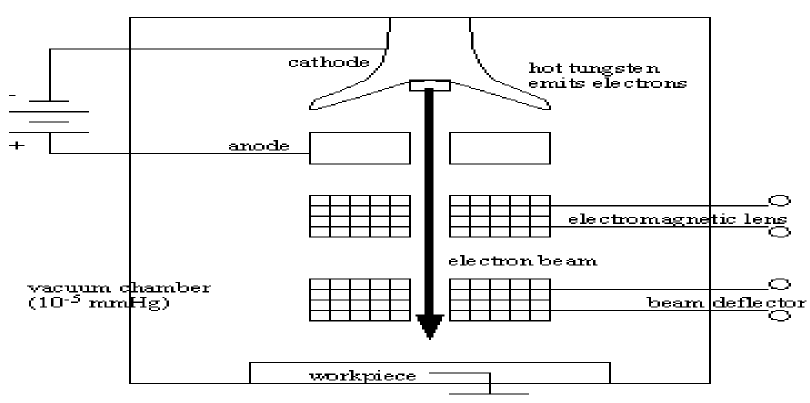


FIGURE- EBM

Procedure:

- The filament is connected to the –ve terminal of the D.C power supply, to act as cathode, and the anode to the +ve terminal, as shown.
- When DC supply is put on the filament wire is heated up to a temperature of about 25000C in the vacuum, which results in a cloud of electrons which emit from the grid cup to travel downwards. As the electrons are attracted by the anode, they pass through its aperture in the form of a controlled beam without colliding with it.
- A potential difference of 50 to 150 KV is maintained between the filament and the anode. As such, the electrons passing out of anode, is maintained by them till such time as they strike the Work piece. It becomes possible because the electrons travel through the vacuum.
- This high velocity electron stream, after leaving the anode, passes through the tungsten diaphragm and then through the electromagnetic focusing coils (or focusing lens). By then, the stream is quite aligned and the focusing lens manages to focus it precisely on to the desired spot on the Work piece.
- The electromagnetic deflector coil then deflects this aligned stream (beam) on to the work, through which the path of cut can be controlled.
- Further, the table, on which the Work piece is loaded, can also be traversed to feed the Work piece as needed.
- This velocity beam of electrons impinges on the Work piece, where its kinetic energy is released and gets converted into heat energy. The high intensity heat, so produced, melts and vaporizes the work material at the spot of beam impingement. By alternately focusing and turning off the cutting process can be continued as long as it is needed.

- Melting and vaporizing of the metal takes only a small fraction of a second and turning off the beam is necessary to conduct away the heat from the Work piece. A suitable viewing device is always incorporated so as to enable the operator to observe the progress of machining operation

- Adequate vacuum is required to be maintained inside the chamber so that the electrons can travel from cathode to anode without any hindrance, there is no arc discharge between the electrons, there is no loss of heat from cathode, there is no contamination of cathode and the high velocity attained by the electron beam while leaving anode is maintained up to the event of its impingement on the work.

Advantages

1. Any material can be machined
2. Work piece is not subjected to any physical or metallurgical damage.
3. Problem of tool wear is non-existent. So, close dimensional tolerances can be achieved.
4. Heat can be concentrated on a particular spot.
5. An excellent technique for micro machining
6. There is no contact between the work and tool

Disadvantages

1. High initial investment needed.
2. Highly skilled operator required to perform the operation.
3. Not suitable for producing perfectly cylindrical deep holes.
4. Suits for small and fine cuts only.
5. Work piece size is limited due to requirement of vacuum in the chamber.
6. Low rate of metal removal
7. High power consumption
8. Difficult to produce slots and holes of uniform shapes and dimensions.

Applications

1. Very effective for machining of materials of low heat conductivity and high melting point.
2. Micro-machining operations on Work piece of thin sections.
3. Micro-drilling operations (up to 0.002 mm) for thin orifices, dies for wire drawing, parts of electron microscopes, fiber spinners, injector nozzles for diesel engines, etc.

LASER BEAM MACHINING (LBM)

Laser is the term used for the phenomenon of ‗amplification of light by stimulated emission of radiation'. The setup consists of a stimulating light source (like xenon flash lamp) and a laser rod (laser tube), from where it is reflected and accelerated in the path. This light is emitted in the form of a slightly divergent beam. A lens is incorporated suitable in the path of this beam of light which converges and focuses the light beam on to the Work piece melts the work material and vaporizes it. It is of laser beam on the Work piece melts the work material and vaporizes it. It is a very costly method and can be employed only when it is not feasible to machine a Work piece through other methods.

The setup for laser beam machining, together with its circuit. It mainly consists of a laser tube or rod, a pair of mirror- one at each end of the tube, a flash tube or lamp (energy source), an amplifying source (laser), a power supply source, a cooling system and lens (focusing source). The main setup is setup is fitted inside an enclosure, which carries a highly reflective surface inside.

In operation, the optical energy (light) is thrown by flash lamp on to the laser tube (Ruby rod). This excites the atoms of the inside media, which absorb the radiation of incoming light energy. This results in the to and fro travel of light between the two reflecting mirrors. But, the partial reflecting mirror does not reflect the total light back and a part of it goes out in the form of a coherent stream of monochromatic light. This highly amplified stream of light is focused through a lens, which converges it to a chosen point on the Work piece. This high intensity converged laser beam, when falls on the Work piece, melts the Work piece material, vaporizes it almost instantaneously and penetrates into it. Thus, it can be called a type of thermal cutting process.

Operation:

1. Ruby crystal is obtained by aluminum oxide dispersed with chromium through it. And two ends are silvered to form mirrors internally; the front mirror has a small aperture for the laser beam to emerge out.
2. A cylindrical ruby crystal is taken over which xenon flash tube is coiled or surrounded. Xenon tube is connected to the capacitor bank which in turn connected to DC supply.

3.	So when power is switch on the capacitor bank supply a high voltage current to the xenon. Which causes a white light to emerge and the white light hits the ruby crystal where the chromium ions are ionized and pumped out with high energy levels and drop to intermediate level with release of energy and heat and after bombarding with other atom of chromium or with the mirrors reach to higher energy levels to form a fluorescent red light. Finally this light reaches a threshold frequency and escapes through the small aperture in the front mirror.

4.	And this light is focused on to the lens and from there on to the work piece.

The lasing medium or laser used in the process can be of solid or gaseous type. The former type is special glass rods carrying reflective coatings at their end faces. They can provide short duration laser beams only. Against these, the letter type, produce continuous laser beam and are, therefore, very suitable for welding and cutting operations.

Advantages:

1. Any material can be easily machined irrespective of its structure and physical and mechanical properties.
2. Unlike conventional machining, there is no direct contact between the tool and the Work piece and no involvement of large scale cutting forces.
3. Tool wear is non-existent.
4. Can be effectively used for welding of dissimilar metals as well.
5. Small heat effected zone around the machined surface.
6. Very small holes and cuts can be made with fairly high degree of accuracy.

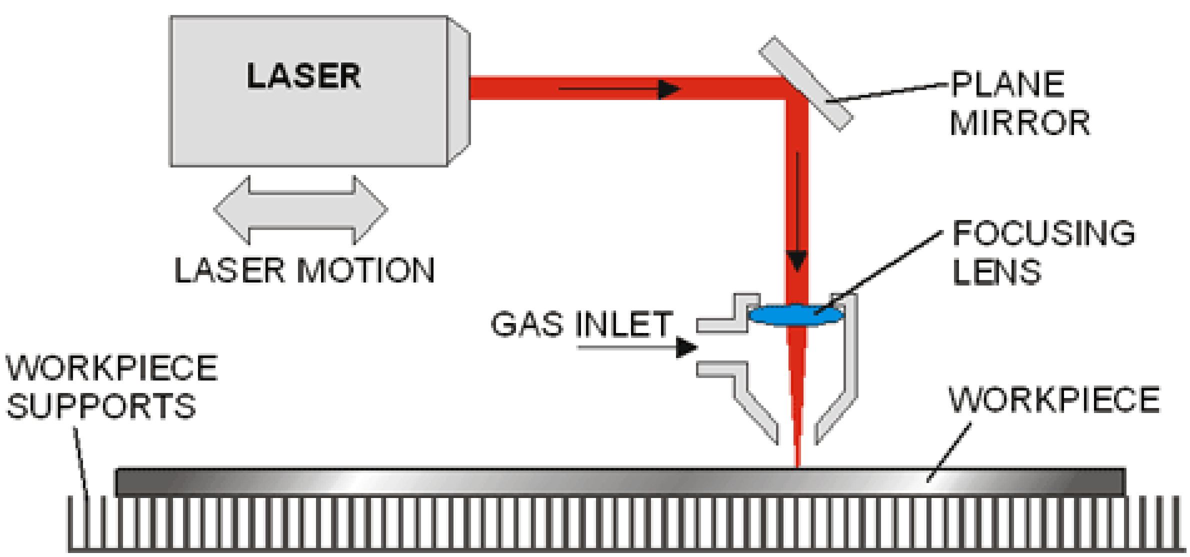


FIGURE: Laser beam machining process

UNIT-IV

Heat Treatment and Surface Finishing

1. Aluminum alloys and heat treatment of Al alloys:

Aluminum and aluminum alloys have many outstanding attributes that lead to a wide range of applications, including good corrosion and oxidation resistance, high electrical and thermal conductivities, low density, high reflectivity, high ductility and reasonably high strength, and relatively low cost.

Types of Aluminum Alloys

Aluminum alloys are normally classified into one of three groups:
wrought non-heat-treatable alloys, wrought heat treatable alloys, and casting alloys.

- **Wrought non-heat-treatable alloys** cannot be strengthened by precipitation hardening; they are hardened primarily by cold working. The wrought non-heat-treatable alloys include the commercially pure aluminum series (1xxx), the aluminum-manganese series (3xxx), the aluminum-silicon series (4xxx), and the aluminum-magnesium series (5xxx). While some of the 4xxx alloys can be hardened by heat treatment, others can only be hardened by cold working.
- **Wrought heat treatable alloys** can be precipitation hardened to develop quite high strength levels. These alloys include the 2xxx series (Al-Cu and Al-Cu-Mg), the 6xxx series (Al-Mg-Si), the 7xxxseries (Al-Zn-Mg and Al-Zn-Mg-Cu), and the aluminum-lithium alloys of the 8xxx alloy series. The 2xxx and 7xxx alloys, which develop the highest strength levels, are the main alloys used for metallic aircraft structure.
- **Casting alloys** include both non-heat-treatable and heat treatable alloys. The major categories include the 2xx.x series (Al-Cu), the 3xx.x series (Al-Si + Cu or Mg), the 4xx.x series (Al-Si), the 5xx.x series (Al-Mg), the 7xx.x series (Al-Zn), and the 8xx.x series (Al-Sn). The 2xx.x, 3xx.x, 7xx.x, and 8xx.x alloys can be strengthened by precipitation hardening, but the properties obtained are not as high as for the wrought heat treatable alloys.

Role of alloying elements or Al alloys and their applications:

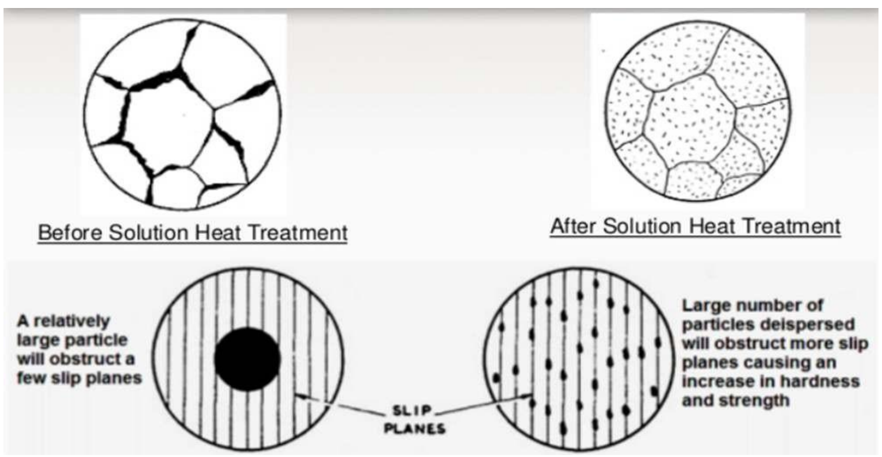
Al-cu, Al-Mn, Al-Mg, Al-Si, Al-Zn (write applications from presentation).

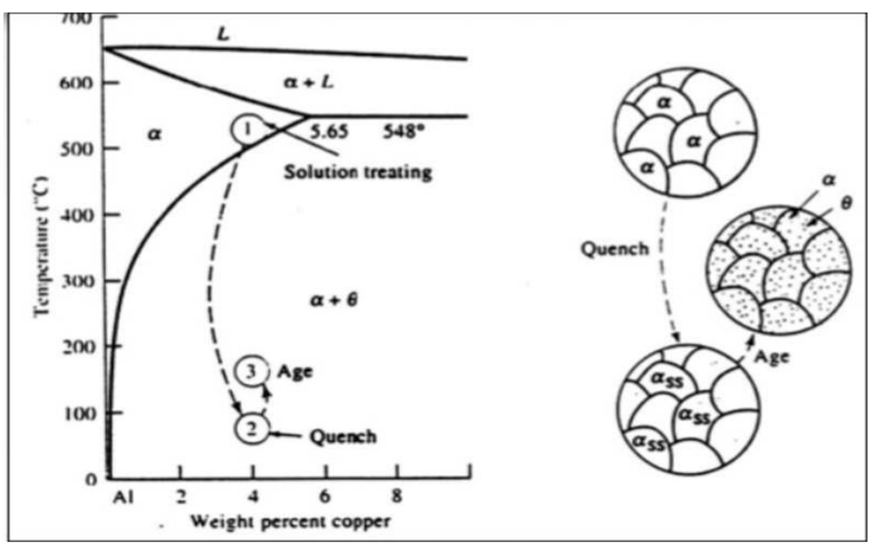
Heat treatment of Al alloys:

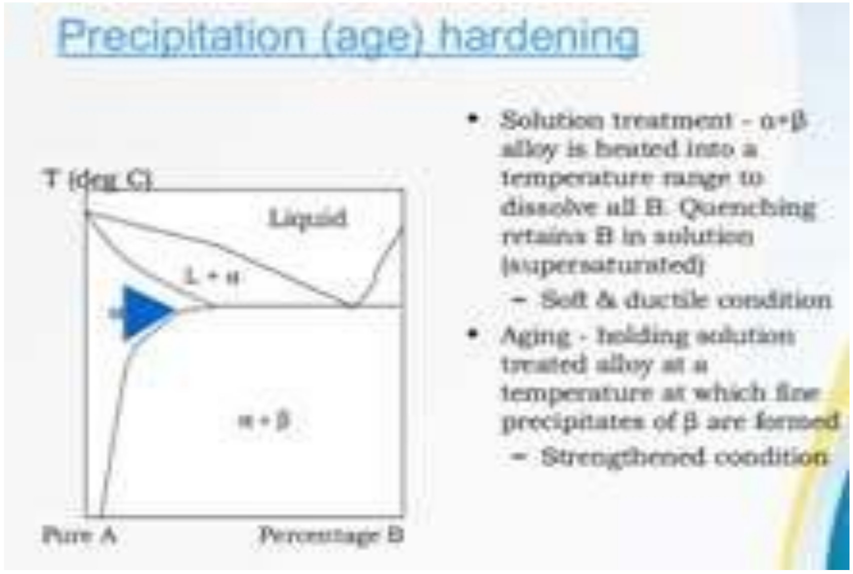
HEAT TREATING in its broadest sense, refers to any of the heating and cooling operations that are performed for the purpose of changing the mechanical properties, the metallurgical structure, or the residual stress state of a metal product. When the term is applied to aluminum alloys, however, its use frequently is restricted to the specific operations' employed to increase strength and hardness of the precipitation hardenable wrought and cast alloys. These usually are referred to as the "heat-treatable" alloys to distinguish them from those alloys in which no significant strengthening can be achieved by heating and cooling. The latter, generally referred to as "non-heattreatable" alloys, depend primarily on cold work to increase strength. Heating to decrease strength and increase ductility (annealing) is used with alloys of both types

Strengthening by Heat Treatment Heat treatment to increase strength of aluminum alloys is a three-step process:

- Solution heat treatment: dissolution of soluble phases
- Quenching: development of supersaturation
- Age hardening: precipitation of solute atoms either at room temperature (natural aging) or elevated temperature (artificial aging or precipitation heat treatment).







Precipitation (age) hardening:

<u>Solution treatment-</u> alpha+beta alloy is heated into a temperature range to dissolve all B. <u>Quenching</u> retains B in solution (supersaturated). Salt and ductile condition.

<u>Aging</u>- holding solution treated alloy at a temperature at which fine properties of beta are formed. Strengthen condition.

(Draw above diagram)

Common defects:

1. Casting defects
   - (i) cracks: centric, radial, loop, transverse
   - (ii) porosity
   - (iii) inclusions
   - (iv) segregation

2. Extrusion defects
   - (i) extrusion tears/cracks
   - (ii) fish scaling
   - (iii) layer formation
   - (iv) scratches
   - (v) uneven wall thickness
   - (vi) coarse grain ring

3. Heat treatment defects
   - (i) unqualified mechanical properties

(ii) over firing
(iii) coarse grain
(iv) quenching cracks

4. Forging defects

Applications:

1. Electrical and Chemical applications (1XXX-pure Al alloys).
2. Aircraft, transportation applications (2XXX-Al-Cu alloys).
3. Heat transfer, packing, roofing, siding applications (3XXX-Al-Mn-alloys).
4. Pistons, complex shaped forgings (4XXX-Al-Si alloys).
5. Building & construction, automotive, cryogenic, marine applications (5XXX-Al-Mg alloys).
6. Building & construction, high way, automotive, marine applications (6XXX-Al-Mg-Si alloys).
7. Aerospace, automotive applications (7XXX-Al-Zn alloys).

2. Heat Treatment of Titanium Alloys:

- Titanium alloys are heat treated to achieve the following:

- **Stress relieving**, to reduce residual stresses developed during fabrication. Stress Relieving Titanium alloys can be stress relieved without adversely affecting strength or ductility. The process for forgings takes place at 595 to 705°C (1100 to 1300°F) for a period of one to two hours, followed by air cooling. It decreases undesirable residual stresses that may result during forging processes.

- **Annealing**, to achieve an optimum combination of ductility, machinability, dimensional stability and structural stability. Which is usually applied to forging bar stock, is not a full anneal, and may leave traces of cold or warm working in some products. Duplex and triplex annealing is used to improve creep resistance and fracture toughness.

- **Solution treating and aging**, to increase strength. This process consists of heating to a specified temperature for the alloy, quenching at a controlled rate in oil, air or water, and aging. Aging consists of reheating to a temperature between 425 and 650°C (800 to 1200°F) for approximately two hours. This process develops higher strengths than are achievable by the other processes.

- Combinations of processes are employed to optimize properties and gain other advantages such as:

  – Fracture toughness

  – Fatigue strength

  – High temperature creep strength

- Resistance to preferential chemical attack
- Prevent distortion
- Condition the forging for subsequent forming and fabricating operations.

Alloy types and response to heat treatment:

- Alloys Ti-5Al-2Sn-2Zr-4Mo-4Cr and Ti-6Al-2Sn-4Zr-6Mo are designed for strength in heavy sections.
- Alloys Ti- 6Al-2Sn-4Zr-2Mo and Ti-6Al-5Zr-0.5Mo-0.2Si for creep resistance.
- Alloys Ti-6Al-2Nb-1 Ta-1Mo and Ti-6Al-4V, for resistance to stress corrosion in aqueous salt solutions and for high fracture toughness.
- Alloys Ti-5Al-2.5Sn and Ti-2.5Cu for weldability; and
- Ti-6Al-6V-2Sn, Ti-6Al-4V and Ti-10V-2Fe-3Al for high strength at low-to-moderate temperatures.

- Based on the types and amounts of alloying elements they contain, titanium alloys are classified as α, near-α, α-β, or β alloys. The response of these alloy types to heat treatment is briefly described below.
- ***Alpha and near-alpha titanium alloys*** can be stress relieved and annealed, but high strength cannot be developed in these alloys by any type of heat treatment (such as aging after a solution beta treatment and quenching).

  Generally non -heat treatable and weldable.

  Medium strength, good creep strength, good corrosion resistance.
- ***The commercial β alloys*** are, in reality, metastable β alloys. When these alloys are exposed to selected elevated temperatures, the retained β phase decomposes and strengthening occurs. For β alloys, stress-relieving and aging treatments can be combined and annealing and solution treating may be identical operations.

  Heat treatable and readily formable.

  Very high strength and low ductility.
- ***Alpha-beta alloys*** are two-phase alloys and, as the name suggests, comprise both α and β phases at room temperature. These are the most common and the most versatile of the three types of titanium alloys.

  Heat treatable, good forming properties.

  Medium to high strength, good creep strength.

Common annealing treatments are:

- Mill annealing
- Duplex annealing
- Recrystallization annealing
- Beta annealing

Advantage of Ti alloys:

- High corrosive resistance
- Bio compatible material
- Non magnetic property
- Low specific gravity
- High specific strength
- Three times as Al and higher than Steel

Applications of Ti alloys:

- Aerospace, marine, chemical , biomedical applications and sports using

Aerospace:

- Civil
- Military
- Space

Medical:

Orthopedic implants
Bone Screws
Trauma Plates
Dental Fixtures
Surgical Instruments

Industrial:

- Petro chemical
- Offshore
- Subsea
- Metal finishing
- Pulp and paper
- General Engineering

specialist:

Body jewellary
Ultrasonic welding
Motor racing components
Marine
Bicycle
Sports equipment

3. Heat treatment of steels:

Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape.

Steels are particularly suitable for heat treatment, since they respond well to heat treatment and the commercial use of steels exceeds that of any other materials.

Generally heat treatment uses phase transformation during heating and cooling to change a microstructure in a solid state.

Various types of heat treatment process are used to modify the following properties or conditionsof the steels:

- Improve the toughness
- Increase the hardness
- Increase the ductility
- Improve the machinability
- Refine the grain structure
- Remove the residual stresses
- Improve the wear resistance

Types of heat treatment processes:

(i) Annealing

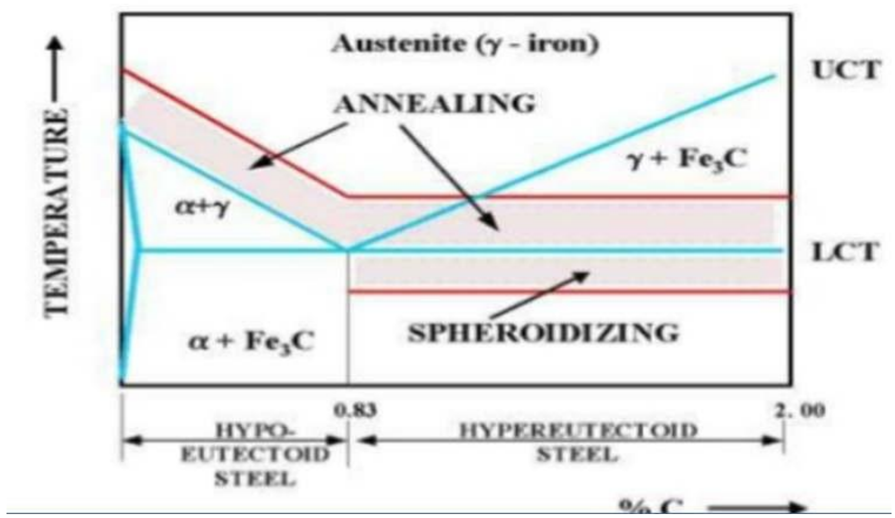
(ii) Normalizing

(iii) Hardening and Tempering

(iv) Case hardening

(i) Annealing:

Annealing is heat process whereby a metal is heated to a specific temperature, held at that temperature and then allowed to cool slowly.



Stages of Annealing: The removal of cold-worked condition or in other words, the annealing process, may be divided into three stages.

Recovery
Recrystallization
Grain growth

Benefits of annealing:

- Improved ductility
- Removal of residual stresses that result from cold working or machinability
- Improved machinability
- Grain refinement

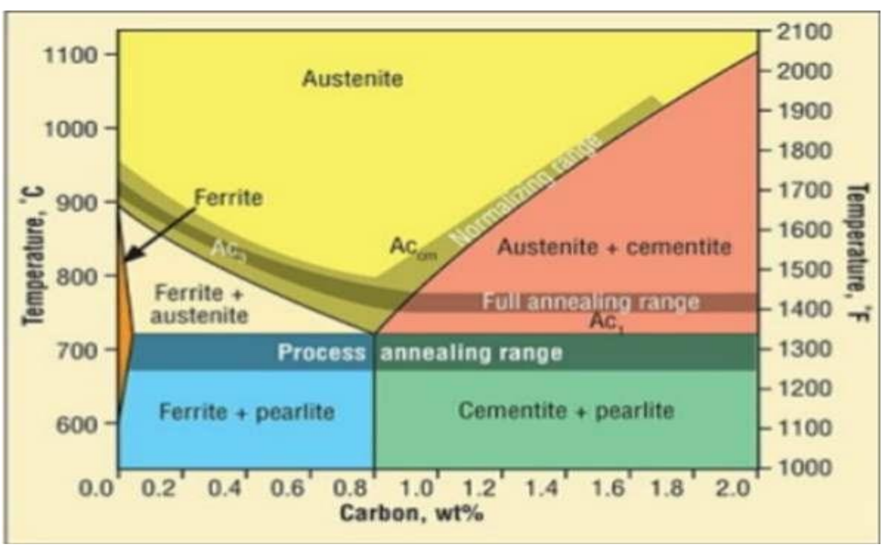
Some Disadvantages also there, it reduces the hardness, and reduces the yield strength and tensile strength of the steel.

- Annealing is to produce an even grain structure
- To relive the internal stresses caused by various manufacturing processes or by previous treatments
- After annealing, the metal becomes soft which improves machinability

Types of annealing:

- Stress relieving
- Process annealing
- Spherodise annealing
- Full annealing

Process annealing:



- To remove the effects of cold work

- To soften and permit further cold work in sheet and wire industries
- Ferrous alloys are heated to a temperature below 723 degrees in the range of (550-650) & then cooled usually in air to soften the alloy for further cold working.
- Associated with partial recrystallisation of the distorted ferrite.
- Doesn't involve any phase change and constituents ferrite and cementite remain present in the structure throughout the process.

Spherodise annealing:

Involves subjecting steel to a selected temperature to produce a spheroidal/ globular form of carbide in steel.

- Improves machinability
- Improves surface finishing during machining
- Facilitates a subsequent cold working operation
- Soften tool steels and some of the air hardening alloy steel.
- Prevents cracking of steel during cold forming operations
- Obtain a desired structure for subsequent heat treatment.

Full annealing:

- Involves prolonged heating just above the 723 degrees to produce globular form of carbide (to improve machinability)
- Annealing a ferrous alloy to a austenitic condition and the cooling slowly in furnance through 723 degrees up to a low temperature.
- Cooling rate 25-30 degrees/hr to600 degrees.

Normalizing:

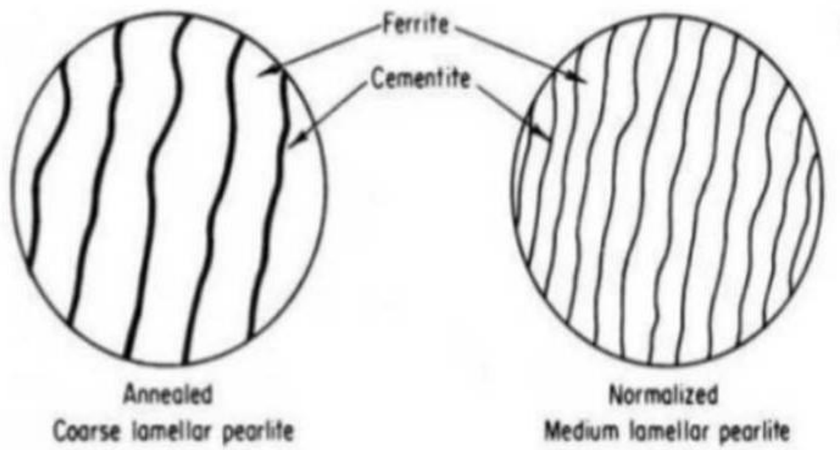
Heating the metal to austenitic temperature range and cooling in air at room temperature

- Produces a uniform structure
- Reduces internal stress
- Refines the grain size of steel
- Improves structures in welds
- Produces a harder and stronger steel than full annealing
- Improves engineering properties of steels.

Effects of heat treatments:

Effects of Heat treatment

Annealing & Normalizing	Hardening or Quenching		
Furnace Cooling	Air Cooling	Oil Quenching	Water Quenching
← Softer, less strong	Harder and stronger →		
← More ductile	More brittle →		
← Less internal stress	More internal stress →		
← Less distortion, cracking	More distortion, cracking →		



Difference in pearlitic structure due to annealing and normalizing

Hardening and Tempering:

- Increases hardness of steel by quenching
- Tool and machine parts subjected to heavy duty are usually hardened
- Hardening of steel requires the formation of martensite
- After hardening tempering is done to:
    - (i) Hardens steel to resist wear
    - (ii) Enables steel to cut other metals
    - (iii) Improves strength, toughness & ductility
    - (iv) Develops best combination of strength
- Steels with sufficient carbon [0.35-0.70%]
- Heated 30-50 degrees above A3 line
- Held at that temperature from 15-30 min
- Cooled rapidly or quenched in a suitable medium [water, brine, oil, etc]
- Produce desired rate of cooling.

4. Case Hardening:

Case-hardening or **surface hardening** is the process of hardening the surface of a metal object while allowing the metal deeper underneath to remain soft, thus forming a thin layer of harder metal (called the "case") at the surface.

- Case hardening is usually done after the part has been formed into its final shape.
- Case hardening can provide a part that will not fracture but also provides adequate wear-resistance on the surface
- The steels best suited for case hardening are the low carbon and low alloy series.

Case hardening methods include: 1. Carburising 2. Nitriding 3. Carbo-nitriding 4. Cyaniding

Flame or induction hardening are processes in which the surface of the steel is heated very rapidly to high temperatures (by direct application of an oxy-gas flame, or by induction heating) then cooled rapidly, generally using water; this creates a "case" of martensite on the surface. A carbon content of 0.3–0.6 wt% C is needed for this type of hardening.

Carburizing:

Carburizing is a process used to case-harden steel with carbon content between 0.1 and 0.3 wt% C. In this process steel is introduced to a carbon rich environment at elevated temperatures for a certain amount of time, and then quenched so that the carbon is locked in the structure; one of the simpler procedures is repeatedly to heat a part with an acetylene torch set with a fuel-rich flame and quench it in a carbon-rich fluid such as oil.

Carburization is a diffusion-controlled process, so the longer the steel is held in the carbon-rich environment the greater the carbon penetration will be and the higher the carbon content. The carburized section will have carbon content high enough that it can be hardened again through flame or induction hardening.

It is possible to carburize only a portion of a part, either by protecting the rest by a process such as copper plating, or by applying a carburizing medium to only a section of the part.

The carbon can come from a solid, liquid or gaseous source; if it comes from a solid source the process is called **pack carburizing**. Packing low carbon steel parts with a carbonaceous material and heating for some time diffuses carbon into the outer layers. A heating period of a few hours might form a high-carbon layer about one millimeter thick.

Liquid carburizing involves placing parts in a bath of a molten carbon-containing material, often metal cyanide; gas carburizing involves placing the parts in a furnace maintained with a methane-rich interior.

Nitriding:

Nitriding heats the steel part to 482–621 °C (900–1,150 °F) in an atmosphere of ammonia gas and dissociated ammonia. The time the part spends in this environment dictates the depth of the case. The hardness is achieved by the formation of nitrides. Nitride forming elements must be present for this method to work; these elements include chromium, molybdenum, and aluminum. The advantage of this process is that it causes little distortion, so the part can be case-hardened after being quenched, tempered and machined. No quenching is done after nitriding.

Carbo-nitriding:

Carbonitriding is similar to cyaniding except a gaseous atmosphere of ammonia and hydrocarbons is used instead of sodium cyanide. If the part is to be quenched, it is heated to 775–885 °C (1,427–1,625 °F); if not, then the part is heated to 649–788 °C (1,200–1,450 °F).

Cyaniding:

Cyaniding is a case-hardening process that is fast and efficient; it is mainly used on low-carbon steels. The part is heated to 871–954 °C (1600–1750 °F) in a bath of sodium cyanide and then is quenched and rinsed, in water or oil, to remove any residual cyanide.

$2NaCN + O_2 \rightarrow 2NaCNO$

$2NaCNO + O_2 \rightarrow Na_2CO_3 + CO + N_2$

$2CO \rightarrow CO_2 + C$

This process produces a thin, hard shell (between 0.25 and 0.75 mm, 0.01 and 0.03 inches) that is harder than the one produced by carburizing, and can be completed in 20 to 30 minutes compared to several hours so the parts have less opportunity to become distorted. It is typically used on small parts such as bolts, nuts, screws and small gears. The major drawback of cyaniding is that cyanide salts are poisonous.

5. CORROSION PREVENTION:

By retarding either the anodic or cathodic reactions the rate of corrosion can be reduced. This can be achieved in several ways:

Conditioning the Metal: This can be sub-divided into two main groups:

(a) Coating the metal, in order to interpose a corrosion resistant coating between metal and environment. The coating may consist of: (i) another metal, e.g. zinc or tin coatings on steel,

(ii) a protective coating derived from the metal itself, e.g. aluminium oxide on “anodised” aluminium,

(iii) organic coatings, such as resins, plastics, paints, enamel, oils and greases. The action of protective coatings is often more complex than simply providing a barrier between metal and environment. Paints may contain a corrosion inhibitor. zinc coating in iron or steel confers cathodic protection.

(b) Alloying the metal to produce a more corrosion resistant alloy, e.g. stainless steel, in which ordinary steel is alloyed with chromium and nickel. Stainless steel is protected by an invisibly thin, naturally formed film of chromium sesquioxide Cr2O3.

Conditioning the Corrosive Environment

(a) Removal of Oxygen By the removal of oxygen from water systems in the pH range 6.5-8.5 one of the components required for corrosion would be absent. The removal of oxygen could be achieved by the use of strong reducing agents e.g. sulphite. However, for open evaporative cooling systems this approach to corrosion prevention is not practical since fresh oxygen from the atmosphere will have continual access.

(b) Corrosion Inhibitors A corrosion inhibitor is a chemical additive, which, when added to a corrosive aqueous environment, reduces the rate of metal wastage. It can function in one of the following ways:
(i) anodic inhibitors – as the name implies an anodic inhibitor interferes with the anodic process.

$$Fe \rightarrow Fe^{++} + 2e^-$$

If an anodic inhibitor is not present at a concentration level sufficient to block off all the anodic sites, localised attack such as pitting corrosion can become a serious problem due to the oxidising nature of the inhibitor which raises the metal potential and encourages the anodic reaction (equation 1). Anodic inhibitors are thus classified as "dangerous inhibitors". Other examples of anodic inhibitors include orthophosphate, nitrite, ferricyanide and silicates.

(ii) cathodic inhibitors – the major cathodic reaction in cooling systems is the reduction of oxygen.

$$\tfrac{1}{2}O_2 + H_2O + 2e \rightarrow 2OH^-$$

There are other cathodic reactions and additives that suppress these reactions called cathodic inhibitors. They function by reducing the available area for the cathodic reaction. This is often achieved by eaction 2(b) precipitating an insoluble species onto the cathodic sites. Zinc ions are used as cathodic inhibitors because of the precipitation of $Zn(OH)_2$ at cathodic sites as a consequence of the localised high pH. Cathodic inhibitors are classed as safe because they do not cause localised corrosion.

(iii) Adsorption type corrosion inhibitors– many organic inhibitors work by an adsorption mechanism. The resultant film of chemisorbed inhibitor is then responsible for protection either by physically blocking the surface from the corrosion environment or by retarding the electrochemical processes. The main functional groups capable of forming chemisorbed bonds with metal surfaces are amino ($-NH_2$), carboxyl (-COOH), and phosphonate ($-PO_3H_2$) although other functional groups or atoms can form co-ordinate bonds with metal surfaces.

(iv) Mixed inhibitors – because of the danger of pitting when using anodic inhibitors alone, it became common practice to incorporate a cathodic inhibitor into formulated performance was obtained by a combination of inhibitors than from the sum of the individual performances. This observation is generally referred to a 'synergism' and demonstrates the synergistic action which exists between zinc and chromate ions.

Electrochemical Control

Since corrosion is an electrochemical process its progress may be studied by measuring the changes which occur in metal potential with time or with applied electrical currents. Conversely, the rate of corrosion reactions may be controlled by passing anodic or cathodic currents into the metal. If, for example, electrons are passed into the metal and reach the metal/electrolyte interface (a cathodic current) the anodic reaction will be stifled while the cathodic reaction rate increases. This process is called cathodic protection and can only be applied if there is a suitable conducting medium such as earth or water through which a current can flow to the metal to be protected In most soils or natural waters corrosion of steel is prevented if the potential of the metal surface is lowered by 300 or 400 mV. Cathodic protection may be achieved by using a DC power supply (impressed current) or by obtaining electrons from the anodic dissolution of a metal low in the galvanic series such as aluminium, zinc or magnesium (sacrificial anodes). Similar protection is obtained when steel is coated with a layer of zinc. Even at scratches or cut edges where some bare metal is exposed the zinc is able to pass protective current through the thin layer of surface moisture.

In certain chemical environments it is sometimes possible to achieve anodic protection, passing a current which takes electrons out of the metal and raises its potential. Initially this stimulates anodic corrosion, but in favourable circumstances this will be followed by the formation of a protective oxidised passive surface film.

6. Protective treatment for aluminum alloys and steel:

(i). Anodizing

- The most popular method of improving corrosion resistance on aluminium is anodisation. It, generally speaking, involves a four step process to achieve protection.
- The first stage of which involves immersing the material in a bath of conductive solution - typically a low pH acid bath - and connecting the alloy to the anode of an electrical circuit. When an electrical current is applied, an oxidation reaction occurs at the metal surface:
- $2Al_{(S)} + 6OH^{-}_{(aq)} - 6e^{-}\ Al_2O_{3(s)} + 3H_2O_{(l)}$
- This causes the natural oxide on the surface metal to thicken, creating a protective outer layer of aluminium oxide. The thickness can be altered through extending the coating time, thus offering a versatile range of applications:
- When applied lightly, it can provide good pretreatment for paint or subsequent coatings
- Specific colour effects can be achieved when dyed
- When applied thinly (typically <20µm), it is translucent which preserves the metallic aesthetic, if so desired.

(ii). PEO:

- Plasma Electrolytic Oxidation (PEO) involves the use of plasma discharges to transform the metallic surface of light metals. It forms an adhesive oxide layer that is both hard and dense.
- Components are immersed in a bath and an electrical current is used to ‘grow’ a uniform layer of oxide on the surface. PEO occurs over a three stage process:
- Oxidation of the substrate (as occurs in the anodising process)
- Co-deposition of the elements from the electrolyte into the coating
- Modification of the resulting layer by plasma discharge
- PEO forms hard, dense and wear-resistant coatings for lightweight metals such as aluminium, titanium and magnesium. When compared directly to anodised coatings, PEO forms coatings with higher hardness, chemical passivity and an advantageous, irregular pore structure that creates high strain tolerance and stronger adhesion.

(iii). Chromate conversion coating:

- Chromate conversion coating as a corrosion resistance technique, even though it’s one of the most effective methods.

- Chromate conversion chemistries do vary widely, but many include the application of chromic acid, sodium, and potassium chromate or dichromate solutions to clean metallic surface along with other additives. The use of such additives causes redox reactions with the surface, leaving a passive film containing chrome (IV) oxide and hydrated compounds on the substrate metal. This provides high corrosion resistance and retains subsequent coatings well.

(iv). Paints

- Surface coating solutions, such as paints, primers and other polymeric systems are seemingly limitless in both presence and variety. The most attractive benefit of working with paints is that they can be coloured, finished or applied in different ways.

- Paints provide a relatively inexpensive method of increasing corrosion resistance. However, the processes involved are highly inefficient; during application, up to 50% of the coating can evaporate and oven curing produces harmful byproducts that are both hazardous and expensive to dispose of at high volume.

(v). Powder coats:

- Powder coatings, much like paints, provide another relatively inexpensive option. Although, the benefits of powder coats are much the same as paints, but thicker protective layers are can be applied more efficiently and at a quicker rate.

- Coatings are thick, which adds bulky layers (usually upwards for 80µm) that substantially increase the corrosion resistance of a material. The cost of this added protection is the thickness added and that produced aesthetic effects are not as attractive and not consistent across material.

7. Anodizing of Titanium:

- Titanium anodizing is an electrolytic finishing process that manipulates the oxide layer on the surface of titanium via electric current. The titanium item forms the anode (positive electrode) of an electrolytic cell; hence the name "anodize."

- Aerospace companies continue to use anodizing processes today to protect metals from effects of aging, wear and corrosion.

Types of Titanium Anodizing

- There are two commonly used types of titanium anodizing: **Type 2** and **Type 3**. Type 1 is far less common, and is used in specialized high-temperature treatments.

Type 2 Titanium anodizing:

- Type 2 is mainly for wear purposes: It protects the metal surface against the effects of wear. When untreated titanium parts rub against each other, they produce titanium dust – a result that is not desirable with orthopedic implants, for example. Type 2 anodizing provides a wear-resistant surface and helps prevent seizing or friction between sliding titanium surfaces.

- The reduced friction, or lubricity, from Type 2 anodized titanium also helps patients with orthopedic implants by improving mobility of joints.

Type 3 Titanium anodizing-color anodizing:

- Type 3 titanium anodizing is also called color anodizing. Type 3 anodizing is widely used in the medical world for quick visual identification of parts. For example, an orthopedic surgeon in mid-procedure can simply ask for a blue bone screw, without having to specify the 12 mm length of the screw.
- Another example of color coding to assist doctors and physicians is bone fixation plates that an orthopedic surgeon uses to treat trauma fractures. These bone fixation plates have drill guides of different colors to indicate the anatomical difference between the left and right plates.
- Type 3 color anodizing is less common in the aerospace industry, but sometimes is used for quick visual identification in complicated assemblies.
- Outside the medical device and aerospace industries, Type 3 colored titanium is also used in jewelry manufacturing.

8. Organic coatings:

Durable protective coating applied to a substance for decorative or specific technical propeeties. The main component responsible for the creation of well adhering film (membrane) are organic compounds: polymers, oligomers, monomers.

- Organic coatings used on steel provide an effective barrier protection by isolating steel from the attacking species.
- Coatings which contain large quantities of metallic zinc provide corrosion protection by galvanic action.
- An important property of a coating is its resistance to water penetration and two related properties are coating dielectric strength and coating resistance to ionic movement.
- Water penetration in coating decreases the dielectric strength, resistivity and makes the coating less insulative.

Types of organic coatings:

1. Primers: Adhesions to the substrate, corrosion protection, paint adhesion.
2. Adhesive cements: material with a suitable consistency coatings used for surfacing.
3. Top coats: with high resistance to external factors.

Varnish: solution of film forming substance in an organic solvent, for example: colorless varnish.

Enamel: solution of film forming substance, pigments (colorants), modifiers additives in an organic solvent.

Paints: solution of film forming substance, pigments (colorants), modifiers, in organic anti corrosion additives in an organic solvent.

The aging of organic coatings:

Changing in the structure of the shell due to external influences resulting in the loss of protective properties of the coating.

The processes of aging are caused by:

- Oxidizing agents (oxygen, ozone)
- High temperature
- Light (UV factors)

Degradation of organic coating:

- There are several types of corrosion found beneath organic coatings and these are blistering, filliform corrosion, rusting, anodic under mining and cathodic delamination.
- Blistering is the one of the first signs of breakdown in the protective nature of the coating.
- Oxygen penetrates through the coating and leaching of ionic materials from the interface.

9. Thermal spraying:

An alternative method of applying a metallic coating to structural steelwork is by thermal (metal) spraying. In this case, either zinc or aluminum can be used. The metal, in powder or wire form, is fed through a special spray gun containing a heat source which can be either an oxy gas flame or an electric arc.

Molten globules of the metal are blown by a compressed air jet onto the previously grit blast cleaned steel surface. No alloying occurs and the coating consists of overlapping platelets of metal and is porous, see figure.

These pores are subsequently sealed, either by applying a thin organic coating which penetrates into the surface or by corrosion products which form during exposure. Sealers may be un-pigmented with colouring agents or aluminium flake. The adhesion of sprayed metal coatings to steel surfaces is considered to be essentially mechanical in nature. It is therefore necessary to apply the coating to a clean roughened surface and blast cleaning with a coarse grit abrasive is normally specified. This would usually be chilled iron grit but for steels with hardness exceeding 360HV alumina or silicon carbide grits may be necessary.

Typically specified coating thicknesses vary between 150-200µm for aluminium and 100-150µm for zinc.

Thermal spray coatings can be applied in the shops or at site and there is no limitation on the size of the workpiece, as there is with hot-dip galvanizing. Since the steel surface remains cool there are no distortion problems. Guidance on the design of articles to be thermally sprayed can be found in BS EN ISO 14713. Thermal spraying is considerably more expensive than hot-dip galvanizing.

For some applications thermal spray coatings are further protected by the subsequent application of paint coatings. This first requires the application of a sealer which fills the pores in the metal spray coating and provides a smooth surface for application of the paint coating. The protection of structural steelwork against atmospheric corrosion by thermal sprayed aluminium or zinc coatings is covered in BS EN 22063.

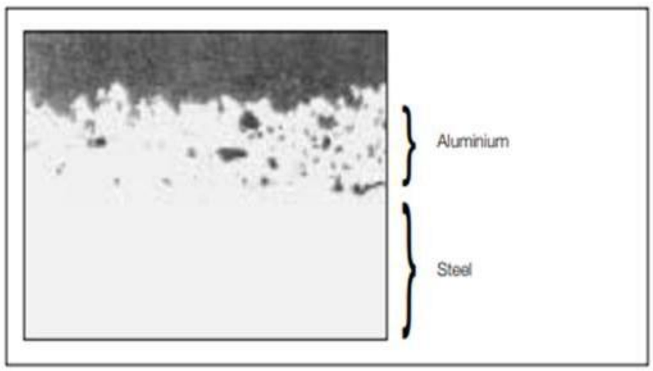


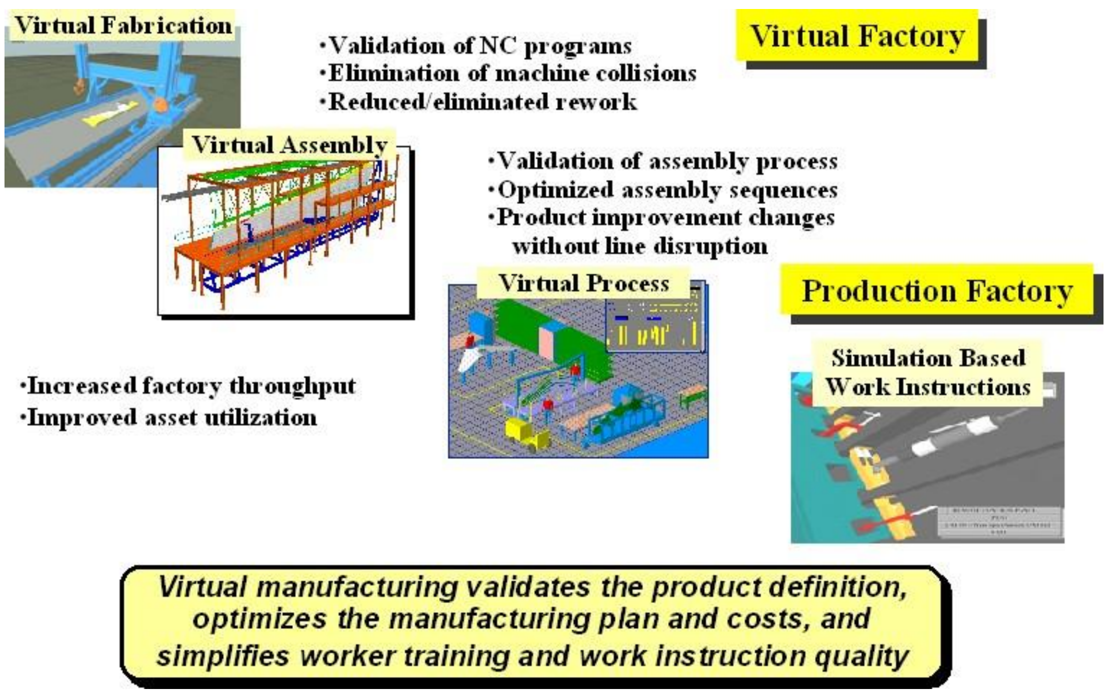
Figure 10
Thermally sprayed coating of aluminium by the electric arc process

UNIT-V

Aircraft Assembly:

The aerospace manufacturing sector is traditionally based on manual operations rather than automation because of the level of accuracy required in assembling aerospace structures. Canadian manufacturers are now realizing that to remain competitive they need to reduce costs by incorporating automation and intelligence into their processes. The NRC Institute for Aerospace Research (NRC Aerospace) is helping Canadian aerospace companies develop and adopt cost-effective, flexible, reconfigurable approaches for aerospace structure assembly using robotics and automation. This will increase the scope of work that aerospace subcontractors can carry out for original equipment manufacturers. Projects are currently underway to develop low cost reconfigurable robotized cells for aircraft component assembly and large-scale machining operations. Virtual manufacturing is also being investigated.

Aircraft Manufacturing Assembly:



Benefits:

- Validates Design/Assembly Integrity Prior to Commitment
- Validates Operation Sequences & Tooling Concepts
- Identifies Assembly Anomalies
- Drives & Validates Design Release Schedule
- Enables Optimization of Assembly Processes
- Reduces Downstream Production Planning (Assembly)
- Creates Consistent Virtual/Simulation Based Work Instructions
- Captures Best Assembly Practices

1. Fixture:

• A Fixture is a *special tool* used for

– Locating the work,

– Clamping the work,
– Supporting the work,
– Holding all the elements together in a rigid unit during a manufacturing operation.
• The most important considerations are:
Accuracy and *rigidity*, followed by *ease of use,* and *economy in construction.*

2. Jig:

A Jig is a type of Fixture with means for positively guiding and supporting tools.
For both Jigs & Fixtures:
– Origin: traced back to Swiss watch and clock industry!
– Objective: to provide *interchangeability*, *reduction of cost*, and *accuracy* of the manufactured Individual detail Parts, Sub-assemblies, Sections, or main components, and finally the complete structure.

Advantages:

• Ensure the interchangeability and accuracy of parts manufactured,
• Minimize the possibility of human error,
• Permit the use of medium-skilled labor,
• Reduce the manufacturing time,
• Allow the production of repeat orders without retooling.

Types:

• Assembly Fixtures,
• Machining Jigs & Fixtures,
• Drilling Jigs, boring Jigs, etc.
• Welding Fixtures,
• Trim Jigs,
• Control or Master Jig,
• Apply Jig; attaching to a larger jig or an assembly of parts, etc. ...

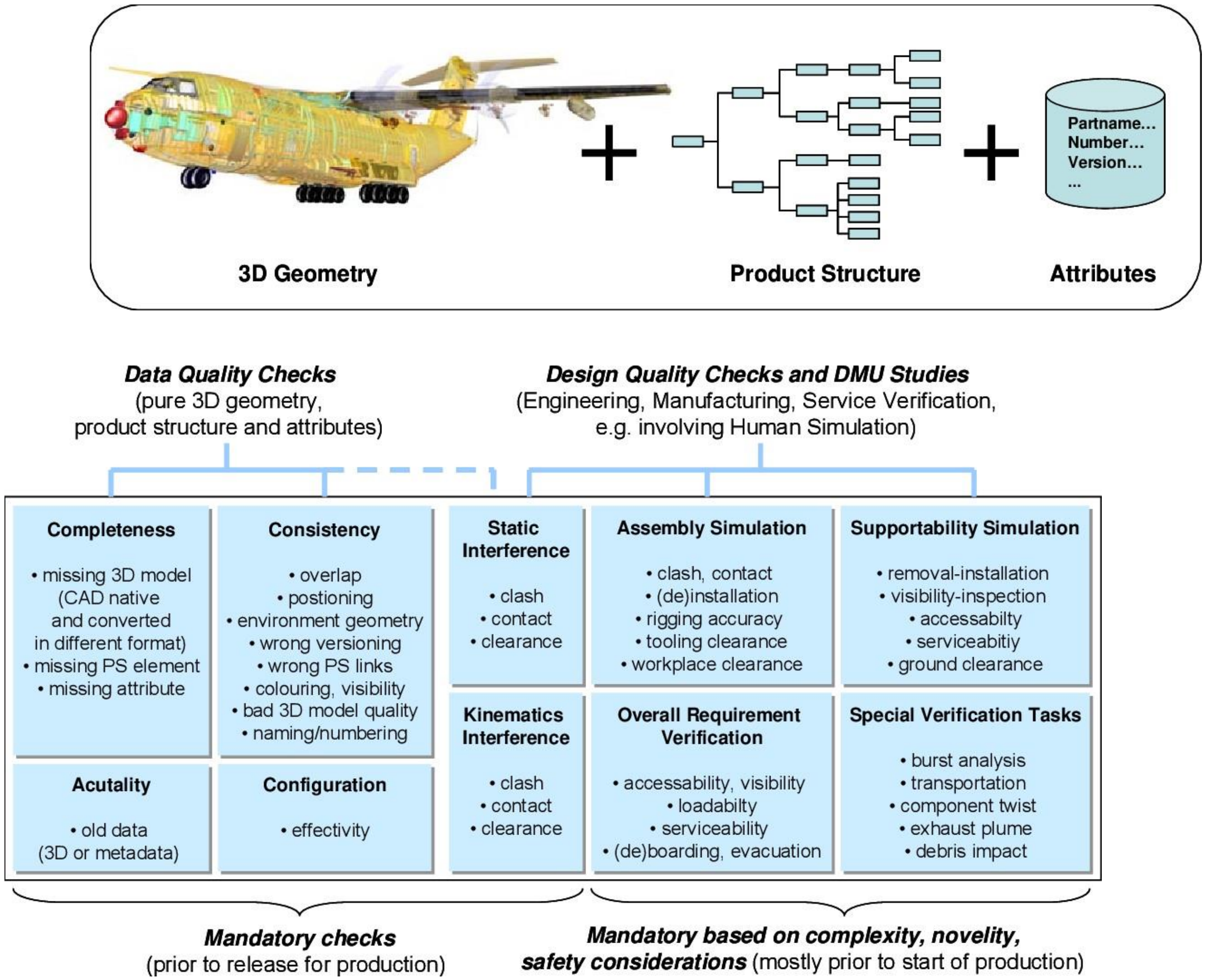
Step-by-Step Procedure for Jigs & Fixtures:

For every part of structure,
• A *mockup* is first designed and is made from material such as wood, plaster, etc.,…
• The mockup is used to design and to build the fixtures ensuring the contours and the external form of the structure,
• The *Master Jig* is then designed in order to complete the fixture providing the important reference points, Jig and pinpoints, and to provide a Reference for the regular checks of the fixture,
• Thermal expansion of fixtures is important.

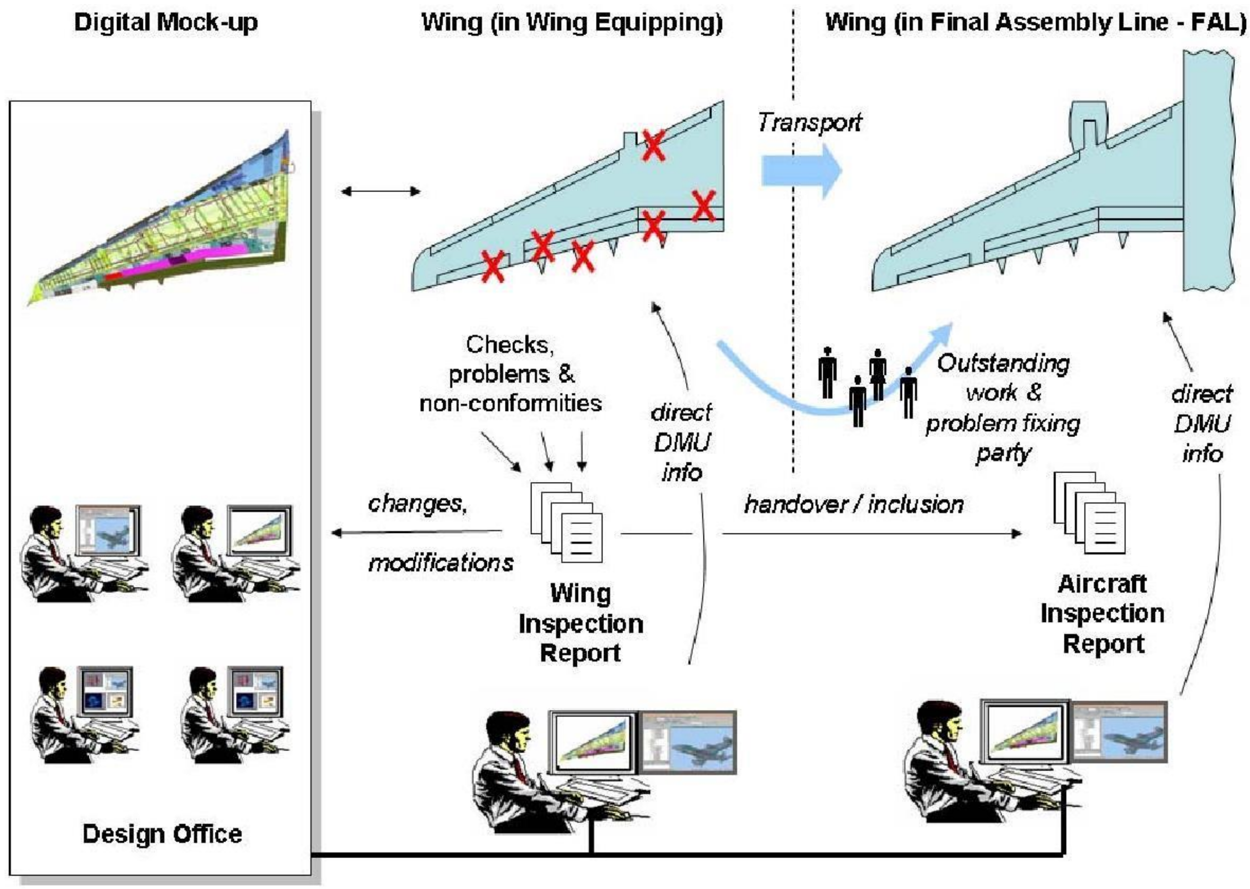
3. Aircraft Tooling

In the engineering industry a tool is defined as an instrument or device used for the manufacture of a product economically and to maintain quality. Tools are broadly classified as

1. **Machine tools**/production equipment used for manufacture.
   Ex: Lathe, Milling m/c, presses, welding equipment, heat treatment furnaces. Process baths, material testing equipment, quality control.
2. **Standard Tools** which are not specified to a particular product, such as hand tools/ gauges and cutters etc.
3. **Project related tools** are tools related to a specific product.

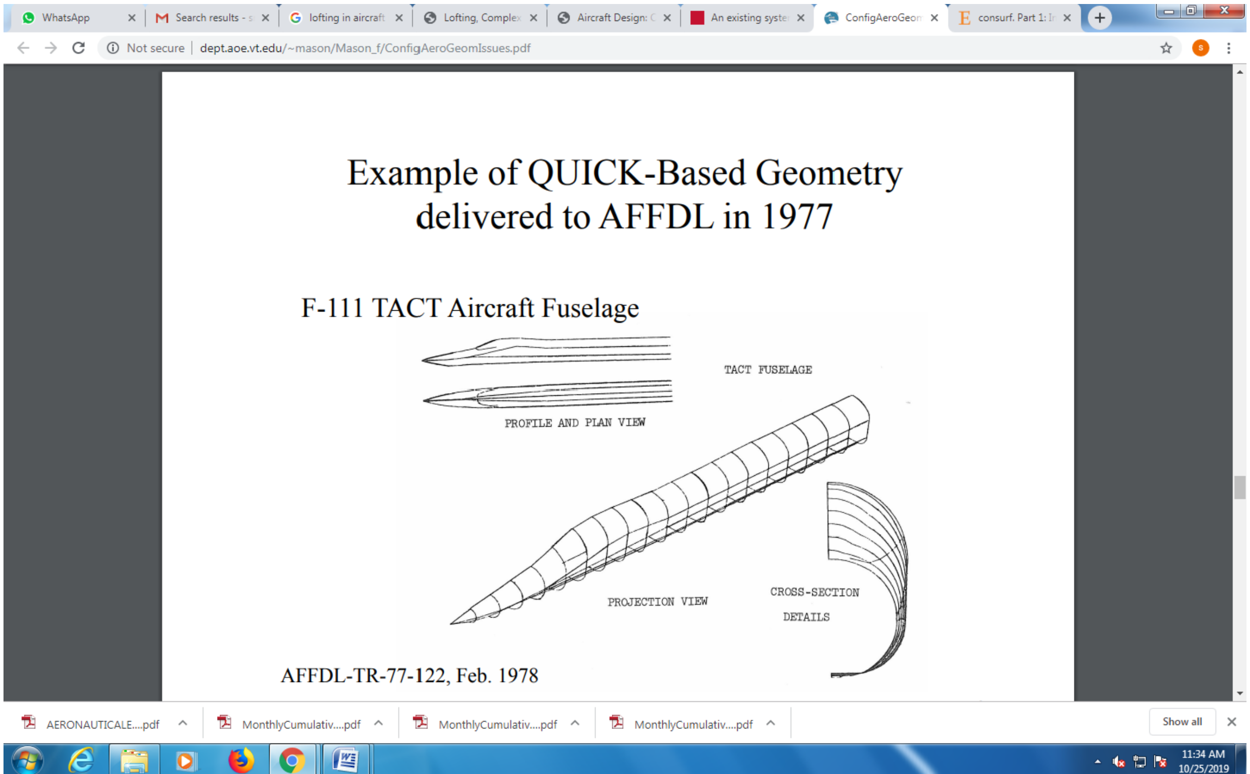


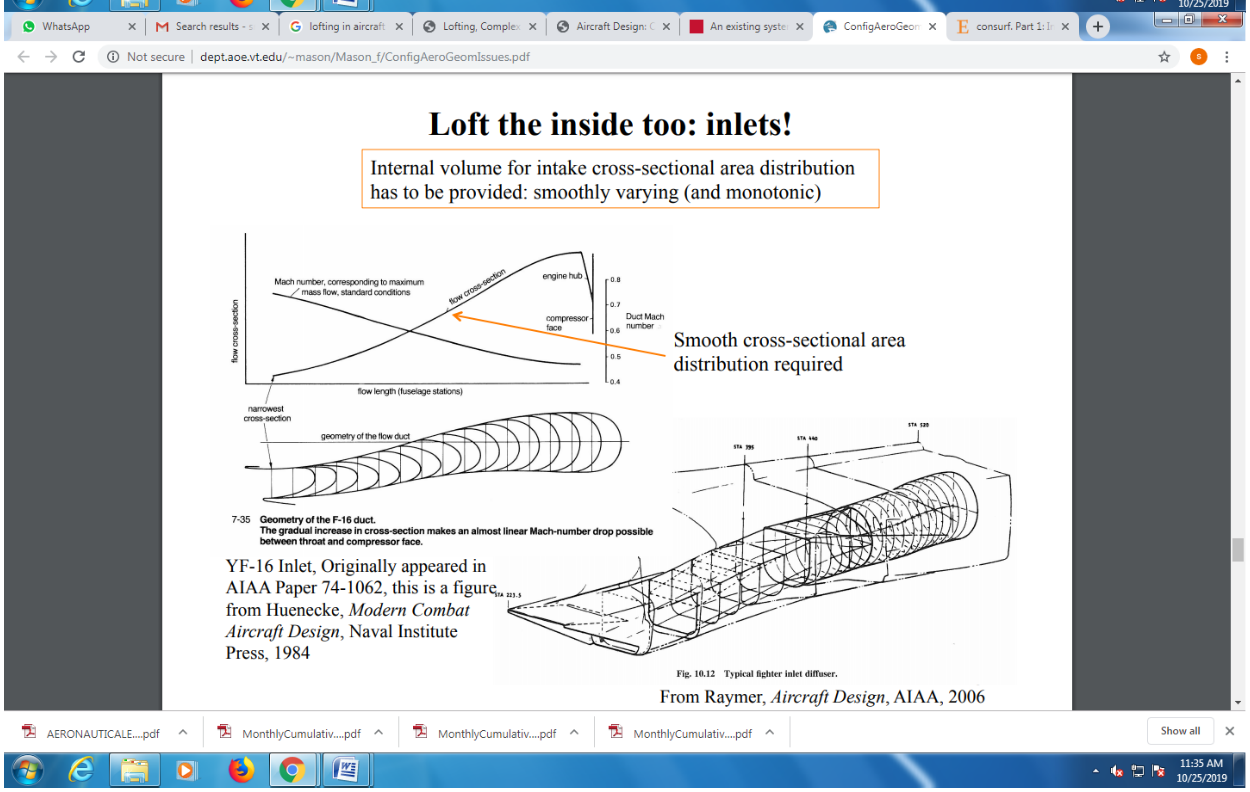
3D Geometry
Product Structure
Partname...
Number...
Version...
...
Attributes
Data Quality Checks
(pure 3D geometry, product structure and attributes)
Design Quality Checks and DMU Studies
(Engineering, Manufacturing, Service Verification, e.g. involving Human Simulation)
Completeness
• missing 3D model (CAD native and converted in different format)
• missing PS element
• missing attribute
Consistency
• overlap
• postioning
• environment geometry
• wrong versioning
• wrong PS links
• colouring, visibility
• bad 3D model quality
• naming/numbering
Acutality
• old data (3D or metadata)
Configuration
• effectivity
Static Interference
• clash
• contact
• clearance
Kinematics Interference
• clash
• contact
• clearance
Assembly Simulation
• clash, contact
• (de)installation
• rigging accuracy
• tooling clearance
• workplace clearance
Overall Requirement Verification
• accessability, visibility
• loadabilty
• serviceability
• (de)boarding, evacuation
Supportability Simulation
• removal-installation
• visibility-inspection
• accessabilty
• serviceabitiy
• ground clearance
Special Verification Tasks
• burst analysis
• transportation
• component twist
• exhaust plume
• debris impact
Mandatory checks
(prior to release for production)
Mandatory based on complexity, novelity, safety considerations (mostly prior to start of production)



Classification of project related tools:

i. **Basic Tools:** the basic tools are not directly used for production of the aircraft components but are used for developing detail tools, assembly tools and interchangeability media. Tools such as lofts, master templates, master models/ mock ups, master parts/ red banded samples.





ii. **Detail Tools:** Which are used for fabricating detail parts in the manufacturing shops such as turning fixtures, milling fixtures, drill jigs, special cutters etc.

iii. **Assembly tools:** which are used for assembly and joining of components, such as jigs and fixtures.
iv. **Interchangeability Media:** tools such as control and tool master gauges and checking gauges.
v. **Test Equipment:** Used for testing proper functioning of aircraft systems. This includes both standard and non standard equipment.
vi. **Ground Handling Equipment:** such as slings, trestles, stands, jacks, tow bars for handling, moving and support of aircraft components and complete aircraft.

Applications

Various projects are currently underway related to development of low-cost reconfigurable robotized cells for aircraft component assembly. NRC Aerospace experts are working with Bombardier Aerospace on the design of a fully integrated vision system for drilling sequence and panel inspection, and design of robotized cell auxiliary hardware components.

4. Rivet & Its Types:

Aircraft raw materials come in different but limited sizes due to manufacturing limitations as well as economical distribution. The designer has to choose materials which are available, can be transported to the manufacturing facility (even the homebuilder's basement or garage), can be cut to required sizes with the minimum tools, and can be handled without causing too many rejects due to mishandling ... and still end up with an aircraft of appreciable size, adequate strength and good looks. Aircraft can't just be made out of one big sheet of material and "wrapped together." Rather, various parts have to be formed out of different types of material and joined together. Each of those parts carries a load and the fastener that brings these parts together has to carry the load from one part to the other. If we have, for example, 1,000 lbs. to be carried over from one skin to another, we can choose various ways of achieving this (see figure 1).

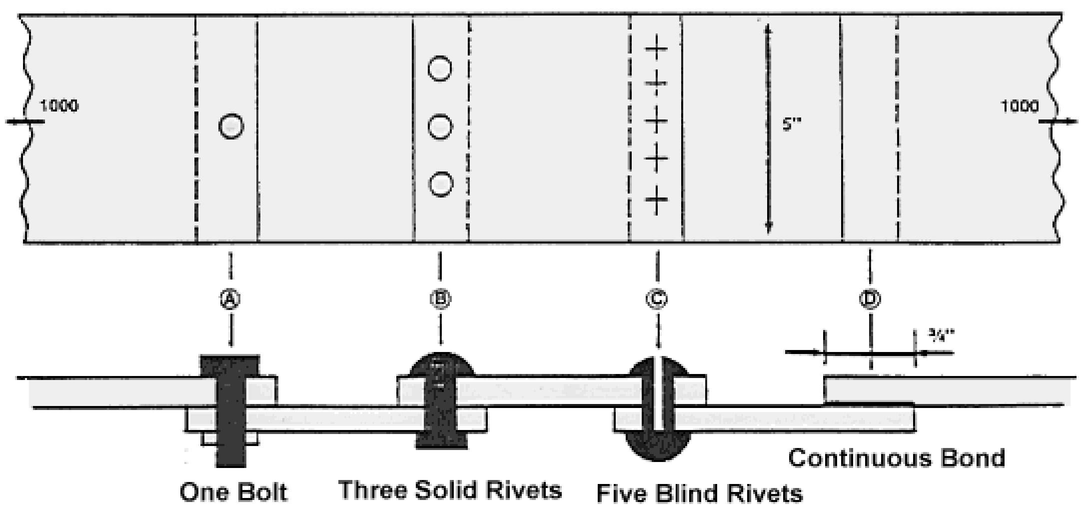


Fig. 1

The designer of an aircraft chooses the solutions best adapted to the materials used - a continuous joint with wood and composites, a single bolt or heavy (thick) fittings with steel; or riveted joints on relatively light gauge materials and/or when the joints are long (to avoid the weight penalty of many steel bolts).

For over 50 years, riveted aluminum structures have been very successful, and are found to varying degrees on virtually all aircraft (whether the complete airframe or just an instrument panel). They do not fail under static or repeated loads and they do not corrode if the rivets are well chosen and properly set.

How to set the rivets correctly can be learned quite easily and should be explained by the designer when he sells drawings or kits to build an aluminum aircraft. The choice of rivets is very simple: only 2017 alloy rivets are commercially readily available (these are the "AD" rivets mentioned in earlier columns). They have good corrosion resistance and are compatible with 2024 and 6061 materials.

Now, let's look at why they are also a good structural fastener. (See figure 2). First the hole is drilled slightly oversized (via the use of number drills) so that the rivet can easily be introduced after deburring (see Figure 2, item E).

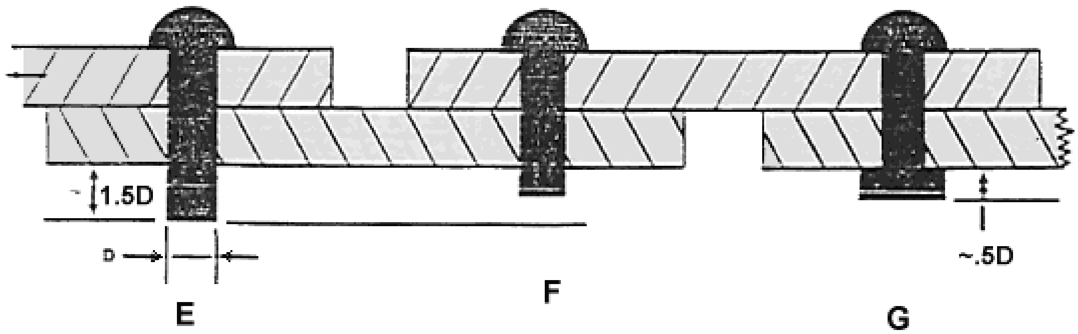


Fig. 2

But it also has some drawbacks:

1. You need special equipment (you'll need to buy an air compressor, rivet gun(s), rivet snaps and bucking bars);
2. You need some expertise and prior practice (you'll need a good teacher for this - errors can be costly in more ways than one);
3. It is noisy (your family and neighbors may object to your setting rivets in your basement or garage after 10 p.m. or on Sunday morning . . . and that is just when you have the time for it);
4. You need access to both sides of the parts to be assembled (and this is obviously not always easy or possible: How will you get the bucking bar inside an aileron of a small aircraft?). You'll often need a helper to "buck" the rivet on the other side, or have long skinny arms and/or a full assortment of bucking bars.

Types

There are a number of types of rivets, designed to meet different cost, accessibility, and strength requirements:

Solid rivets

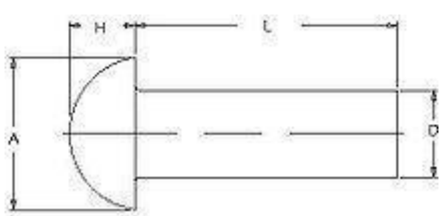


Figure3: Universal head solid rivet

Solid rivets are one of the oldest and most reliable types of fasteners, having been found in archaeological findings dating back to the Bronze Age. Solid rivets consist simply of a shaft and head which are deformed with a hammer or rivet gun. The use of a rivet compression or crimping tool can also be used to deform this type of rivet; this tool is mainly used on rivets close to the edge of the fastened material, since the tool is limited by the depth of its frame. A rivet compression tool does not require two people and is generally the most foolproof way to install solid rivets.

Solid rivets are used in applications where reliability and safety count. A typical application for solid rivets can be found within the structural parts of aircraft. Hundreds of thousands of solid rivets are used to assemble the frame of a modern aircraft. Such rivets come with rounded (universal) or 100° countersunkheads. Typical materials for aircraft rivets are aluminium alloys (2017, 2024, 2117, 7050, 5056, 55000, V-65), titanium, and nickel-based alloys (e.g. Monel). Some aluminum alloy rivets are too hard to buck and must be softened by annealing prior to being bucked. "Ice box" aluminum alloy rivets harden with age, and must likewise be annealed and then kept at sub-freezing temperatures (hence the name "ice box") to slow the age-hardening process. Steel rivets can be found in static structures such as bridges, cranes, and building frames.

The setting of these fasteners requires access to both sides of a structure. Solid rivets are driven using a hydraulically, pneumatically, or electromagnetically driven squeezing tool or even a handheld hammer. Applications in which only one side is accessible require the use of blind rivets.

Semi-tubular rivets

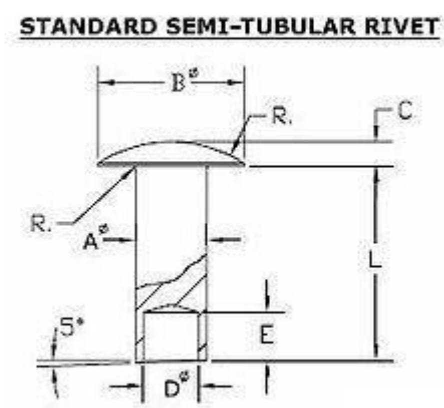


Figure4: Oval head semi-tubular rivet

Semi-tubular rivets (also known as tubular rivets) are similar to solid rivets, except they have a partial hole (opposite the head) at the tip. The purpose of this hole is to reduce the amount of force needed for application by rolling the tubular portion outward. The force needed to apply a semitubular rivet is about 1/4 of the amount needed to apply a solid rivet. Tubular rivets can also be used as pivot points (a joint where movement is preferred) since the swelling of the rivet is only at the tail. Solid rivets expand radially and generally fill the hole limiting movement. The type of equipment used to apply semi-tubular rivets range from prototyping tools (less than $50) to fully automated systems. Typical installation tools (from lowest to highest price) are hand set, manual squeezer, pneumatic squeezer, kick press, impact riveter, and finally PLC-controlled robotics. The most common machine is the impact riveter and the most common use of semitubular rivets is in lighting, brakes, ladders, binders, HVAC duct work, mechanical products, and electronics. They are offered from 1/16-inch (1.6 mm) to 3/8-inch (9.5 mm) in diameter (other sizes are considered highly special) and can be up to 8 inches (203 mm) long. A wide variety of materials and platings are available, most common base metals are steel, brass, copper, stainless, aluminum and most common platings are zinc, nickel, brass, tin. All tubular rivets are waxed to facilitate proper assembly. The finished look of a tubular rivet will have a head on one side, with a rolled over and exposed shallow blind hole on the other. Semi-tubular rivets are the fastest way to rivet in mass production but require a capital investment.

Blind rivets

Figure5: Three aluminium blind rivets: 1/8", 3/32", and 1/16"

Blind rivets are tubular and are supplied with a mandrel through the center. The rivet assembly is inserted into a hole drilled through the parts to be joined and a specially designed tool is used to draw the mandrel into the rivet. This expands the blind end of the rivet and then the mandrel snaps off. (A **POP rivet** is a brand name for blind rivets sold by Emhart Teknologies.) These types of blind rivets have non-locking mandrels and are avoided for critical structural joints because the mandrels may fall out, due to vibration or other reasons, leaving a hollow rivet that will have a significantly lower load carrying capability than solid rivets. Furthermore, because of the mandrel they are more prone to failure from corrosion and vibration. Unlike solid rivets, blind rivets can be inserted and fully installed in a joint from only one side of a part or structure, "blind" to the opposite side.

Prior to the adoption of blind rivets, installation of a solid rivet typically required two assemblers: one person with a rivet hammer on one side and a second person with a bucking bar on the other side. Seeking an alternative, inventors such as Carl Cherry and Lou Huck experimented with other techniques for expanding solid rivets. The blind rivet was developed by the United Shoe Machinery Corporation.

Due to this feature, blind rivets are mainly used when access to the joint is only available from one side. The rivet is placed in a pre-drilled hole and is set by pulling the mandrel head into the rivet body, expanding the rivet body and causing it to flare against the reverse side. As the head of the mandrel reaches the face of the blind side material, the pulling force is resisted, and at a predetermined force, the mandrel will snap at its break point, also called "Blind Setting". A tight joint formed by the rivet body remains, the head of the mandrel remains encapsulated at the blind side, although variations of this are available, and the mandrel stem is ejected.

Most blind rivets have limited use on aircraft and are never used for structural repairs. However, they are useful for temporarily lining up holes. In addition, some "home built" aircraft use blind rivets. They are available in flat head, countersunk head, and modified flush head with standard diameters of 1/8, 5/32 and 3/16 inch. Blind rivets are made from soft aluminum alloy, steel, copper, and Monel.

Drive rivet

A drive rivet is a form of blind rivet that has a short mandrel protruding from the head that is driven in with a hammer to flare out the end inserted in the hole. This is commonly used to rivet wood panels into place since the hole does not need to be drilled all the way through the panel, producing an aesthetically pleasing appearance. They can also be used with plastic, metal, and other materials and require no special setting tool other than a hammer and possibly a backing block (steel or some other dense material) placed behind the location of the rivet while hammering it into place. Drive rivets have less clamping force than most other rivets.

Flush rivet

A flush rivet is used primarily on external metal surfaces where good appearance and the elimination of unnecessary aerodynamic drag are important. A flush rivet takes advantage of a countersink hole, they are also commonly referred to as countersunk rivets. Countersunk or flush rivets are used extensively on the exterior of aircraft for aerodynamic reasons. Additional post-installation machining may be performed to perfect the airflow.

Friction-lock rivet

One early form of blind rivet that was the first to be widely used for aircraft construction and repair was the Cherry friction-lock rivet. Originally, Cherry friction-locks were available in two styles, hollow shank pull-through and self-plugging types. The pull-through type is no longer common, however, the self -plugging Cherry friction-lock rivet is still used for repairing light aircraft.
Cherry friction-lock rivets are available in two head styles, universal and 100 degree countersunk. Furthermore, they are usually supplied in three standard diameters, 1/8, 5/32 and 3/16 inch.

A friction-lock rivet cannot replace a solid shank rivet, size for size. When a friction-lock is used to replace a solid shank rivet, it must be at least one size larger in diameter.the reason behind this is that friction-lock rivet loses considerable strength if its center stem falls out due to vibrations or damage.

5. **Bolted joints** are one of the most common elements in construction and machine design. They consist of fasteners that capture and join other parts, and are secured with the mating of screw threads.

- There are two main types of bolted joint designs: tension joints and shear joints.
- In the tension joint, the bolt and clamped components of the joint are designed to transfer an applied tension load through the joint by way of the clamped components by the design of a proper balance of joint and bolt stiffness. The joint should be designed such that the clamp load is never overcome by the external tension forces acting to separate the joint. If the external tension forces overcome the clamp load (bolt preload) the clamped joint components will separate, allowing relative motion of the components.
- The second type of bolted joint transfers the applied load in shear of the bolt shank and relies on the shear strength of the bolt. Tension loads on such a joint are only incidental. A preload is still applied but consideration of joint flexibility is not as critical as in the case where loads are transmitted through the joint in tension. Other such shear joints do not employ a preload on the bolt as they are designed to allow rotation of the joint about the bolt, but use other methods of

maintaining bolt/joint integrity. Joints that allow rotation include clevis linkages, and rely on a locking mechanism (like lock washers, thread adhesives and lock nuts).

- Anchor Bolts
- Blind Bolts
- Carriage Bolts
- Double End Bolts
- Eye Bolts
- Hex Bolts
- Machine Bolts
- Penta-Head Bolts
- Round Head Bolts
- Shoulder Bolts
- Socket Head Bolts
- T-Head Bolts
- U-Bolts

- Aircraft bolts are fabricated from cadmium- or zincplated **corrosion** resistant steel, unplated **corrosion** resistant steel, or anodized aluminum alloys. Most bolts used in aircraft structures are either general purpose, AN bolts, or NAS internal wrenching or close **tolerance bolts**, or MS bolts.

- AN bolts come in three head styles—hex head, clevis, and eyebolt. NAS bolts are available in hex head, internal wrenching, and countersunk head styles. MS bolts come in hex head and internal wrenching styles.

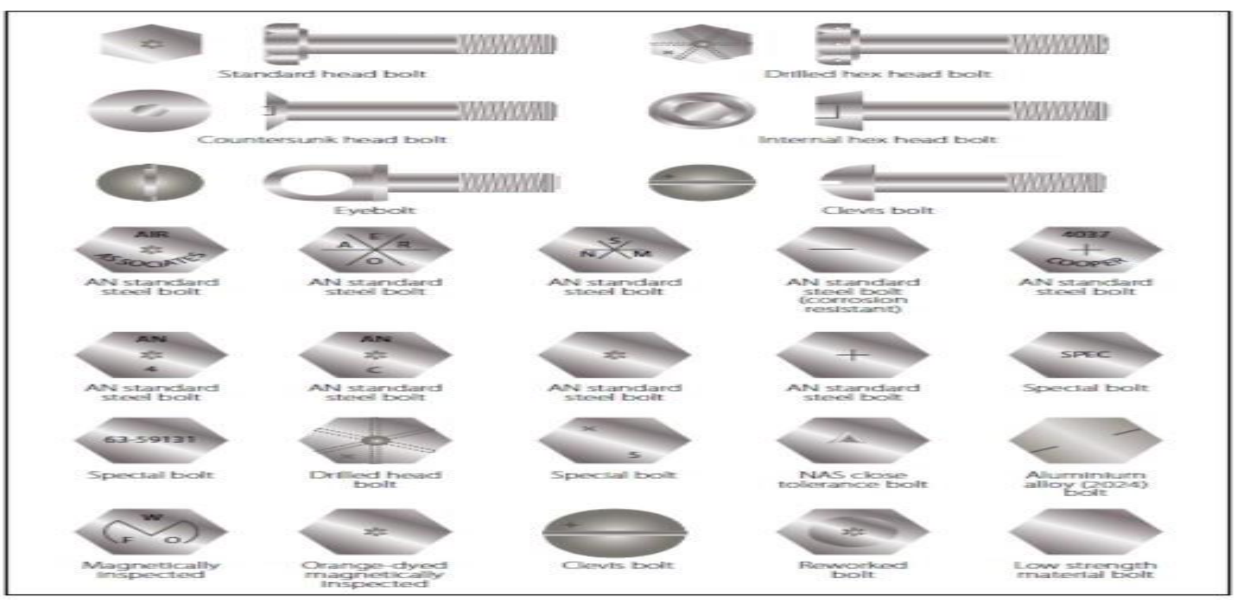


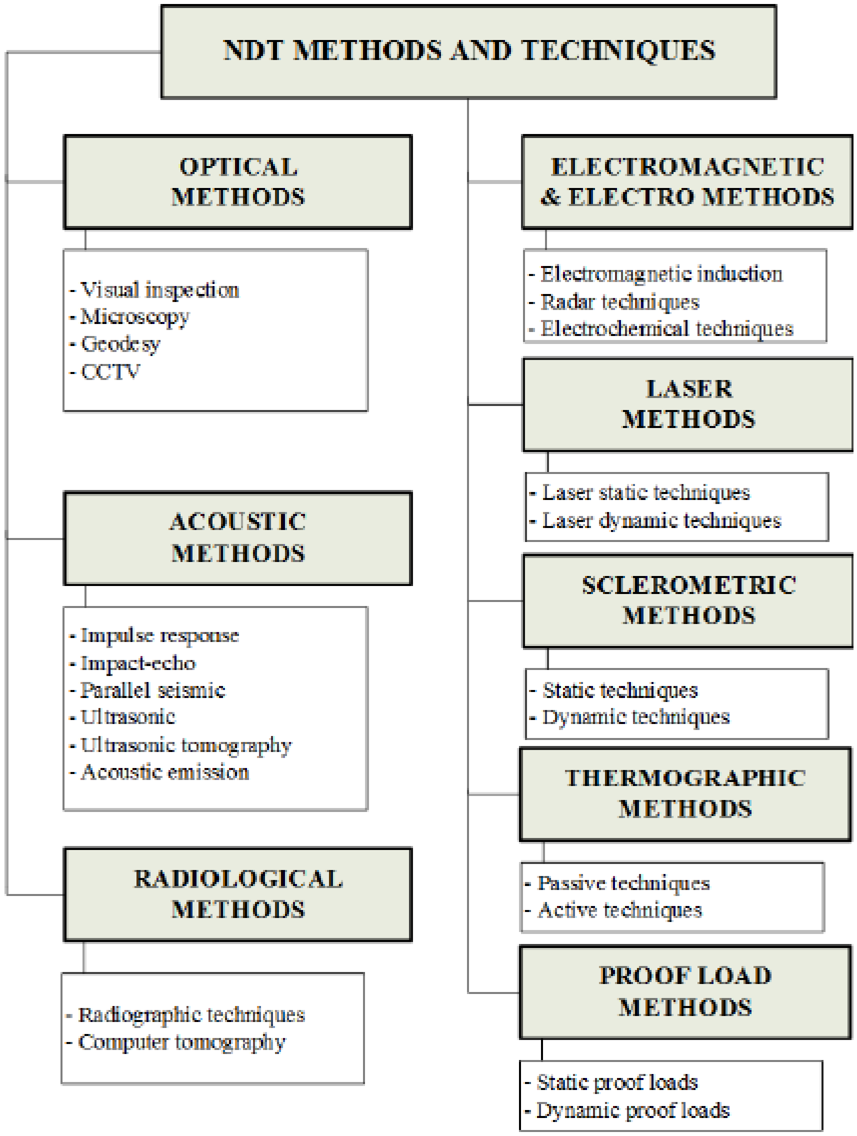
Figure 5-19. Aircraft bolt identification.

NDT

DIFFERENCE BETWEEN DESTRUCTIVE AND NON DESTRUCTIVE TEST

NON DESTRUCTIVE TEST	DESTRUCTIVE TEST
Used for finding out defects of materials	Used for finding out the properties of the material
Load is not applied on the material	Load is applied on the material
No load applications, so no chance for material damage	Due to load application, material gets damaged
No requirement of special equipments	Special equipments are required
Non expensive	Expensive
Less skill	Skill is required
e.g: dye penetrate test, ultrasonic, radiography, etc	e.g: tensile test, compression test, hardness test, etc

Destructive Testing DT		Non Destructive Testing	
Benefits	Limitation	Benefits	Limitation
Reliable and accurate data from the test specimen	Data applies only to the specimen being examined	The part is not altered and can be used after testing	It is usually quite operator dependent
Extremely useful data for design purposes	Most destructive test specimens cannot be used once the test is complete	Every item of the material can be examined with no adverse consequences	Some methods do not provide permanent records of the examination
Data achieved through DT usually quantitative	Require large, expensive equipment and a laboratory	Materials can be examined internal and externally	Orientation of discontinuities must be considered
Various service conditions are capable of being measured		Parts can be examined while in service	Evaluation of some test results are subject to dispute
Information can be used to establish standards		Portable and can be taken to the object to be examined	can be expensive *i.e.* radiography
		NDT is cost effective, overall	Defined procedures that have been quali-



1. Dye Penetrant Inspection:

What is Dye Penetrant Inspection?

Dye Penetrant Inspection (DPI), also called Liquid Penetrant Inspection (LPI) or Penetrant Testing (PT), is one of the oldest and simplest NDT methods where its earliest versions (using kerosene and oil mixture) dates back to the 19th century .Liquid penetrant inspection is used to detect any surface-connected discontinuities such as cracks from fatigue, quenching, and grinding, as well as fractures, porosity, incomplete fusion, and flaws in joints.

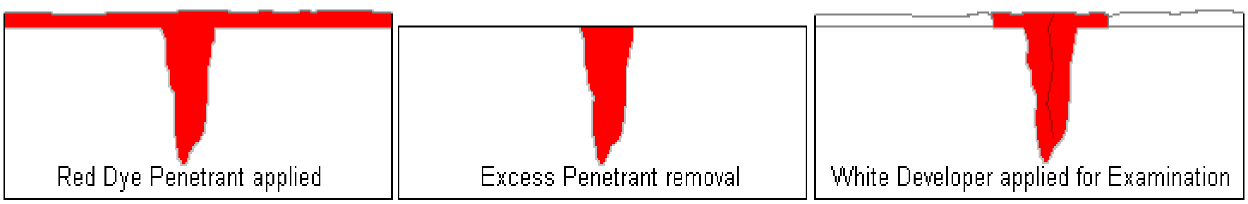
Principles

DPI is based upon capillary action, where low surface tension fluid penetrates into clean and dry surface-breaking discontinuities. Penetrant may be applied to the test component by dipping, spraying, or brushing. After adequate penetration time has been allowed, the excess penetrant is removed, a developer is applied. The developer helps to draw penetrant out of the flaw where an invisible indication becomes visible to the inspector. Inspection is performed under ultraviolet or white light, depending upon the type of dye used - fluorescent or nonfluorescent (visible).

Materials

Penetrants are classified into sensitivity levels. Visible penetrants are typically red in color, and represent the lowest sensitivity. Fluorescent penetrants contain two or more dyes that fluoresce when excited by ultraviolet (UV-A) radiation (also known as black light). Since Fluorescent penetrant inspection is performed in a darkened environment, and the excited dyes emit brilliant yellow-green light that contrasts strongly against the dark background, this material is more sensitive to defects.

When selecting a sensitivity level one must consider many factors, including the environment under which the test will be performed, the surface finish of the specimen, and the size of defects sought. One must also assure that the test chemicals are compatible with the sample so that the examination will not cause permanent staining, or degradiation. This technique can be quite portable, because in its simplest form the inspection requires only 3 aerosol spray cans, some lint free cloths, and adequate visible light. Stationary systems with dedicated application, wash, and development stations, are more costly and complicated, but result in better sensitivity and higher samples through-put.



Inspection steps

1. **PRE-CLEANING:**
   The test surface is cleaned to remove any dirt, paint, oil, grease or any loose scale that could either keep penetrant out of a defect, or cause irrelevant or false indications. Cleaning methods may include solvents, alkaline cleaning steps, vapor °reasing, or media blasting. The end goal of this step is a clean surface where any defects present are open to the surface, dry, and free of contamination. Note that if media blasting is used, it may "work over" small discontinuities in the part, and an etching bath is recommended as a post-blasting treatment.

2. **APPLICATION OF PENETRANT:**
   The penetrant is then applied to the surface of the item being tested. The penetrant is allowed "dwell time" to soak into any flaws (generally 5 to 30 minutes). The dwell time mainly depends upon the penetrant being used, material being tested and the size of flaws sought. As expected, smaller flaws require a longer penetration time. Due to their incompatible nature one must be careful not to apply solvent-based penetrant to a surface which is to be inspected with a water-washable penetrant.

3. **EXCESS PENETRANT REMOVAL:**
   The excess penetrant is then removed from the surface. The removal method is controlled by the type of penetrant used. Water-washable, solvent-removable, lipophilic post-emulsifiable, or hydrophilic post-emulsifiable are the common choices. Emulsifiers represent the highest

sensitivity level, and chemically interact with the oily penetrant to make it removable with a water spray. When using solvent remover and lint-free cloth it is important to not spray the solvent on the test surface directly, because this can remove the penetrant from the flaws. If excess penetrant is not properly removed, once the developer is applied, it may leave a background in the developed area that can mask indications or defects. In addition, this may also produce false indications severely hindering your ability to do a proper inspection.

4. **APPLICATION OF DEVELOPER:**
After excess penetrant has been removed a white developer is applied to the sample. Several developer types are available, including: non-aqueous wet developer, dry powder, water suspendable, and water soluble. Choice of developer is governed by penetrant compatibility (one can't use water-soluble or suspendable developer with water-washable penetrant), and by inspection conditions. When using non-aqueous wet developer (NAWD) or dry powder, the sample must be dried prior to application, while soluble and suspendable developers are applied with the part still wet from the previous step. NAWD is commercially available in aerosol spray cans, and may employ acetone, isopropyl alcohol, or a propellant that is a combination of the two. Developer should form a semi-transparent, even coating on the surface. The developer draws penetrant from defects out onto the surface to form a visible indication, commonly known as bleed-out. Any areas that bleed-out can indicate the location, orientation and possible types of defects on the surface. Interpreting the results and characterizing defects from the indications found may require some training and/or experience.

5. **INSPECTION:**
The inspector will use visible light with adequate intensity (100 foot-candles or 1100 lux is typical) for visible dye penetrant. Ultraviolet (UV-A) radiation of adequate intensity (1,000 micro-watts per centimeter squared is common), along with low ambient light levels (less than 2 foot-candles) for fluorescent penetrant examinations. Inspection of the test surface should take place after 10 to 30 minute development time, depends of product kind. This time delay allows the blotting action to occur. The inspector may observe the sample for indication formation when using visible dye. It is also good practice to observe indications as they form because the characteristics of the bleed out are a significant part of interpretation characterization of flaws.

6. **POST CLEANING:**
The test surface is often cleaned after inspection and recording of defects, especially if post-inspection coating processes are scheduled.

Advantages and Disadvantages

The primary advantages and Disadvantages when compared to other NDT methods are:

ADVANTAGES

- High sensitivity (small discontinuities can be detected).
- Few material limitations (metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected).
- Rapid inspection of large areas and volumes.
- Suitable for parts with complex shapes.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Portable (materials are available in aerosol spray cans)
- Low cost (materials and associated equipment are relatively inexpensive)

DISADVANTAGES

- Only surface breaking defects can be detected.
- Only materials with a relatively nonporous surface can be inspected.
- Pre-cleaning is critical since contaminants can mask defects.
- Metal smearing from machining, grinding, and grit or vapor blasting must be removed.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed and controlled.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling and proper disposal is required.

2. X-Ray

Industrial radiography is a modality of non-destructive testing that uses ionizing radiation to inspect materials and components with the objective of locating and quantifying defects and degradation in material properties that would lead to the failure of engineering structures. It plays an important role in the science and technology needed to ensure product quality and reliability.

Industrial Radiography uses either X-rays, produced with X-ray generators, or gamma rays generated by the natural radioactivity of sealed radionuclide sources. After crossing the specimen, photons are captured by a detector, such as a silver halide film, a phosphor plate, flat panel detector or CdTe detector. The examination can be performed in static 2D (named radiography), in real time 2D, (fluoroscopy) or in 3D after image reconstruction (computed tomography or CT). It is also possible to perform tomography nearly in real time (4-dimensionnal computed tomography or 4DCT). Particular techniques such as X-ray fluorescence (XRF), X-ray diffractometry (XRD), and several other ones complete the range of tools that can be used in industrial radiography.

Inspection techniques can be portable or stationary. Industrial radiography is used in welding, casting parts or composite pieces inspection, in food inspection and luggage control, in sorting and recycling, in EOD and IED analysis, aircraft maintenance, ballistics, turbine inspection, in surface characterisation, coating thickness measurement, in counterfeit drug control, ...

X- Ray generators

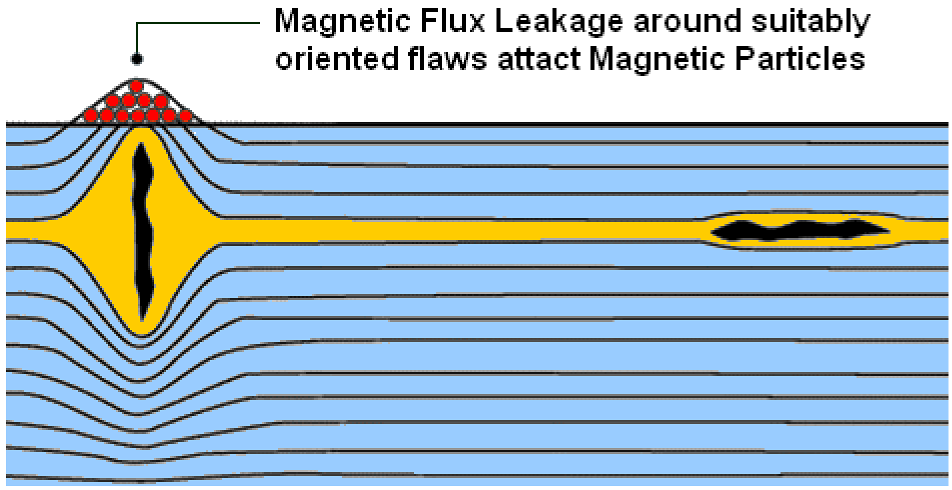
X-ray generators produce X-rays by applying a high voltage between the cathode and the anode of an X-ray tube and in heating the tube filament to start the electron emission. The electrons are then accelerated in the resulting electric potential and collide with the anode, which is usually made of Tungsten

The X-ray that are emitted by this generator are directed towards the object to control. They cross it and are absorbed according to the object material's attenuation coefficient. The attenuation coefficient is compiled from all the cross sections of the interactions that are happening in the material. The three most important inelastic interactions with X-rays at those energy levels are the photoelectric effect, compton scattering and pair production. After having crossed the object, the photons are captured by a detector, such as a silver halide film, a phosphor plate or flat panel detector. When an object is too thick, too dense, or its effective atomic number is too high, a linac can be used. They work in a similar way to produce X-rays, by electron collisions on a metal anode; the difference is that they use a much more complex method to accelerate them.

Petroleum, automotive, aerospace and other vital industries perform testing on metal components and structures before putting them into service. Aside from x ray testing, they might also perform ultrasonic inspection, dye penetrant testing and magnetic particle inspection. Each of these methods has their own weaknesses and strengths.

3. Magnetic particle inspection:

- Magnetic particle inspection (often abbreviated MT or MPI) is a nondestructive inspection method that provides detection of linear flaws located at or near the surface of ferromagnetic materials. It is viewed primarily as a surface examination method.
- Magnetic Particle Inspection (MPI) is a very effective method for location of surface breaking and slight sub-surface defects such as cracking, pores, cold lap, lack of sidewall fusion in welds etc in magnetic materials.
- There are many different techniques. The most versatile technique is using a 110v AC hand held electromagnetic yoke magnet, a white strippable paint as contrast background and a magnetic "ink" composed of iron powder particles in a liquid carrier base.
- The area is magnetised with the yoke magnet. In the event of a surface or slightly sub surface defect being present, the lines of magnetic force will deform around the defect.
- The magnetic ink is applied and the iron powder particles will bridge the gap caused by the defect and give a visible indication against the white contrast background.
- Magnetic Particle Inspection (MPI) provides very good defect resolution and is used extensively on:
  Welded fabrications in magnetic material, Castings, Locating fatigue cracks in items subject to cyclical stress



- Schematic of flux lines flowing past both a perpendicular and parallel defect, and flux leakage occurring around the perpendicular flaw.

MAGNETIC PARTICLE INSPECTION IS PERFORMED IN FOUR STEPS:

1. Induce a magnetic field in the specimen
2. Apply magnetic particles to the specimen's surface
3. View the surface, looking for particle groupings that are caused by defects
4. Demagnetize and clean the specimen

ADVANTAGES OF MAGNETIC PARTICLE INSPECTION

- Can find both surface and near sub-surface defects
- Some inspection formats are extremely portable and low cost
- Rapid inspection with immediate results
- Indications are visible to the inspector directly on the specimen surface
- Can detect defects that have been smeared over
- Can inspect parts with irregular shapes (external splines, crankshafts, connecting rods, etc.)

LIMITATIONS OF MAGNETIC PARTICLE INSPECTION

- The specimen must be ferromagnetic (e.g. steel, cast iron)
- Paint thicker than about 0.005" must be removed before inspection
- Post cleaning and post demagnetization is often necessary
- Maximum depth sensitivity is typically quoted as 0.100" (deeper under perfect conditions)
- Alignment between magnetic flux and defect is important

4. Ultrasonic Testing:

Ultrasonic testing (UT) is a non-destructive testing techniques based on the propagation of ultrasonic waves in the object or material tested.

Ultrasonic Testing

In most common UT applications, very short ultrasonic pulse-waves with center frequencies ranging from 0.1-15 MHz, and occasionally up to 50 MHz, are transmitted into materials to detect internal flaws or to characterize materials.

A common example is ultrasonic thickness measurement, which tests the thickness of the test object, for example, to monitor pipework corrosion.

Ultrasonic testing is often performed on steel and other metals and alloys, though it can also be used on concrete, wood and composites, albeit with less resolution. It is used in many industries including steel and aluminium construction, metallurgy, manufacturing, aerospace, automotive and other transportation sectors.

- **How Ultrasonic Testing Works ?**

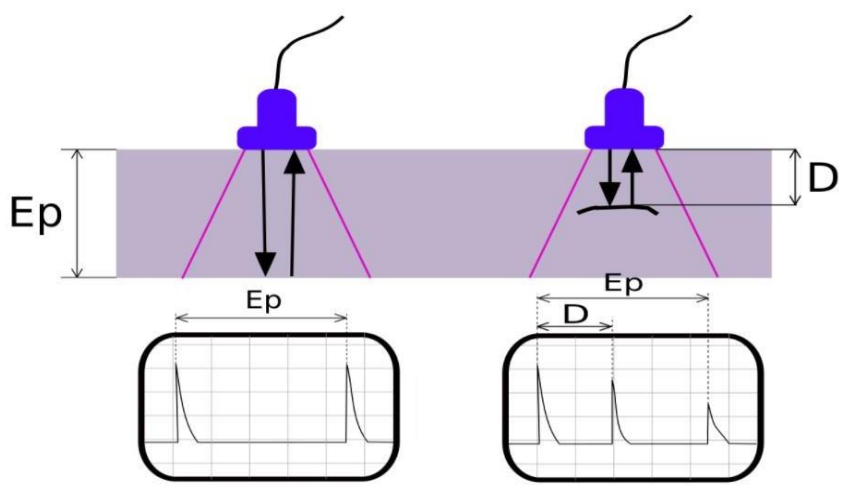
- In ultrasonic testing, an ultrasound transducer connected to a diagnostic machine is passed over the object being inspected. The transducer is typically separated from the test object by a couplant (such as oil) or by water, as in immersion testing.

- However, when ultrasonic testing is conducted with an Electromagnetic Acoustic Transducer (EMAT) the use of couplant is not required.

- **Principle of Ultrasonic Testing**

- As shown in below figure (left): A probe sends a sound wave into a test material. There are two indications, one from the initial pulse of the probe, and the second due to the back wall echo.

As shown in below figure (right): A defect creates a third indication and simultaneously reduces the amplitude of the back wall indication. The depth of the defect is determined by the ratio D/E



There are two methods of receiving the ultrasound waveform.

They are

- Reflection and
- Attenuation.
- **Reflection method**
- In reflection (or pulse-echo) mode, the transducer performs both the sending and the receiving of the pulsed waves as the “sound” is reflected back to the device. Reflected ultrasound comes from an interface, such as the back wall of the object or from an imperfection within the object.
- The diagnostic machine displays these results in the form of a signal with an amplitude representing the intensity of the reflection and the distance, representing the arrival time of the reflection
- **Attenuation method**
- In attenuation (or through-transmission) mode, a transmitter sends ultrasound through one surface, and a separate receiver detects the amount that has reached it on another surface after traveling through the medium.
- Imperfections or other conditions in the space between the transmitter and receiver reduce the amount of sound transmitted, thus revealing their presence. Using the couplant increases the efficiency of the process by reducing the losses in the ultrasonic wave energy due to separation between the surfaces.

Advantages of Ultrasonic Testing:

- High penetrating power, which allows the detection of flaws deep in the part.
- High sensitivity, permitting the detection of extremely small flaws.
- In many cases only one surface needs to be accessible.
- Greater accuracy than other nondestructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces.
- Some capability of estimating the size, orientation, shape and nature of defects.
- Some capability of estimating the structure of alloys of components with different acoustic properties
- Non hazardous to operations or to nearby personnel and has no effect on equipment and materials in the vicinity.
- Capable of portable or highly automated operation.
- Results are immediate. Hence on the spot decisions can be made.

Disadvantages of Ultrasonic Testing:

- Manual operation requires careful attention by experienced technicians. The transducers alert to both normal structure of some materials, tolerable anomalies of other specimens (both termed “noise”) and to faults therein severe enough to compromise specimen integrity. These signals must be distinguished by a skilled technician, possibly requiring follow up with other nondestructive testing methods.

- Extensive technical knowledge is required for the development of inspection procedures.
- Parts that are rough, irregular in shape, very small or thin, or not homogeneous are difficult to inspect.
- Surface must be prepared by cleaning and removing loose scale, paint, etc., although paint that is properly bonded to a surface need not be removed.
- Couplants are needed to provide effective transfer of ultrasonic wave energy between transducers and parts being inspected unless a non-contact technique is used. Non-contact techniques include Laser and Electro Magnetic Acoustic Transducers.
  Inspected items must be water resistant, when using water based couplants that do not contain rust inhibitors. In these cases anti-freeze liquids with inhibitors are often used