AERODYNAMICS AND PROPULSION

LABORATORY MANUAL

B.TECH
(III YEAR – I SEM)
(2016-17)

Prepared by:
Mr. RAMAKRISHNUDU, Associate Professor
Mr. YUGENDER MALOTHU, Assistant Prof

Department of Aeronautical Engineering

MALLA REDDY COLLEGE
OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)
Recognized under 2(f) and 12 (B) of UGC ACT 1956
Affiliated to JNTUH, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2008 Certified)
Maisammaguda, Dhulapally (Post Via. Hakimpet), Secunderabad – 500100, Telangana State, India

DEPARTMENT OF AERONAUTICAL ENGINEERING

VISION

Department of Aeronautical Engineering aims to be indispensable source in Aeronautical Engineering which has a zeal to provide the value driven platform for the students to acquire knowledge and empower themselves to shoulder higher responsibility in building a strong nation.

MISSION

a) The primary mission of the department is to promote engineering education and research.

(b) To strive consistently to provide quality education, keeping in pace with time and technology.

(c) Department passions to integrate the intellectual, spiritual, ethical and social development of the students for shaping them into dynamic engineers.

PROGRAMME EDUCATIONAL OBJECTIVES (PEO'S)

PEO1: PROFESSIONALISM & CITIZENSHIP To create and sustain a community of learning in which students acquire knowledge and learn to apply it professionally with due consideration for ethical, ecological and economic issues.
PEO2: TECHNICAL ACCOMPLISHMENTS To provide knowledge based services to satisfy the needs of society and the industry by providing hands on experience in various technologies in core field.
PEO3: INVENTION, INNOVATION AND CREATIVITY To make the students to design, experiment, analyze, interpret in the core field with the help of other multi disciplinary concepts wherever applicable.
PEO4: PROFESSIONAL DEVELOPMENT To educate the students to disseminate research findings with good soft skills and become a successful entrepreneur.
PEO5: HUMAN RESOURCE DEVELOPMENT To graduate the students in building national capabilities in technology, education and research.

PROGRAM SPECIFIC OBJECTIVES (PSO's)

1. To mould students to become a professional with all necessary skills, personality and sound knowledge in basic and advance technological areas.
2. To promote understanding of concepts and develop ability in design manufacture and maintenance of aircraft, aerospace vehicles and associated equipment and develop application capability of the concepts sciences to engineering design and processes.
3. Understanding the current scenario in the field of aeronautics and acquire ability to apply knowledge of engineering, science and mathematics to design and conduct experiments in the field of Aeronautical Engineering.
4. To develop leadership skills in our students necessary to shape the social, intellectual, business and technical worlds.

PROGRAM OBJECTIVES (PO'S)

Engineering Graduates will be able to:

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

CONTENTS

AERODYNAMICS LAB

PROPULSION LAB

Experiment -1

CONSTANT SPEED AIR BLOWER TEST RIG:

AIM : To conduct test on the given blower and to determine the overall efficiency using various Vanes provided.

APPARATUS: Blower

DESCRIPTION:

The given blower is a single stage centrifugal type. Air is sucked from atmosphere in rhe suction side and the slightly compressed air passes through the spiral case before it comes out through the outlet.

The given blower is provided with three interchangeable impellers namely straight curved; forward curved and backward curved vanes. The vanes are pressed out of sheet metal and riveted to the shrouds. This volute contour helps in reducing eddy current losses along the path. The casing is designed such that it can separated to facilitate easy interchanging of impellers.

The blower is directly coupled to a swinging field induction motor of 5HP, 2880rpm. The outlet of the blower is connected to a pipe line of 3 meters length. A Venturimeter, a flow control valve and pressure toppings are provided along the pipe. Pitot tube for measuring the head is also provided on the suction and delivery of the blower.

A Panel mounted on sturdy iron stands, with switch starter for the blower motor, the 3-phase energy meter to measure the input energy for the blower, and manometer to measure the flow, static and total head.

Experimental Procedure:

1. Fill mercury in the Manometer provided for Venturimeter, the levels must equal, if not remove air blocks.
2. Fill water in the manometer provided for Paddle Pitot tubes, provided on the suction and delivery side, Close the cock connected to the inner pipe of the Pitot tube, and leave this column of the manometer open to the atmosphere. Open the cock connecting the statics pressure end Pitot tube.
3. Close the delivery control valve, and start the unit.
4. Open the delivery valve to ¼th level.
5. Note the time taken for 10 revolution of energy meter reading.

6. Note spring balance reading connected to the torque arm of the swinging field motor; Note the speed of the motor.
7. Note the manometer readings.
8. Repeat the experiment for different openings of the delivery valve and for different impeller vanes.

Calculation:

To find the blower discharge $Q_t = K$

Where K = constant, g = 9.81 m/sec^2

$H = h_1 - h_2 {}_{(S1/S2-1)}$ m of air column

Where S1 and S2 are densities of manometric fluid and air respectively.

$h_1 - h_2$ are manometer readings in m of mercury column.

a_1 = Area of Venturimeter in let, diameter of inlet = 100mm

a_2 = Area of Venturimeter in throat, diameter of throat = 60mm

To find the total head $H= H_D + H_S$ of the blower,

H_D & $H_S = h_1 - h_2$ (S1/S2-1) m of air column Where S1 and S2 are densities of manometer fluid and air respectively.

$h_1 - h_2$ are manometer readings in m of water column

Blower Output P = ρa*Q*9.81*H Watts. Where ρa is the density of the air.

The Input to the Blower Pi = 3600/E*10/t Watts,
Where E = energy meter constant and‘t’ is the time taken (Seconds) for 10 revolution of energy meter disc.

Hence the efficiency of the Blower = Po/Pi *100%.

In the case of blower provided with swinging field motor the Input power may also be calculated as follows.

Input power Pi =2π NT/60 watts.

Where T is the torque arm length * spring balance reading in Kg*g &N is the speed of the motor.

S.No 1	Venturi head		Delivery Head		Suction Head		Time for2Rev Energy m/sec	Spring Balance Kg	Blower efficiency %
	h1m	h2m	h1m	h2m	h1m	h2m			
1	0	0.162	0.135	0.172	0.235	0.24	49.8	3.2	25.34329
2	0.137	0.178	0.14	0.165	0.234	0.237	44.9	3.8	49.37441

Sample Calculation:

To find the blower discharge $Q_t = K\sqrt{h}$ m3 /sec 0.091879

0.294155

Where K= a1* a2 $\sqrt{2g}$ / $\sqrt{(a1^2 - a2^2)}$. Where g=9.81m/sec = 2 0.013417

h1=(h1-h2)(S1/S2-1) m of air column Where S1 and S2 are densities of manometric fluid and air respectively.

46.89255 Specific gravity of mercury= 13600

480.6487 Specific gravity of air = 1.16

h1- h2 are manometer reading in m of mercury column Specific gravity of water = 1000

a1 = Area of Venturimeter inlet, diameter of inlet = 0.1 0.00785

a2 = Area of Venturimeter throat, diameter of throat = 0.06 0.002826

To find the total head H = HD + Hs of the blower,

HD & Hs = h1 – h2 (S1/S2-1) m of air column. Where S1 and S2 are densities of manometric fluid and air respectively.

H1-h2 is manometer reading in m of water column.

Delivery Head = 433.7561

293.0784

Suction Head = 4.305345

2.583207

Total Head = 438.0614

295.6617

Blower Output Po = $\rho a*Q_t*9.81*H$ Watts The

input to the blower Pi = 3600/E*10/t KW

Where E = energy meter constant = 80Rev/Kwh

Hence the efficiency of the Blower = Po/Pi *100% 25.34329 %

RESULT:

Experiment – 2

CALIBRATION OF SPEED IN THE WIND TUNNEL

AIM: To find the maximum velocity of the wind tunnel.

APPARTUS: Wind Tunnel Test Rig,

DESCRIPTION:

A wind tunnel is equipment used to examine the stream lines and forces that are induced as the fluid past a fully submerged body. The wind tunnel consisting of a square test section with transparent side walls, size 300x300x1000 mm long the bottom and sides of the test section with window opening to enable fix models.

A bell mouthed entry with honey comb network and screens with smooth settling length provided before the test section. Air flow is generated by a suitably designed axial flow fan, with a D.C motor of 5H.P, 2800 rpm and a thyristor drive for speed control. The approx. volume flow rate 10,000 cm h with static pressure of 50 mm of W.C, under free running condition .sturdy angular stand are provided for vibration free running.

A prandtl pitot tube is provided to messure the velocity of air flow. The aerofoil is two dimensional body, which is stream lined so that the separation occurs only at the extreme range of the body. The aerofoil model confirms to NACA 0018 axial chord 16cm and spam 29cm with 12 piezometric tapping for pressure distribution studies. The separation point is near the trailing edge and width of the resulting wake is small so as to provide low drag.

The drag coefficient is small at low angles because of appearance of wake behind the body and the separation of flow from the upper surface. The aerofoil is made out of seasoned teakwood to provide long lasting usage.

A suitable stand provided with precision 2 components force transmitter to mount the aerofoil model. A digital force indicator to measure lift force of 5-kgf and drag force of 5kgf is provided. The indicator is calibrated to read in grams.

Types of wind tunnels:

- Based on set up models
    - Closed-type wind tunnel
    - Open-type wind tunnel
    - Aerodynamic wind tunnel
    - Environmental wind tunnel
    - Low turbulence level wind tunnel
- Based on cross section of the test section

- rectangular (general purpose)
- circular (axi-symmetric model)
- elliptical (aircraft model)

COMPONENTS OF WIND TUNNEL:

Fan drive: provide a pressure increase of flow, to overcome the pressure loss in the tunnel circuit.

Test section: provide desirable flow condition and space for model testing or experiment, where the instrumentation is situated. (Reynolds number is of the major concern to manage the issue of dynamic similarity.)

Diffuser: a device to lower the air flow speed, consequently reduce the pressure loss due to friction

Guide vanes: to guide the flow through the turning duct, and reduce the extent of secondary flows.

Transition duct: the device to connect the upstream and downstream components of different cross-sectional shapes.

Settling Chamber: A large space in front of the Nozzle to lower the air flow speed, and to maintain the flow in uniform distribution and lower turbulence intensity.

Nozzle (Convergent section): to accelerate the flow speed to reach the desirable level in the test section, meanwhile reduce the turbulence intensity.

EXPERIMENTAL PROCEDURE:

- Switch on the motor and set up motor rpm.
- Note the manometer reading H1 and H2.
- By using relation between H1, H2 and density of water and air calculate velocity.
- Calculate Mach number and velocity

Calibration of Wind Tunnel:

Velocity Head of Air: Velocity $v=\sqrt{2gh_a}$ Velocity =31.85635865m/sec

Dynamic Pressure: $V^2/2g=\rho_w/\rho_a*(h_1-h_2)/100 = 51.72m$

ρ_w Density of water = 1000kg/m^3

ρ_a Density of air = 1.16 kg/m^3

Acceleration due to Gravity = 9.81m/s

Result:

Viva Questions

1. What is an Incompressible Flow?
2. Explain Speed of Sound?
3. Define Mach number?
4. What is a Potential Flow?
5. Define Stream Function, Velocity Potential?

Experiment – 3

THE PRESSURE DISTRIBUTION ACROSS A SYMMETRIC AIR FOIL

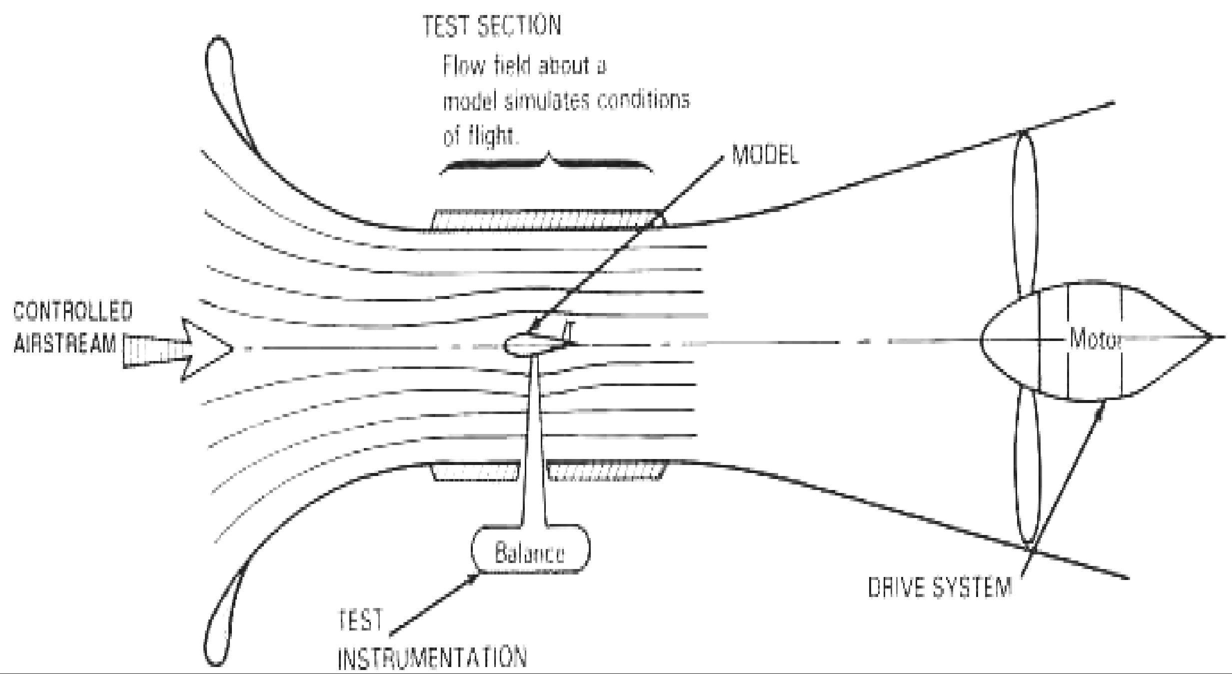
To conduct Experiments by using wind tunnel to find out the pressure distribution, velocity distribution and Aerodynamic forces acting on various model.

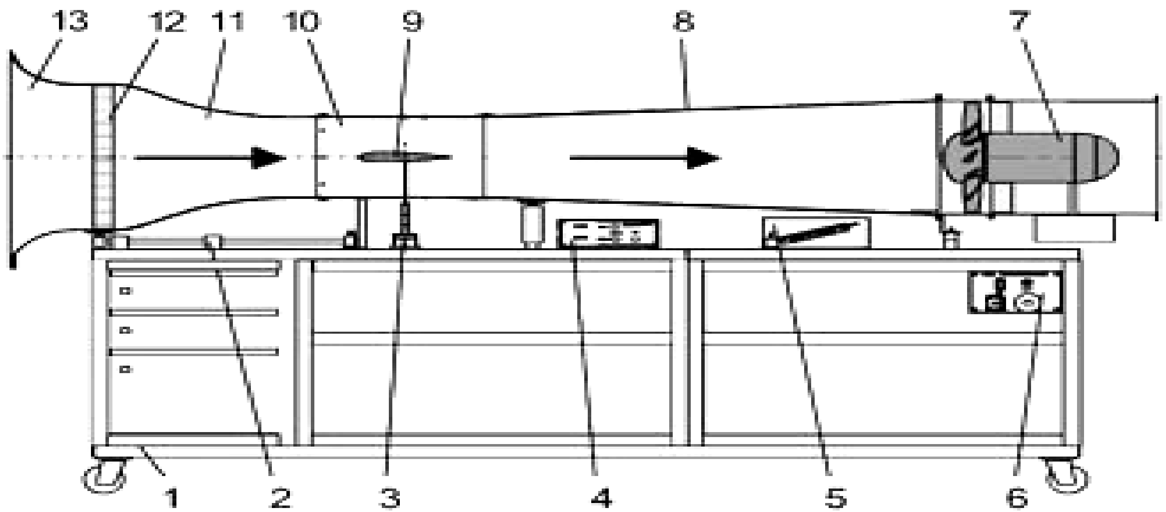
APPARTUS:

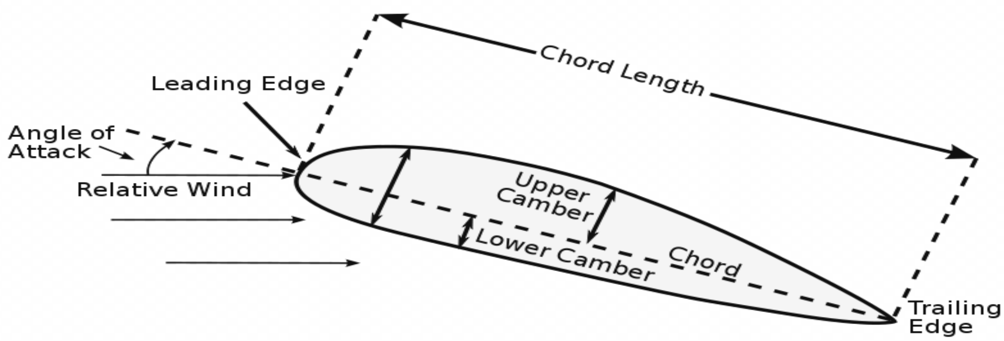
Wind Tunnel Test Rig, Aerofoil model (NACA 0012)

DESCRIPTION:

A multitude monometer is providing to measure the pressure distribution.







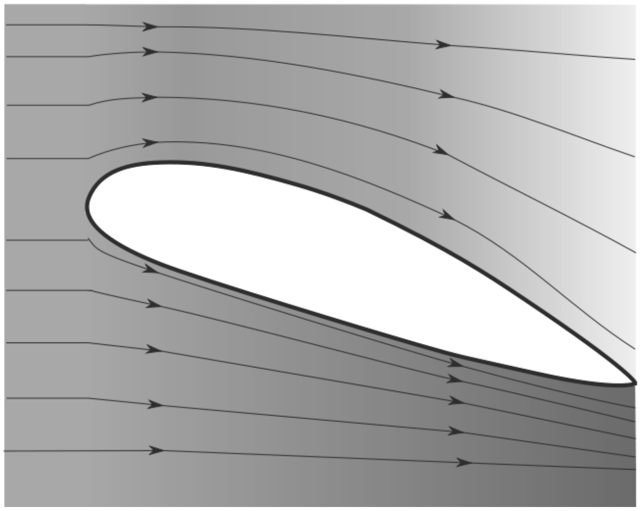
Subtract the reading P_1 to P_{12} from P_{13} (P_{ref}) to find the gauge pressure in each of the pressure tapping located on the aerofoil model and the velocity head using the Pitot tube. All these values must be multiplies by sin (a) where (a) is the angle of inclination of the manometer to get vertical heights.

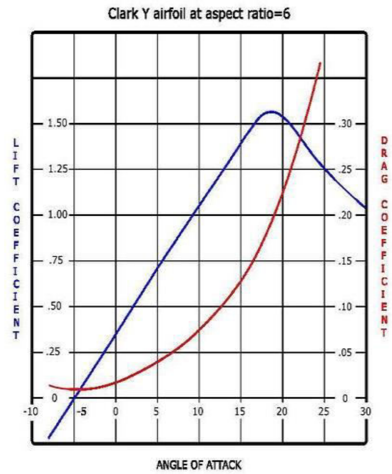
The distance of all the aerofoil surface pressure tapping from the leading edge are given Pressure tap 1to 6 on the lower surface, 7 on the leading edge and 8 to 12 the upper surface. Find the Static pressure Coefficient Cp=P- P_{ref}/h1-h2-(h1-h2) for Aerofoil model. For Cylinder Cp=P- Pref/h1-h2-(h1-h2) Where Perf = P1-(h1-h2) and P1= Pressure at stagnation point.

Plot graph between Cp as a function of distance. The area included gives the Lift force perpendicular to the Aerofoil chord.

Note: In the multitude manometer due to the position of the scales higher number denotes the lower pressure. Hence the scale readings are read as negative values.

The Distance between the aerofoil surface pressures tapping from LE is shown in mm.





EXPERIMENTAL PROCEDURE:

- Mount the aerofoil model on the stand provided and keep the model in wind tunnel through the opening at the bottom. The tail edge facing the fan. Care should be taken to ensure the rod connecting the model to the balance does not touch the wind tunnel wall. This should be checked even when the wind tunnel is in operation.
- Calibrate the strain gauge balanced to indicate an initial value for lift force 0 and drag force 0.
- Connect the pressure tapping to the multitude monometer as per the table A shown. And note the angles of incidence of air on the model. The incidence angle is changed by loosening the bolts and manually positioning the aerofoil at the required incidence angle. Give pitot tube connections
- Connect constant 220V, A.C power supply to thyristor unit using suitable rating wire. Connect the D.C motor with the thyristor through 4 wires A,AA,(Armature) and Z,ZZ(field coil) properly
- If the direction of rotation of fan to be changed , interchanged the field coil wire Z,ZZ in the thyristor unit
- Ensure that the speed control knob is in minimum position and turn on the main switch.
- Operate the push button switch and turn the speed control knob slowly to obtain the require test section velocity.
- Note the reading on differential pressure water monometer connected to the Pitot tube.

  Note the readings on the multitude monometer P1 to P12, and P13 corresponding to the atmospheric pressure.

- Note the angles of inclination of the monometer.
- For the different angle of incidence of aerofoil model and for different airflow rate the experiment maybe repeated.

CALCULATIONS

TABLE -1 PRESSURE TAPPING POINTS:

Points	1	2	3	4	5	6	7	8	9	10	11	12
Distance in mm	160	120	80	50	30	10	0	10	30	50	80	120

TABLE -2 Multi tube manometer /Pitot tube Utube Manometer reading.

Sl no	Deg	P ref	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	h1	h2

Velocity Head of Air: Velocity v= $\sqrt{2gh_a}$

$h_a = \rho_w/\rho_a * (h_1 - h_2)/100 = 51.72$m

ρ_w Density of water = 1000kg/m^3

ρ_a Density of air = 1.16 kg/m^3

Acceleration due to Gravity = 9.81m^2/s

Velocity =31.85635865m/s

The pressure distribution is expressed in dimensionless form by the pressure coefficient **Cp**

$$\mathbf{Cp} = \frac{2(P_i - P_\infty)}{\rho V^2}$$

Where $P_{ref} = P_\infty$

S.No	Degrees	C_P1	C_P2	C_P3	C_P4	C_P5	C_P6	C_P7	C_P8	C_P9	C_P10	C_P11	C_P12
1	0												
2	5												

MODEL CALCULATION:

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
	26.4	28.2	30.3	32.7	37.1	44	32.5	22.8	26.2	26.5	26.7	26.9
Cp	1.067	1.367	1.72	2.12	2.85	4	2.08	0.47	1.03	1.08	1.12	1.15
Axial chord distance	160	120	80	50	30	10	0	10	30	50	80	120

Pitot **Pref manometer**

Ref	h1	h 2
20	**28**	**34**

Aerofoil:- **chord length=160mm**

Span = 290mm

RESULTS: Plot coefficient of pressure for different stations of chord length

VIVA QUESTIONS

1. What is angle of attack?

   In aerodynamics, angle of attack specifies the angle between the chord line of the wing of a fixed-wing aircraft and the vector representing the relative motion between the aircraft and the atmosphere.

2. What is critical angle of attack?

   The critical angle of attack is the angle of attack which produces maximum lift coefficient. This is also called the "stall angle of attack".

3. Explain stagnation point.

   When the airfoil is located in a stream of air of velocity, the flow has to part near the leading edge and pass along the upper and the lower airfoil surface. At the location, where the flow is splitting up, the flow velocity is reduced to zero. This point is called stagnation point. It is located close to the leading edge of the airfoil, but its position moves with angle of attack.

4. Explain coefficient of pressure.

   It is possible to plot a *pressure distribution* instead of the velocity distribution (usually not the pressure, but the ratio of the local pressure to the stagnation pressure is plotted and called pressure coefficient *Cp*):

Experiment – 4

THE PRESSURE DISTRIBUTION AND DRAG ACROSS A CIRCULAR CYLINDER & A SPHERE.

AIM:

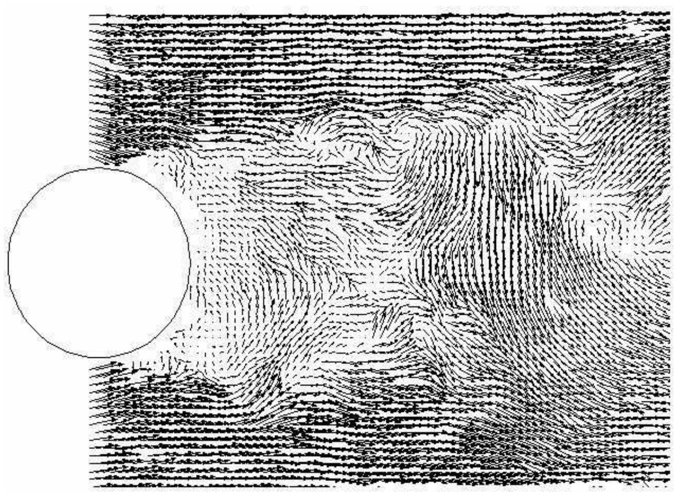
To determine the Drag over different bodies

APPARTUS:

1 Low Speed Wind Tunnel Set-up
2. Models(Bodies of Different Shapes)

DESCRIPTION:

For the cylinder and Sphere models the pressure tapping are made at 30 degree interval, as per rough Sketch.



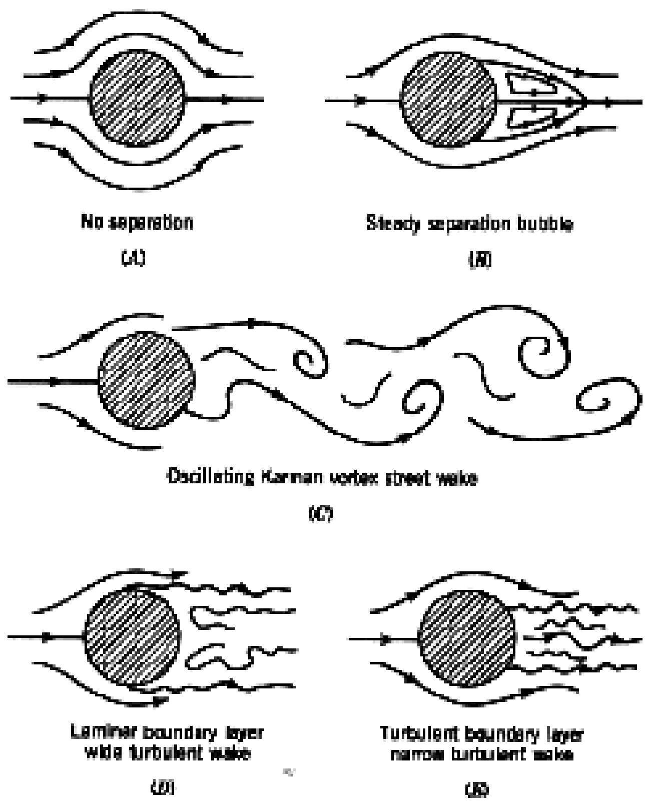
As seen from the results the lift and drag increase with incidence angle with the Lift/Drag ratio reaching a maximum at 15 degree and begins to fall beyond.

Drag of Blunt Bodies and Streamlined Bodies:

A body moving through a fluid experiences a drag force, which is usually divided into two components: frictional drag and pressure drag. Frictional drag comes from friction between the fluid and the surfaces over which it is flowing. This friction is associated with the development of boundary layers, and it scales with Reynolds number as we have seen above. Pressure drag comes from the eddying motions that are set up in the fluid by the passage of the body. This drag is associated with the formation of a wake, which can be readily seen behind a passing boat, and it is usually less sensitive to Reynolds number than the frictional drag. Formally, both types of drag are due to viscosity (if the body was moving through an an inviscid fluid there would be no drag at all), but the distinction is useful because the two types of drag are due to different flow phenomena. Frictional drag is important for attached flows (that is, there is no separation), and it is related to the surface area exposed to the flow. Pressure drag is important for separated flows, and it is related to the cross-sectional area of the body.

We can see the role played by friction drag (sometimes called viscous drag) and pressure drag (sometimes called form drag or profile drag) by considering an airfoil at different angles of attack. At small angles of attack, the boundary layers on the top and bottom surface experience only mild pressure gradients, and they remain attached along almost the entire chord length. The wake is very small, and the drag is dominated by the viscous friction inside the boundary layers. However, as the angle of attack increases, the pressure gradients on the airfoil increase in magnitude. In particular, the adverse pressure gradient on the top rear portion of the airfoil may become sufficiently strong to produce a separated flow. This separation will increase the size of the wake, and the pressure losses in the wake due to eddy formation Therefore the pressure drag increases. At a higher angle of attack, a large fraction of the flow over the top surface of the airfoil may be separated, and the airfoil is said to be stalled. At this stage, the pressure drag is much greater than the viscous drag.

When the drag is dominated by viscous drag, we say the body is streamlined, and when it is dominated by pressure drag, we say the body is bluff. Whether the flow is viscous-drag dominated or pressure-drag dominated depends entirely on the shape of the body. A streamlined body looks like a fish, or an airfoil at small angles of attack, whereas a bluff body looks like a brick, a cylinder, or airfoil at large angles of attack. For streamlined bodies, frictional drag is the dominant source of air resistance. For a bluff body, the dominant source of drag is pressure drag. For a given frontal area and velocity, a streamlined body will always have a lower resistance than a bluff body. For example, the drag of a cylinder of diameter can be ten times larger than a streamlined shape with the same thickness (see figure 1).



EXPERIMENTAL PROCEDURE:

1. Mount the model on the stand provided and keep the model in the Wind Tunnel through the opening at the bottom. The tail edge facing the fan. Care should be taken to ensure that the rod connecting the model to the balance does not touch the wind tunnel wall. This should be checked even when the wind tunnel is in operation.
2. Calibrate the strain gauge balance to indicate an initial value of Lift=0 and Drag=0.
3. Connect the pressure tapping to the multi tube manometer as per the table give and note the angle of incidence of air on the model. The incidence angle is changed by loosening the bolts and manually positioning the aerofoil at the required incidence angle. Give pitot tube connections.
4. Switch on the Drive unit.
5. Note the reading on strain gauge balance
6. Note the reading of Prandtl Pitot tube.
7. Calculate the velocity of flow using the readings in Prandtl Pitot tube.
8. Note the angle of inclination of the manometer connected to Prandtl Pitot tube.
9. For different angle of incidence of model and for different air flow rate, the experiment may be repeated.

CALCULATIONS

TABLE -1 Multi tube manometer /Pitot tube Utube Manometer reading.

Sl no	Deg	P ref	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	h1	h2

Velocity Head of Air: Velocity $v=\sqrt{2gh_a}$

$h_a=\rho_w/\rho_a*(h_1-h_2)/100 = 51.72m$

ρ_w Density of water = 1000kg/m^3

ρ_a Density of air = 1.16 kg/m^3

Acceleration due to Gravity = 9.81m^2/s

Velocity =31.85635865m/s

The pressure distribution is expressed in dimensionless form by the pressure coefficient **Cp**

$$\mathbf{Cp} = \frac{2(P_i - P_\infty)}{\rho V^2}$$

Where $P_{ref} = P_\infty$

S.No	Model	Cp1	Cp2	Cp3	Cp4	Cp5	Cp6	Cp7	Cp8	Cp9	Cp10	Cp11	Cp12
1	Cylinder												
2	Sphere												

RESULTS:

Plot coefficient of pressure for different stations of cylinder or sphere.

Viva Questions

1. What is Drag?
2. What is the significance of Coefficient of Drag?
3. Explain different types of Drag?
4. What is Reynolds Number and Explain its significance wrt Drag?
5. What is Wake?
6. Explain Laminar and Turbulent Flow

Experiment-5

Lift / Drag Characteristics of Aerofoil model for a constant speed

AIM: To calculate the drag coefficient (C_d) and lift coefficient (C_l) of NACA-2312 Airfoil.

APPARTUS:

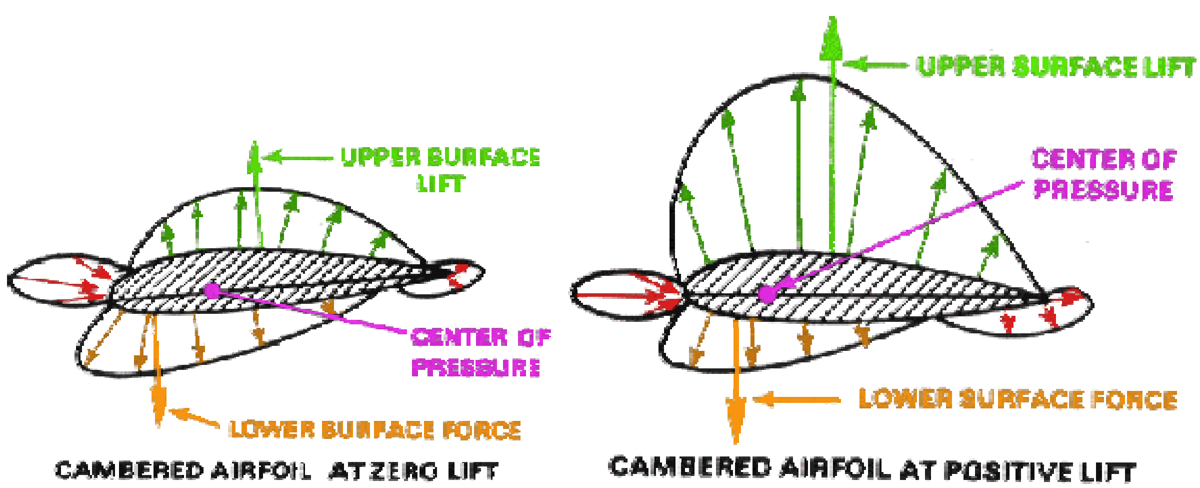
1 Low Speed Wind Tunnel Set-up
2 NACA-2312 Airfoil

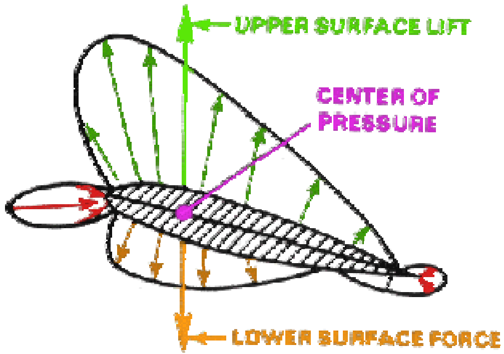
DESCRIPTION:

Distribution of pressure over an airfoil section may be a source of an aerodynamic twisting force as well as lift. A typical example is illustrated by the pressure distribution pattern developed by this cambered (nonsymmetrical) airfoil:

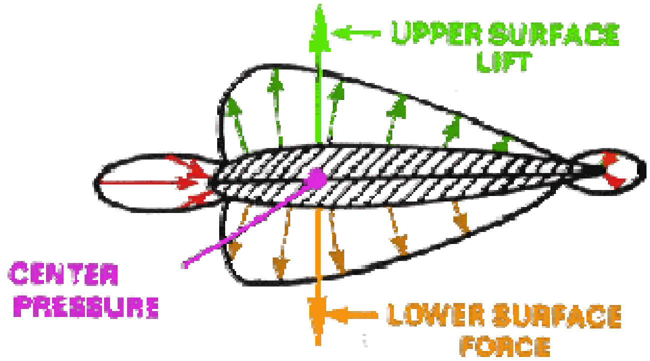
The upper surface has pressures distributed which produce the upper surface lift. The lower surface has pressures distributed which produce the lower surface force. Net lift produced by the airfoil is the difference between lift on the upper surface and the force on the lower surface. Net lift is effectively concentrated at a point on the chord called the Center Of Pressure.
When the angle of attack is increased: Upper surface lift increases relative to the lower surface force. Since the two vectors are not located at the same point along the chord line, a twisting force is exerted about the center of pressure. Center of pressure also moves along the chord line when angle of attack changes, because the two vectors are separated. This characteristic of nonsymmetrical airfoils results in undesirable control forces that must be compensated for if the airfoil is used in rotary wing applications.

When the angle of attack is increased to develop positive lift, the vectors remain essentially opposite each other and the twisting force is not exerted. Center of pressure remains relatively constant even when angle of attack is changed. This is a desirable characteristic for a rotor blade, because it changes angle of attack constantly during each revolution.





SYMMETRICAL AIRFOIL AT POSITIVE LIFT



Measurements in Wind Tunnel: Boundary layer Measurements, Wake Survey:

The effective free stream Mach number at the position of the model was obtained by correcting a value measured far upstream of the model for the blockage effect of the model, its support system and the wakes of these items. This correction was made by representing the model, etc., by suitable distributions of sources and sinks and then calculating the ratio between

(i) The sum of centre line pressure increments due to image arrays of the model, etc., in the tunnel walls, and

(ii) The sum of roof or floor pressure increments due to both image arrays and the direct effect of the model, etc.

A selection of measured roof and floor pressures and knowledge of the 'empty tunnel' calibration 3 then permitted the corrected Mach number to be calculated. These calculations also showed that the mean corrected Mach number at mid-span of the model did not differ from that at any particular chord wise point at the same span wise position by more than 0.0015. The mean corrected Mach number is that quoted as the free stream Mach number for each survey condition and is that used in computing force and pressure coefficients.

EXPERIMENTAL PROCEDURE:

1. Mount the model on the stand provided and keep the model in the Wind Tunnel through the opening at the bottom. The tail edge facing the fan. Care should be taken to ensure that the rod connecting the model to the balance does not touch the wind tunnel wall. This should be checked even when the wind tunnel is in operation.
2. Calibrate the strain gauge balance to indicate an initial value of Lift=0 and Drag=0.
3. Connect the pressure tapping to the multi tube manometer as per the table give and note the angle of incidence of air on the model. The incidence angle is changed by loosening the bolts and manually positioning the aerofoil at the required incidence angle. Give pitot tube connections.
4. Switch on the Drive unit.
5. Note the reading on strain gauge balance
6. Note the reading of Prandtl Pitot tube.
7. Calculate the velocity of flow using the readings in Prandtl Pitot tube.
8. Note the angle of inclination of the manometer connected to Prandtl Pitot tube.
9. For different angle of incidence of model and for different air flow rate, the experiment may be repeated.
10. Take the Readings of Drag from the strain gauge balance.

CALCULATIONS:

Velocity Head of Air: Velocity $v = \sqrt{2gh_a}$

$h_a = \rho_w/\rho_a * (h_1 - h_2)/100 = 51.72m$

ρ_w Density of water = $1000 kg/m^3$

ρ_a Density of air = $1.16 kg/m^3$

Acceleration due to Gravity = $9.81 m^2/s$

Velocity =31.85635865m/s

Co-efficient of drag(C_d) = Actual Drag (Kgf) / (dynamic pressure*area)

Co-efficient of drag(C_l) = Actual Lift (Kgf) / (dynamic pressure*area)

Actual lift force measured on the digital indicator.

Dynamic pressure = $[\rho_a * V^2 /2]$

a - Plan form area for body

ρ_a -Density

Planform area of aerofoil a = $0.046 m^2$

TABLE -1

S.No	**Deg**	**Lift Kgf**	**Drag Kgf**	C_L	C_D	C_L / C_D

Viva Questions

1. What is NACA?
2. Explain NACA 4 Digit Series Airfoil?
3. What is Cambered Airfoil?
4. What is Lift and Drag and Explain significance of Lift and Drag coefficient?
5. What is Center of Pressure and Aerodynamic Center?

Experiment – 6

ROTARY AIR COMPRESSOR TEST RIG (CENTRIFUGAL FLOW COMPRESSOR):

AIM; To conduct test on rotary air compressor and to determine volumetric efficiency at various delivery pressure.

DESCRIPTION: Rotary air compressor is a rotary type driven by primary mover AC motor through belt. The test rig consists of a base on which the tank (air reservoir) is mounted. The outlet pressure of the air is indicated by the pressure gauge. The suction is connected to the air tank with a calibrated orifice plate through water manometer.

SPECIFICATION.

1. Displacement : 300 ltr/ min at 1440 RPM.
2. Standard speed : 1440 RPM.
3. Working temperature : 850C
4. Power : 1 HP

Centrifugal compressors, sometimes referred to as **radial compressors**, are a sub-class of dynamic axisymmetric work-absorbing turbomachinery

The idealized compressive dynamic turbo-machine achieves a pressure rise by adding kinetic energy/velocity to a continuous flow of fluid through the rotor or impeller. This kinetic energy is then converted to an increase in potential energy/static pressure by slowing the flow through a diffuser.

Imagine a simple case where flow passes through a straight pipe to enter centrifugal compressor. The simple flow is straight, uniform and has no swirl. As the flow continues to pass into and through the centrifugal impeller, the impeller forces the flow to spin faster and faster. According to a form of Euler's fluid dynamics equation, known as pump and turbine equation," the energy input to the fluid is proportional to the flow's local spinning velocity multiplied times the local impeller tangential velocity. In many cases the flow leaving centrifugal impeller is near or above 1000 ft./s or approximately 300 m/s. It is at this point, in the simple case according to Bernoulli's principle, where the flow passes into the stationary diffuser for the purpose of converting this velocity energy into pressure energy

PROCEDURE:

1. Provide the necessary electrical connections to the panel.
2. Check for the direction of the motor.
3. Close the ball valves of pressure arrangements.
4. Switch on the Starter.
5. Allow the system to attain the steady state.
6. Now, open the valves of the respective pressure tappings and note down the values from the manometer.
7. Repeat the experiment and calculate average values.

NOTE: The experiment is designed for one particular speed only.

CALCULATIONS:

1. HNTP = hm = h X $\frac{\rho w}{\rho a}$

   ρw = density of water = 100 kg/m3

   ρa = density of water = 100 kg/m3

2. DENSITY OF AIR AT R.T.P.= $\sqrt{\frac{\rho a \times 273}{273 + \text{room temp}}}$

3. ACTUAL VOLUME OF AIR DRAWN AT R.T.P CONDITIONS

   Va = Cd X A X 2gh $\frac{\rho w}{\rho a}$ m3/ sec

   Where Cd, coefficient of discharge of orifice= 0.62.

   Area of cross-section of orifice = π (d) 2/ 4 m2

   D= Dia of the orifice = 10 mm

   h= (ha $\frac{\rho w}{\rho a}$) m

   ρa= 1.193 kg/m3 (density of air)

   ρw= 1000 kg/m3 (density of water)

   ha= manometer reading in m.

4. Theoretical discharge Qt= $\frac{Aln}{60}$ m3/ sec

   A= area between the two vanes (38 X 10mm)

   l = length of the vane (80mm)

   n= speed in RPM.

5. Volumetric efficiency = $\frac{\text{Actual Discharge}}{\text{Theoritical discharge}}$.

PRECAUTIONS:

- Do not run the motor if supply voltage is less than 380V
- Do not forget to give electrical earth and neutral connections correctly.
- Frequently, at least once in three months, grease all visual moving parts.
- At least once in week, operate the unit for five minutes to prevent any clogging of moving parts.
- It is recommended to run the compressor at less than **1500rpm.**

RESULT:

Experiment – 7

FLOW VISUALIZATION TECHNIQUES:

Aim:

To visualize the flow separation over Aerofoil and Cylinder at different angles of attack

Apparatus:

Wind tunnel, Test model and Smoke Generator.

Description:

Flow visualization is the study of methods to display dynamic behavior in liquids and gases. The field dates back at least to the mid-1400, where sketched images of fine particles of sand and wood shavings which had been dropped into flowing liquids. Since then, laboratory flow visualization has become more and more exact, with careful control of the particulate size and distribution. An advance in photography has also helped extend our understanding of how fluids flow under various circumstances. More recently, computational fluid dynamics (CFD) has extended the abilities of scientists to study flow by creating simulations of dynamic behavior of fluids under a wide range of conditions. The result of this analysis is usually a 2-D or 3-D grid of velocity vectors, which may be uniformly or non-uniformly spaced. The goal is then to analyze this vector field to identify features such as turbulence, vortices, and other forms of structure.

Procedure:

1. Mount the test model at various angles on the stand provided in the test section of wind tunnel. The trailing edge should be faced towards fan.
2. On the Smoke Generator and wait for few minutes to generate smoke.
3. Visualize the flow over test model and the streamlines separating from thesurface.
4. Take the pictures of Separation.

Precautions:

1. Do not stand behind the wind tunnel while operating it.
2. Wait for few minutes to generate the smoke after switching on Smoke generator.

Result:

Experiment – 8

AXIAL FLOW COMPRESSOR TEST RIG

Aim: Axial compressors are rotating, airfoil based compressors in which the working fluid principally flows parallel to the axis of rotation. This is in contrast with other rotating compressors such as centrifugal, axial- centrifugal land mixed –flow compressors where the air may enter axially but will have a significant radial component on exit.

DESCRIPTION OF THE APPARATUS:

The apparatus consist of MECHTRIX make Five Stage Compressor according to the standard design.

1. The compressor is directly coupled to **KIRLOSKAR** motor of 2hp capacity by means of Flange coupling.
2. The motor is controlled by means of AC Drive of same capacity to conduct the experiment at different speeds.
3. **Pressure Tappings** are provided at inlet, stags and outlet, with manometer for measuring.
4. **Multi Tube Manometer Manometers** are made of **Clear Acrylic** with vinyl sticker scale to for better readings.
5. Starter for the motor and Energy meter for power measurement are provided in the control panel with other necessary instruments.
6. Compressor assembly with motor is mounted on the separate frame made of C – Channel. This makes the complete assembly sturdy.
7. The control panel is made of MS tube with powder coating with panel made of **NOVAPAN BOARD**.
8. The entire assembly is aesthetically designed considering all safety precautions.

AIM:

The experiment is conducted at various pressures to

a. Determine the Overall efficiency.
b. Determine the Isothermal efficiency.

PROCEDURE:

1. Provide the necessary electrical connections to the panel.
2. Check for the direction of the motor.
3. Close
4. Switch on the system to attain the steady state.
5. Allow the system to attain the steady state.
6. Now, Open the valves of the respective pressure tappings and note down the values from the manometer.
7. Repeat the experiment and calculate average values.

Note: The experiment is designed for one particular speed only.

TABULAR COLUMNS AND OBSERVATIONS:

SLNO	**FLOW MEASURMENT, mm OF WATER COLUMN**						
	inlet	1st stage	2nd stage	3rd stage	4th stage	5th stage	outlet
	hi	**h1**	**h2**	**h3**	**h4**	**h5**	**h0**
1							
2							
3							

CALCULATIONS:

1. Head of the air, Ha

$$H_a = \frac{\rho_w \; x \; h_{suffix}}{\rho_a} \; m \; of \; air$$

ρ_a = Density of air = 1.2kg/~~cm²~~ m^3

ρ_w = Density of water = 1000kg/~~cm²~~ m^3

h_{suffix} = is for either inlet, outlet or stage head in 'm' of water.

2. Overall Efficiency / Compression Efficiency, η_o %

$$\eta_0 \% = \frac{H_{a\,inlet}}{H_{a\,outlet}} \; x \; 100$$

3. Isothermal workdone, W_{iso}

$$W_{iso} = \rho_a \; x \; Q_a \; x \; \ln r \;\; kW$$

Where,

$Q_a = A \times V$ m^3/s

Where, A = Area of duct at the inlet = $A = \frac{\pi D^2}{4} \; m^2$

D = Dia at the inlet = 0.3m

V = Velocity at the inlet $= \sqrt{2 \; x \; 9.81 \; x \; H_{a\,inlet}} \; m$

lnr = compression ratio

$$\ln r = \frac{H_{a\,outlet}}{H_{a\,inlet}}$$

4. Input power, ip

$$ip = \frac{N * 3600}{K * T}$$

Where

N=no of blinks of energy meter=10^5

K=energy meter constant=1600revs/kw-hr

T=time for n rev. of energy meter in seconds

5. Isothermal efficiency, η_{iso} %:

$$\eta_{iso} = \frac{W_{iso}}{ip}$$

RESULT:

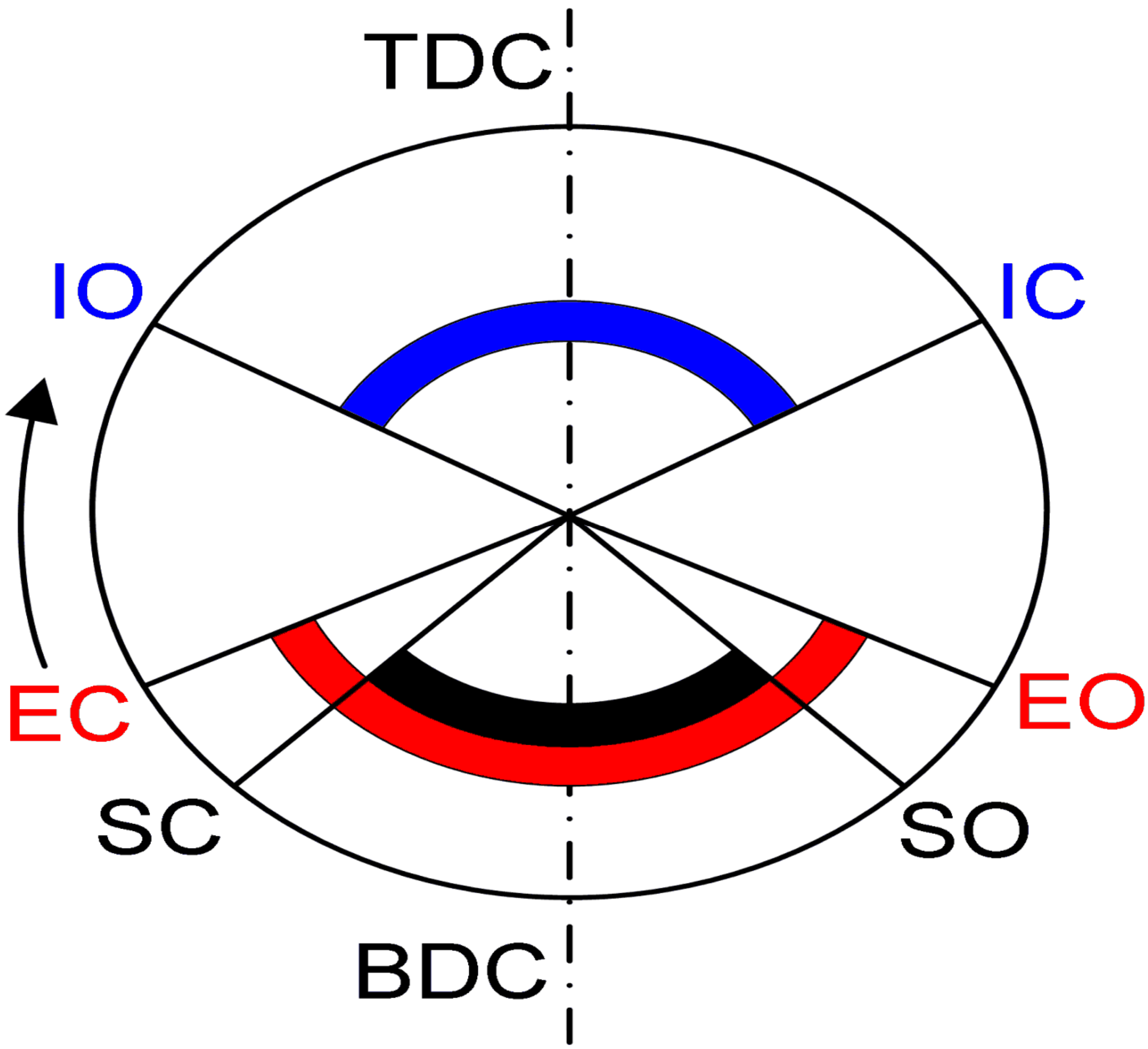
Experiment 1

CUT SECTION MODEL OF A SINGLE CYLINDER TWO STROKE PETROL ENGINE FOR PLOTTING PORT TIMING DAGRAM

AIM: To find out the timing of the inlet port and exhaust port operation of the given petrol engine and to represent the result through a port timing diagram.

THEORY: The timing sequence of the two stroke petrol engine is represented graphically. The events such as opening and closing of inlet ports, transfer ports and exhaust ports are shown graphically with respect to crank angles from dead center portions .This is known as port timing diagram.

PORT TIMING DIAGRAM OF SINGLE CYLINDER TWO STROKE PETROL ENGINE



The inlet port is uncovered by the piston 45^o to 55^o before the top dead center position .The inlet port is covered 45^o -55^0 after the top dead position. The exhaust port is uncovered and covered 65^o and 75^o before and after bottom dead center respectively .The transfer port is uncovered and covered 55^o and 65^o before top dead centre.

PRECAUTIONS:

1. Lubricate all the parts for smooth operation before doing the experiment.
2. Note the correct the direction of the crank shaft and mark the direction of rotation of fly wheel.
3. Rotate the crank shaft always in the correct direction.

PROCEDURE:

Remove the port covers, if necessary to see the ports. Throughout the experiment the rotations of the fly wheel has to be in one direction –clockwise or anti clockwise direction .Mark the fixed or reference point on the frame or note the pointer attached to the frame .Rotate the flywheel and before the piston reaches the top dead center coincide the piston top or one of the piston ring edges with the exhaust port top edge. Have a mark on the flywheel with respect to the fixed point (say TDC 1). Rotate the flywheel again and the piston ring edge again coincides with the same exhaust port edge, mark this point on the flywheel with respect to the fixed point (say TDC 2).

INLET PORT (CRANK CASE COMPRESSION ON PETROL ENGINE)

When the piston just opens the inlet port, mark a point on the flywheel with respect to the fixed point (TPO).When the piston completely closes the exhaust port, mark a point on the flywheel with respect to the fixed point (EPC).Measure the circumference of the flywheel, measure the peripheral length from TDC 1 to TDC 2 along the direction of rotation. Take half of this timing length and mark a line from TDC 1 along the direction of rotation. Indicate the line as TDC BDC line. Measure the timing length from TDC to TPO and TPC .Measure the timing length from BDC to TPO, TPC, EPO and EPC. Tabulate the readings as below.

TABULAR COLUMN

S .No.	Operation	Reference Point	Position	Time in degree
01.	IPC	TDC	After	
02.	EPC	BDC	Before	
03.	TPC	BDC	Before	
04.	TPC	BDC	After	
05.	EPC	BDC	After	
06.	IPO	TDC	Before	

****

Experiment 2

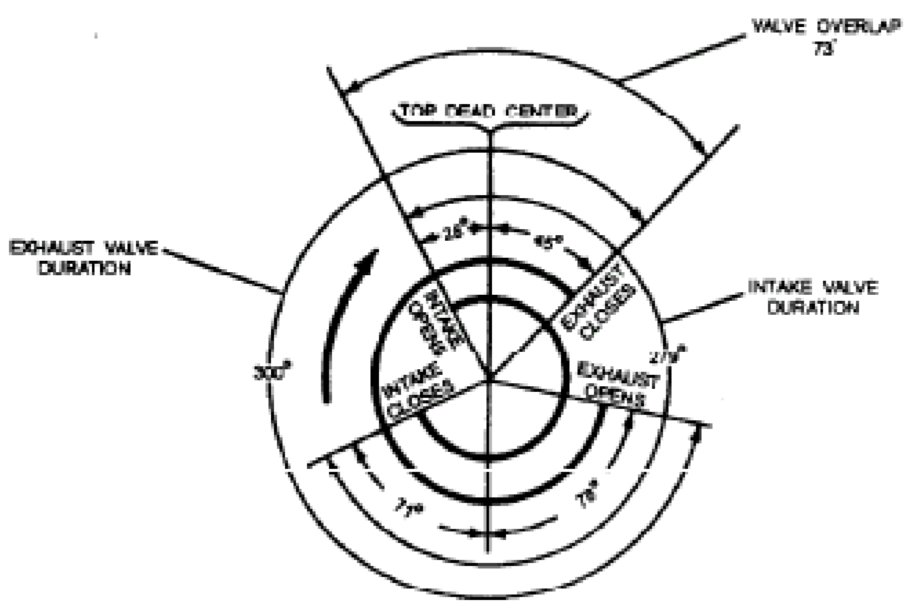
CUT SECTION MODEL OF A SINGLE CYLINDER FOUR STROKE DIESEL ENGINE FOR PLOTTING VALVE TIMING DAGRAM

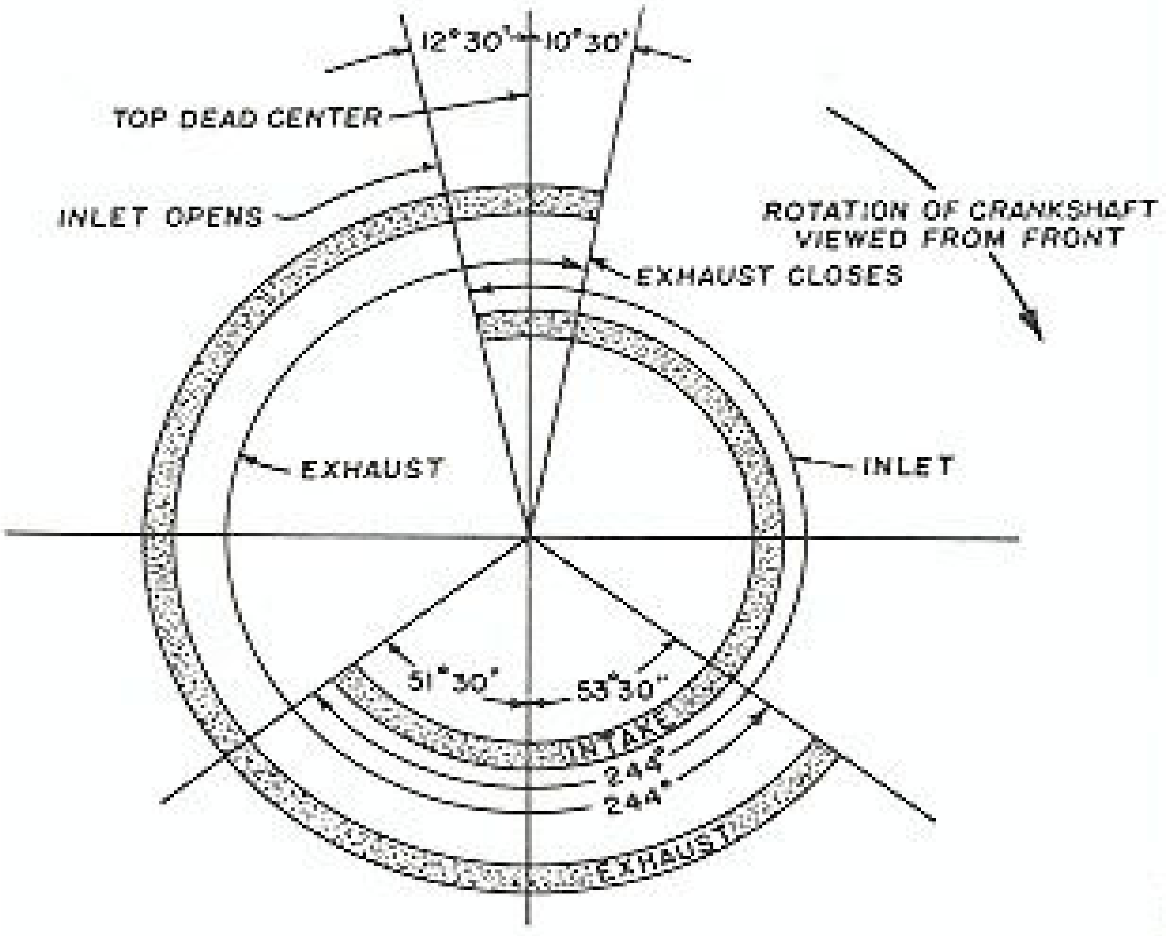
AIM: To find out the timing of the inlet port and exhaust VALVE operation of the Engine and to represent the result through a valve timing diagram.

THEORY:

The valve open and close at the dead centre positions of the piston But in actual practices they do not open and close instantaneously at dead centers. They operate at some angular position before or after the dead center. The ignition is timed to occur a little before top dead center. The tinning of tins sequence of events such as inlet value closing ,ignition, exhaust value opening and closing to be shown graphically in terms of crank angles from dead centre positions.

VALVE TIMING DIGRAM OF SINGLE CYLINDER FOUR STROKE DIESEL ENGINE:





The inlet valve opens at 25^0 crank angles before top dead centre position, fresh air enters in to the engine cylinder till the inlet valve closes. The inlet valve closes at 15^0 to 0^0 after the bottom dead centre. Compression of air takes place and the fuel injection starts at 5^0 to 10^o before top dead centre. Fuel injection ceases at 15^0 to 25^0 after the dead centre in the working stroke. The combustion process is initiated and the pressure and temperature increases. The exhaust valve opens before the bottom dead centre. The exhaust gas is forced out of the engine till the exhaust valve closes. The exhaust valve is closed 10^0 to 15^0 before the top dead centers. The inlet valve and exhaust valve are operating for a common period and is known as overlap period. The angle between these two events is known as angle of overlap.

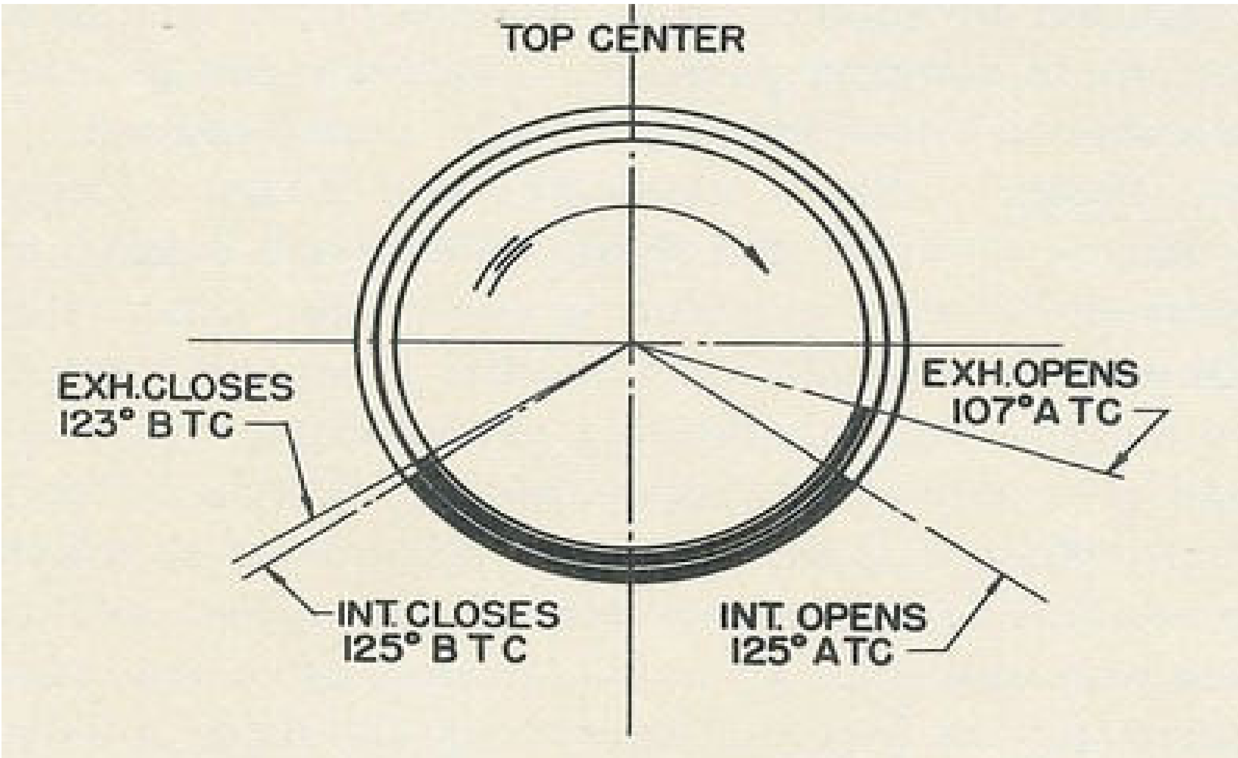


Figure: Valve timing diagram

PRECAUTIONS:

1. Check the engine for its smooth operation of crank shaft, cam shaft and rocker arms otherwise pour some oil for smooth operation.
2. Find out the proper direction of the rotation of the crank shaft with the help of starting handle and mark it on the flywheel.
3. Identify the inlet and exhaust valves.
4. Rotate the flywheel in the correct direction.

PROCEDURE:

1. The flywheel should be rotated in the proper direction and mark the BDC on the flywheel by adjusting the position mark out the half the circumference of the flywheel this point indicates the TDC.
2. The connecting rod should be perpendicular to the crank shaft.
3. Insert a paper strip in the clearance of the inlet valve and the push rod.
4. Slowly rotate the flywheel in the correct direction of the rotation; stop the flywheel when the paper is just gripped.

5. Make a mark on the flywheel with respect to the fixed point (TDC or BDC).

6. This is the position at which the inlet valve started opening. Rotate the crank shaft further in the same direction.

7. The inlet valve is fully opened, when the paper strip is just free to move and stop the crank and make a mark on the flywheel with respect to the fixed point.

8. This point represents the complete crank of the inlet valve.

9. The exhaust valve opening and closing can be determined in a similar way by respecting the above procedure for fixing the exhaust valve opening and closing.

10. measuring the circular distance of all the opening along the moved periphery of the rim of the flywheel with respect to the nearest dead centre and tabulate the reading.

TABULAR COLUMN

S .No.	Opening	Peripheral distance along the rim (Timing length) (cm)	Angle in degree Before/ after TDC/BDC
01.	IVO		
02.	IVC		
03.	EVO		
04.	EVC		

FORMULA:

Circumference of the flywheel = $2\pi r$

$$Q = \text{Arc length} / 2\pi r \ \text{X}\ 360^0$$

$$X\ cm = 360^0$$

$$1\ cm = 360^0 / X$$

$$\text{Angle in Degree} = (360^0 / X)\ \text{X Timing length.}$$

Experiment 3

FOUR STROKE SINGLE CYLINDER PETROL ENGINE TEST RIG WITH DC GENERATION

OBJECTIVE:

To conduct a performance test on four stoke single cylinder petrol engine.

INSTRUMENTATION:

1. Digital RPM Indicator to measure the speed of the engine.
2. Digital temperature indicator to measure various temperatures.
3. Differential manometer to measure quantity of air sucked into cylinder.
4. Burette with manifold to measure the rate consumed during test.

ENGINE SPECIFICATION

ENGINE	:	BIRLA POWER
BHP	:	3 HP
RPM	:	3000 RPM
FUEL	:	PETROL
No. OF CYLINDERS	:	SINGLE
BORE	:	61.9 mm
STOROKE LENGTH	:	60 mm
STARTING	:	ROPE & PULLEY STARTING
WORKING CYCLE	:	FOUR STROKE
METHOD OF COOLING	:	AIR COOLED
METHOD OF IGNITION	:	SPARK IGNITION
ORIFICE DIA	:	20 mm
COMPRESSION RATIO	:	4.67
SPARK PLUG	:	MICO W 160Z2
CARBURATOR	:	BIRLA POWER
GOVERNOR SYSTEM	:	MECHANICAL GOVERNOR
TYPE	:	SELF-EXCITEDDCSHUNT GENERATOR

POWER	:	1.5 Kw
SPEED	:	3000 RPM
RATED VOLTAGE	:	220v DC

(Max. speed to run as dc motor: 2600 RPM)

RESISTANCE LOAD BANK SPECIFICATION:

RATING	:	2.5 Kw, 1Φ (single phase)
VARIATION	:	In 10 steps, by dc switches.
COOLING	:	Air cooled

OBSERVATIONS:

Indicated power	:	IP
Brake power	:	BP
Specification fuel consumption	:	Sfc

LOADING SYSTEM

The engine shaft is directly coupled to the DC Generator which can be loaded by resistive load bank. The load can be varied by switching ON the load bank switches for various loads.

PROCEDURE:

1. Connect the instrumentation power input plug to a 230v, 50 Hz AC single phase AC supply. Now all the digital meters namely, RPM indicator, temperature indicator display the respective readings.
2. Fill up the petrol to the fuel tank mounted behind the panel.
3. heck the lubricating oil level in the oil sump with the dipstick provided.
4. Start the engine with the help of rope and pulley arrangement.
5. Allow the engine to stabilize the speed i.e. 2800 RPM by adjusting the accelerator knob.
6. Keep the change over switch in the generator direction.
7. Apply 1/4 Load (1.9 Amps).
8. Note down all the required parameters mentioned below.
    a. Speed of the engine in RPM.
    b. Load from ammeter in amps.

c. Burette readings in cc.
d. Manometer readings in mm.
e. Time taken for consumption of X cc petrol.
f. Exhaust gas temperature in degree C.

9. Load the engine step by step with the use of dc switches provided on the load bank such as,
   a. ½ load =
   b. ¾ load =
   c. Full load =
10. Note down all required readings.

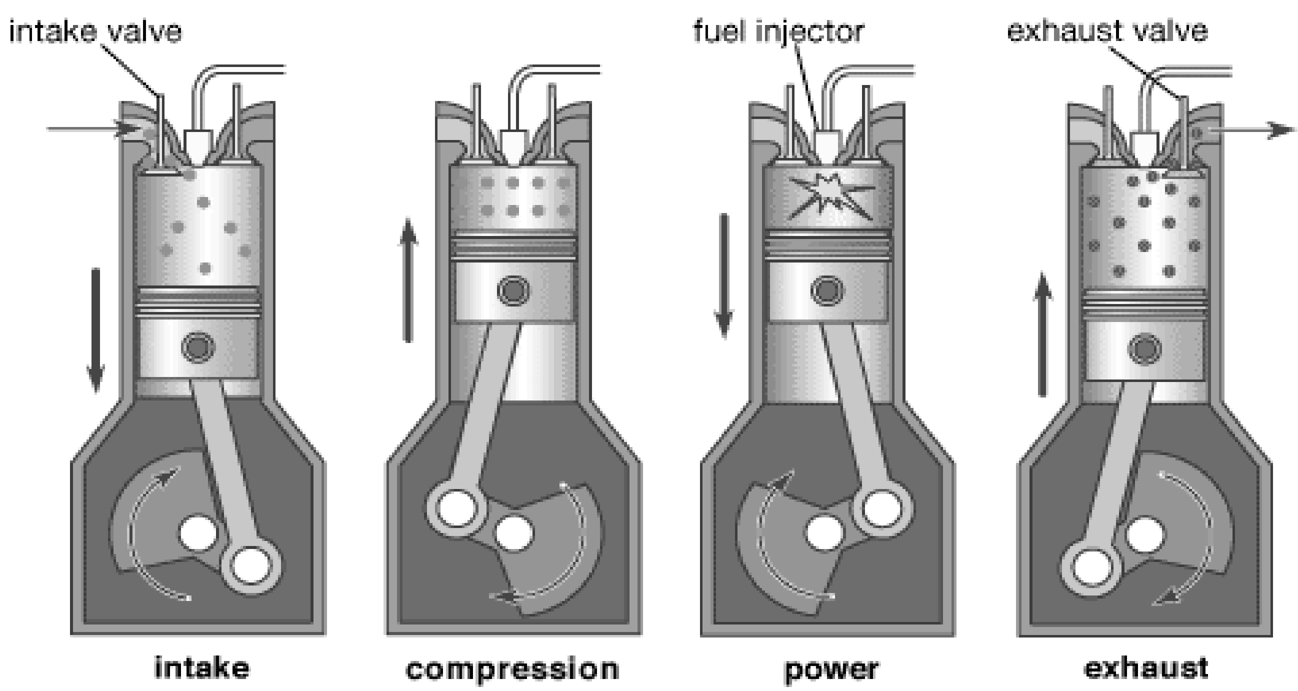
ENGINE PERFORMANCE:

1. BRAKE POWER

V I Watts or Vi/1000 K.W.

Where, V = DC voltage in volts.

I = DC current in amps.



2. MASS OF FUEL CONSUMED:

Actual volume	:	V_a
Brake thermal efficiency	:	η_{bth}
Indicated thermal efficiency	:	η_{ith}
Swept volume	:	V_s
Mechanical efficiency	:	η_{mech}
Volumetric efficiency	:	η_v
Frictional power	:	FP

Description:

The engine is a four stroke single cylinder, air-cooled, spark ignition engine. The output is coupled to DC GENERATOR. The load is given to engine by DC Generator having a resistive load bank which will take load with the help of dc switches and also providing motoring test facility to find out power of engine.

Fuel measurement:

The fuel is supplied to the engine from the main feel tank through a graduated measuring fuel gauge (Burette) with 3-way clock. To measure the fuel consumption of the engine, fill the burette by opening the cock. By starting a stop clock, measure the time taken to consume Xcc of fuel by the engine.

***AIR INTAKE MEASUREMENT*:**

The suction side of the engine is connected to an Air tank. The atmospheric air is drawn into the engine cylinder through the air tank. The manometer is provided to measure drop across and orifice provided in the intake pipe of the Air tank. This pressure drop is used to calculate the volume of air drawn into the cylinder. (Orifice diameter is 20 mm.)

***LUBRICAITON*:**

The engine is lubricated by mechanical lubrication.

Lubricating oil recommended is SAE-40 OR Equivalent.

TEMPARATURE MEASUREMENT

A digital temperature indicator with selector is provided on the panel to read temperature in degree centigrade, directly sensed by respective thermocouples located at different places on the test rig.

Thermocouple details:

T1 = inlet water temperature to calorimeter

T2 = outlet water temperature to calorimeter

T3 = exhaust gas inlet to calorimeter

T4 = exhaust gas outlet to calorimeter

T5 = ambient temperature

$$Mfc = \frac{X \times 0.72 \times 3600}{1000 \times T} \text{……………………kg/hr}$$

Where, X = burette reading in cc

0.72 = density of petrol in gram/cc

T = time taken in seconds.

3. ***SPECIFIC FUEL CONSUMPTION*****:**

$$BSfc = \frac{Mfc}{BP} \text{………………kg/K w hr}$$

4. ***ACTUAL VOLUME OF AIR SUCKED IN TO THE CYLINDER***

$$V_a = C_d \times A \times \sqrt{2gH} \times 3600 \text{ …………………..m}^3\text{ / hr}$$

Where, $H = \left(\frac{h}{1000}\right) \times \left(\frac{\delta w}{\delta a}\right)$ ……………………Meter of water.

A = area of orifice = $\frac{\pi d^2}{4}$

H = manometer readings in mm

δw (Density of water) = 1000kg/m^3

δa (Density of air) = 1.193 kg/ m^3

C_d (Coefficient of discharge) = 0.62.

5. Swept Volume

$$Vs = = \frac{\pi m3}{4} \text{ X L X } \frac{N}{2} \text{ X } 60 \quad mm^3/hr$$

Where, d = dia of bore = 61.9 mm == 0.07

L = length of stroke = 60 mm = 66.7 mm = 0.0667

N=Speed of the engine in RPM.

6. Volumetric Efficiency

$$\eta_v = \left(\frac{V_a}{V_s}\right) \times 100 ---------\%$$

7. Brake Thermal Or Over All Efficiency

$$\eta_{bth} = \left(\frac{BP \times 3600 \times 100}{Mfc \times CV}\right) ------------\%$$

Where, CV = calorific value of patrol = 45000 kJ/kg.

BP = Brake Power in KW.

8. MECHANICAL EFFICIENCY:

$$\eta_{ith} = \left(\frac{IP \times 3600 \times 100}{Mfc \times CV}\right) -------------\%$$

9. MECHANICAL EFFICIENCY:

$$\eta_{mech} = \left(\frac{BP}{IP}\right) \times 100 -------------\%$$

Where, BP = Brake Power in Kw.

IP = Indicated power in KW.

MOTORING TEST

OBJECTIVE

To measure the FP of the given four stroke single cylinder petrol engine by MOTAEING TEST.

PROCEDURE:

1. To conduct the motoring test, first connect the rectifier to the panel board.
2. Remove the spark plug connection from the engine & switch off the ignition switch.
3. Keep the change – over switch in the motoring direction.
4. Now slowly increase the power using Varies provided in the rectifier circuit.
5. Increase the speed up to 2800 RPM and note down the armature current and voltage.
6. Now slowly decrease the power and turn the change- over switch to OFF condition.

FRICTIONAL POWER OF THE ENGINE:

FP (Engine) = FP (Total) – FP (Motor)

Where, FP (Motor) = No load generator losses.

FP (Total) = Total frictional Power.

$$= \left(\frac{V \times I}{1000 \times \eta}\right) --------------- KW$$ ……………………..KW

There fore, FP = …………KW.

INDICATED POWER

$IP = BP + FP$ (Engine)

Heat input = $\frac{Mfc \times CV}{60}$ ……………KJ/min

Heat equivalent to BP = BP X 60 ………..KJ/min

Heat carried away by cooling water (calorimeter)

$$= m_w \times Cp_w \left(T_2 - T_1\right)$$

Where, m_w = mass of water = $V_W \times \delta W$

V_W =volume of water flow in to calorimeter through rotameter R2

δW = density of water in kg/m^3

Heat carried away by exhaust gas

$$= m_g \times Cp_g \left(T_3 - T_5\right)$$

Where, m_g = mass of gas = $V_g \times \delta g$

V_g = volume of gas

δ_g = density of gas =1.193 kg/m^3

Cp_g = specific heat of burnt gas = 0.24 KJ/Kg K

E. Unaccounted Heat

= A-(B+D+E)…………….KJ/min

Experiment 4

PERFOMANCE TESTS ON 5 HP KIRLOSKAR ENGINE ROPE BRAKE DYNAMOMETER

AIM: To study the variations of total fuel consumption, specific fuel consumption, brake thermal efficiency &mechanical efficiency with brake power at constant speed, by conducting the performance test on the engine & to draw the following characteristics curves.

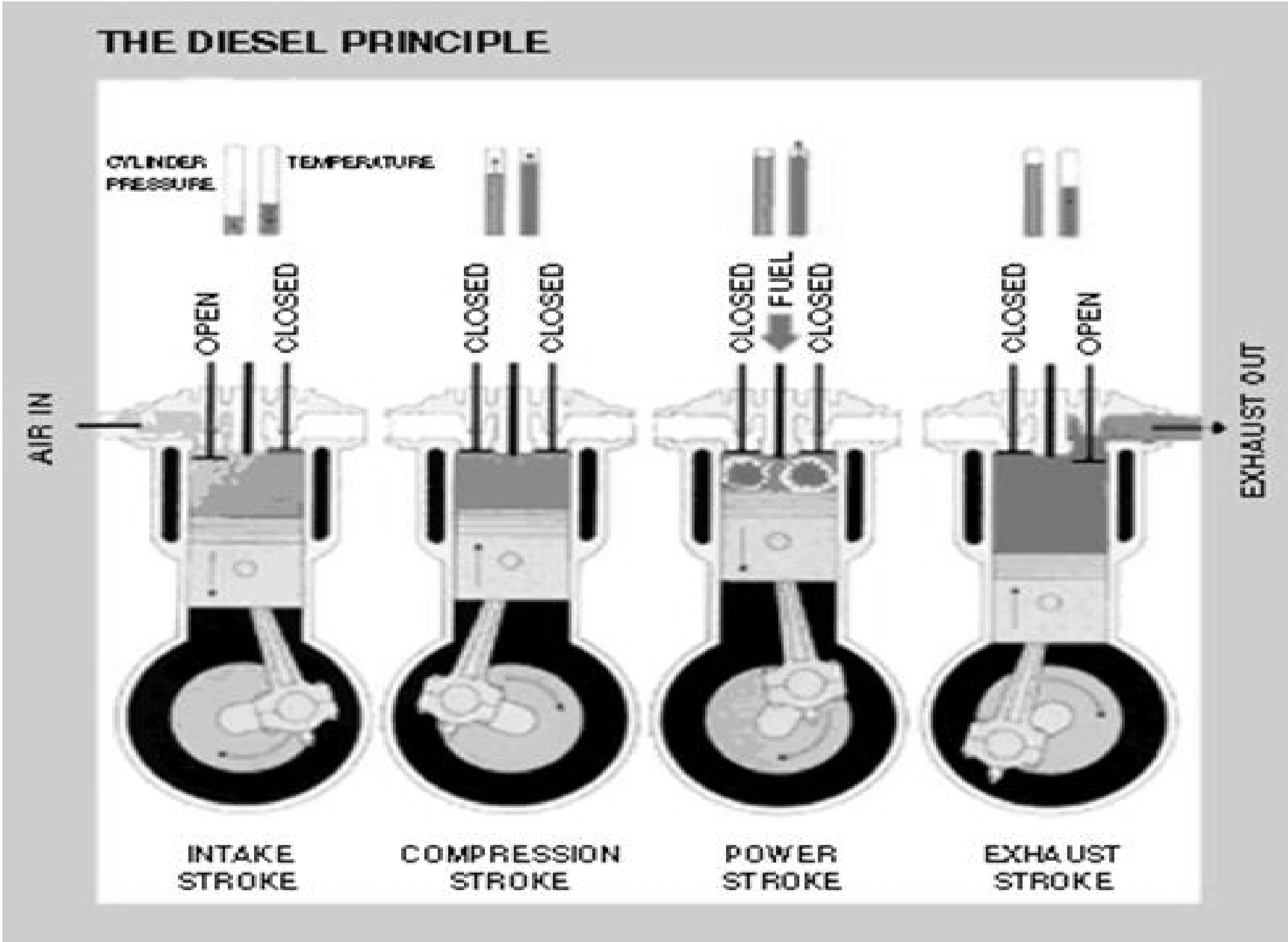
i. B.P. (vs.) T.F.C
ii. B.P(vs.) S.F.C
iii. B.P.(vs.) brake thermal efficiency
iv. B.P.(vs.) indicated thermal efficiency
v. B.P(vs.)mechanical efficiency

APPARATUS REQUIRED:

1. Stopwatch
2. Hand Tachometer

SPECIFICATION:

NAME OF THE MANUFACTURER	: KIRLOSKAR
RATED SPEED	: 1500RPM
BHP	: 5HP
FUEL	: DIESEL
NO OF CYLINDER	: SINGLE
BORE DIA	: 80MM
STROKE LENGTH	: 110MM
STARTING	: CRANKING
METHOD OF COOLING	: WATER COOLED
METHOD OF IGNITION	: COMPRESSION IGNITION
SFC	: 0.272KG/KW-HR
ORIFICE DIAMETER	: 20MM



THEORY: Engine performance is an indication of the degree of success with which it does its assigned job, conversation of chemical energy contained in the fuel in to the useful mechanical work. In evaluation of engine performance certain basic parameters are chosen & the effect of various operating conditions, design concepts &modifications on these parameters is studied. The basic performance parameters arte numerated &discussed below

i. Power &mechanical efficiency
ii. Mean effective pressure torque
iii. Specific output
iv. Volumetric efficiency
v. Air fuel ratio
vi. Specific fuel consumption
vii. Thermal efficiency

viii. Specific weight

Indicated power: The total power developed by combustion of fuel in the combustion chamber is called as indicated power. (I.P). The IP is measured from the indicator diagram obtained from indicator coupled to the engine.

Brake power: The brake power is the useful power available at the crank shaft (or) clutch shaft. The brake power obtained by applying the load at brake drum .the brake power is less than the Indicated power since it takes into account of the following

i. Pump losses due to indication &exhaust
ii. Mechanical losses in the bearings
iii. Resistance of air on flywheel rotation

Frictional power: The difference between IP& BP is called frictional power.

Specific fuel consumption: It is the mass of fuel consumed per kilowatt power developed per hour & is a criterion of economical power production.

Indicated thermal efficiency: Indicated thermal efficiency of IC engine is the ratio of heat converted into indicated work to the heat energy in the fuel supplied to the engine.

PROCEDURE: After taking all the precautions, engine is started with no load on it. Time taken for consumption of 10cc fuel & water manometer reading are noted. Now the load is applied in the steps of 2, 4, 6, 8, 10&12kgs.

The corresponding time taken for 10cc of fuel consumption, water consumption &water manometer reading are noted.

PRECAUTIONS:

1. Parallax error should be avoided while taking readings.
2. Before starting the engine check the cooling water supply and lubrication system.

RESULT: hence the performance test is conducted on 5 h.p kirlosker engine

s.no	load		Time taken for 10cc of fuel consumption 't'sec
	X(kgf)	X 9.81 (N)	
1.			
2			
3			
4			

MAXIMUM LOAD:

$$BP = \left(\frac{2\pi NT}{60}\right)$$

$$T = W \times R_{eff}$$

$$R_{eff} = R_{drum} + R_{beltthickness}$$

$$2\pi R = 9705$$

$$R = 0.15517\text{mm}$$

$$R_{eff} = 0.15517\text{m}$$

SAMPLE CALUCLATIONS

BRAKE POWER:

$$BP = \left(\frac{2\pi NT}{60}\right)$$

TOTAL FUEL CONSUMPTION:

Total fuel consumption $TFC = \left(\frac{mf \times 10}{t}\right) \times \frac{3600}{1000} \times sp$

Heat input:

Heat input=TFC x calorific value of diesel KJ/hr

BREAKE THERMAL EFFICENCY:

$$\eta_{bth} = \left(\frac{BP(KW) \times 3600}{heatinput\left(\frac{KJ}{hr}\right)} \right) \times 100$$

Specific fuel consumption:

$$sfc = \frac{TFC}{BP(KW)}$$

Indicated thermal efficiency:

$$\eta_{ith} = \left(\frac{IP \times 3600}{TFC \times CV} \right) \times 100$$

<u>DESCRIPTION OF TEST RIG</u>:

Air intake measurement: inlet end of the engine is connected to the intake air of the tank fitted with orifice plate.

Fuel intake measurement: the engine fuel inlet is connected to the fuel tank through 3 locks for running down the fuel.

a. Directly from tank to engine
b. To fill the burette from the fuel tank

MAXIMUM LOAD CALCULATIONS:

Brake power rating and rated speed are noted from name plate details .the max load is calculated using the formula supplied by the manufacturer itself.

$$Bhp=WN/2000$$

PROCEDURE: Before starting the check the fuel supply, cooling water supply and lubrication system. See that no-load should act on the hydraulic device. Engage the decompression lever. Crank the engine with the help of cranking handle .Since the lever is engaged with the decompression lever disengagement mechanism, the engine starts as soon as the lever disengages. Keeping the load at zero, adjust the fuel supply so that the engine attains its rated speed or the desired speed. Run the engine till the steady state conditions are attained. Note down the inlet and outlet temperatures of the cooling water. Note down the exhaust gas temp and manometer readings.

Set the hydraulic dynamometer to 20% of the full load and adjust the fuel supply so that the engine attains the desired speed. After the steady state is reached note down the hydraulic dynamometer reading, fuel consumption rate, cooling water flow rate, manometer reading and temps of cooling water and exhaust gases.

Repeat the experiment at 40%, 60%, 80%&100% of the full load at constant speed. Stop the engine after removing load on hydraulic dynamometer. Calculate the heat energy supplied in the fuel, heat energy equivalent to output power, heat energy carried away by cooling water, exhaust gases & miscellaneous heat energy loss as per calculations shown.

Precautions:

1. Parallax error should be avoided while taking readings
2. Before starting the engine check the cooling water supply lubrication system
3. All loads on the engine should be removed while starting and stopping of the engine.

Result: various heat transfers in the cycle are noted &the values are tabulated in heat balance sheet

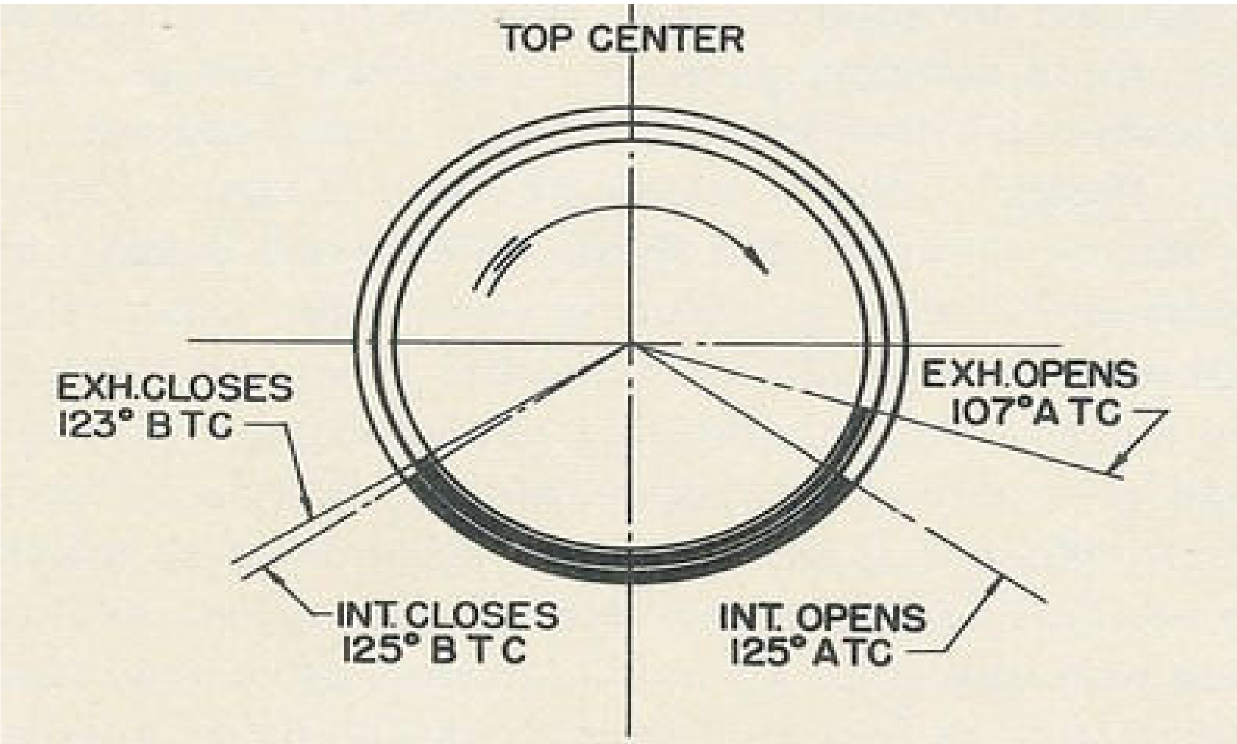


Fig. 2 - Valve port timing diagram

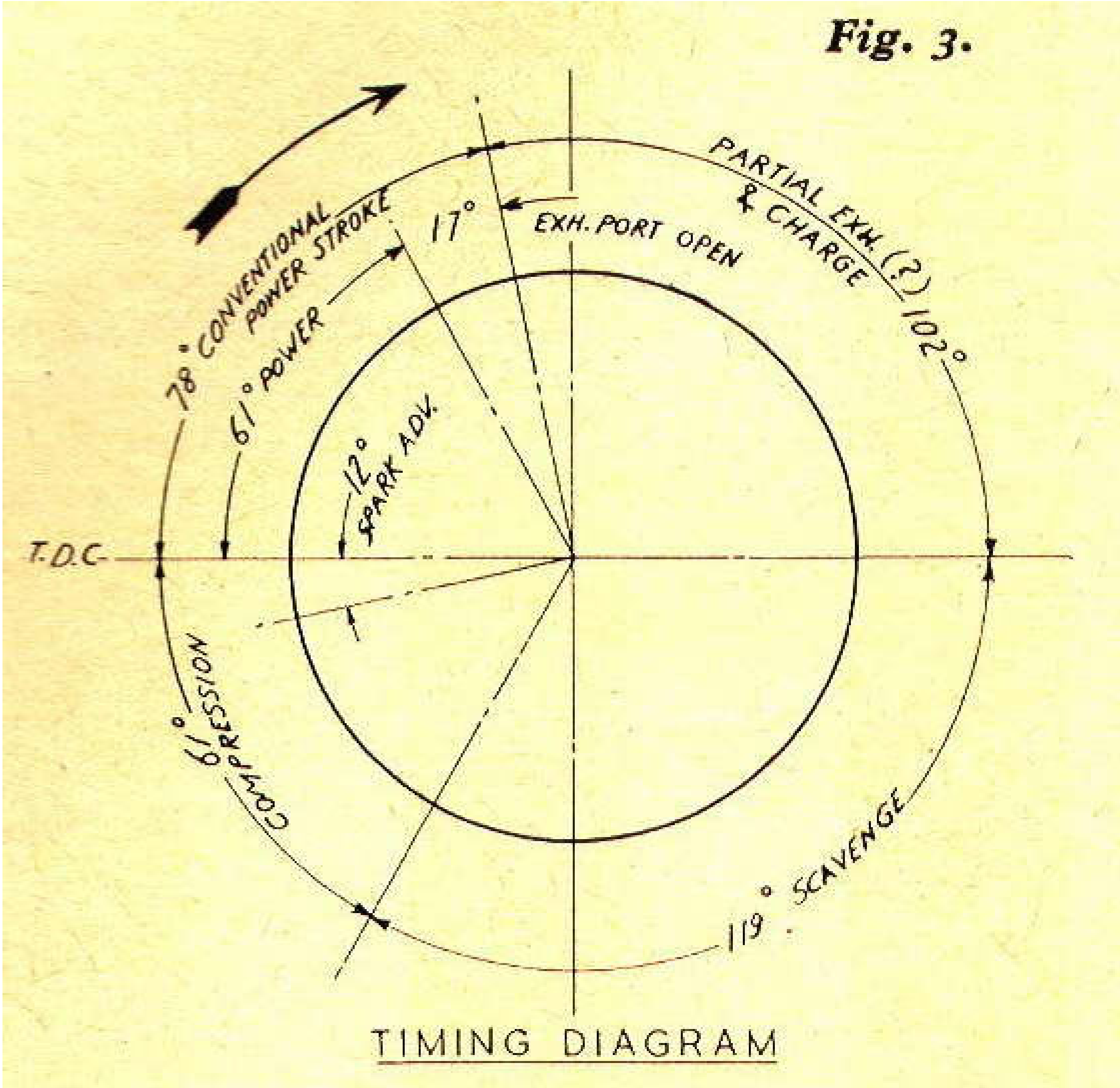
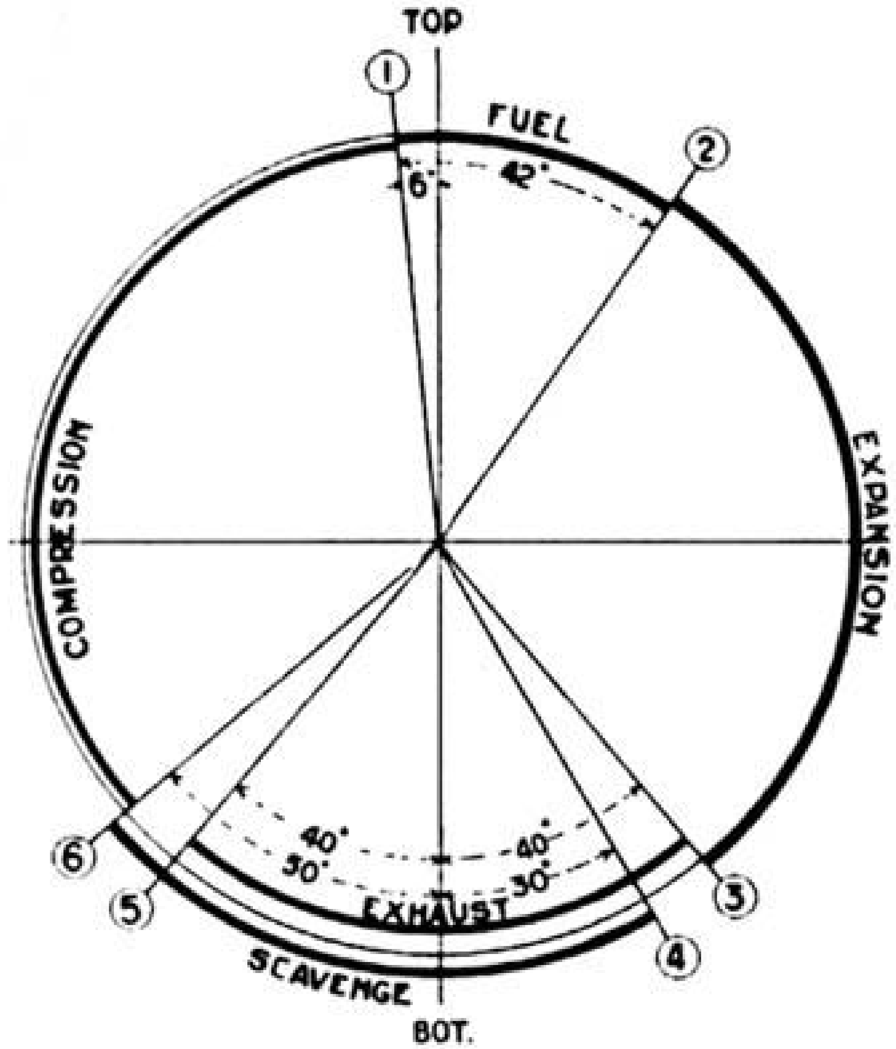
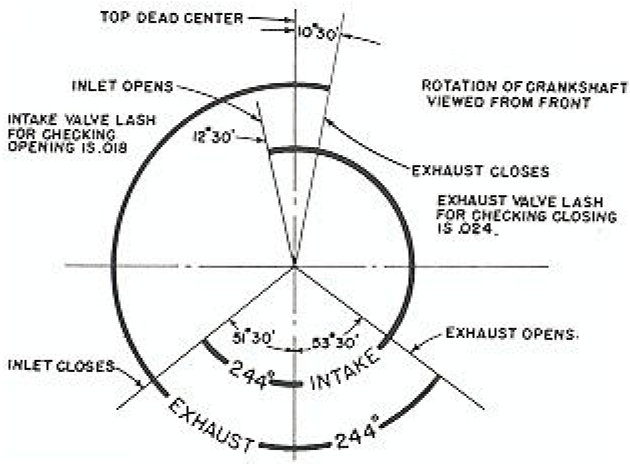
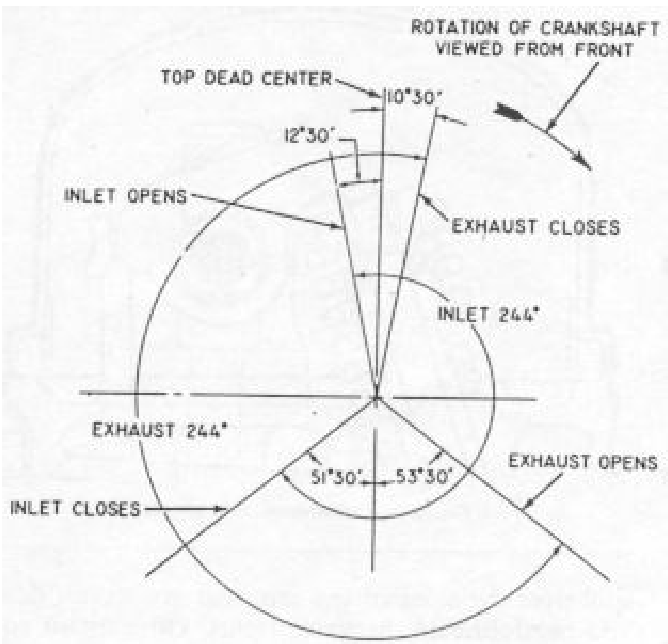


Fig. 3.
78° CONVENTIONAL POWER STROKE
61° POWER
17°
EXH. PORT OPEN
PARTIAL EXH. (?) & CHARGE
102°
12° SPARK ADV.
T.D.C.
61° COMPRESSION
119° SCAVENGE
TIMING DIAGRAM


TOP
1
FUEL
2
6°
42°
COMPRESSION
EXPANSION
40°
50°
40°
30°
6
5
3
4
EXHAUST
SCAVENGE
BOT.


TOP DEAD CENTER
10°30'
INLET OPENS
ROTATION OF CRANKSHAFT VIEWED FROM FRONT
INTAKE VALVE LASH FOR CHECKING OPENING IS .018
12°30'
EXHAUST CLOSES
EXHAUST VALVE LASH FOR CHECKING CLOSING IS .024
51°30'
53°30'
EXHAUST OPENS.
INLET CLOSES
244°
INTAKE
EXHAUST
244°


ROTATION OF CRANKSHAFT VIEWED FROM FRONT
TOP DEAD CENTER
10°30'
12°30'
INLET OPENS
EXHAUST CLOSES
INLET 244°
EXHAUST 244°
51°30'
53°30'
EXHAUST OPENS
INLET CLOSES

EXPERIMENT 5

BOMB CALORIMETER

1. **INTRODUCTION** :

A Bomb Calorimeter will measure the amount of heat generated when matter is burnt in a sealed chambar (Bomb) in an atmosphere of pure oxygen gas.

The ADVANCE ISOTHERMAL BOMB CALORIMETER provides a simple inexpensive yet accurate method for determination of heat of combustion, calorific value and the sulphur content of solid and liquid fuels. The outfit supplied is complete for analysis as per methods recommended by the Indian Standards Institution (IS: 1359-1959), British Standards Institution (BS 1016: Part 5 :1967) and the Institute of Petroleum (IP 12/63 T).Each part of the outfit has been finished and tested according to the specifications laid down by these Institutions.

2. **PRINCIPLE OF OPERATION:**

A known amount of the sample is burnt in a sealed chamber (Hereafter we shall refer to this chamber as Bomb'). The air is replaced by pure oxygen. The sample is ignited electrically. As the sample burns, heat is produced. The rise in temperature is determined. Since, barring loss of heat, the amount of heat produced by burning the sample must be equal to the amount of heat absorbed by the calorimeter assembly, acknowledge of the water equivalent of the calorimeter assembly and of the rise in temperature enables one to calculate the heat of combustion of the sample.

If W = Water equivalent of the calorimeter assembly in calories per degree centigrade;
T = Rise in temperature (registered by a sensitive thermometer) in degrees centigrade,
H = Heat of combustion of material in calories per gram: and
M = Mass of sample burnt in grams.
Then WT = HM

H is calculated easily since W, T and M are known.

3. **DEFINITIONS AND UNITS:**

Calorimetric measurements involve the use of various temperature and energy units. In order to avoid errors and confusion in the interpretation of these data, their relationships should be well understood.

TEMPERATURE: May be measured in either Fahrenheit or centigrade degrees. A temperature change of 1°C corresponds **to a** change of 1.8° F.

TIME : is customarily measured in minutes and second. For convenience in calorimetric calculations, it is expressed in minutes and decimal fraction thereof.

MASS: is expressed in grams.

HEAT ENERGY: may be expressed either as calories (cal) or British Thermal Units (Btu). The International Steam Table calorie is the basic unit in this system and equals 4.1868 absolute joules, and is equivalent to heat energy required to raise the temperature of one gram of water by one degree centigrade at 15.56°C. The British thermal unit equals 251.996 calories, or 1055.07 absolute joules, and is roughly equivalent to the heat energy required to raise the temperature of one pound of water by one degree fahrenheit at 60°F.

HEAT OF COMBUSTION : (also thermal value, heating value and calorific value) as determined with an oxygen bomb calorimeter is defined as the number of heat units liberated by a unit mass of the substance when burnt in a sealed enclosure of constant volume in an atmaophere of pure oxygen gas. In this reaction the substance and the oxygen are initially at the same temperature, and the products of the combustion are cooled to within a few degrees of the initial temperature; also the water vapour formed by the combustion is condensed to the liquid state. Therefore, a more exact definition would specify the temperature at which the reaction begins and ends. However, the change in the specific heat of water with the possible variations in the initial temperature is so small that this specification is not necessary.

It is commonly expressed either in calories per gram (cal/g) or British thermal unit per pound (Btu/lb). One cal/g equals 1.8 Btu/lb.

4. **CHARACTERISTIC REQUIREMENTS:**

(i) BOMB; When the sample burns, the pressure of gases increases rapidly, The Bomb walls, lid and joints should be strong enough to withstand the maximum working pressures, and there should be no leaks.Normal working pressures are about 30 atmospheres and overload pressures peak upto 100 atmospheres.

(ii) The capacity of Bomb should be large enough to store enough oxygen to ensure complete burning of the sample.

(iii) During burning the nitrogen and sulphur contents are oxidized to gases and then to nitric acid and sulphuric acid. The Bomb lining must therefore be resistant to acidic or basic ash and should be corrosion proof.

(iv) The stirrer unit should not generate excessive amount of heat due to stirring. Further, motor heat should not reach the colorimeter; otherwise the calculations will lead to erroneous results.

(v) All surfaces should have high reflectance to minimise losses.

(vi) Water equivalent of the calorimeter assembly should be small to ensure maximum rise in temperature of water following ignition.

5. **DESCRIPTION:**

Essentially the apparatus consists of the following parts:—

BOMB: The Bomb consists of three parts viz. Bomb Body, Lid and the Union Nut.

The Bomb vessel and the lid are machined from an ultra strong corrosion resistent stainless steel alloy rod, containing Chromium, Nickel and Molybdenum and satisfying special ringing and bending tests for intercrystalline corrosion. The

Bomb body is a cylindrical vessel having capacity of 303 ml. The walls are strong enough to easily support the normal operating pressure (30 atmospheres) and also extreme pressures as high as 300 atmospheres. During burning at high pressure the nitrogen and sulphur contents are oxidized to nitric acid and sulphuric acid respectively. The corrosion resistant nature of the Bomb material projects if from the corrosive vapours. The lid is provided with two terminals. Two metallic rods pass through these terminals one of which is provided with a ring for placing the sample crucible with a small hook and the other with a groove. The method of attaching fuse wire is given in section 7. Each rod is also provided with a ring to press the fuse wire attached to it.

The upper side of the lid is also provided with a small hook for lifting it and with a Schrader valve for filling oxygen in the Bomb. The Schrader valve is provided with a metallic cap.

EACH BOMB IS TESTED FOR ITS PERFORMANCE AS PER THE REQUIREMENTS OF THE INSTITUTE OF PETROLEUM (IP 12/63 T).THE TEST IS CONDUCTED AT A PRESSURE OF 300 ATMOSPHERES AND THE PRESSURE IS MAINTAINED FOR A PERIOD OF 10 MINUTES WITHOUT ANY SIGN OF LEAKAGE.

WATER JACKET: It is made of copper and is highly chromium plated on the outside and also inside to minimise radiative losses. The top of the jacket carries a rod to hold the stirrer unit, a threaded adopter to support the Beckman thermometer holder rod, and a small pipe through which water is added. This pipe also supports the thermometer for measuring temperature inside this jacket.

OFFSET STIRRER: It consists of a stirrer with fan driven at a constant speed of 800 R.P.M. by a motor through a heat insulator rubber belt. The motor unit is kept at sufficient distance from the vessel to eliminate radiative heating and a heat insulator bakelite divides the two parts of the stirrer rod. This arrangement does not raise the temperature of water by even .01°C in ten minutes, thus easily meeting the specific requirements laid down by the British Standards Institution and the Institute of Petroleum and accepted by the Indian Standards Institution. The electric supply for the stirrer motor is obtained through the terminals provided on firing unit.

CALORIMETER VESSEL : is made of copper and is brightly polished outside.

BOMB FIRING UNIT, VIBRATOR, TIMER AND ILLUMINATOR WITH MAGNIFIER :

The Firing Unit is operated by A. C. Mains (230 Volts, 50 Hz); and is provided with terminals for the Stirrer Unit. Vibrator-Timer-Illuminator Unit and for the Bomb Fuse Wire. The Firing Unit is provided with terminals for the Stirrer unit, the Vibrator-Timer-Illuminator Unit and for the Bomb Fuse Wire.

PRESSURE GAUGE ON STAND An accurate pressure gauge is supplied for measurement of pressure of oxygen in the Bomb. The dial is graduated from 0 to 70 kg/cm2 (0 to about 1000 lb./in2). Normally the oxygen is filled in the Bomb at a pressure of 25 kg/cm2.

PELLET PRESS : The pellet press has approximately 12 m.m. diameter puncn and die. Coal or other powdered samples are compressed into pellets before weighing and burning. This retards the burning rate and tends to retain the particles in the capsule, thereby reducing chances for incomplete combustion. The pellets are easier to handle than loose samples. The pellets should not be made very hard as excessive hardness leads to bursting, upon ignition with consequent with incomplete combustion.

CRUCIBLE:Stainless Steel crucibles are offered as standard with instrr nickel crucibles are being offered as accessories.
IGNITION WIRE:Nichrome wire is supplied with the instrument; but as an also being offered,Jment• quartz, platinum and alternative platinum wire is also being offered.

6.REAGENTS, SAMPLES AND SAMPLE HOLDERS, STANDARD SAMPLES :

BENZOIC ACID:is most commonly used as a calorific standard. It burns easily and completelyand can be compressed into pellets.

NAPHTHALENE:is sometimes used as a combustion standard. It is not hygroscopic but due to its volatility it is necessary to use care to avoid errors from sublimation.
SUCROSE OR CANE SUGAR : is also used as a standard sample and as a combustion aid. This material is neither volatile nor strongly hygroscopic but it is rather difficult to ignite and sometimes does not burn completely. The crystalline material should be ground to a powder before using.
STANDARD ALKALI SOLUTION The washing from an oxygen Bomb test must be titrated against *a* standard alkali solution to determine the acid correction. A 0.1 N Sodium carbonate solution is recommended. This is prepared by dissolving 5.2996 grams Nat CO3 in water and diluting to one litre. Sodium hydroxide or potassium hydroxide solutions of the same normality are acceptable. If sulphur is present in the sample other reagents as described in article **11** are required.
METHYL ORANGE OR METHYL RED INDICATORS : These are the usual indicators used for acid-alkali titrations.

ALLOWABLE SAMPLE SIZE : Care should be taken to avoid overcharging the Bomb. The mass of combustible charge (sample plus combustion aid) should not be more than 1,100 grams. When starting tests with new or unfamiliar materials, it is, always best to use samples of less than one gram. Not more than 10, 000 calories should liberated in any tests and it is advisable to work with mass liberating less than 7000 calories.

SELECTION AND PREPARATION OF SOLID SAMPLES : It is necessary that solid samples be air-dry and ground until all particles will pass through a 60 mesh screen. The particle size is important because the combustion reaction proceeds to completion within a few seconds, and if any of the individual particles are too large they will not burn completely. A sample that is too finely divided may also *be* difficult to burn, because extremely small particles can be swept out of the combustion capsule by the turbulent gases, and if they fall to the bottom of the Bomb without being ignited the test will give erroneous results.

Toshniwal pellet press offers a possible solution to the problem of incomplete combustion in the case of finally divided samples.

ANTHRACITES AND COKE: While testing anthracites coals, coke or other material of slow burning characteristics, it may be difficult to secure ignition and complete combustion of the entire sample. In **these** cases, the sample is ground fine enough to pass through IS sieve 20 (211 microns).A small weighed amount of a standard combustible material such as powdered benzoic acid, should be mixed with such samples to facilitate combustion.

FOOD STUFFS AND CELLULOSIC MATERIALS : The moisture content of most food stuffs will usually require that they be dried before making calorific tests. The operator will have to select a method for preparing the sample that will not destroy or remove any of the combustible constituents. It may be necessary to make several preliminary tests to determine the approximate maximum allowable moisture content at which the sample can be ignited in the Bomb without difficulty.

GELATINE CAPSULES : Volatile liquid samples to be burnt in an oxygen Bomb can be weighed and handled in gelatine capsules. The capsules consist of two cups which telescope together with a friction fit adequate to retain most liquids, correction must be made for the heat of combustion of the gelatine when used in calorimetry.

HEAVY OILS : Oils and other liquids which are not volatile at room temperature can be weighed directly into crucibles. The loop of the fuse should be positioned just above the surface of the sample. Nonvolatile liquids also can be weighed and handled in gelatine capsules.

EXPLOSIVES AND HIGH ENERGY FUELS : Special precautions must be observed when testing materials which release large volumes of gas upon ignition, or which denorate with explosive force. It is possible to test many slowburning gun powders and rocket propellents in conventional bombs, but the user must understand that these bombs are not designed to withstand the shock pressure produced by certain primers and other mixtures which denorate with explosive force. It is much safer to test these in a special high pressure oxygen bomb.

Each new explosive sample or high energy fuel inti °duces special problems which can be solved only by careful experimentation. Usually it will be welt to observe the burning of a small amount of sample over an open frame to determine the explosive behaviour and then to proceed to bomb combustions using only one tenth or one fifth of the usual amount of sample. Further increases up to the 10,000 calorie maximum permissible should be made gradually, and only after all evidence indicates the absence of violent behaviour.

7. **SETTING UP AND ASSEMBLY :**

GENERAL ARRANGEMENT : The laboratory in which the calorimeter is to operate should be equipped with many of the facilities commonly used for chemical analysis. These include desk space, running water, an analytical balance, apparatus for making volumetric titrations, and miscellaneous items of laboratory ware. The calorimeter should be used in a room where fluctuations in temperature can be avoided. In particular, the instrument should not be taken from one chamber to another chamber maintained at a different temperature immediately before use. Sufficient time must be allowed for equalisation of temperature throughout the jacket before starting to use the calorimeter. All parts of the calorimeter should be kept clean and dry, and the inside of the jacket should be wiped clean to remove any moisture which may have condensed on the walls. Before starting to use a new calorimeter it is advisable to assemble all parts of the apparatus without a charge in the bomb and without water in the bucket, to be sure that everything is in perfect working order.

ASSEMBLY OF CALORIMETER PARTS : Place the star supporter at the bottom of the jacket and set it so that the two pins provided inside the jacket do not allow it to be displaced. Place the bucket on the star supporter fitting the bucket pin into the supporter groove. Lift the bomb on its stand by hook and place it inside the bucket. Attach the supply connections to the electrodes provided on the lid of the Bomb. Place the combined lid of bucket and outer jacket in such a way that a pin provided on the cover plate of jacket fits into the smaller groove provided in the lid. Screw the support rod into the supporting plate on the cover. Attach the vibratortimer magnifier unit clamp and the thermometer bracket and screws to the rod. The thermometer support bracket and the vibrator clamp must be raised to its top position before opening the calorimeter.and it should be allowed to remain 'UP' at all times while the cover is off.

Unpack the Beckman thermometer with great care, check for mercury separations and reunite the mercury, if necessary. Hold the Beckman thermometer into the clamp by passing it through the hold in the magnifier unit. The bulb of Backman thermometer should extend about halfway to the bottom of the water jacket. This requires that approximately 15 centimeters of the thermometer be below the top of the cover. Mount the stirrer assembly on the stirrer rod provided on the cover plate of the calorimeter jacket passing the stirrer pipe through the opening provided in the combined lid of bucket and the outer jacket. The connecting leads attached with terminals provided on the bomb lid are now connected to the two terminals provided on cover of the calorimeter jacket. The connections are then further taken to the firing unit box terminals marked 'BOMB'. Similarly the vibrator and the stirrer connections are made to respective terminals on the firing unit box. The firing unit box is connected to the A.C. Mains (230 Volt to 50 Hz).

ATTACHING THE FUSE : All manipulations prior to closing the Bomb can be performed by holding the Bomb lid in the support stand- Cut a single length of fuse wire 10 cms long and attach it to the electrodes.

It is not necessary to submerge the wire in a powder sample. In fact, better combustion will usually be obtained if the loop of the fuse is set slightly above the surface. When using pelleted samples, bend the wire so that the loop bears against the edge of the pellet firmly enough to hold it against the side of the capsule. In case of liquid fuels, the capsule should be held as a loop of this wire. It is also a good practice to tilt the capsule slightly to one side so that the flame emerging from it will not impinge directly on the top of the straight electrode.

PLATINUM FUSE ARRANGEMENT : Platinum fuse wire can be attached to the electrodes in the manner described above but most platinum wire ignition procedures require cotton or nylon thread to carry on ignition flame to the sample. A coil is formed by winding out five turns of wire around a 2 mm diameter rod and removing the rod. The resulting coil is then connected between the electrodes and arranged to one side of the cup, with the axis of the coils pointing toward the sample. A short length of thread is than inserted through the coil and into the crucible.

WATER IN THE BOMB : Place 2.0 mt. of distilled water in the Bomb from a pipette.

FILLING THE BOMB WITH OXYGEN : While closing the Bomb always make certain that the head gasket or sealing ring is in good condition and care must be taken not to disturb the sample. Commercial oxygen produced by rectification of liquid air can be used directly from the supply cylinder.

To attach the filling connection place the Bomb on its stand. Put the high pressure valve in oxygen cylinder's outlet and connect copper tube to valve outlet. Draw up the union nut tightly. Connect copper tube to pressure gauge, pressure gauge to filling tube and filling tube to Bomb valve and make the connections perfectly tight. Open the filling connection control valve of cylinder slowly. Observe the gauge and allow the pressure to rise until the desired point is reached (about 25 atmospheres), then close the collection of gases control valve. To decrease pressure of Bomb the gas release valve can be used. By rotating the gas release valve in clockwise direction the pressure can be reduced to the desired extent.

FILLING WATER IN THE BUCKET : On a accurate balance determine the weight of the completely dry bucket, then add 2000 (± 0.5) grams of distilled water. Prior to weighing, the water should be brought to a temperature above 2°C below that of the calorimeter jacket. This initial adjustment generally will ensure a final temperature slightly above that of the jacket. The calorimeter water should be cooled or heated in an auxiliary container and not in the calorimeter bucket. The operator must also make sure that there is no moisture on the outside surface of the bucket when it is placed in the jacket.

8. **OPERATING THE ISOTHERMAL BOMB CALORIMETER :** Accurately weigh in the crucible of the calorimeter about one gram of the air-dried material ground to pass through IS Sieve 20 (211 microns).

If considered desirable, the sample may be compressed into a cylindrical pellet before weighing.

Stretch a piece of the firing wire across the electrodes within the Bomb. Tie about 10 cm length of sewing cotton around the wire; place the crucible in position and arrange the loose ends of the thread so that they are in contact with the material; use the same amount of thread in each determination. Introduce into the body of the bomb to milliliters of distilled water.

Reassemble the Bomb, screw home with the fingers, finally tightening it as necessary, avoiding excessive pressure. Charge the bomb slowly with oxygen from a cylinder to a pressure of 25 atmospheres without displacing its original air content. Close the valve effectively, using as little pressure as possible and detach the bomb from the oxygen supply.

Weigh into the calorimeter vessel a quantity of the water sufficient to submerge the nut of the bomb to a depth of at least two millimeter leaving the terminals projecting. Using the same weight of water in all tests. Transfer the calorimeter vessel water jacket, lower the bomb carefully into the calorimeter vessel, and having ascertained to be gas-tight, connect it to the ignition circuit through a switch for subsequent firing of the charge. Adjust the stirrer; place the thermometer and covers in position and start the stirring mechanism, which must be kept in continuous operation at a constant speed during the experiment. After an interval of not less than ten minutes, read the temperature to 0.001'C and continue the readings for five minutes, at equal intervals of not more than one minutes, tapping the thermometer lightly during 10 seconds prior to each reading. If, over a period of five minutes, the average deviation of the individual values of the rate of change of temperature is less than 0.00072°C per minute, close the circuit momentarily to fire the charge and continue the observations of the temperature at intervals of similar duration to those of the preliminary period. If the rate of change of temperature is not constant within this limit, extend the preliminary period until it is constant. In the chief period which extends from the instant of firing until the time after which the rate of change of temperature again becomes constant, take the earlier readings to the nearest 0.01°C since it will not be possible to take the earlier readings to 0.001°C. Resume the readings to thisnprecision as soon as possible.
Determine the rate of change of temperature in the after period (which follows the chief period by taking readings at 1 minute intervals for at least five preferably ten minutes).

NOTE : It is desirable to keep the jacket temperature and the room temperature as close to the calorimeter temperature as possible. The jecket and room temperature should therefore be recorded.
Remove the bomb from the calorimeter and after a lapse of about half an hour from the time of firing allowing the acid mist to settle, release the pressure by opening the valve. Verify that the combustion has been completed by noting the absence of any sooty deposit within the bomb. The presence of any trace of sooty deposit, indicates incomplete combustion and invalidates the test.
Wash out the contents of the bomb with hot distilled water into a hard glass beaker washing the bomb cap and the crucible. Add a measured excess, say 25 ml. of 0.1 **N** sodium carbonate solution and boil down to 16 ml. to convert any metallic sulphates or nitrates to the less soluble carbonate or hydroxide; the consumption of alkali carbonate is equivalent to the sulphates or nitrates together with the free sulphuric and nitric acids. Filter, wash and make upto 100 ml. To determine the sulphur content take 50 ml. portion of this solution and follow the method as given in Section 11.

Determine the total acidity by titrating a 50 ml. portion with 0.1 N hydrochloric acid using methyl orange as indicator, the titre representing the excess alkali in one half of the quantity of sodium carbonate solution added to the washings.

9.STANDARDIZING THE CALORIMETER :

DEFINITION: The water equivalent is the weight of water which is equivalent in effective heatcapacity to the entire system (Calorimeter vessel containing a specified weight of water; calorimeter bomb charged with oxygen; fuel and water; thermometer and stirrer). Since the specific heat of water is 1.00010.002 cal/VC in the range 10° to 40`C, the water equivalent is approximately equal to the effective heat capacity (cal/°C), the factor that is determined experimentally. Since the true water equivalent is not required and is never evaluated, it is the effective heat capacity which should be considered. The effective heat capacity is the heat required to effect unit temperature rise in the system under the conditions of a calorimetric determination. The effect heat capacity has a temper- ature dependence since the specific heats of the constituent parts of the system vary with temperature. 25°C has been chosen as the reference temperature because of its use in thermochemical calculations and because the specific heat of water in the range 25° to 40`C is constant within ± 0.002cal/g°C.

PRINCIPLE : The effective heat capacity of the system is determined by burning pure and dry benzoic acid weighing not less then 0.9 and more then 1.1 gram.Determine the corrected temperature rise T, from the observed test data, also titrate the bomb washings to determine the nitric acid correction, and measure the unburnt fuse wire, compute the energy equivalent by substitution in the following equation :-

$$W=(HM+E1+E2)/T$$

Where: W energy equivalent of calorimeter in calories per degree centigrade;

Heat of combustion of standard benzoic acid in calories per gram;
M mass of standard benzoic acid sample in grams;
T — corrected temperature rise in degrees centigrade;
E1 correction for heat of formation of nitric acid in calories; and
Ez correction for heat of combustion of firing wire, in calories

DISCUSSION In determination of calorific value, principle observation is that of temperature-rise which when corrected and multiplied by the effective heat capacity at the mean temperature of the chief period gives the heat release. The thermometer readings at the begining and end of the chief period are corrected, using *the* certificate, obtainable from NPL, New Delhi upon request to allow for the inacuracy of the thermometer. Further allowance is necessary for three sources of variable heat change (the cooling loss, the sulphur correction and the nitrogen correction) and under certain circumstances for a source of constant heat gain (the heat of firing due to cotton and wire). The variable sources of heat change must be allowed for in each test, but the source of constant heat gain can be treated as one correction and under specified conditions neglected. It is convenient to calculate the cooling loss as a temperature, rise. The correction is multiplied by the appropriate effective heat capacity to get the total heat release. To the heat release so calculated, the corrections for sulphur, nitrogen and, if necessary, for the source of constant heat gain, are applied to give the true heat release.

10.1 **PRECAUTIONS :** The Operator must follow the following basic point in order to operate this oxygen bomb safely.

(a) Do not use too much sample. The bomb cannot be expected to withstand the effects of combustible charges which liberate more than10,000 calories.This generally limits the total weight of combustible material (sample plus gelatine, firing oil or any combustionaid) to not more than 1.10 gram. Do not charge with more oxygen then is necessary and do not fire the bomb if an overcharge of oxygen should accidentally be admitted.

(b) Keep all parts of the bomb especially the insulated electrode assembly - in good repair at all times. Do not fire the bomb if gas bubbles are leaking from the bomb when it is submerged in water.

(c)Stand back from the calorimeter for at least 15 seconds after firing and above all, keep clear of the top of the calorimeter. If the bomb should explode, it is most likely that the force of explosion will be directed upward.

(d)Proceed with caution and use only a fraction of the allowable maximum sample when testing new materials which burn rapidly, or have explosive characteristics.

AEROSPACE STRUCTURES

LABORATORY MANUAL

B.TECH
(III YEAR – I SEM)
(2016-17)

Prepared by:
Mr. K. Durga rao, Associate Professor
Mr. G. Sai sathyanarayana, Assistant Professor

Department of Aeronautical Engineering

MALLA REDDY COLLEGE
OF ENGINEERING & TECHNOLOGY

(Autonomous Institution – UGC, Govt. of India)

Recognized under 2(f) and 12 (B) of UGC ACT 1956
Affiliated to JNTUH, Hyderabad, Approved by AICTE - Accredited by NBA & NAAC – 'A' Grade - ISO 9001:2015 Certified)
Maisammaguda, Dhulapally (Post Via. Hakimpet), Secunderabad – 500100, Telangana State, India.

DEPARTMENT OF AERONAUTICAL ENGINEERING

VISION

Department of Aeronautical Engineering aims to be indispensable source in Aeronautical Engineering which has a zeal to provide the value driven platform for the students to acquire knowledge and empower themselves to shoulder higher responsibility in building a strong nation.

MISSION

a) The primary mission of the department is to promote engineering education and research.

(b) To strive consistently to provide quality education, keeping in pace with time and technology.

(c) Department passions to integrate the intellectual, spiritual, ethical and social development of the students for shaping them into dynamic engineers.

PROGRAMME EDUCATIONAL OBJECTIVES (PEO'S)

PEO1: PROFESSIONALISM & CITIZENSHIP To create and sustain a community of learning in which students acquire knowledge and learn to apply it professionally with due consideration for ethical, ecological and economic issues.
PEO2: TECHNICAL ACCOMPLISHMENTS To provide knowledge based services to satisfy the needs of society and the industry by providing hands on experience in various technologies in core field.
PEO3: INVENTION, INNOVATION AND CREATIVITY To make the students to design, experiment, analyze, interpret in the core field with the help of other multi disciplinary concepts wherever applicable.
PEO4: PROFESSIONAL DEVELOPMENT To educate the students to disseminate research findings with good soft skills and become a successful entrepreneur.
PEO5: HUMAN RESOURCE DEVELOPMENT To graduate the students in building national capabilities in technology, education and research.

PROGRAM SPECIFIC OBJECTIVES (PSO's)

1. To mould students to become a professional with all necessary skills, personality and sound knowledge in basic and advance technological areas.
2. To promote understanding of concepts and develop ability in design manufacture and maintenance of aircraft, aerospace vehicles and associated equipment and develop application capability of the concepts sciences to engineering design and processes.
3. Understanding the current scenario in the field of aeronautics and acquire ability to apply knowledge of engineering, science and mathematics to design and conduct experiments in the field of Aeronautical Engineering.
4. To develop leadership skills in our students necessary to shape the social, intellectual, business and technical worlds.

PROGRAM OBJECTIVES (PO'S)

Engineering Graduates will be able to:

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

CONTENTS

CODE OF CONDUCT FOR THE LABORATORIES

- All students must observe the Dress Code while in the laboratory.
- Sandals or open-toed shoes are NOT allowed.
- Foods, drinks and smoking are NOT allowed.
- All bags must be left at the indicated place.
- The lab timetable must be strictly followed.
- Be PUNCTUAL for your laboratory session.
- Program must be executed within the given time.
- Noise must be kept to a minimum.
- Workspace must be kept clean and tidy at all time.
- Handle the systems and interfacing kits with care.
- All students are liable for any damage to the accessories due to their own negligence.
- All interfacing kits connecting cables must be RETURNED if you taken from the lab supervisor.
- Students are strictly PROHIBITED from taking out any items from the laboratory.
- Students are NOT allowed to work alone in the laboratory without the Lab Supervisor
- USB Ports have been disabled if you want to use USB drive consult lab supervisor.
- Report immediately to the Lab Supervisor if any malfunction of the accessories, is there.

Before leaving the lab

- Place the chairs properly.
- Turn off the system properly
- Turn off the monitor.
- Please check the laboratory notice board regularly for updates.

INTRODUCTION

COLUMNS

A long vertical bar subjected to an axial compressive load is called a column.

Terminology:

1. Slenderness ratio: It is the ratio of length of column to the minimum radius of gyration of the cross-section of the column. A column is said to short column when slenderness ratio is less than 32 and if the slenderness ratio is between 32 to 120 the column is said to be medium column and if the slenderness ratio is more than 120 the column is called long column.
2. Blucking load: It is the minimum load at which the column tends to have lateral displacement or tends to buckle. Buckling load is also called as crippling or critical load.
3. End Conditions: A loaded column can have any one of the following end conditions.

- Both ends hinged
- One end fixed and other hinged
- Both ends fixed
- One end rigidly fixed and other entirely free

Let L = length o f column

l_e = equivalent length

= L when both ends are hinged

=L/√2 when one ends is fixed and other hinged

=L/2 when both ends are fixed

= 2L when one end rigidly fixed and other entirely free

Crippling load is calculated as follows:

i). Using Euler's formula:

$P = \pi^2 EI / l_e^2$

Where P = crippling load

E = Young's modulus of elasticity

I = moment of inertia

l_e = Equivalent length

ii). Using Rankine's Formula

$P = f_c .A / [1+ \alpha(l_e /K)^2]$

Where f_c =intensity of stress at yield point in compression

A = area of cross-section of column

K = Least radius of gyration of cross section of column

α = Rankine's constant (depending on end condition and material of column)

The values of f_c and constant 'α 'of some of the materials are shown in table below:

Material	**Compressive stress($\sigma_c$in M Pa)**	**Young's Modulus E, G Pa**	**Rankin's Constant 'α' or 'a'**
Cast iron	562.5	91.189	1/1600
Wrought iron	233.6	213	1/9000
Mild steel	276.3	210	1/7500
Medium carbon steel	414.5	210	1/5000
Aluminum	199.1	70	1/5000
Timber	473.6	96	1/2000

RIVETED JOINTS

In engineering practive, there are many items which are built up of a number of separate pieces rigidly attached together by means of permanent joints. For example, boilers, water-tanks and various other vessels which are subjected to internal pressure are constructed out of separate steel sheets joined together permanently. Further, steel structures, such as cranes, bridges, beams, trusses, etc., are also built up of separate steel sections rigidly fastened together. Riveting is one of the most commonly used methods of producing rigid and permanent joints in all such cases.

Rivet:

A rivet is a small metal rod of circular cross section. It consists of two parts,viz., head and shank. Mild steel, wrought iron, copper and aluminum are some of the metals commonly used for making rivests; the choice will naturally depend upon the application.

Riveting:

The rivet is placed in a hole drilled or punched through the two parts to be joined, and the shank end is made into a rivet head, either by cold working or by applying pressure in red-hot condition. If this is done under the application of a steady force by means of hydraulic or pneumatic pressure, the shank of the rivet will bulge uniformly, filling the rivet hole more tightly. The rivet hole is always made slightly larger in diameter than the rivet so as to facilitate the insertion of the rivet before riveting.

Classification of riveted joints:

Riveted joints in common use can be classified as structural joints and boiler joints.

Structural joints:

These joints are used in forming steel structures out of rolled steel sections of different shapes and sizes, some of which are shown in fig.

Fig shows an angle joint used to connect two plates at right angles to each other. Here the two plates are riveted to the two faces of an equal angle rolled steel bar, employing a single row of rivets. The position of the rivets and other proportions are also marked in the fig.
Fig. shows a column and beam and fig a compound girder illustrating some forms of the structural joints built up of roller steel sections.
In all sectional joints the length of the joints decided by the loads that are to be resisted by the joints.

TYPES OF RIVET HEADS

The rivet heads classified as follows:

i). Indian standard rivets for general and structural purposed below 12 mm diameter.
ii).Indian standard rivets for general and structural purposed 12 to 48mm diameter.
iii).Indian standards boiler rivets 12 to 48mm diameter.

Indian standard rivets for general and structural purposes below 12mm diameter are generally made of mild steel, brass, copper or aluminum depending upon the purpose and place where to be used. Fig. shows various types of rivet heads for rivets below 12mm diameter:

Fig. shows rivet heads used for rivets for structural and general purposes are 12 to 48mm diameter.

Indian standard boiler rivets heads are shown in Fig.

Rivet Hole Diameter

In structural and pressure vessel riveting, the diameter of the hole is usually 1.5mm larger than nominal of rivet.

Table 1 gives diameters of rivets and corresponding rivet holes in mm for boiler joints.

Table 1

Nominal diameter of rivet	Rivet hole diameter	Nominal diameter of rivet	Rivet hole Diameter
12	13.5	27	29
14	15.5	30	32
16	17.5	33	35
18	19.5	36	38
20	21.5	39	41
22	23.5	42	44
24	25.5	48	50

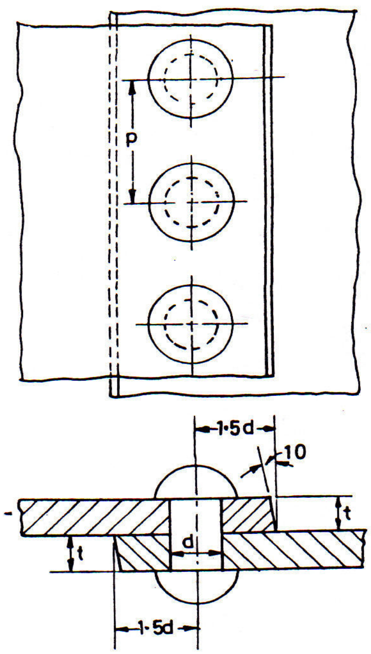


Fig. . Single riveted lap joint.

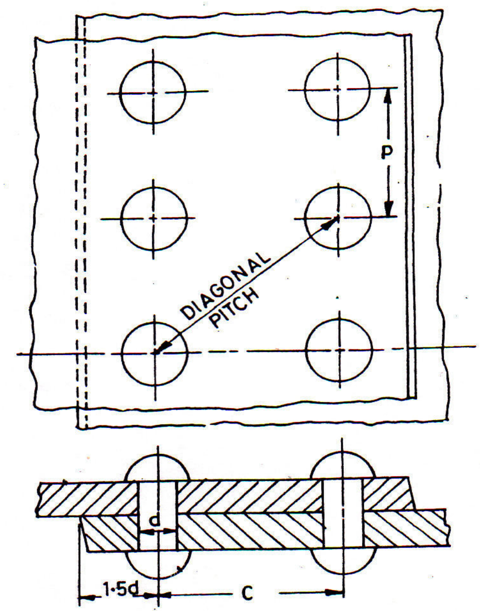


Fig. . Double-riveted lap joint (Chain Riveting)

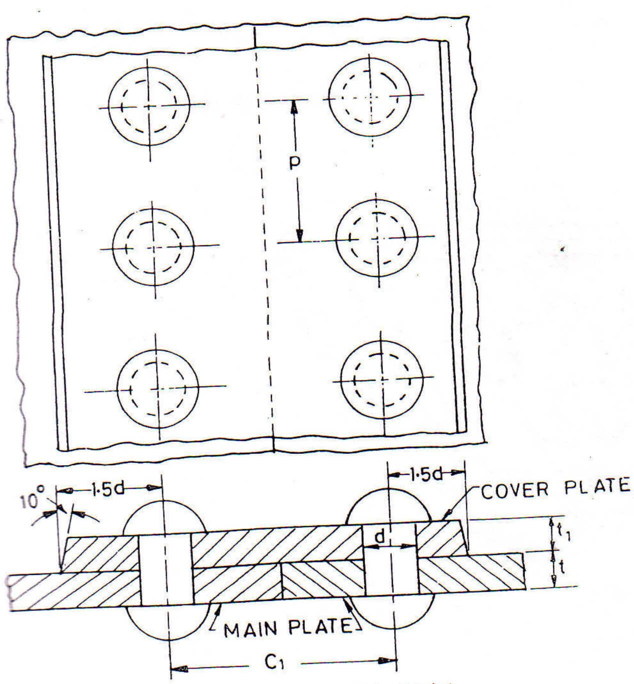


Fig. . Single riveted butt joint.

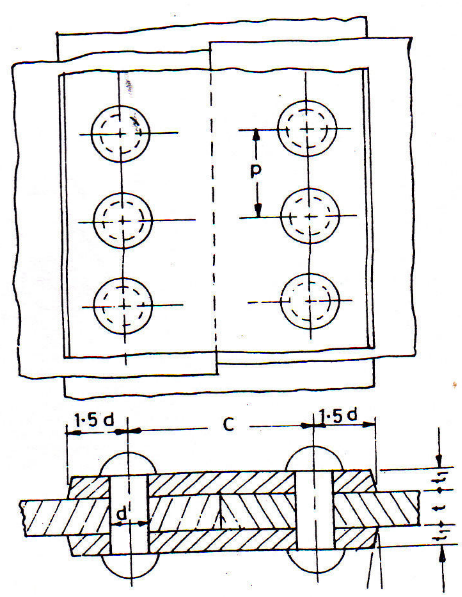


Fig. . Single riveted butt joint.

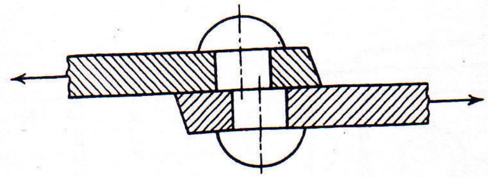


Fig. 5.20. Rivets in single shear.

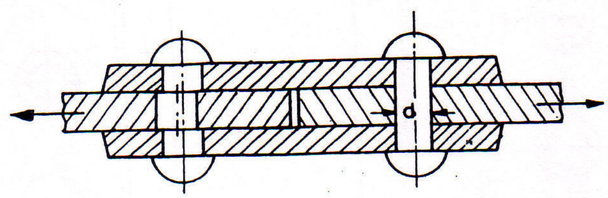


Fig. . . Rivets in double shear.

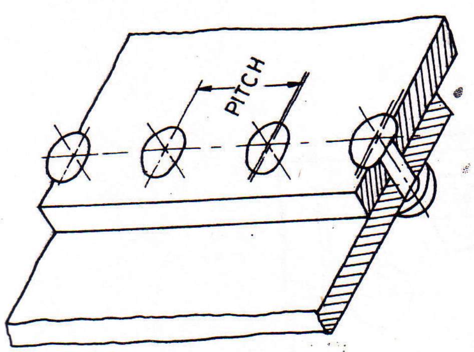


Fig. . . Single riveted lap joint.

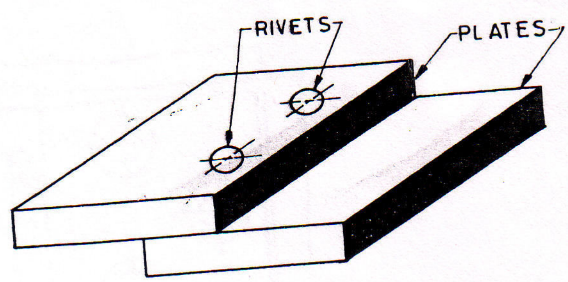


Fig. . Lap joint.

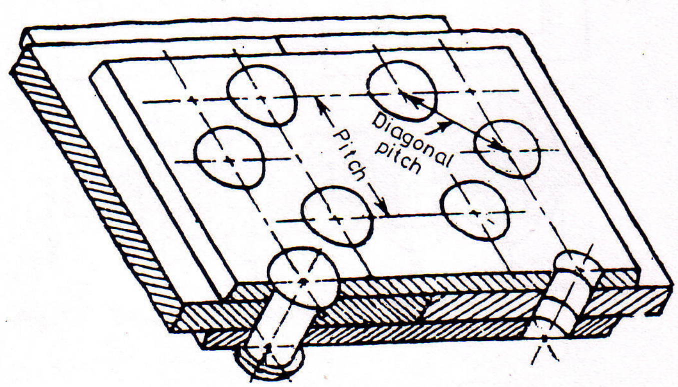


Fig.

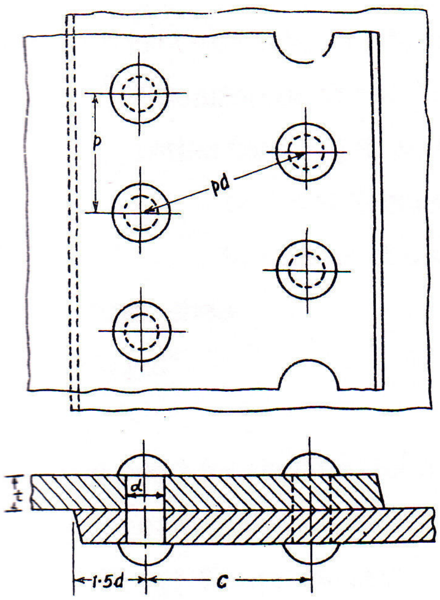


Fig. .. Double-riveted lap joint (Zig-zag riveting).

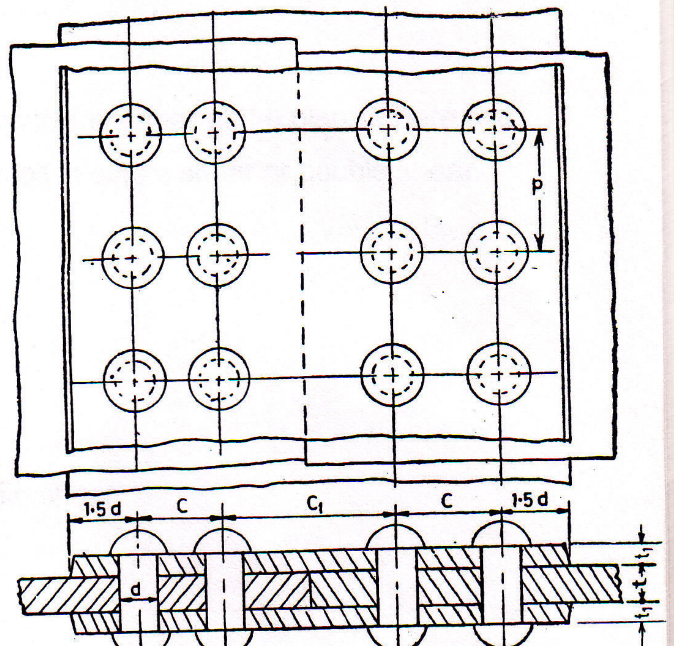


Fig. ... Double riveted double cover butt joint (Chain Riveting).

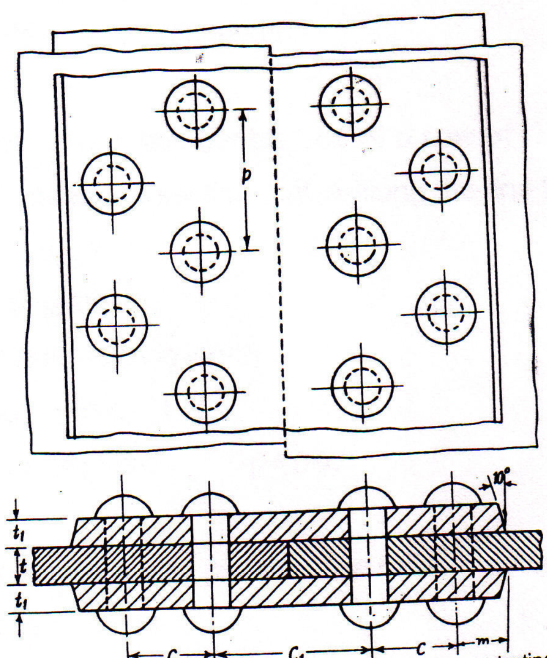


Fig. 5 -- Double riveted double cover butt joint (Zig-zag riveting).

Failure of Riveted joints

A riveted joint may fall in the following ways.

I. Shearing of rivets. The rivets may fall in shear at the plane where two plates meet together. A rivet may fail in single shear or double shear.

d = Rivet diameter

f_s = Shear stress of rivets.

A = area_ shear

$= K \times \frac{\pi . d^2}{4}$

Where

k=1 for single shear and

for double shear

K=2(theoretically)

=1.75 to 1.875(practically)

P_s =shear strength =A x f_s

$= n. K \times \frac{\pi . d^2}{4} \times f_s$

n = Number of rivets in one pitch length

(ii)Tearing of plate along the center line of a row of rivets. The plate may tear along the line of minimum section that is along through the centre of holes.

f_t = tensile stress of plates

A = area of plate under tearing =(p-d).t

P_t = tearing strength = (p-d).t. f_t

Where t = thickness of plate; p = pitch

(iii).Crushing of rivets and plates. The rivets may fail under crushing.

f_c = crushing stress of rivets

A = area under crushing = n.d.t

P_c = crushing strength

$= A \times f_c = n.d.\ f_c\ .\ t$

Strength of a riveted joint. The least value out of shearing, tearing strength and crushing strength is called strength of the riveted joint.

Rivets should always be placed at right angles to the acting forces, and the maximum stress induced in them should be either shear or crushing. In a long rivet the initial stress set up at the junction of the shank and the point. When the rivet cools is dangerous. This initial stress increases with the relative length of the rivets, and in a very long rivet, it may cause the head to snap off without any load. For this reason, the length of the rivet between the heads should not exceed four or five times its diameter.

Efficiency of a riveted joint: It is the ratio of the strength of the joint to the tearing strength of the unpunched plate.

P = Tearing strength of unpunched plate

$= p \times t \times f_t$

η_s = Shearing efficiency

$$= \frac{P_s}{P} = \frac{n.k.(\pi/4)d^2 \times f_s}{p.t.f_t}$$

$$\eta_c = \text{Crushing efficiency} = \frac{P_c}{P} = \frac{n.\ d\ .t\ .f_c}{p \times t \times f_t}$$

$$\eta_t = \text{Tearing efficiency} = \frac{P_t}{P} = \frac{(p-d).t.f_t}{p \times t \times f_t}$$

$$= \frac{p - d}{p}$$

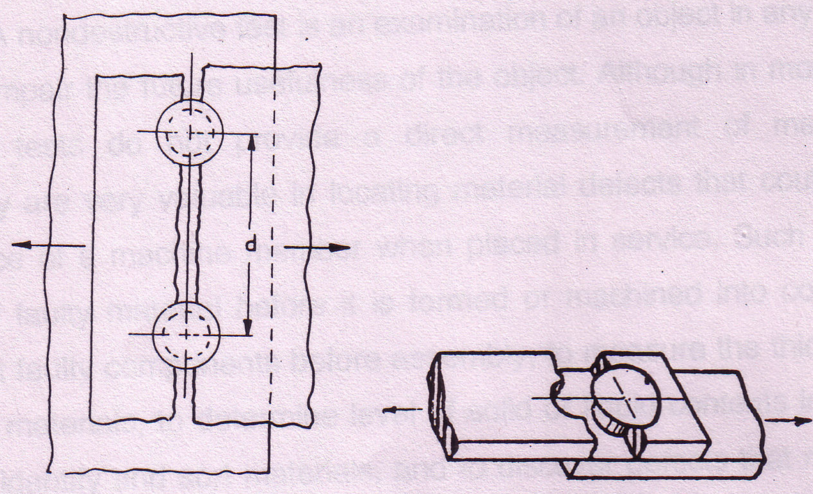
The lowest of the three efficiencies is called as the efficiency of the joint.

Table 2 indicates the average efficiency and the maximum pitch for some types of commercial boiler joints.

Table 2

Type of a joint	Efficiency	Maximum pitch (cms)
Lap joints		
Single riveted	45-65	1.31 t = 4.128
Double riveted	63-70	2.62 t = 4.128
Triple riveted	72-80	3.47 t = 4.128
Butt joints(2 cover plates)		
Single riveted		
Double riveted	55-60	1.75 t = 4.128
Triple riveted	70-85	3.5 t = 4.128
	80-90	6 t = 4.128

The Indian Boiler regulations (I.B.R) allows a maximum of 85% efficiency for the best riveted joint.



(a) (b) Tearing of plate.

Fig. [illegible]

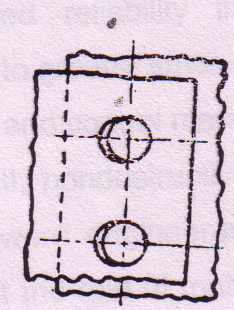


Fig. [illegible]

NON DESTRUCTIVE TESTING

Introduction:

Defects of many types and sizes may be introduced to a material or a component during manufacture and the exact nature and size of any defects will influence the sub salient performance of the component. Other defects such as fatigue cracks or corrosion cracks, may be generated within a material service. It is therefore necessary to have reliable means for detecting the presence of defects at the manufacturing stage and also for detecting & monitoring the rate of growth of defects during the service life of a component or assembly.

Much valuable information is obtained from test like tensile test, compression test, shear & impact tests for different properties of material, but such tests are of destructive nature.

In addition, the material properties as determined in a standard to destruction, do not necessarily give a clear guide to the performance characteristics of a complex- shaped component which forms part of some larger Engineering assembly.

Hence, many systems have been developed which will provide information on the quality of a material or component and which do not alter or damage the components or assemblies which are tested. These are nothing but NON – DESTRUCTIVE TESTING TECHNIQUES.

A nondestructive test is an examination of an object in any manner which will not impair the future usefulness of the object. Although in most cases nondestructive tests do not provide a direct measurement of mechanical properties, they are very valuable in locating material defects that could impair the performance of a machine member when placed in service. Such a test is used to detect faulty material before it is formed or machined into component parts, to detect faulty components before assembly, to measure the thickness of metal or other materials, to determine level of solid or liquid contents in opaque containers, to identify and sort materials, and to discover defects that may have developed during processing or use. Parts may also examined in service, permitting their removal before failure occurs.

Nondestructive tests are used to make the products more reliable, safe, and economical. Increased reliability improved the public image of the manufacturer, which leads to greater sales and profits. In addition, manufacturers use these tests to improve and control manufacturing processes.

Before World War II, nondestructive testing was not urgent because of large safety factors that were engineered into almost every product. Service failures did take place, but the role of material imperfection in such failures was not then fully recognized, and, therefore little concentrated effort was made to find them. During, and just after, World War II the significance of imperfections to the useful life of a product assumed greater importance. In aircraft design, in nuclear technology, and space exploration, high hazards and cost have made maximum reliability essential. At the same time, there has been extensive growth of all inspection methods in industrial and scientific applications.

There are five basic elements in any non destructive test.

1. Source: A source which provides some probing medium, namely, a medium that can be used to inspect the item under test.
2. Modification: This probing medium must change or be modified as a result of the variations or discontinuities within the object being tested.
3. Detection: A detector capable of determining the changes in the probing medium.
4. Indication: A means of indicating or recording the signals from the detector.
5. Interpretation: A method of interpreting these indications. While there are a large number of nondestructive tests in use, this section will concentrate on the most common methods and on one recent development. The most common methods of nondestructive testing or inspection are:

Radiography

Magnetic- particle inspection

Fluorescent – penetrant inspection.

Ultrasonic inspection

Eddy current inspection

Radiography of metals The radiography of metals may be carried out by using X-rays or gamma rays – short – wavelength electromagnetic rays capable of going through relatively large thickness of metal. Gamma rays may be obtained from a naturally radioactive material such as radium or a radioactive isotope such as cobalt -60. Gamma radiation is more penetrating than that of x- ray but the inferior sensitivity limits its application. There is no way that the source may be regulated for constrast or variable thickness, and it usually requires much longer exposure times than the x- ray method.

X – rays are produced when matter is bombarded by a rapidly moving stream of electrons. When electrons are suddenly stopped by matter, a part of their kinetic energy is converted to energy of radiation, or X – rays. The essential conditions for the generation of X- rays are (1) a filament (cathode) to provide the source of electrons proceeding towards the target, (2) a target (anode) located in the path of electrons,(3) a voltage difference between the cathode and anode which will regulate the velocity of the electrons striking the target and thus regulate the wavelength X- rays produced, and (4) a means of regulating tube current to control the number of electrons striking the target. The first two requirements are usually incorporated in an X-ray tube. The use of X-rays for the examination of a welded plate is shown schematically in Fig. X –rays are potentially dangerous, and adequate safeguards must be employed to protect operating personnel.

A Radiograph is a shadow picture of a material more or less transparent to radiation. The X – rays darken the film so that regions of lower density which readily permit penetration appear dark on the negative as compared to regions of higher density which absorb more of the radiation. Thus a hole or crack appears as a darker area, where as copper inclusions in aluminum alloy appear as lighter areas.

While the radiography of metals has been used primarily for the inspection of castings and welded products, it may also be used to measure the thickness of materials. Fig shows a simple radiation thickness gauge. The radiation from the source is influenced by the material being tested. As the thickness increases the radiation intensity reaching the detector decreases. If the response of the detector is calibrated for known thicknesses, the detector reading can be used to indicate the thickness of the inspected material. With the suitable feedback circuit the detector may be used to control the thickness between predetermined limits.

Magnetic – particle inspection (Magna flux): This is the method of detecting the presence of cracks, laps, tears, seams, inclusions, and similar discontinuities in ferromagnetic materials such as iron and steel. The method will detect surface discontinuities too fine to be seen by the naked eye and will also detect discontinuities which lie slightly below the surface. It is not applicable to nonmagnetic materials.

Magnetic particle inspection may be carried out in several ways. The piece to be inspected may be magnetized and then covered with the fine magnetic particles (iron powder). This is known as the residual method. Or, the magnetization and application of the particles may occur simultaneously. This is known as the continuous method. The magnetic particles may be held in suspension in a liquid that is flushed over the piece, or the piece may be immersed in the suspension (wet method). In some applications, the particles, in the form of a fine powder, are dusted over the surface of the work piece (dry method). The presence of a discontinuity is shown by the formation and adherence of a particle pattern on the surface of the work piece over the discontinuity. This pattern is called an indication and assumes the approximate shape of the surfaces projection of the discontinuity. The magnaglo method developed by the Magna Flux Corporation is a variation of the magna flux test. The suspension flowed over the magnetized work piece is then viewed under blank light, which make the indications stand out more clearly. When the discontinuity is open to the surface, the magnetic field leaks to the surface and form small north and poles that attract the magnetic particles (see fig).
When fine discontinuities are under the surface, some part of the field may still be deflected to the surface, but the leakage is less and fewer particles are attracted, so that the indication obtained is much weaker. If the discontinuity is far below the surface, no leakage of the field will be obtained and consequently no indication. Proper use of magnetizing methods is necessary to ensure that the magnetic field set up will be perpendicular to the discontinuity and give the clearest indication.

As shown in fig., for longitudinal magnetization, the magnetic field may be produced in a direction parallel to the long axis of the work piece by placing the piece in a coil excited by an electric current so that the long axis of the piece is parallel to the axis of the coil. The metal part then becomes the core of an electromagnet and is magnetized by induction from the magnetic field created in the coil. Very long parts are magnetized in steps by moving the coil along the length. In the case of circular magnetization also shown in fig. magnetic field transverse to the long axis of the work piece is readily produced by magnetizing current through the piece along the axis.

Direct current, Alternating current and Rectified alternating current are all used for magnetizing purposes .Direct current is more sensitive than Alternating current for detecting discontinuities that are not open to the surface. Alternating current will detect discontinuities open to the surface and is used when the detection of this type of discontinuity is the only interest. When Alternating current is rectified it provides a more penetrating magnetic field.

The sensitivity of the magnetic particle inspection is affected by many factors, including strength of the indicating suspension, time in contact with the suspension, time allowed for indications to form, time subject to magnetizing current, strength of the magnetizing current. Some examples of the cracks detectable by magna flux or magnaglo are shown in fig,

All machine parts that have been magnetized for inspection must be put through a demagnetizing,they will attract filings, grindings, chips and other steel particles which may cause scoring of bearings and other engine parts. Detection of parts which have not been demagnetized is usually accomplished by keeping a compass on the assembly bench.

Ultrasonic inspection: The use of sound waves to determine defects is a very ancient method. If a piece of metal is struck by a hammer, it will radiate certain audible notes, of which the pitch and damping may be influenced by the presence of internal flaws. However this technique of hammering and listening is useful only for the determination of the large defects.

A more refined method consists of utilizing sound waves above the audible range with a frequency of 1 to 5 million Hz (cycles per second) – hence the term ultrasonic .Ultrasonic is a fast, reliable nondestructive testing method which employs electronically produced high-frequency sound waves that will penetrate metals, liquids, and many other materials at a speed of several thousand feet per second. Ultrasonic waves for nondestructive testing are usually produced by piezoelectric materials. These materials undergo a change in physical dimension when subjected to an electrical field. This conversion of electrical energy to mechanical energy is known as piezoelectric effect. If an alternating electrical field is applied to a piezoelectric crystal will expand during the first half of the cycle and contract when the electrical field is reversed. By varying the alternating electric field, we can vary the frequency of the mechanical vibration (sound wave) produced in the crystal. Quartz is a widely used ultrasonic transducer. A transducer is a device for converting one form of energy to another.

Two common ultrasonic test methods, the through – transmission and the pulse – echo methods, in fig. The through – transmission method uses an ultrasonic transducer on each side of the object being inspected. If an electrical pulse of the desired frequency is applied to the transmitting, the ultrasonic waves produced will travel through the specimen to the other side. The receiving transducer on the opposite side receives the vibrations and converts them into an electrical signal that can be amplified and observed on the cathode- ray tube of an oscilloscope, a meter, or some other indicator. If the ultrasonic wave, travels through the specimen without encountering any flaw, the signal received is relatively large .if there is a flaw in the path of the ultrasonic wave, part of the energy will be reflected and the signal received by the receiving transducer will be reduced.

The pulse- echo method uses only one trasducer which serves as both transmitter and receiver. The pattern on an oscilloscope for the pulse-echo method would look similar to that shown in fig., As the sound wave enters the material being tested; part of it is reflected back to the crystal where it is converted back to an electrical impulse. This impulse is amplified and rendered visible as an indication or pip on the screen of the oscilloscope. When the sound wave reaches the other side of the material it is reflected back and shows as another pip on the screen farther to the right of the first pip. If there is a flaw between the front and back surfaces of the material, it will show as a third pip on the screen between the two indications for the front and back surfaces, since the indication on the oscilloscope screen measures the elapsed time between reflection of the pulse from the front and back surfaces, the distance between indications is a measure of the thickness of the material. The location of a defect may therefore be accurately determined from the indication on the screen.

In general, smooth surfaces are more suitable for the higher frequency testing pulse and there by permit the detection of smaller defects. Proper transmission of the ultrasonic wave has a great influence on the reliability of the test results. For a large part, a film of oil ensures proper contact between the crystal searching unit and the test piece. Smaller parts must be placed in a tank of water, oil, or glycerin. The crystal searching unit transmits sound waves through the medium and into the material being examined. Close examination of the oscilloscope in this picture shows the presence of three pips. The left pip indicates the front of the piece, the right pip the back of the piece, and smaller center pip is an indication of a flaw.

Ultrasonic inspection is used to detect and locate such defects as shrinkage cavities, internal bursts or cracks, porosity, and large nonmetallic inclusions. Wall thickness can be measured in closed vessels or in cases where such measurement cannot otherwise be made.

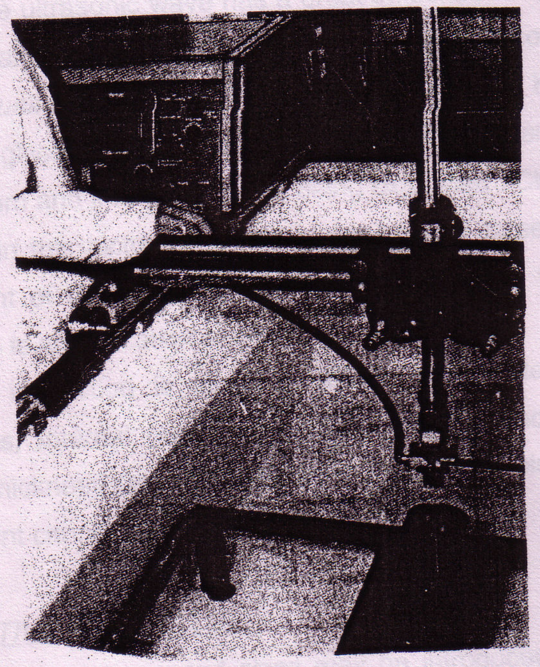


Fig. Ultrasonic inspection by immersion in a water tank. (Fansteel Metallurgical Corporation)

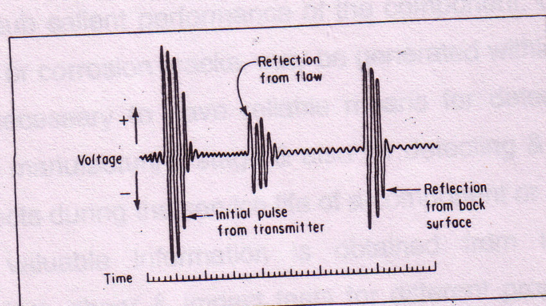


Fig. Oscilloscope pattern for the pulse-echo method of ultrasonic inspection.

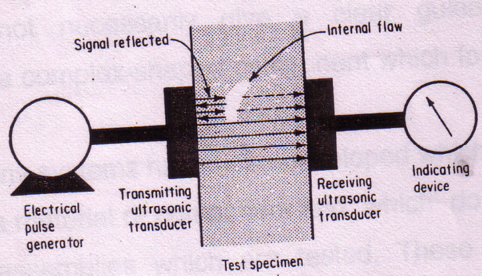


Fig. The through-transmission and pulse-echo methods of ultrasonic inspection.

Reliability of Defect detection:-

The reliability of any NDT technique is a measure of the efficiency of the technique in detecting flaws of a specific type, shape & size. After inspection has been completed it can be stated that there is a certain probability that a component is free of defects of a specific type & size.

It must be always borne probes may be inserted into cavities, ducts & pipes.

NDT systems coexist & depending on the application may either be used singly or in conjugation with one another.

There is some overlap between the various test methods but they are complementary to one another. The fact that, for example ultrasonic testing can reveal both internal & surface flaws does not necessarily mean that it will be the best method for all inspection applications.

Much will depend upon the type of flaw present & shape of the components to be examined.

Quality of inspection:-

When NDT systems are used, care must be taken & processes controlled so that not only qualitative but quantitative information is received and this information is both accurate and useful. If NDT is in mind that ND inspection is carried out for most part by human beings and number of people will perform same task all the time. Hence decision must be estimated from statistical data.

Benefits of NDT:-

Clear benefits of NDT is the identification of defects which if they remained undetected, could result in a catastrophic failure which would be very costly.

INSPEC-TION METHOD	WHEN TO USE	WHERE TO USE	ADVANTAGES	LIMITATIONS
Eddy current	Measuring variations in wall Thickness of thin metals or coatings; detecting longitudinal seams or cracks in tubing; determining heat treatments and metal compositions for sorting	Tubing and bar stock parts of uniform geometry, flat stock, or sheets and wire.	High speed, Non contact, automatic.	False indications result from many conductive materials; limited depth of penetration.
Radiography: X-rays	Detecting internal flaws and defects; finding welding flaws, cracks, seams ,porosity, holes, inclusions, lack of fusion; measuring variations in thickness	Assemblies of electronic parts, casting, welded vessels; field of testing of welds; corrosion surveys. Components of nonmetallic materials	Provides permanent record on film; works well on thin sections; high sensitivity; fluoroscopy techniques available; adjustable energy level.	High initial cost; power source required; radiation hazard; trained techniques needed.
Gamma X - ray	Detecting internal flaws, cracks, seams, holes, inclusions, weld defects; measuring thickness variations	Forgings, castings, tubing, welded vessels; field testing welded pipe; corrosion surveys.	Detects variety of flaws; Provides a permanent record; portable; low initial cost; source is small(good for inside shots)makes panoramic exposures	One energy level per source; radiation hazard; trained technicians needed; source loses strength continuously.

Magnetic particle	Detecting surface or shallow subsurface flaws, cracks, porosity, non metallic inclusions and weld defects;	Only for ferromagnetic materials; parts of any size, shape, composition or heat treatment.	Economical , simple in principle, easy to Perform; portable(for field testing);fast for production testing	Material must be magnetic; demagnetizing after testing is required power source needed; parts must be cleaned before finishing.
Penetrant	Locating surface cracks, porosity, laps, cold shuts, lack of weld bond, fatigue and grinding cracks.	All metals, glass and ceramics, castings, forgings, machined parts and cutting tools; field inspections	Simple to apply, portable, fast, low in cost; results easy to interpret; no elaborate setup required.	Limited to surface defects; surfaces must be clean
Ultrasonic pulse echo	Finding internal defects, cracks. lack of bond, laminations, inclusions, porosity, determining grain structure and thicknesses.	All metals and hard non metallic materials; sheets, tubing, rods, forgings, castings; field and production testing; in service part testing; brazed and adhesive bonded joints.	Fast dependable, easy to operate; lend itself to automation, results of test immediately known; relatively portable, highly accurate, and sensitive.	Requires contact or immersion of part; interpretation of readings requires training.

TENSILE TEST

Aim:-

To conduct tensile test on a mild steel specimen and determine the following.

- Ultimate strength
- Young's Modules.
- Percentage reduction in area.
- Malleability
- Percentage elongation
- True stress & true strain.

Test Material Required:

Tensile testing machine, specimen, steel rule, venires caliper, micrometer.

Theory:

In order to study the behavior of ductile material in tension, tensile test is conducted on standard specimen who is made up of ductile material, in a U.T.M up to destruction. The testing machine is called UTM because in this machine more than one test can be conducted

For ex:-tension, compression, bending, shearing etc.

The end of specimen is gripped in U.T.M and one of the gips moved apart, thus exerting tensile load on specimen. The load applied is indicated on a dial and extension is measured by using extensometer. Almost all the U.T.M's are provided with and autographic recorder which records load Vs deformation curve.

The figure shows a typical stress-strain curve for mild steel from stress-strain graph the mechanical behavior of the material is obtained.

The straight line portion from 0 to A represents the stress is proportional to strain. The stress at A is called "Proportionality limit". In this range of loading the material is elastic in nature. At B, elastic limit is reached. At point C, there is an increase in strain without appreciable increase in load is called Yielding.

Point C is called "Upper Yield Point".
Point D is called "Lower Yield Point".

After Yielding , any further increase in load will cause considerable increase in strain and the curve rises till the point 'E' which is known as point of Ultimate Stress.

The deformation in the range is plastic. At this stress, the bar will development break at point E.

Procedure:-

- Measure the original gauge length and diameter of the specimen.
- Insert the specimen into grips of the test machine.

- Begin the load application and record the load vs. elongation load.
- Take the readings more frequently as yield point is approached.
- Measure elongation values.
- Continue the test till fracture occurs.

Sl.No	Stress	Strain

Observation:

Graph:

Result:

VERIFICATION OF MAXWELL'S RECIPROCAL THEOREM

Aim:

To verify Maxwell's Reciprocal Theorem for a given simply supported beam.

Equipment:

- MS beams
- End supports
- Scale
- Weights
- Dial gauge

DIMENSIONS:

Length of the beam = ------------cm

Width = ----------------------------cm

Thickness = -----------------------cm

THEORY:

Maxwell's Reciprocal Theorem states that in any beam or truss the deflection at any point 'C' due to the load 'W' at any point 'D', is same as the deflection at 'D' due to the same load 'W' at point 'C'.

PROCEDURE:

1. Consider a simply supported beam.
2. Apply load in steps at point 'D', L/4 distance at one end and note the deflection at C , L/4 distance from the other end for each loading.
3. Now repeat the same at the point C and note the readings at D for each load.
4. Repeat the above procedure for different locations of loads and deflection point from each end.

PRECAUTIONS:

- Make sure that dial gauge tip should just touch the beam under stand.
- The dial gauge needle should be adjusted to zero before taking the initial reading without parallax error.

Sl.No	Load (gms)	Deflection (P)	Deflection (Q)

RESULT:

It is observed that Maxwell's Reciprocal Theorem is proved.

DEFLECTION OF CANTILEVER BEAM

Aim:-

To find the deflection of the cantilever beam.

Work Material Required:

Cantilever beam

Test Material Required:

- Dail gauge
- Loads
- Scale

Theory:

A beam fixed at one end and free at the other end is known as cantilever beam and when ever a cantilever beam is being loaded deflects from the original position. The amount of beam deflection depends upon the cross section and the Bending moment (B.M). The parameters in the basic design of cantilever are the following.

Strength

Stiffness

As there are many methods for finding the slope and deflection at a section in the loaded cantilever beam the following are widely used methods to find the deflection.

1. Double integration method
2. Moment area method.

1. DOUBLE INTEGRATION METHOD:-

The bending moment at a point is given by

$$M = EI.\frac{d^2y}{dx^2}$$

Now integrating

$$EI.\frac{dy}{dx} = \int M$$

Again integration

$$EI.y = \iint M$$

First equation gives slope, later one gives deflection

2. MOMENT AREA METHOD:-

This method gives the slope and deflection of the beam.

I method:-

The change of slope between any two points on an elastic curve is equal to the net area of B.M diagram between these points divided by EI

I= A / EI

II method:-

The intercept (between) taken on a given vertical reference line of tangents at any points on an elastic curve is equal to the moment of B.M diagram between these points about the reference line divided by EI

Y=A(x)/EI

PROCEDURE

- Measure the dimensions of the given cantilever beam.
- Fix the deflection angle gauge of some specified position and vary the loads of the free end of beam.
- By applying suitable conditions increasing loads at the free end note down the deflections reading at the specified position.

- Now in second experiment, reverse the position of the load and deflection gauge respectively.

- Note down the corresponding deflections for the varying loads.

ANALYSIS:

The cantilever is being tested for the design criteria i.e., for its strength and the stiffness purpose. It should be strong enough to resist the bending loads.
Shear stress and the deflection of the beam,

APPLICATIONS:

- Building constructions

- Aircraft design and fabrication of all structural elements

- Industrial applications

- Designing of huge and medium structures

PRECAUTIONS:

- Load the cantilever at the free end properly
- Place (or) get the initial readings of the gauge to zero
- Carefully note the deflection reading

CALCULATIONS:

Length of the Beam l = ______

Sl.No.	Load	Deflection by experiment			Deflection by Theoretical
		During Loading	During Un-loading	Average	

Theoretical deflection δ = ______

RESULT:

Deflection of the cantilever beam is _____

LONG COLUMN

Aim :

To find out the young's modulus of the given long column.

Formula:

$$P_{cr} = \frac{\Pi^2 EI}{l^2}$$

Euler formula for crippling load.

Where P_{cr} = crippling load

E=Young's modulus of elasticity

I=moment of inertia

l=Equivalent length

Specimen: long column

Machine: UTM

Instruments: scale , vernier calipers.

Description:

Here we are taking a long column and finding out its crippling load in the UTM machine by keeping it in between two flat plates. And then finding out its young's modules by applying Euler's formula.

For applications of Euler's theory the column should satisfy the following conditions

1) The column should be perfectly straight and axially loaded.
2) The section of column should be uniform.
3) The column material & perfectly elastic homogeneous and isotropic & obeys Hooke's law.
4) The length of the column is very compared to the lateral dimension.
5) The direct stresses are very small compared with the bending stress
6) The weight will fail by buckling alone.

Now we will consider a long column with both ends hinged.

Let AB be a column of length 'L' and uniform sectional area A hinged at both the ends A & B. Let P be the crippling load at which the column has just buckled.

Consider any section at a distance 'X' from the end B. Let 'y' the be the deflection (lateral displacement) at the section.

The bending moment at the section is given by El $\frac{d^2y}{dx^2}$ = --P_y

$$El\frac{d^2y}{dx^2} + P_y = 0$$

$$\frac{d^2y}{dx^2} + P_y / EI = 0$$

The solution to the above different equation is

$Y=c_1 \cos (x\sqrt{p/El}) + c_2 \sin (x\sqrt{p/El})$

Where c_1 & c_2 are constants of integration

At B, the deflection is Zero

Therefore At x=0, y=0

$C_1=0$

At A also, the deflection is Zero

Therefore At x=l, y=0

$0= c_2 \sin (l\sqrt{p/El})$

Since $c_1 = 0$ we conclude that c_2 cannot be Zero.

Because if both c_1 & c_2 are zeros the column will not bend at all

Hence $\sin(l\sqrt{p/El}) = 0$

$l\sqrt{p/El}=0, \pi, 2\pi, 3\pi, 4\pi$

Considering the least particle value

$l\sqrt{p/E}= \pi$

$$P= \pi^2 EI / l^2$$

Here the effective length of the column i.e, L= l because both ends are hinged putting

$l = AK^2$

$$P= \pi^2 EA/ (l/k)^2$$

Where l/k = slenderness ratio.

For long column it is >120

So the buckling load is

$$P= \pi^2 EI/l^2 = \pi^2 EA/(l/k)^2$$

Procedure:

1) Measure the specimen & find its moment of inertia.
2) Fix the specimen between the two plates.
3) Before starting the experiment the load gauge of deflection scale is kept at zero
4) Start the machine & apply the load over the column.
5) After the experiment is done i.e. when the column starts buckling we get the crippling load.

And hence the Young's modulus of the material can be found out by Euler's formula.

Precautions:

1) Keep the column perfectly perpendicular to the jaws.

Calculations:

Cross-sectional area of the specimen = A =

Moment of the inertia ,M.I. = I =

Radius of gyration, K =

$P_{cr} = \pi^2 EI/l^2 =$

E =

Result:

The young's modulus of the given specimen is MPa

SHORT COLUMN

Aim:

To find the compressive stress of a short column for a given material.

Equipment:

1. Universal testing machine
2. Test specimen (short column)
3. Scale, Vernier callipers.

Dimensions:

- Diameter = __________ mm or Cross section of the specimen = ________
- Length = __________mm

Theory:

- slenderness ratio = $\frac{\text{length of the column } (l)}{\text{Least radius of gyration}}$

- If slenderness ratio is less than 20 then the column is short column.
- A very short column will fail by crushing load, given by

$P_C = F_C . A$

Where,

F_C --- Ultimate crushing stress

A ----Uniform cross sectional area of short column,

By adding the crushing load of a suitable factor of safety, safe load for the member can be computed.

Rankine's Formula:-

- Short columns fail by crushing the load at the failure point given by $P_C = F_C . A$
- Long columns fail by buckling and the buckling load is given by $P_b = \pi^2 EI / l^2$

The struts and columns which we come across are neither too short nor too long but the failure is due to combined effect of direct and bending stress.

Rankin revised an empirical formula which converts both the cases,

$1/p = 1/p_e + 1/p_b$

p --- Actual crippling load.

$P = \frac{F_C . A}{1+\alpha(l/k)^2}$ where $\alpha = \frac{F_C}{\pi^2 E}$ constant for given material.

Procedure:

- Place the given short column specimen in the UTM.
- Ensure that the specimen is vertical with its end or cross section is in contact with the

loading surfaces.

- Now gradually apply the compressive load.
- Note the failure load from the universal testing machine.

Precautions:

- Place the given short column specimen in the UTM.
- Ensure that the specimen is vertical with its end or cross section is in contact with the loading surfaces.
- Column should be firmly gripped without any slip.
- Maintain a safe distance from the UTM during the experiment.

Calculations:

Cross-sectional area of the specimen = A =

Moment of the inertia ,M.I. = I =

Radius of gyration, K =

$$P = \frac{F_C . A}{1+\alpha(l/k)^2} =$$

Result:

The compressive stress of the given material is ___________ MPa.

RIVETED JOINT

Aim:-

To make a riveted joint (double riveted Zig-Zag lap joint) between two given metal pieces.

Work Material Required:-

- Two aluminum plates (60 x 90 x6) mm.
- Aluminum rivets.

Tools Required:-

- Sheet metal cutter
- Steel rule
- Mallet
- Files
- Bench vice
- Centre punch

- Dolly and snap
- Drilling machine
- Scriber

Theory:-

Riveted joints are permanent fastening and riveting is one of the commonly used method manufacture of boilers , storage tanks etc, involve joining of steel sheets, by means of riveted joints. A rivet is a round rod of circular cross section. It consists of two parts viz., head, shank. HS, WI and AL-alloys are some of the metals commonly used for rivets the choice of particular metal will depend upon the place of application. Riveting is the process of forming. Riveted joints for this, a rivet is first placed in the hole drilled through the two parts to be riveted then the shank end is made into a rivet head by applying pressure, when it is either cold or hot condition.

The pressure may be applied to form the second rivet head, either by direct hammering or through hydraulic or pneumatic means, The commonly used riveted joints are of two types.

1. Lap joint.
2. Butt joint.

In the lap joint the plates to be connected overlap each other when the joint is made only with one row of rivets it is called single – riveted lap joint. A joint is said to be double riveted it's according to the no. of row of rivets. In butt joint the edges of the plates are connected against each other and the joint between them is covered by butt plates.

Procedure:-

1. Take the given Aluminum sheet and cut it in to the required dimension with the help of sheet metal cutter.
2. Place the cut end aluminum sheet in the bench vice and files for the right angles.
3. Mark the dimensions of the rivet hole with the help of the scriber, dot punch and center punch.
4. Drill the holes on the two aluminum plates with the help of the drilling machine.
5. Now take the rivets and punch them with the ball peen hammer in the required holes.
6. Before driving the rivets, clamp them properly and make the riveting and be sure that the plates are properly joined.

Analysis:-

The riveted joint are usually performed in the areas where other means of joints are impossible. It makes a strong joint with less material and less applied force.

Applications:

The riveted joint usually finds the application in the

- Ship building
- Construction of steel buildings
- Bridges
- Boilers and Tanks
- Wings and fuselage construction of aircraft.

Precautions:

- Cut the aluminum sheets in the required size
- Clamp the plates properly
- Properly drill the holes on the punched areas

FAILURE STRENGTH OF RIVETED JOINT

Aim: To analyze the strength of the riveted joint

Equipment: universal testing machine, riveted joint, specimen

Dimension:

- Al sheet of size = -------
- Al rivets diameter = --------

Theory:

A riveted joint may fail in any of the following manner

- By tearing of the plate between the rivet hole and the edge of the plate

- By tearing of the plates between rivets .The safe tensile load that the plate can withstand for one pitch length is called the tearing strength

  Tearing strength per pitch length = P x t

  $P_t = F_t$ x net area of the plate

  $P_t = F_t$ (p-d) t

- Failure due to shearing of rivet for a lap joint if load /pitch length is large it is possible that the rivet may shear off

  $P_s= F_s \times \pi d^2/4$

  In general in a lap joint if rivets are covered load per pitch length would be

  $P_s= n \times F_s \times \pi d^2/4$

where n = number of rivets per pitch length.

- Failure by bearing or crushing of rivet or plate .The safe load on rivet

  $P_b= F_b x d t$ where

  P_b= allowance bearing stress

  F_b = bearing value of rivet

Efficiency of a joint:

Let P_t, P_s, P_b be the safe load per pitch length from tearing, shearing and bearing considerations.

Let p be the pitch of the rivets and t is the thickness of the plate

Safe pull on a solid plate for a length would be

$$P = F_t . p. t$$

$$\eta = \frac{\text{least of } P_t, P_s, P_b}{p}$$

Procedure:

- Place the riveted joint in the universal testing machine.
- Make sure that plates are held at equal distance from both ends
- Gradually apply tensile load
- Note the readings from universal testing machine at which rivet joint fails
- Observe the type of failure

Precautions:

Check that the plates are firmly gripped without any slip

Calculations:

Diameter of the rivet d =

Pitch p =

Thickness of the plate t =

Tearing strength P_t =

Shearing strength P_t =

Crushing or Bearing strength P_b =

Solid plate strength P =

Efficiency of the rivet, $\eta = \frac{\text{least of } P_t, P_s, P_b}{p}$

Result:

Failure of riveted joint is due to the __________________________

BLOTED JOINT

Aim:

To make a lap bolted joint of two aluminum plates.

Work Materials:-

- Two aluminum plates
- Bolts and nuts.

Tools required:

- Bench vice
- Files
- Scriber and scale
- Drilling machine
- Metal sheet cutter

Theory:

Bolted joints are used for connecting two parts in structural connections, where strength is required. Screw fastenings are different types.

- Tap bolts and cap screws.
- Machine screws
- Jet screws.
- Studs

Procedure:

1. Cut 2 Al plates as per given dimensions(60 X90)
2. File the edges to set the correct dimensions.
3. With the help of scriber, make the holes as per the dimensions.
4. Drill the holes with the drilling machines at the markings.
5. Insert the bolts and nuts and fit the nuts on them.
6. Tighten the bolts with help of spanner.

For bolted joints we use through bolts. These bolts and nut are subjected to axial and shear loads in the joints and they can withstand.

Precautions:

- Take the dimensions without any error.
- While drilling, put the plates in proper position and hold firmly.
- Use the appropriate tools for various specific operations.

Result:

Hence, required lap bolted is obtained.

FAILURE STREGNTH OF BOLTED JOINT

Aim:-

To analyze the strength of the bolted joint.

Equipment:-

Universal testing machine(UTM), bolted joint specimen.

Dimensions:-

90 X 60 mm – 2 AL sheets.

Theory:-

A bolted joint may fail in any of the following manner.

By tearing of the plate between bolt hole and the edge of the plate.

By tearing the plates between bolts. The safe load that the plate can

withstand for one pitch length is called the tearing strength.
Tearing strength per pitch length = P_t
$P_t = F_t$ x net area of the plate.

$P_t = F_t (P\text{-}d)\ t$

Failure due to shearing of bolt for a lap joint if load / pitch length is large it is possible that the bolt may shear off

$P_s = F_s .\pi\ d^2 / 4$; $F_s \rightarrow$ safe shearing stress.

In general in a lap joint n no. of bolts are covered load per pitch length would be

$P = F_t . P.t$

$$\eta = \frac{\text{least of } P_t, P_s, P_b}{P}$$

Procedure:-

- Place the lap joint in the Universal testing machine.
- Make sure that plates are held at equal distance from both ends.
- Gradually apply tensile load.
- Note the readings from Universal testing machine at which bolted joint fails.
- Observe the type of failure.

Precautions:-

Check that the plates are firmly gripped without any slip.

Results:-

Failure of bolted joint is due to the ______________..

ULTRASONIC TEST

Aim:-

To detect the internal defects in the given specimen.

Equipments:-

Specimen, Ultrasonic 4400AV.

Theory:-

Ultrasonic techniques are very widely used for detecting of internal defects in materials, but they can also be used for the surface cracks. Ultrasonic are used for quality control, inspection of finished components, parts processed materials such as rolled steel slabs etc...

Elastic waves with frequency higher than audio range are described as Ultrasonic. The waves used for NDT inspection of materials are usually within the frequency range of 0.5 MHz - 20 MHz .In fluids sound waves are zero longitudinal comp.type in which particle displacement in the direction of wave propagation but in solids, they are shear waves, with particle displacement normal to the direction of wave travel.

In solids, velocity of compression waves is given by

V_c = [E (1-Y)/ (1+Y) (1-2Y) e]   Y= gama-poissons ratio

Where E → Young's modules

Y → Poisson's ratio.

In most ultrasonic test (U.S) equipment, the signals are displayed on the screen of a C.R. oscilloscope. The presence of a defect within a material may be found using U.S. with either a transmission technique or reflection technique.

Test probes & U.S equipment can be calibrated by using reference blocks & calibration standards.

Ideally a smooth surface is required on a material for effective U.S inspection. The rough surface of casting or forging may present a problem. The use of a thick grease as coolant may overcome this.

Procedure:-

1. Take the given specimen and match with the C.R.T screen.
2. Place the transducer where the flaws to be detected and find out the position of flaw.
3. Repeat the same procedure for specimen.

Precautions:-

1. See that the battery of U.S flaw detector is properly charged.
2. Note the reading without any parallax error.

Result:-

Position of discontinuity & flaw is detected.

DYE PENETTRATION TEST

Aim:

To detect the flaws on the surface of a given material.

Apparatus:

The required apparatus to perform the experiment are:

(i) Cylindrical specimen

(ii) Developer orion 115PD

(iii) Red dye penetration orion 115P

(iv) Penetration remover, orion 115 PR

Theory:

Liquid penetration inspection is a technique which can be used to detect defects in a wide range of components, provided that the defect breaks the surface of the material.

The principle of the technique is that a liquid is drawn by capillary attraction into the defect and after subsequent development, any surface –breaking defects may be under visible to the human eye. In order to achieve good defect visibility, the penetrating liquid should be bright colored. In general the dye is red and developed surface can be viewed in natural or artificial light, but in later case, the component must be viewed under ultra violet light if defect indications are to be seen.

Liquid penetration inspection is applicable to any type of configuration. It is employed for inspection of wrought and cast products in both ferrous and some polymer components.

There are five essential steps in Penetrant inspection method. They are,

a) Surface preparation

b) Application of Penetrant

c) Removal of excess Penetrant

d) Development

e) Observation and inspection.

A liquid Penetrant must posses certain characteristics for inspection to be efficient.

a) Penetration

b) Body

c) Fluidity

d) Solution ability

e) Stability

f) Wash ability

g) Drying characteristics

h) Visibility

Procedure:

- Take the specimen on which NDT red dye Penetrant test will be performed
- Clean the specimen with remover-ORION 115PR
- Shake well before the use of the remover to clean the foreign materials which are present on the surface.
- Now apply the red dye Penetrant ORION 115P to specimen, take necessary care that red dye Penetrant will cover total surface of specimen.
- Allow it to penetrate into the flaws for 2-5 min.
- After penetration, remove the excess red dye Penetrant remover ORION 115PR gently.
- Now apply developer ORION-115PD on complete specimen, and then the cracks on the surface will be visible in 'Red' color.

Precautions:

1. Use adequate ventilation.
2. Don't use in vicinity of fire.
3. Use in ambient temperature, don't store in direct sunlight
4. Contents are highly inflammable.
5. Don't throw empty cans in fire.
6. Apply the developer and Penetrant from a distance of 8-10 inches from the specimen.

Result: The flaws on specimen are detected.

MAGNETIC PARTICLE DETECTION

Aim:

To analyze the intensity of cracks or surface and sub layer flaws in a given specimen.

Apparatus:

Electro Magnetic yoke, steel specimen, iron oxide powder etc.,

Theory:

Magnetic particle inspection is used for Ferro magnetic components. When a Ferro magnet is magnetized, magnetic discontinuities that lie in a direction approximately perpendicular to the field will results in form of a strong ‘Leakage field’. This leakage field is present at above the surface of magnetized component and its presence can be visibly detected by utilization of finely divided magnetic particles. The application of dry or wet particles in a liquid carrier, over surface of component results in a collection of magnetic particles at a discontinuity. The magnetic bridge, so formed indicates the location, size and shape of discontinuity.

Magnetization may be introduced in a component by using permanent magnets, (E.Ms) or by passing high currents through or around component.

Procedure:

- Clean the surface of a given specimen.
- Place the EM yoke on specimen vertically with its foldable legs on it.
- Switch on the power supply.
- Pour the iron oxide powder on the specimen.
- After the observation, demagnetize the specimen.

Observation:

We observe the lines of accumulation of powder on the surface of crack position depending upon its intensity of crack.

Precautions:

1. The power should be distributed uniformly on the specimen.
2. The iron oxide powder should not be distributed during the experiment.

Result:

Flaws are detected. _____ lines of accumulation of iron oxide are observed.

BONDING

Aim:

To prepare a bonded structure made up of wood and aluminum with the aid of glue (araldite).

Work material:

1. Wood
2. Two Al sheets

Theory:

Bonding is a method of joining of components with the help of a bonding material called glue, which is to be placed between the members to be joined. Generally, bonding is done between the members so that the resultant bonded structure will have hybrid properties i.e., the combustion of properties of both the materials.

Bonded structures are widely used in the construction of various aircraft components like wing, fuselage etc., as a bonded joint between aluminum and wood has an increased strength to weight ratio compared with the individual materials, which is the primary requirement for an aircraft.

Procedure:

- Take a given wooden piece and saw it to the required dimensions.
- With the help of rasp, give the surface finish.
- Make the Al sheet to 75x75mm with the help of scale and scriber and cut it from the main sheet by using cutter.
- With the aid of metal file, give the metals a good edge finish.
- Finally bond the aluminum sheets and wooden piece with adhesive araldite.
- Change it in order to make the bond dry and strong.

Precautions:

- Mark the dimensions without any parallax error.
- Proper care is to be taken which sawing the wood piece and filing of the aluminum sheet.
- Only adequate quantity of glue is to be used.

- Bonded structure is properly clamped and is allowed to dry properly.

Result:

The required bonded structure is obtained.

STUDY AND CALIBRATION FOR

MEASUREMENT OF SPEED

Aim:

To study the speed of the shaft of a motor using stroboscope and to compare it with manual tachometer reading.

Apparatus:

Stroboscope, RPM indicator, tachometer.

Theory:

Tachometer is designed to measure the speeds of rotating shafts, gear turbines etc. The sensor employed to sense is of the variable reluctance type. This sensor picks up tachometer pulses from any rotating ferrous object such as a gear. The number of such pulses being equal to the number of times, the flux lines emanating from the sensor is cut by the alternate presence of gap and teeth of the gear. The sensor is mounted in close proximity to the rotating body to ensure a sufficiently large voltage output for accurate indication of speed in RPM.

The indicating instrument consists of a 4 – digit counter, one second clock generation circuit. Input signal conditioning preamplifier, latches and decoding circuit etc. Bright RED, seven segment LEDs are used for clear display of speed in RPM.

Tachometers with 5 digit for measurements of speeds more then 10,000rpm are also available. Tachometer with analog voltage output or 4-20 mA current output for feed back control application also can be available as per the users requirements.

Specifications:

1.Display : 4 digit display of RED, 7 segment LED of 12.7mm character height.

2.RPM range : 0-9999 rpm

3.Accuracy : Within + 0.1%, F.S.R + 1 count

4.Input :From non-contact reluctance type sensor models.

5.Measuring time : 1 second (one sample per second)

6.Over-range indicator :For reading in excess of 9999 rpm, display indicates 0.0.0.0.

7.Operating temperature : $10^{o}C$ to $45^{o}C$.

8.Power supply requirement: 230 V + 10%, 50Hz, AC mains

9.Cabinet(W x H x D) :96 x 96 x 150mm

Procedure:

1.Before connecting power to the indicator, verify whether the power available matches with the requirements of the indicator as mentioned on the rear panels. After verification, connect one end of the mains cable to the socket on the rear panel and the other end to the power supply source.

2.Connect the cable to input socket on the rear panel.

3.Switch on the indicator.

4.Mount the tachometer in proximately to the gear wheel on the rotating shaft whose speed is to be measured. The distance between the sensor force and the gear wheel teeth should not be more than 1.5mm.

5.The display indicates the speed of the rotating shaft directly in RPM if only 60 teeth gear wheel is used.

6.For any other gear wheel of N teeth, the RPM is to be calculated as follows:

$$RPM = \frac{\text{Displayed value} \times 60}{N}$$

7.When the speed being measured goes beyond 9999 rpm, over range is indicated by lighting off all four decimal points of the display.

Observations:

S.No	Stroboscope	Tachometer reading(rpm)	Digital tachometer reading(rpm)	Error(rpm)	% Error
1	929	920	927	9	0.96
2	1284	1279	1283	5	0.38
3	1370	1365	1368	5	0.36
4	1459	1457	1458	2	0.137
5	1610	1601	1610	9	0.55
6	1650	1642	1648	8	0.48
7	1797	1790	1796	7	0.389
8	1867	1860	1866	7	0.374

Sample Calculation:

Stroboscope reading : 929 rpm

Tachometer reading :920 rpm

Error :Stroboscope reading – tachometer reading

: 929 – 920 = 9 rpm

We have % error : 9/929 = 0.96

Graph:

A graph is drawn by taking % error on X-axis and stroboscope reading (rpm) on Y-axis.

Model Graph:

Result:

The speed of shaft of given motor is found out and the readings of hand tachometer are compared with digital tachometer readings and the graph is drawn.

SHEAR CENTER OF OPEN SECTION

DESCRIPTION OF APPARATUS

The Apparatus consists of:

1. Thin walled section of the OPEN CHANNEL of material Aluminium or GI or Mild steel is provided.
2. Two dial gauges to monitor the deflection is provided.
3. Weights of 500gm upto 5000gm has being provided for loading purpose.
4. Loading is applied by means of hanger on the section.
5. Vernier Caliper to measure the sizes.
6. Sturdy Frame for attachment is provided with good aesthetic looks.

EXPERIMENTATION:

i. AIM:

The experiment is conducted to determine the shear center of the OPEN SECTION

ii. PROCEDURE:

1. The given channel section consisting of two flanges and one web is first fixed in a particular position.
2. The dimensions of the flange are calculated so as to facilitate determination of shear centered.
3. Mount two dial gauges on the flange at a known distance apart at the free end of the beam.
4. Place a two kilogram load on left side hook and note the dial gauge readings
5. Remove one load from the left end and place on right end, note the dial gauge readings.
6. Transfer carefully all the load pieces and finally the hook one by one to the other hook, noting each time the dial gauge readings. Calculate the distance 'e' of the line of action from the web thus

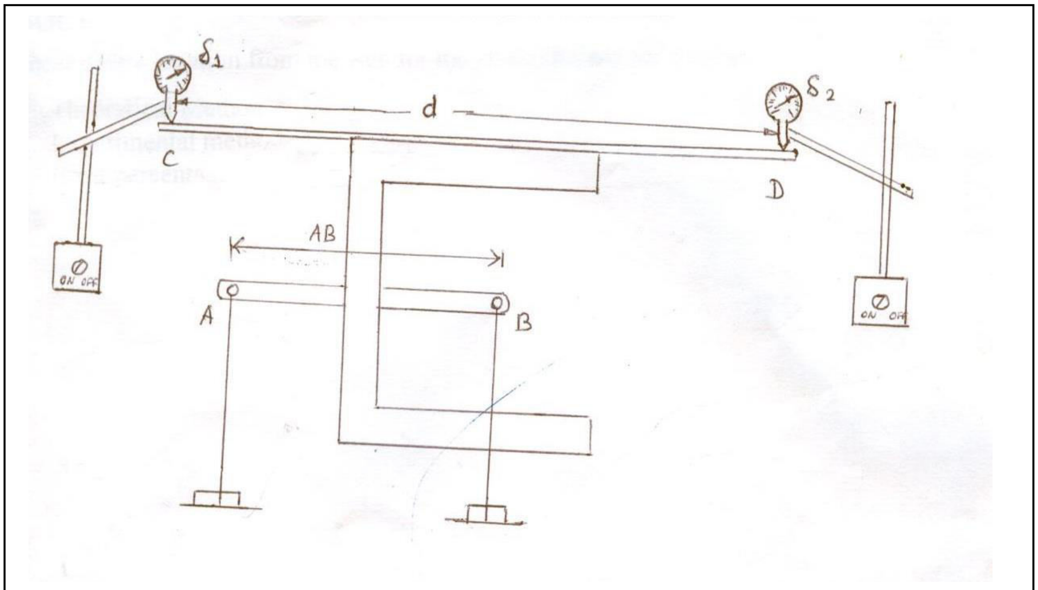
$$e = \frac{AB}{2} + \frac{w_a - w_b}{w_t}$$

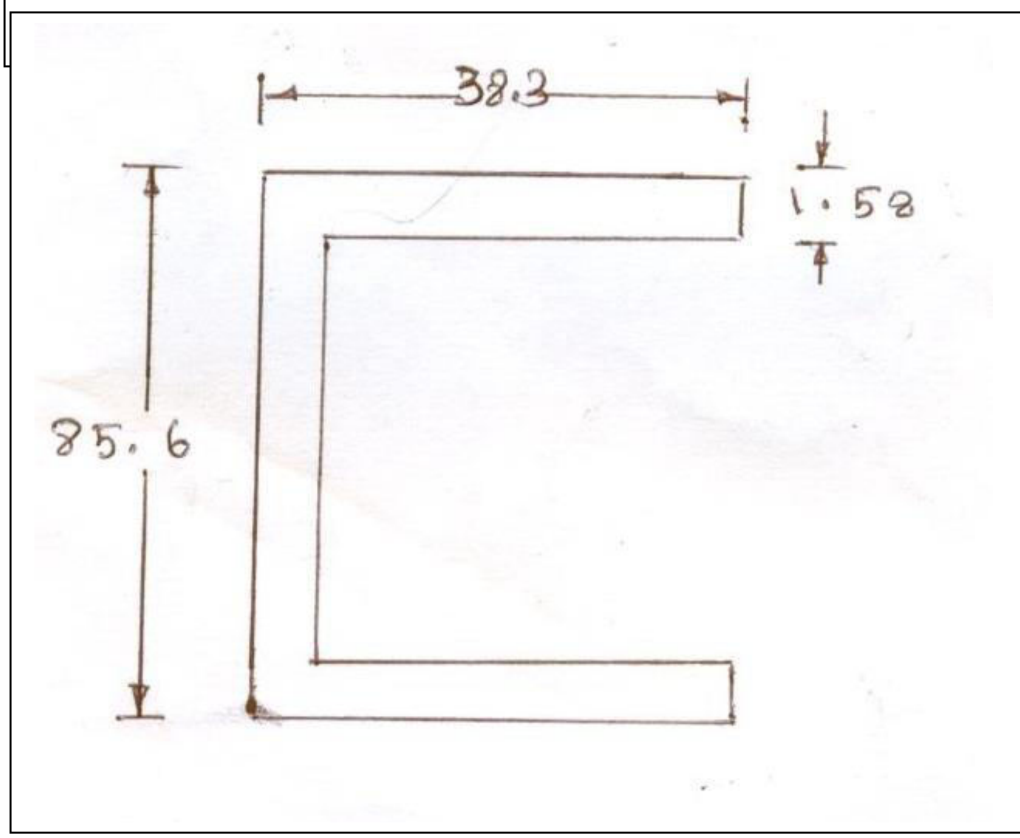
7. For every load case calculate the algebraic difference between the dial gauge readings as the measure of the angle of twist θ suffered by the section.
8. Plot θ against e and obtain the meeting point of the curve (a straight line in this case) with the e-axis (i.e., θ, the twist of the section is zero for this location of the resultant vertical load). This determines the shear center.
9. The distance from the origin to the point where the curve crosses the x-axis is given as the distance of the shear center of origin.

OBSERVATIONS:

DIMENSION MEASURED	MSR mm	VSR	VSC mm	TOTAL READING mm
Thickness Of Flange And Web				
Breadth Of Flange				
Height Of The Section				

iii. PICTORIAL REPRESENTATION:





iv. CALCULATION:

1. Theoretical Location of Shear Center, eth

$$e_{th} = \frac{3b^2 t_f}{6bt_f + ht_w}$$

2. Experimental Location of Shear Center, eexp

$$\boldsymbol{e_{exp}} = \frac{AB}{2} + \frac{w_a - w_b}{w_t}$$

3. Vertical Weight, Wt

$$\boldsymbol{W_t} = (\boldsymbol{W_a} + \boldsymbol{W_b})$$

4. Angle of plane of displacement, θ

$$\theta = \frac{\delta_1 - \delta_2}{d}$$

Where,

AB- Distance between the 2 loads

W_a – Load applied at point A

W_b – Load applied at pouint B

W_t – Total load applied

e- Location of shear centre from the web

b – width of the flange

h- height of the web

t_f – Thickness of the flange

t_w –Thickness of the web

δ_1- Deflection at point 1

δ_2 - Deflection at point 2

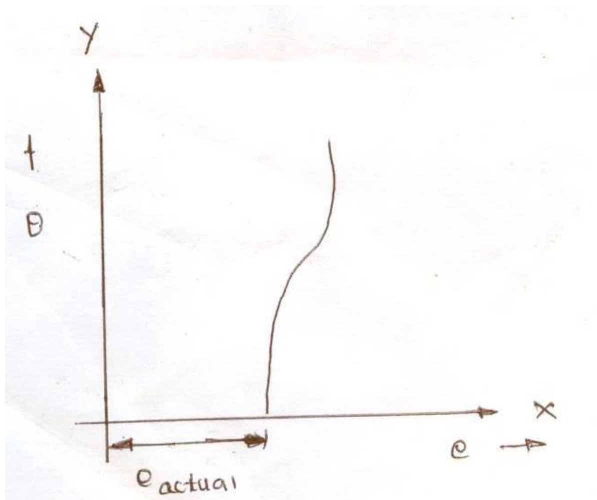
$d -$ Distance between point 1 and point 2

θ - Angle of plane of displacement

TABULATIONS:

SL	W_a	W_b	W_t	δ_1 mm	δ_2 mm	θ	e

Model Graph



RESULT:

The shear center location from the web for the given channel section of

a. Theoretical Method = ____________________
b. Experimental Method = ____________________
c. Error Percentage = ____________________

SHEAR CENTER OF CLOSED SECTION

DESCRIPTION OF APPARATUS

The Apparatus consists of:

1. Thin walled section of the closed box of material Aluminium or GI or Mild steel is provided.
2. Two dial gauges to monitor the deflection is provided.
3. Weights of 500gm upto 5000gm has being provided for loading purpose.
4. Loading is applied by means of hanger on the section.
5. Vernier Caliper to measure the sizes.
6. Sturdy Frame for attachment is provided with good aesthetic looks.

EXPERIMENTATION:

i. AIM:

The experiment is conducted to determine the shear center of the CLOSED SECTION

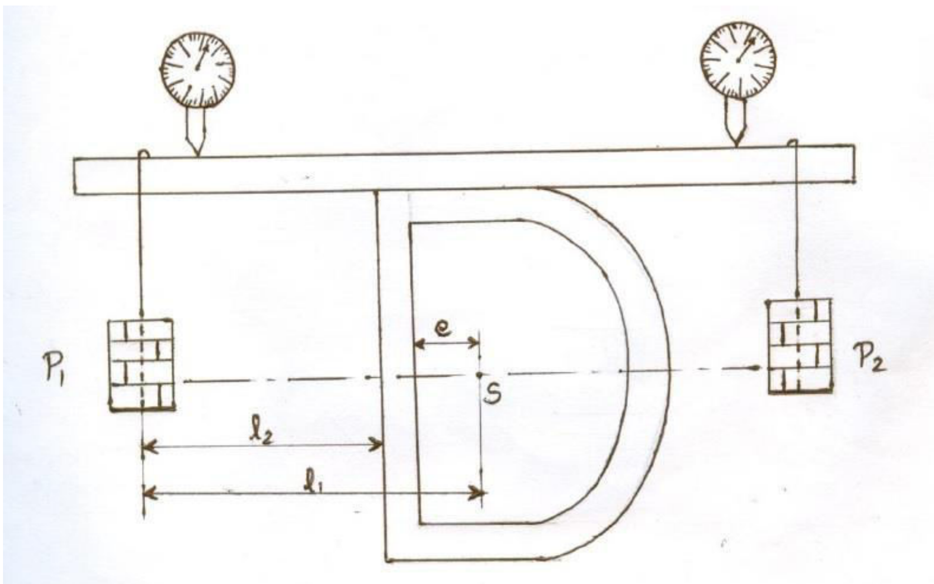
ii. PROCEDURE:

1. Set the apparatus by properly placing the Dial gauges on the Closed Section.
2. Apply the load P1 (say 500gm) on pan1 and then load the weights on P2 pan such that the dial gauges read same values.
3. Repeat the above procedure for increasing loads say 1000, 1500gm etc upto required.
4. Now Calculate L1 and Shear Center using the formula given.

OBSERVATIONS:

Sl. No.	Load Applied	
	P1	P2

iii. PICTORIAL REPRESENTATION:



iv. CALCULATION:

Shear Center, L1

$$l1 = \left(\frac{P_1}{P_2}\right) * (l - l_2)$$

Where,

P1 = load on Pan 1

P2 = load on Pan 2

l = Distance b/w P1 and P2

l2 = Distance b/w P1 to vertical web

Eccentricity, e

$$\boldsymbol{e = (l_1 - l_2) \quad mm}$$

RESULT:

1. Location of Shear Center from Vertical Web = ____cm.
2. The eccentricity measure is ______ cm.

BEAM SETUP

INTRODUCTION:

The problem of bending probably occurs more often than any other loading problem in design. Shafts, axels, cranks, levers, springs, brackets, and wheels, as well as many other elements, must often be treated as beams in the design and analysis of mechanical structures and system. A beam subjected to pure bending is bent into an arc of circle within the elastic range, and the relation for the curvature is:

$$\frac{1}{\rho} = \frac{M(x)}{EI} \qquad (1)$$

Where: ρ is the radius of the curvature of the neutral axis
X is the distance of the section from the left end of the beam

The curvature of a plane curve is given by the equation :

$$\frac{1}{\rho} = \frac{\frac{d^2y}{dx^2}}{\left[1+\left(\frac{dy}{dx}\right)^2\right]^{\frac{3}{2}}} \qquad (2)$$

(dy/dx) is the slope of the curve and in the case of elastic curve the slope is very small :

$$(dy/dx)=0$$

$$\frac{1}{\rho} = \frac{d^2y}{dx^2}$$

$$\frac{d^2y}{dx^2} = \frac{M(x)}{EI} \qquad (3)$$

Multiply both sides by EI which is constant and integrating with respect to x:

$$EI\left(\frac{dy}{dx}\right) = \int M(x)dx + C_1 \qquad (4)$$

Noting that
(dy/dx)= tan θ θ= θ(x) because the angle θ is very small. And integrating the equation again.

$$EI\ y = \int dx + \int M(x)dx + C_1x + C_2 \qquad (5)$$

The constants C_1 and C_2 are determined from the boundary conditions (constants) imposed on the beams by its supports
1. Simply supported beam
2. Cantilever beam

Case: 1. Simply supported beam

At the supports, deflections are zero y=0 (at A & B)
Now we have two equations to be solved for C_1 & C_2, solving equations (Eq-5) and substituting boundary conditions give us

$$y = \frac{Pbx}{6EIL}(x^2 + b^2 - l^2) \quad \text{(Between A\&C)}$$

$$y = \frac{Pa(l-x)}{6EIL}(x^2 + a^2 - 2lx) \quad \text{(Between C\&B)}$$

Case: 2 Cantilever beam

The deflection and slope is zero at A

$$y = \frac{Px^2}{6EI}(x - 3a) \quad \text{(Between A\&C)}$$

$$y = \frac{Pa^2}{6EI}(a - 3x) \quad \text{(Between C\&B)}$$

DESCRIPTION OF APPARATUS:

The apparatus consists of :

1. Aluminium sections of C , L and flat type of cantilever beams are provided for conducting the experiments at different loads.
2. All sections are gauged into measure the strain in the beam and are indicated using the strain indicator
3. Loading is applied by the means of gear box assembly and the applied load is indicated by means of load indicator which is attached with load cell
4. Lateral deflection can also be found using the similar loading arrangement as the one for direct loading
5. Option for the movement of the loading point is provided to apply the load at different point of the beam.
6. Sturdy frame for attachment of different types of cantilever beams is provided.

EXPERMENTATION:

AIM:

The experiment is conducted to determine the deflection of beam on different cross section and loading points and comparing the theoretical values.

PROCEDURE:

1. Fix the beam of required cross section.
2. Adjust the load unit at the required distance.
3. Connect the under test beam strain wires to the strain indicators.
4. Connect the loads cell cable to the load indicator respectively.
5. Fit the dial guage at required position and set to Zero.
6. Provide necessary electrical connections (230V 1Ph 5Amps with neutral and earthing) to the indicator provided .
7. Now on the digital multi strain indicator set the display knob (right hand side of the display) to first position and set to zero using zero adjustment knob(below the display)
8. Similarly do the above step for other positions.
9. Now, using the hand wheel provided load the beam slowly.
10. Note down the deflections from the dial guage at different load conditions (max deflection is 10mm).
11. Also, note the strain guage reading at different positions of the beam.
12. Repeat the steps 10 and 11 for different load conditions.

13. Now calculate the deflections from the standard formula and compare with measured deflections.
14. Using the strain reading calculate the stress induced different directions of the beam.

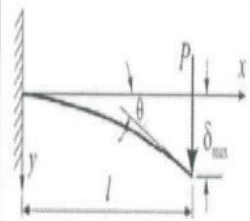
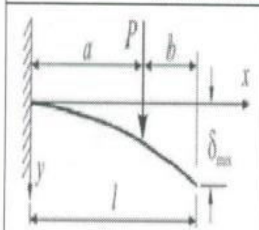
OBSERVATIONS:

S.No	Load Applied		Deflection, δ mm	Micro strain at different directions		
	Kg	N		X	Y	z

CALCULATIONS:

1. USE THE BELOW FORMULA TO CALCULATE MAXIMUM DEFLECTION AND DEFLECTION AT ANY POINT OF CROSS SECTION

BEAM DEFLECTION FORMULAE

BEAM TYPE	SLOPE AT FREE END	DEFLECTION AT ANY SECTION IN TERMS OF x	MAXIMUM DEFLECTION
1. Cantilever Beam – Concentrated load P at the free end			
	$\theta = \frac{Pl^2}{2EI}$	$y = \frac{Px^2}{6EI}(3l - x)$	$\delta_{max} = \frac{Pl^3}{3EI}$
2. Cantilever Beam – Concentrated load P at any point			
	$\theta = \frac{Pa^2}{2EI}$	$y = \frac{Px^2}{6EI}(3a - x)$ for $0 < x < a$ $y = \frac{Pa^2}{6EI}(3x - a)$ for $a < x < l$	$\delta_{max} = \frac{Pa^2}{6EI}(3l - a)$

Where,
P=load applied, N
E=Young's modulus, GPa
a=load distance from fixed end, in mm
b=load distance from free end, in mm
L=length of the beam
I=moment of inertia of the given cross section

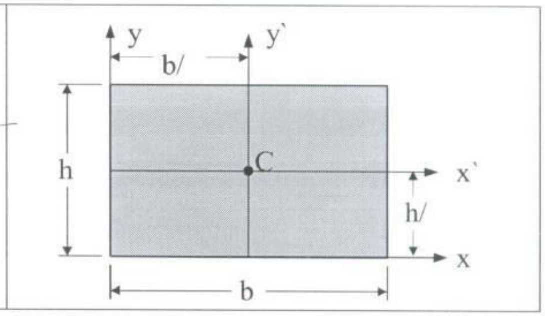
2. MOMENT OF INERTIA OF DIFFERENT SHAPES

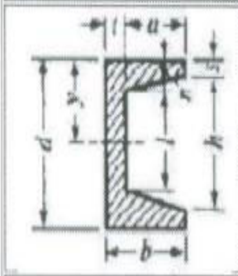
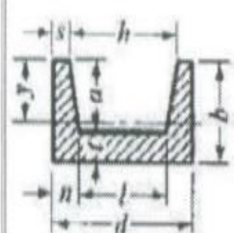
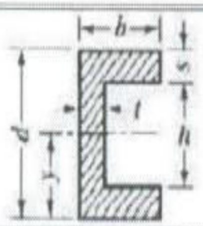
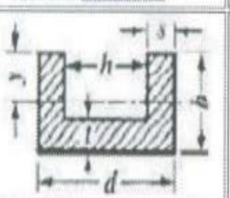
Rectangle:

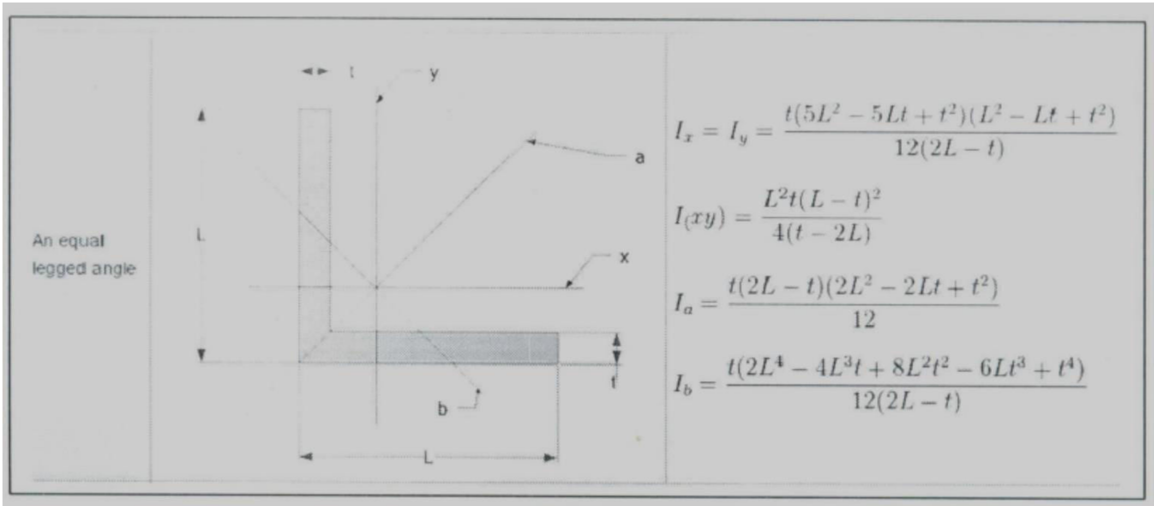
$\bar{I}_{x'} = \frac{1}{12}bh^3$ $\quad I_x = \frac{1}{3}bh^3$

$\bar{I}_{y'} = \frac{1}{12}b^3h$ $\quad I_y = \frac{1}{3}b^3h$

$\bar{I}_{xy'} = 0$ $\quad Area = bh$



Section	Moment of Inertia	Radius of Gyration	Area	y
	$\frac{1}{12}\left[bd^3 - \frac{1}{8g}(h^4 - l^4)\right]$ g = Flange slope (Standard Channels) $= \frac{h-l}{2(b-t)}$	$\sqrt{\frac{\frac{1}{12}\left[bd^3 - \frac{1}{8g}(h^4 - l^4)\right]}{dt + a(s+n)}}$	$dt + a(s+n)$	$\frac{d}{2}$
	$\frac{1}{3}\left[2sb^3 + lt^3 + \frac{g}{2}(b^4 - t^4)\right] - A(b-y)^2$ $= \frac{h-l}{2(b-t)}$	$\sqrt{\frac{I}{A}}$	$dt + 2a(s+n)$	$b - \left[b^2 s + \frac{ht^2}{2} + \frac{g}{3}(b-t)^2 \times (b+2t)\right] \div A$ g = slope of flange $= \frac{h-l}{2(b-t)}$
	$\frac{bd^3 - h^3(b-t)}{12}$	$\sqrt{\frac{bd^3 - h^3(b-t)}{12[bd - h(b-t)]}}$	$bd - h(b-t)$	$\frac{d}{2}$
	$\frac{2sb^3 + ht^3}{3} - A(b-y)^2$	$\sqrt{\frac{I}{A}}$	$bd - h(b-t)$	$b - \frac{2b^2 s + ht^2}{2bd - 2h(b-t)}$



3. STRESS AT DIFFERENT DIRECTIONS

$$\sigma_{DIRECTION} = (E * \varepsilon_{DIRECTION})MPa$$

S.No	Load Applied N	Deflection, δ mm		Micro strain at different directions		
		Actual	Calculated	X	Y	z

PRECAUTIONS:

1. Clean the equipment regularly and grease all visual rotational parts periodically say for every 15days.
2. Do not run the equipment if the voltage is below 180V.
3. Do not leave the load to the maximum.
4. Check all the electrical connections before running.
5. Before starting and after finishing the experiment the main control valve should be in closed position.
6. Do not attempt to alter the equipment as this may cause damage to the whole system.

THICK / THIN WALL CYLINDER

INTRODUCTION:

In relation to stress analysis, cylinders are divided into two groups: thick and thin. The distinction between the two relates to the ratio of internal diameter to wall thickness of particular cylinder. A cylinder with a diameter to thickness ratio of more than 20 is considered to be thin. A ratio of lee than 20 is considered to be thick. This distinction is made qas the analysis of a cylinder can be simplified by assuming it is thin.

Thin cylinders or shells are common place in engineering.

Examples of thin walled cylinders are:

- Pressure pipes,
- Aircraft fuselages and
- Compressed gas containers.

Thick walled cylinders are less common, an example being a gun barrel.

For a closed cylinder with an internal pressure there can be three direct stresses acting upon it.

- **Longitudinal stress**- the cylinders resistance to stretching a long its length (axis).
- **Hoop or circumferential stress**- the cylinders resistance to grow in diameter.
- **Radial stress**: gas or fluid compressing there walls of the cylinder. It is equal to the pressure on the inside and zero on the outside.

The longitudinal stress and hoop stresses are directly proportional to the pressure and the ratio of diameter to thickness of the cylinder. However the radial stress is related to the pressure alone.

Because of their relationship to the geometry, the Longitudinal and Hoop stresses are far greater and more significant than the radial stress in a thin cylinder. It is reasonable and recognized to assume that the radial stress is small enough for it to be ignored for basic calculations.

DESCRIPTION OF APPARETUS

The Apparatus consists of:

1. CYLINDER of thickness mm and 100mm diameter made of SS304 material. (t/D ratio of 1/50).
2. Drain value and Pressure gauge fitting option is provided on the cylinder.
3. Cylinder is mounted between the studs with End plates for good aesthetic looks.
4. Gauging has being done on Longitudinal and Circumferential plane to measure the strain in their respective directions.
5. Pressure gauge is provided to measure the pressure exerted on the system.
6. Hydraulic Hand pump is provided to create the required pressure in the cylinder.
7. Digital strain Indicator is provided to measure the strains at different positions.
8. The whole setup is mounted on the table frame for easy and better operation.

EXPERIMENTATION:

AIM:

The experiment is conducted to

- Determine the **CIRCUMFERENTIAL AND LONGITUDINAL strain** at different Pressure condition.
- Also, Compare the calculated values with the obtained values.

PRESSURE

1. Fill clean water in the Hydraulic Hand pump.
2. Fix the connecter of the pump to the pressure vessel or cylinder provided.
3. Provide necessary electrical connection (230 V 1ph 5Amps with neutral and earthing) to the indicator provided.
4. Now on the digital Multi-strain indicator set the display knob (right hand side of the display) to first position and set to zero using zero adjustment knob (below the display).
5. Similarly do the above setup for the second position.
6. Now, using the Hand pump provided load the vessel/cylinder.
7. Set the pressure by noting the value on the pressure gauge.
8. Note the strain reading at the Longitudinal and circumferential positions from the indicator and display knob.
9. Repeat steps 6 & 8 until loaded maximum. (25 kg/cm^2)
10. Once completed release the drain so the pressure inside the cylinder reduces to zero.

CALCULATIONS

NOMENCLATURE USED:

P =Pressure measured in kg/cm^2

D =Mean Diameter of the cylinder = 102mm

L = Length of the Cylinder =500mm

σ_D= Circumferenctial or Hoop's stress, Mpa

σ_L =Longitudinal Stress, Mpa

γ =Poisson's ratio = 0.305 for SS304 material.

E = Youngs modulus, Gpa

t =Thickness of the cylinder = 2mm

TABULATIONS:

SL No.	Pressure on the cylinder		Micro Strain	
	Kg/cm^2	Mpa	Longitudinal	Circumferential

CALCULATIONS:

1. **HOOP'S STRESS OF CIRCUMFERENTIAL STRESS,**

$$\sigma_D = \frac{P\,D}{2t} Mpa$$

2. **LONGITUDINAL STRESS,**

$$\sigma_L = \frac{P\,D}{4t} Mpa$$

3.CALCULATED STRAIN ALONG THE CIRCUMFERENCE,

Calculated $\mathcal{E}_D = \frac{(P\,D) * (2 - \gamma)}{4\,t\,E}\ \mu\mathcal{E}$

4. **CALCULATED STARIN ALONG THE LONGITUDE**

Calculated $\mathcal{E}_L = \frac{(P\,D) * \ (1 - 2\gamma)}{4\,t\,E}\ \mu\mathcal{E}$

TABULAR COLUMN

Sl No	Pressure on the cylinder		Micro Strain			
	Kg/ Cm^2	Mpa	Longitudinal		Circumference	
			Measured	Calculated	Measured	Calculated

Sl No	Pressure on the cylinder		Stress, Mpa	
	Kg/Cm^2	Mpa	Longitudinal	Circumference

PRECAUTIONS

1) Clean the water tank regularly, say for every 15days.
2) Do not run the equipment if the voltage is below 180V.
3) Check all the electrical connections before running.
4) Before starting and after finishing the experiment the main control valve should be in close position.
5) Do not attempt to alter the equipment as this may cause damage to the whole system.