

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **Lecture-wise Plan**

**Subject Name: Numerical Methods**

**Year: 2<sup>nd</sup> Year**

**Subject Code-M(CS))401**

**Semester: Fourth**

<b>Module Number</b>	<b>Topics</b>	<b>Number of Lectures</b>
1	<b>: Approximation in numerical computation:</b>	<b>4L</b>
	) Approximation of numbers	1
	) Types of errors	2
	) Calculation of errors	1
2	<b>Interpolation:</b>	<b>6L</b>
	) Finite differences	1
	) Newton forward/backward interpolation	2
	) Lagrange's method	1
	) Newton's divided difference Interpolation	2
3.	<b>Numerical integration:</b>	<b>3L</b>
	) Trapezoidal rule	2
	) Simpson's 1/3 rule	1
4	<b>Numerical solution of a system of linear equations:</b>	<b>6L</b>
	) Gauss elimination method	1
	) Matrix inversion	1
	) LU Factorization method	2
	) Gauss-Seidel iterative method	2
5	<b>Numerical solution of Algebraic equation:</b>	<b>5L</b>
	) Bisection method	2
	) Regula-Falsi method	1
	) Newton-Raphson method	2
6	<b>Numerical solution of ordinary differential equation:</b>	<b>8L</b>
	) Euler's method	2
	) Runge-Kutta methods	2
	) Predictor- Corrector methods	2
	) FiniteDifference method	2

### **Assignment:**

#### **Module-1:**

1. Find the relative error if  $\frac{2}{3}$  is approximated to 0.667.
2. Find the percentage error if 625.483 is approximated to three significant figures.
3. Find the relative error in taking  $f = 3.141593$  as  $\frac{22}{7}$ .
4. The height of an observation tower was estimated to be 47 m, whereas its actual height was 45 m. calculate the percentage relative error in the measurement.

- Two numbers are 3.5 and 47.279 both of which are correct to the significant figures given. Find their product.

### Module-2:

- Apply Newton's backward Interpolation to the data below, to obtain a polynomial of degree 4 in  $x$   
 $x:$  1      2      3      4      5  
 $f(x):$  1      -1      1      -1      1
- Using Newton's backward Interpolation, find the value of  $f(2)$  from the following table:  
 $x:$  1      3      4      5      6      7  
 $f(x):$  2.68      3.04      3.38      3.68      3.96      4.21
- Using Newton's Forward Interpolation, the area  $A$  of a circle of diameter  $d$ .  
 $d:$  80      85      90      95      100  
 $A:$  5026      5674      6362      7088      7854  
 Calculate the area of a circle of diameter 105.
- Estimate the value of  $f(22)$  and  $f(42)$  from the following available data:  
 $x:$  20      25      30      35      40      45  
 $f(x):$  354      332      291      260      231      204  
 Using Newton's Forward Interpolation
- Find  $f(x)$  as a polynomial in  $x$  for the following data by Newton's divided difference method:  
 $x:$  -4      -1      0      2      5  
 $f(x):$  1245      33      5      9      1335
- Using Newton's divided difference method to find  $f(x)$  from the following available data:  
 $x:$  0      1      2      4      5      6  
 $f(x):$  1      14      15      5      6      19.

### Module-3:

- Apply trapezoidal rule to find the integral  $\int_0^1 \sin x \, dx$ .
- Find, from the following table the area bounded by the curve and the x-axis from  $x = 7.47$  to  $x = 7.52$ ,  
 $f(7.47) = 1.93, f(7.48) = 1.95, f(7.49) = 1.98, f(7.50) = 2.01,$   
 $f(7.51) = 2.03, f(7.52) = 2.06$ .
- Evaluate  $\int_0^1 \frac{1}{1+x^2} dx$ , correct to three decimal places and also find the approximate value of  $f$ .
- A solid of revolution is formed by rotating about the x-axis the area between the x-axis, the lines  $x = 0$  and  $x = 1$  and a curve through the points with the following coordinates:  
 $(0, 1), (0.25, 0.9896), (0.5, 0.9589), (0.75, 0.9089), (1, 0.8415)$

### Module-4:

- Solve the following system of equations:

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$$4x + y + z = 4$$

$$x + 4y + 2z = 4$$

$$3x + 2y + z = 6$$

by matrix-inversion method.

2. Solve the above system by matrix-inversion method:

$$x + y + z = 2$$

$$2x + 3y + 5z = 3$$

$$3x + 2y + z = 6$$

3. The following system of equations are given:

$$4x + y + z = 4$$

$$x + 4y + 2z = 4$$
, Solve the above system by LU decomposition method.

$$3x + 2y + z = 6$$

4. Solve the given system of equations by LU decomposition method:

$$x + y + z = 2$$

$$2x + 3y + 5z = 3$$

$$3x + 2y + z = 6$$

### **Module-5:**

1. Find the root of the following equations correct three decimal places by the Regula-falsi method:  
 $x^3 + x - 1 = 0$ .
2. Using Regula-falsi method, compute the real root of the following equation correct to four decimal places:  
 $xe^x - 2 = 0$ .
3. Find the root of the following equations correct three decimal places by the Regula-falsi method:  
 $x^6 - x^4 - x^3 - 1 = 0$ .
4. Find the root of the following equations correct three decimal places by the bisection method :  
 $xe^x - 1 = 0$
5. Find the root of the following equations, using the bisection method correct three decimal places:  
 $x - \cos x = 0$
6. Using the bisection method to find a root of the equation to four decimal places:  
 $x^3 - 9x - 1 = 0$

### **Module-6:**

1. Using Runge-kutta method of order 4, find  $y(0.2)$  given that  $\frac{dy}{dx} = 3x + \frac{1}{2}y$ ,  $y(0) = 1$  taking  $h = 0.1$ .

2. Using Runge-kutta method of order 4, compute  $y(0.2)$  and  $y(0.4)$  from  $10 \frac{dy}{dx} = x^2 + y^2$ ,  $y(0) = 1$  taking  $h = 0.1$ .
3. Using Milne's predictor-corrector method to obtain the solution of the equation  $\frac{dy}{dx} = x + y^2$  at  $x = 0.8$  given that  $y(0) = 0.0000$ ,  $y(2) = 0.0200$ ,  $y(4) = 0.0795$ ,  $y(6) = 0.1762$ .
4. Given  $2 \frac{dy}{dx} = (1 + x^2)y^2$  and  $y(0) = 1$ ,  $y(0.1) = 1.06$ ,  $y(0.2) = 1.12$ ,  $y(0.3) = 1.21$ , evaluate  $y(0.4)$  by Milne's predictor-corrector method.

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## **Lecture-wise Plan**

**Subject Name: Values & Ethics in Profession**

**Subject Code-HU401**

**Year: 2<sup>nd</sup> Year**

**Semester: Fourth**

<b>Module Number</b>	<b>Topics</b>	<b>Number of Lectures</b>
1	<b>Introduction:</b>	<b>19L</b>
	Rapid Technological growth and depletion of resources, Reports of the Club of Rome. Limits of growth: Sustainable development	3
	Energy Crisis: Renewable Energy Resources Environmental degradation and pollution. Eco-friendly Technologies. Environmental Regulations, Environmental Ethics	5
	Appropriate Technology Movement of Schumacher; later developments Technology and developing notions. Problems of Technology transfer, Technology assessment impact analysis.	6
	Human Operator in Engineering projects and industries. Problems of man, machine, interaction, Impact of assembly line and automation. Human centered Technology.	5
2	<b>Ethics of Profession:</b>	<b>9L</b>
	Engineering profession: Ethical issues in Engineering practice, Conflicts between business demands and professional ideals.	3
	Social and ethical responsibilities of Technologists. Codes of professional ethics. Whistle blowing and beyond.	6
	<b>Profession and Human Values</b>	<b>8L</b>
3.		
	Values Crisis in contemporary society Nature of values: Value Spectrum of a good life	3
	Psychological values: Integrated personality; mental health Societal values: The modern search for a good society, justice, democracy, secularism, rule of law, values in Indian Constitution. Aesthetic values: Perception and enjoyment of beauty, simplicity, clarity Moral and ethical values: Nature of moral judgements; canons of ethics; ethics of virtue; ethics of duty; ethics of responsibility.	5

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **Lecture-wise Plan**

Subject Fluid mechanics & Hydraulic Machines  
Year: 2<sup>nd</sup> Year

Subject Code-ME401  
Semester: Fourth

Module Number	Topics	Number of Lectures
<b>1</b>	<b>1. Introduction to Fluid Mechanics</b>	<b>12L</b>
	Review of fluid properties and fluid statics	2
	Viscosity-dynamic and kinematic	1
	Surface Tension. Fluid Statics: Basic equation of fluid statics	2
	Manometers	2
	Hydraulic forces on submerged surfaces; forces on vertical, horizontal surfaces	1
	Hydraulic forces on inclined and curved surfaces	2
	Buoyant force, Stability of floating and Submerged bodies.	2
<b>2</b>	<b>2. Kinematics of fluid flow:</b>	<b>3L</b>
	fluid flow and classifications. Continuity equation in 1-D	1
	Continuity equation in 3-D	1
	Potential flow & Stream function; types of flow lines	1
<b>3</b>	<b>3. Dynamics of fluid:</b>	<b>4L</b>
	Equations of motion; Euler's equation;	1
	Bernoulli's equation; Applications of Bernoulli's	2
	Problems on Bernoulli's equation	1
<b>4</b>	<b>4. Momentum Analysis of flow systems;</b>	<b>4L</b>
	The linear momentum equation for steady flow	1
	The linear momentum equation for steady flow (differential approach)	2
	Problems	1
<b>5</b>	<b>5. Flow through pipes;</b>	<b>4L</b>
	Darcy – Weisbach equation of friction loss;	1
	Hydraulic grade line and total energy line	2
	Problems	1
<b>6</b>	<b>6. Basic principle for flow through orifices;</b>	<b>4L</b>
	Derivation of discharge through V-notches	1
	Derivation of discharge through weirs (rectangular)	1
	Flow through open channels; use of Chezy's formula	1
	Problems	1
<b>7</b>	<b>7. Dimensional Analysis &amp; Model investigation applied to flow systems</b>	<b>4L</b>
	Introduction to dimensional analysis and its applications	1
	Buckingham Pi theorem.	1
	Dimensionless numbers in fluid flow	1
	Problems	1
<b>8</b>	<b>8. Application of fluid;</b>	<b>4L</b>

	Hydraulic press, Hydraulic accumulator	1
	Hydraulic Ram, Hydraulic lift,	1
	Hydraulic coupling, Hydraulic torque convertor	1
	Gear pump	1
<b>09</b>	<b>09. Hydraulic Turbines;</b>	<b>6L</b>
	Hydraulic Turbines; Principles and Classifications	1
	working principle of a Pelton Wheel, Francis Turbine, Kaplan Turbine	1
	working principle of Kaplan Turbine	1
	Function of Draft Tube. Cavitation in Turbines.	2
	Problems	1
<b>Total Number Of Hours = 45</b>		

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## **Lecture-wise Plan**

### **Assignments 1**

1. Define fluid with examples.
2. Define Ideal Fluid & Real Fluid.
3. Distinguish between Newtonian and non-Newtonian fluids.
4. Define the term centre of pressure of the plane area immersed in a fluid .Do the Centre of pressure and centre of gravity ever coincide and if so under what conditions?
5. Define the following terms with their units.
  - i. Specific weight ii. Specific gravity iii. Surface Tension iv. Dynamic viscosity v. Specific weight or Weight density vi. Specific volume vii. Specific gravity or Relative density viii. Bulk modulus and compressibility
6. How does the dynamic viscosity of (a) liquids and (b) gases vary with temperature?
7. Calculate specific weight, density, specific volume and specific gravity of one liter of liquid which weighs 7.836 N.
8. Calculate dynamic viscosity of an oil, which is used for lubrication between a square plate of size 0.8m  $\times$  0.8m and an inclined plane with angle of inclination 30°. The weight of square plate is 300 N and is slide down the inclined plane with a uniform velocity of 0.3 m/s. The thickness of oil film is 1.5mm. [Ans: 11.7 poise]
9. A 50 mm diameter shaft rotates with 500 rpm in a 80 mm long journal bearing with 51 mm internal diameter. The annular space between the shaft and bearing is filled with lubricating oil of dynamic viscosity 1 poise. Determine the torque required and power absorbed to overcome friction.
10. A plate 0.03 mm distant from a fixed plate, moves at 70 cm/s and requires a force of 3 N/m<sup>2</sup> to maintain this speed. Calculate the fluid viscosity between the plates.
11. Derive the expression for total pressure and centre of pressure for a vertical plate submerged in the liquid with usual notations.
12. Determine the total pressure and depth of centre of pressure on a plane rectangular surface of 1 m wide and 3 m deep when its upper edge is horizontal and (a) coincides with water surface (b) 2 m below the free water surface.
13. A vertical sluice gate is used to cover an opening in a dam. The opening is 2m wide and 1.2m high. On the upstream side of the gate, the liquid of sp. gr. 1.45, lies up to a height of 1.5 m above the top of the gate, and on the down steam side the water is available up to a height touching the top of the gate. Find the resultant force acting on the gate and position of centre of pressure. Find also the force acting horizontally at



the top of the gate which capable of opening it. Assume that the gate is hinged at the bottom.

### **Assignments 2**

1. Derive an expression for continuity equation for three dimensional flow and reduce it for steady, incompressible 2-D flow in Cartesian co-ordinate system.
2. Explain the following in brief:
  - a. Total acceleration, Convective acceleration & Local acceleration
  - b. Velocity potential function & Stream function
  - c. Vorticity & Circulation
  - d. Stream line, Streak line & Path line
3. Prove that equipotential line and stream line are perpendicular to each other. How do you classify cutting tool? Brief them.
5. Define vortex flow. Also derive expressions of potential function and stream function for vortex flow.
6. Differentiate between free and forced vortex flow
7. Explain various types of fluid flow.

### **Assignments 3**

1. Derive Euler's equation of motion along a stream line and hence obtain Bernoulli's equation. Also state Bernoulli's theorem with its assumptions.
2. Explain Venturimeter in brief and Derive an expression for discharge through Venturimeter.
3. What is pitot tube. Derive an expression for the measurement of velocity of flow at any point in a pipe by pitot tube.
4. Derive an expression for discharge over triangular notch.
5. Derive an expression for discharge over rectangular orifice.
6. Define following terms
  - I. Kinetic energy correction factor
  - II. Momentum energy correction factor
7. The water is flowing through a pipe having diameters 20 cm and 15 cm at sections 1 and 2 respectively. The rate of flow through pipe is 40 litres/s. The section 1 is 6 m above datum and section 2 is 3 m above datum. If the pressure at section 1 is  $29.43 \text{ N/cm}^2$ , find the intensity of pressure at section 2.
8. velocity in the duct is 0.85 of the central velocity. Determine the discharge through the duct if the difference between the static and total pressure is 80 mm of water.. In a duct of 400 mm diameter, a pitot static tube is placed in the centre. The mean The coefficient of pitot tube as  $C_v = 0.98$
9. An oil of sp. gr. 0.9 is flow through a venturimeter having inlet diameter 20 cm and throat diameter 10 cm. The oil-mercury differential manometer shows a reading of 20 cm. Calculate the discharge of oil through the horizontal venturimeter. Take  $C_d=0.98$ .
10. An orifice-meter with orifice diameter 15 cm is inserted in a pipe of 30 cm diameter. The

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pressure gauges fitted upstream and downstream of the orifice meter give readings of  $14.715 \text{ N/cm}^2$  and  $9.81 \text{ N/cm}^2$  respectively. Find the rate of flow of water through the pipe in litres/s. Take  $C_d = 0.6$ .

### **Assignments 4**

1. What is difference between momentum equation and impulse momentum equation?
2. Define and derive moment of momentum equation.
3. Derive expression for force exerted by flowing fluid on a pipe bend.
4. A 300mm diameter pipe carries water under a head of 20meters with a velocity of 3.5m/s. if the axis of the pipe turns through 45 degree; find the magnitude and direction of the resultant force at the bend.

### **Assignments 5**

1. Derive the expression for Darcy- Weisbach formula for friction loss in the pipe.
2. Explain total energy line (T.E.L) and Hydraulic gradient line (H.G.L).
3. Two reservoirs are connected by a pipeline which is 15 cm in diameter for the first 5 m and 25 cm diameter for the remaining 15 m. Entry to and exit from the pipe is sharp and the water surface in the upper reservoir is 7.5 m above that in the lower reservoir. Represent layout and calculate the head losses and flow rate by assuming the friction co-efficient is 0.01 for both the pipes. Also draw hydraulic gradient line (H.G.L) and Total energy line (T.E.L).

### **Assignments 6**

1. Derive an expression for uniform flow through an open channel by using Chezy's formula.
2. Water flow over a rectangular weir 1m wide at a depth of 150mm and afterwards passes through a triangular right-angled weir. Taking C for the rectangular and triangular weir as 0.62 and 0.59 respectively, find the depth over the rectangular weir.
3. Derive an expression for discharge over triangular or v-notch.

### **Assignments 7**

1. State Buckingham's -theorem. What do you mean by repeating variables? How the repeating variables are selected in dimensional analysis?
2. State the various dimensionless numbers with their significance in fluid flow situations. Explain Froude, Euler and Weber model law with applications.
3. Discuss different types of similarities that must exist between a prototype and its model.
4. Explain Rayleigh's methods of dimensional analysis.
5. Find an expression for the drag force F on smooth sphere of diameter D, moving with a uniform velocity V in a fluid of density and dynamic viscosity  $\mu$ .
6. The efficiency of a fan depends on density, dynamic viscosity  $\mu$  of the fluid, angular velocity, diameter D of the rotor and the discharge Q. Express in terms of dimensionless parameters.

### **Assignments 8**

1. Explain the components & working of the Francis turbine with the help of a neat sketch.
2. What is the function of draft tube? Explain various types of draft tube.
3. Explain various components & working of Kaplan turbine with the help of a neat sketch.
4. What is Cavitation? What are the effects & precaution of cavitation in hydraulic turbine?

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **Lecture-wise Plan**

Subject Name: Primary Manufacturing Processes  
Year: 2<sup>nd</sup> Year

Subject Code-ME403  
Semester: Fourth

<b>Module Number</b>	<b>Topics</b>	<b>Number of Lectures</b>
1	<b>Introduction</b>	<b>1L</b>
2	<b>Casting</b>	<b>14L</b>
	Introduction, History, Definition, Major Classification, Casting Materials	1L
	Type of patterning, use of a core	1L
	Sand mould casting, Moulding sands: composition, properties & testing	2L
	Design of gating system: sprue, runner, ingate & riser, Problem practice	2L
	Estimation of powering time. Problem practice.	1L
	Foundry equipments, Furnaces Melting, pouring and solidification,	2L
	Different type of sand mould casting, Floor mould casting, Centrifugal casting, Shell mould & CO2 casting, Investment casting, Permanent mould casting	2L
	Die casting, types, methods, advantages & applications Slush casting, principle & use	1L
	Casting defects, types, causes & remedy, problems	2L
3	<b>Welding</b>	<b>12L</b>
	Introduction to metallic parts, Major grouping of joining processes, welding, brazing and soldering. Broad classification of welding processes, types and principles	1L
	Fusion welding, types, principles, equipments, characteristics & applications, Sources of heat-chemical action	2L
	Gas welding & thermit welding, Sources of heat-electrical energy	2L
	Arc welding, Submerged arc welding	1L
	TIG & MIG; Plasma arc welding, Resistance welding; Spot & butt welding	1L
	Solid state welding, Principles, advantages & applications of: Hot forge welding, Friction welding, Pressure & percussion welding	2L
	Precision welding processes: Ultrasonic welding, Laser beam welding, Electron beam welding	2L
	Welding defects, types, causes & remedy	1L
	<b>Forming Processes</b>	<b>13L</b>
	Forging Introduction, definition, classification, hot forging & cold forging characteristics & applications	4L
	Rolling	4L

	Introduction, basic principles, hot rolling & cold rolling, characteristics & applications, Rolling processes & applications, operations, equipments & roll stands	
	Wire drawing & extensions, Basic principles & requirements, Classification, methods & applications	2L
	Press tool works Basic principles, systems, operations & applications	1L
	Shearing, parting, blanking, piercing & notching Cupping(drawing), Spinning & deep drawing	1L
	Blanks & forces needed for shearing & drawing operations Coining & embossing	1L
	<b>Total Number Of Hours = 40</b>	

## **ASSINMENT:**

### **Unit1: (Introduction)**

1. Explain why the understanding of manufacturing process is essential for better products.
2. Describe various ways in which a break-even analysis plot could be made.
3. What are the broad classifications of the manufacturing processes?
4. Why is it necessary for all engineers to be familiar with manufacturing process?

### **Unit 2 :( Casting)**

1. List the main advantages of the casting process.
2. Distinguish clearly between the following casting terms  
Moulding sand, backing sand, and facing sand.
3. Briefly explain the procedure to be followed for making a sand mould.
4. Describe the allowance given on a pattern for shaking and distortion.
5. What do you mean by double-shrinkage allowance?
6. What do you mean by grain-fineness number? Explain the procedure for determining the number for a moulding sand.
7. Describe the method used for determining the permeability of any moulding sand.
8. "Natural sand is often not suitable for moulding purposes". Comment the statement giving reasons.
9. A cast iron cylinder 450 mm outside dia, 80 mm inside dia, and 150 mm long is to be obtained by sand casting. Design the requisite pattern assuming that the internal hole is to be finished by machining.
10. Describe the objectives of gating system in any casting.
11. Explain why the sprue should be tapered?
12. What are the functions served by the pouring basin in a sand casting? Give the sketch of a design of a pouring basin with an arrangement for trapping slag.
13. Describe the types of risers and their uses with suitable sketches.
14. Write a short note on whirl gate.
15. Define casting yield and explain its importance.

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Semester: Fourth

16. Define the choke area of casting. Explain reasons why normally sprue base is used as the choke area for ferrous casting.
17. Describe how runner extension is helpful for good casting quality.
18. Briefly explain the rationale of Chvorinov's empirical rules for rising.
19. Two casting are moulded in green sand. They differ in weight by a factor 3.8 but they are both cubes. An experiment has shown that the lighter casting solidifies in 8.7 mins. How much time would you estimate that it would take for the larger casting to solidify?
20. Describe briefly the feeding aids used in steel castings.

### **Unit 3: (Welding)**

1. Why is the strength of a rolled part considered usually better than a cast piece?
2. Give a line diagram of the various processes involved in the manufacture of the steel sheet, starting from steel ingots.
3. How does cold rolling differ from hot rolling in terms of the process and product?
4. List the advantages of forging of metals. Why is press forging preferred over hammer-forging process
5. Explain how forging improves the mechanical properties of the component.
6. Explain with sketches the difference between direct and indirect extrusion.
7. Distinguish between wire drawing and tube drawing with sketches.
8. What is meant by trimming related to forging components?
9. What is meant by grain flow in the case of forged or rolled components?
10. Explain what you understand by the terms ingot, slab, bloom and billet.
11. Explain the method of obtaining a weld in horizontal position by SMAW.
12. Briefly explain the coding method used for the electrodes used in SMAW.
13. How arc is obtained in arc welding?
14. Explain the TIG and MIG systems of arc welding. Give application of each .
15. State the important functions of flux coatings of electrodes used in manual metal arc welding process.
16. What do you mean by the term Kerf in gas cutting? Explain its relevance.
17. Explain the effects of the torch speed on the cut in gas cutting.
18. What is a bead? Explain with a sketch.
19. Why is it normally necessary to use filler material in welding with tungsten arc? Give reasons.
20. In a arc welding operation, the power source is at 50 v and current at 300 A. If the electrode travel speed is 6mm/s, calculate the cross-section area of the joint. The heat transfer efficiency is taken as 0.80 and melting efficiency as 0.30. Heat required to melt the steel is 10 J/mm<sup>3</sup>.

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **Lecture-wise Plan**

Subject Mechanisms

Subject Code-ME403

Year: 2<sup>nd</sup> Year

Semester: Fourth

<b>Module Number</b>	<b>Topics</b>	<b>Number of Lectures</b>
<b>1</b>	<b>1.</b> Introduction to mechanisms, Difference between Machine and Mechanism	<b>1L</b>
	Classification of Pairs of Elements, Kinematic chain, types of joints in a chain	1
	Four-bar linkage: motions of links	2
	Grashof's criterion of movability. Degrees of freedom for plane Mechanisms	2
	Gruebler's criterion for plane mechanism, Kinematic inversions – four Inversions of a Slider-Crank Chain.	2
<b>2</b>	<b>2</b> Velocity analysis in Mechanisms: Relative velocity method – slider crank mechanism,	<b>1L</b>
	four bar mechanism, Crank and slotted lever mechanism	1
	; Instantaneous centre method – Kennedy's theorem;	1
	Acceleration analysis: Acceleration Images	2
	, Klein's construction, analytical expression of velocity & acceleration.	2
<b>3</b>	<b>3.</b> Belt-drive – introduction;	<b>2</b>
	Law of belting, Length of flat belt for open and cross belt connections;;	1
	Stepped pulley for open flat belt;	1
	Tension in flat belt and V-belts; Power transmitted in belt drive	2
<b>4</b>	<b>4.</b> Gear terminology, Laws of gearing,	<b>2L</b>
	types of gears – Spur, Bevel, Helical, Worm; tooth profile	1

	, interference; Gear trains – simple, compound,	2
	epicyclic gear train; Speed-torque analysis of gear trains.	2
<b>5</b>	<b>5. Classification of Cams and followers;</b>	<b>2L</b>
	Radial Cam, Analysis of knife-edge, roller and flat face follower motion – constant velocity,.	3
	simple harmonic, constant acceleration & deceleration;	2
	Offset follower	1
<b>6</b>	<b>6. Kinematic Synthesis: Introduction to problems of function generation</b>	<b>2L</b>
	, path generation and rigid body guidance; Type, Number and Dimensional Synthesis;	1
	Two and three position synthesis of four bar mechanism and slider –crank mechanism :	2
	Graphical – pole, Relative pole and Inversion method; Analytical solution -	1
	Freudenstein's Method.	2
	Study of lower pair Mechanisms- Pantograph	
	, Parallel linkage mechanisms, Straight line mechanism,	1
	Automobile steering mechanism, Hooks joint.	1
<b>Total Number Of Hours = 46</b>		

### Assignment No. 1

- 1 Classify kinematic pair based on nature of contact. Give examples.
- 2 When a linkage become mechanism
- 3 Classify the constrained motion
- 4 List the inversion of four bar mechanism?
- 5 Distinguish between kinematics and kinetics?
- 6 Discuss toggle position?



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## **Lecture-wise Plan**

- 7 Describe pantograph?
- 8 Illustrate the applications of single slider crank mechanism?
- 9 Define kinematics pairs with example
- 10 Discuss Elliptical trammel
  
11. The Crank of a slider crank mechanisms rotates clockwise at a Constant speed of 300 rpm. The crank is 125 mm and connecting rod is 600 mm long. Determine  
1. Linear velocity and acceleration of the mid Point of the connecting rod, and 2. Angular velocity and angular acceleration of the connecting rod, at a crank angle of  $45^\circ$  from inner dead centre position
  
12. In a four link mechanism, the dimensions of the links are  $AB=200$  mm,  $BC=400$ mm,  $CD=450$  mm and  $AD=600$ mm. At the instant when  $\angle DAB=90^\circ$ , the link AB has angular velocity of 36 rad/s in the clockwise direction. Determine (i) The velocity of point C, (ii) The velocity of point E on the link BC When  $BE = 200$  mm (iii) the angular velocities of links BC and CD, iv) acceleration of link of linkBC.
  
13. The dimensions of the various links of a mechanism, as shown in fig. are as follows:  $OA=300$  mm;  $AB=1200$ ;  $BC=450$  mm and  $CD=450$  mm. if the crank OA rotates at 20 r.p.m. in the anticlockwise direction and gives motion to the sliding blocks B and D, find, for given configuration: (1) Velocity of sliding at B and D, (2) Angular velocity of CD (3) Linear acceleration of D and (4) angular acceleration of CD.

### **Assignment No. 2**

1. Define 'degrees of freedom'
2. Explain transmission angle?
3. Explain transmission angle?
4. Describe Grashof's Law for a four bar mechanism?
5. Define Kutzbach criterion for planar mechanism.
6. Explain Grubler's criterion for spatial mechanism.
7. Compare instantaneous center & instantaneous axis?
8. Illustrate the types of links and define it.

9. Distinguish between machine and mechanism.
10. Describe spatial mechanism
11. a) Derive the expressions for Velocity and acceleration of piston in reciprocating steam engine mechanism with neat sketch  
b). Derive the expression for Coriolis component of acceleration with neat sketch
  
12. In a slider crank mechanism, the length of the crank and the connecting rod are 100 mm and 400 mm respectively. The crank [position is  $45^\circ$  from IDC, the crank shaft speed is 600 r.p.m. clockwise. Using analytical method Determine (1) Velocity and acceleration of the slider, and (2) Angular velocity and angular acceleration of the connecting rod.
  
13. Locate all instantaneous centers of the slider crank mechanism; the length of crank OB and Connecting rod AB are 125 mm and 500 mm respectively. The crank speed is 600 rpm clockwise. When the crank has turned  $45^\circ$  from the IDC. Determine (i) velocity of slider 'A' (ii) Angular Velocity of connecting rod 'AB'

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## **Lab Manual**

**Title of Course: Numerical Methods Lab**

**Course Code: M(CS)491**

**L-T-P scheme: 0-0-3**

**Course Credit: 2**

### **Objectives:**

1. To give an overview of *what* can be done
2. To give insight into *how* it can be done
3. To give the confidence to tackle numerical solutions

An understanding of how a method works aids in choosing a method. It can also provide an indication of what can and will go wrong, and of the accuracy which may be obtained. To gain insight into the underlying physics.

"The aim of this course is to introduce numerical techniques that can be used on computers, rather than to provide a detailed treatment of accuracy or stability"

### **Learning Outcomes:**

On completion of this course, the student will be able to:

1. Demonstrate skills in using computer programming tools for engineering calculations;
2. Demonstrate ability to construct simple computer algorithms using a programming tool;
3. Apply simple numerical methods to solve mathematical problems with relevance to civil engineering;
4. Appreciate the limitations and the applicability of the numerical methods;
5. Apply computer-based numerical methods for the solution of engineering problems.

### **Course Contents:**

**Exercises that must be done in this course are listed below:**

1. Assignments on Newton forward /backward, Lagrange' s interpolation.
2. Assignments on numerical integration using Trapezoidal rule, Simpson' s 1/3 rule.
3. Assignments on numerical solution of a system of linear equations using Gauss elimination and Gauss-Seidel iterations.
4. Assignments on numerical solution of Algebraic Equation by Regular-falsi and Newton Raphson methods.
5. Assignments on ordinary differential equation: Euler' s and Runge-Kutta methods.

### **Text Book:**

1. Introductory method of numerical analysis, Sastry S.S
2. Computer Programming in fortran 77, Rajaraman V
3. Numerical methods: for scientific and engineering computation, Mahinder Kumar Jain

### **Recommended Systems/Software Requirements:**

1. Intel based desktop PC with minimum of 166 MHZ or faster processor with at least 64 MB RAM and 100 MB free disk space.
2. Turbo C or TC3 compiler in Windows XP or Linux Operating System.

### **Experiment No: 1(a) Newton forward interpolation**

**Aim: Write a C program to implement the Newton forward interpolation.**

#### **Description:**

Interpolation is the process of finding the values of  $y$  corresponding to the any value of  $x$  between  $x_0$  and  $x_n$  for the given values of  $y=f(x)$  for a set of values of  $x$ . Out of the many techniques of interpolation, Newton's Forward and Backward Interpolation are two very widely used formulas. In this tutorial, we're going to discuss a C program for Newton Forward Interpolation along with its sample output.

Both of Newton's formulas are based on finite difference calculus. These formulas are very often used in engineering and related science fields. Before going through the source code for Newton Forward Interpolation, let's go through the forward interpolation formula and the variables used in the C program.

Newton's forward interpolation formula contains  $y_0$  and the forward differences of  $y_0$ . This formula is used for interpolating the values of  $y$  near the beginning of a set of tabulated values and extrapolation the values of  $y$  a little backward (i.e. to the left) of  $y_0$ . The formula is given below:

$$P(x) = y_0 + q \Delta y_0 + \frac{q(q-1)}{2!} \Delta^2 y_0 + \frac{(q+1)q(q-1)}{3!} \Delta^3 y_0 + \dots + \frac{(q-1)q(q-1)(q-2)}{4!} \Delta^4 y_0 + \frac{(q+2)(q+1)q(q-1)(q-2)}{5!} \Delta^5 y_0 + \dots + \frac{(q+n-1) \dots (q-n+1)}{(2n-1)!} \Delta^{2n-1} y_{-(n-1)} + \frac{(q-n-1) \dots (q-n)}{(2n)!} \Delta^{2n} y_{-n},$$

Compared to forward interpolation, the backward interpolation formula contains  $y_n$  and the backward differences of  $y_n$ . This formula is used for interpolating the values of  $y$  near the end of a set of tabulated values and also for extrapolating the values of  $y$  a little ahead (i.e. to the right) of  $y_n$ .

#### Algorithm:

1. Function NFI ()
2. Read n, x
3. For I = 1 to n by 1 do
4. Read x[i], y[i]
5. End for
6. If ((x < x[i] or (x > x[n]))
7. Print "Value lies out of boundary"
8. Exit
9. End if
10. //Calculating p
11.  $p = (x - x[1]) / (x[2] - x[1])$
12. // Forward diff table
13. For j = 1 to (n-1) by 1 do
14. For i = 1 to (n - j) by 1 do
15. If (j=1) Then
16.  $d[i][j] = y[i+1] - y[i]$
17. Else
18.  $d[i][j] = d[i+1][j-1] - d[i][j-1]$
19. End if
20. End For
21. End For
22. // Applying Formula
23. Sum = y[1]
24. For I = 1 to (n-1) by 1 do
25. Prod = 1
26. For j = 0 to (i-1) by 1 do
27. Prod = prod \* (p-j)
28. End for
29. m = fact(i)
30. Sum = sum + (d[1][i] \* prod) / m
31. End For
32. Print "Ans is", Sum
33. End Function

**/\* Program to implement Newton's forward interpolation\*/**

```

1  #include<stdio.h>
2  #include<conio.h>
3  #include<math.h>
4  #include<stdlib.h>
5  main()
6  {
7      float x[20],y[20],f,s,h,d,p;
8      int i,n;
```

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```
10  scanf("%d",&n);
11  printf("enter the elements of x:");
12  for(i=1;i<=n;i++)
13  {
14      scanf("%f",&x[i]);
15  }
16      printf("enter the elements of y:");
17      for(i=1;i<=n;i++)
18      {
19          scanf("%f",&y[i]);
20      }
21  h=x[2]-x[1];
22  printf("Enter the value of f:");
23  scanf("%f",&f);
24  s=(f-x[1])/h;
25  p=1;
26  d=y[1];
27  for(i=1;i<=(n-1);i++)
28  {
29      for(j=1;j<=(n-i);j++)
30      {
31          y[j]=y[j+1]-y[j];
32      }
33      p=p*(s-i+1)/i;
34      d=d+p*y[1];
35  }
36  printf("For the value of x=%6.5f THe value is %6.5f",f,d);
37  getch();
38  }
```

### **OUTPUT:**

how many record you will be enter: 5  
enter the value of x0: 2.5  
enter the value of f(x0): 9.75  
enter the value of x1: 3  
enter the value of f(x1): 12.45  
enter the value of x2: 3.5  
enter the value of f(x2): 15.70  
enter the value of x3: 4  
enter the value of f(x3): 19.52  
enter the value of x4: 4.5  
enter the value of f(x4): 23.75  
Enter X for finding f(x): 4.25  
u = -0.500  
f(4.25) = 21.583750

### **Experiment No: 1(b) Newton backward interpolation**

**Aim:** Write a C program to implement Newton backward interpolation.

#### **Algorithm:**

1. Function NBI ()
2. Read n, x
3. For I = 1 to n by 1 do
4. Read x[i], y[i]
5. End for

7. Print "Value lies out of boundary"
8. Exit
9. End if
10. //Calculating p
11.  $p = (x - x[1]) / (x[2] - x[1])$
12. // Forward diff table
13. For j = 1 to (n-1) by 1 do
14. For i = 1 to (n - j) by 1 do
15. If (j=1) Then
16.  $d[i][j] = y[i+1] - y[i]$
17. Else
18.  $d[i][j] = d[i+1][j-1] - d[i][j-1]$
19. End if
20. End For
21. End For
22. // Applying Formula
23. Sum = y[n]
24. For I = 1 to (n-1) by 1 do
25. Prod = 1
26. For j = 0 to (i-1) by 1 do
27. Prod = prod \* (p+j)
28. End for
29. m = fact(i)
30. Sum = sum + (d[n-1][i] \* prod) / m
31. End For
32. Print "Ans is", Sum
33. End Function

**/\* Program to implement Newton's forward interpolation \*/**

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
#include<stdlib.h>
main()
{
    float x[20],y[20],f,s,d,h,p;
    int j,i,k,n;
    printf("enter the value of the elements :");
    scanf("%d",&n);
    printf("enter the value of x: \n\n");
    for(i=1;i<=n;i++)
    {
        scanf("%f",&x[i]);
    }
    printf("enter the value of y: \n\n");
    for(i=1;i<=n;i++)
    {
        scanf("%f",&y[i]);
    }
    h=x[2]-x[1];
    printf("enter the searching point f:");
    scanf("%f",&f);
    s=(f-x[1])/h;
    d=y[1];
    p=1;
    for(i=n,k=1;i>=1,k<n;i--,k++)
    {
```

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```
{
    y[j]=y[j]-y[j-1];
}
p=p*(s+k-1)/k;
d=d+p*y[n];
}
printf("for f=%f ,ans is=%f",f,d);
getch();
}
```

### **OUT PUT:**

how many record you will be enter: 5  
enter the value of x0: 2.5  
enter the value of f(x0): 9.75  
enter the value of x1: 3  
enter the value of f(x1): 12.45  
enter the value of x2: 3.5  
enter the value of f(x2): 15.70  
enter the value of x3: 4  
enter the value of f(x3): 19.52  
enter the value of x4: 4.5  
enter the value of f(x4): 23.75  
Enter X for finding f(x): 4.25

---

x(i)	y(i)	y1(i)	y2(i)	y3(i)	y4(i)
------	------	-------	-------	-------	-------

---

2.500 9.750

3.000 12.450 2.700

3.500 15.700 3.250 0.550

4.000 19.520 3.820 0.570 0.020

4.500 23.750 4.230 0.410 -0.160 -0.180

u = -0.500

f(4.25) = 21.583750 -

### **Experiment No: 1(c)Lagrange' s interpolation**

**Aim: Write a C program to implement Lagrange' s interpolation.**

#### **Algorithm:**

1. Input number of Observation n
2. For i = 1 to n
3. Input Xi
4. Input Yi
5. Next i
6. Input xp at which yp to be computed
7. Initialize yp = 0
8. For i = 1 to n
9. t = 1
10. For j = 1 to n
11. If j = i

13. End If
14. Next j
15. yp = yp + t \* Yi
16. Next i
17. Print yp as output
18. Stop

**/\* Program to implement Lagrange' s interpolation\*/**

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
int main()
{
    float x[10],y[10],temp=1,f[10],sum,p;
    int i,n,j,k=0,c;

    printf("\nhow many record you will be enter: ");
    scanf("%d",&n);
    for(i=0; i<n; i++)
    {
        printf("\n\nenter the value of x%d: ",i);
        scanf("%f",&x[i]);
        printf("\n\nenter the value of f(x%d): ",i);
        scanf("%f",&y[i]);
    }
    printf("\n\nEnter X for finding f(x): ");
    scanf("%f",&p);

    for(i=0;i<n;i++)
    {
        temp = 1;
        k = i;
        for(j=0;j<n;j++)
        {
            if(k==j)
            {
                continue;
            }
            else
            {
                temp = temp * ((p-x[j])/(x[k]-x[j]));
            }
        }
        f[i]=y[i]*temp;
    }

    for(i=0;i<n;i++)
    {
        sum = sum + f[i];
    }
    printf("\n\n f(%.1f) = %f ",p,sum);
    getch();
}
```

### **OUTPUT:**

enter the value of n 4  
enter the value to be found 2.5



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1 1  
2 8  
3 27  
4 64  
X = 2.500000  
sum = 15.625000

### **Experiment No:2.Trapezoidal rule**

**Aim:** Write a C program to implement Trapezoidal rule.

#### **Description:**

A number of definite integrals need to be solved in applied mathematics, physics and engineering. The manual analytical solution of definite integrals is quite cumbersome and time consuming. So, in this post I have presented source code in C program for Trapezoidal method as one of the computer-programming-based solutions of definite integrals. The techniques of numerical methods are used to solve this equation; it involves a number of calculations and efforts have been made to minimize error in the program.

The trapezium or trapezoidal rule can be used as a way of estimating the area under a curve because the area under a curve is given by integration. So, the trapezoidal rule gives a method of estimating integrals. This is useful when you come across integrals that you don't know how to evaluate. So, the program for trapezoidal method in C given here is applicable to calculate finite integral or area under a curve.

$$h=(x_n-x_0)/n$$

After that, the C source code for trapezoidal method uses the following formula to calculate the value of definite integral:

$$\int_{x_0}^{x_n} f(x) dx = \frac{1}{2} [(y_0 + y_n) + 2(y_1 + y_2 + \dots + y_{n-1})]$$

#### **Algorithm:**

1. Read x1, x2, e {x1 and x2 are the two end points of the interval the allowed error in integral is e}
2. h = x2 - x1
3. SI = (f(x1) + f(x2))/2;
4. I = h - si
5. i = 1 Repeat
6. x = x1 + h/2
7. for J= 1 to I do
8. SI = SI + f(x)
9. x = x + h
10. End for
11. i = 21
12. h = h/2 {Note that the interval has been halved above and the number of points where the function has to be computed is doubled}
13. i0 = i1
14. i1 = h.si. until / I1 - i0 / <= c./i1/
15. Write I1, h, i
16. Stop.

**/\* Program to implement Trapezoidal rule \*/**

#include<stdio.h>

#include<math.h>

main()

{

float h, a, b, n, x[20], y[20], sum = 0, integral;

int i;

clrscr();

```

scanf("%f %f %f", &a, &b, &n);
printf("enter the values of x:");
for(i = 0; i <= (n-1); i++)
{
    scanf("%f", &x[i]);
}
printf("\n enter the values of y:");
for(i = 0; i <= (n-1); i++)
{
    scanf("%f", &y[i]);
}
h = (b-a)/n;
x[0] = a;
for(i = 1; i <= n-1; i++)
{
    x[i] = x[i-1] + h;
    sum = sum + 2 * y[i];
}
sum = sum + y[b];
integral = sum * (h/2);
printf("approximate integral value is: %f", integral);
getch();
}

```

#### OUTPUT :

```

enter the values of a, b, n
123
enter the values of x:
123
enter the values of y:
123
approximate integral value is 2.166667

```

#### Experiment No:2(a)Simpson' s 1/3 rule

**AIM: Write a C Program to implement Simpson' s 1/3 rule.**

#### Description:

In the source code below, a function  $f(x) = 1/(1+x)$  has been defined. The calculation using **Simpson 1/3 rule in C** is based on the fact that the small portion between any two points is a parabola. The program follows the following steps for calculation of the integral.

- ) As the program gets executed, first of all it asks for the value of lower boundary value of x i.e.  $x_0$ , upper boundary value of x i.e.  $x_n$  and width of the strip, h.
- ) Then the program finds the value of number of strip as  $n = (x_n - x_0)/h$  and checks whether it is even or odd. If the value of 'n' is odd, the program refines the value of 'h' so that the value of 'n' comes to be even.
- ) After that, this C program calculates value of  $f(x)$  i.e 'y' at different intermediate values of 'x' and displays values of all intermediate values of 'y'.
- ) After the calculation of values of 'c', the program uses the following formula to calculate the value of integral in loop.  

$$\text{Integral} = ((y_0 + y_n) + 4(y_1 + y_3 + \dots + y_{n-1}) + 2(y_2 + y_4 + \dots + y_{n-2}))$$
- ) Finally, it prints the values of integral which is stored as 'ans' in the program.

If  $f(x)$  represents the length, the value of integral will be area, and if  $f(x)$  is area, the output of Simpson 1/3 rule C program will be volume. Hence, numerical integration can be carried out using the program below; it is very easy to use, simple to understand, and gives reliable and accurate results.

$$f(x) = 1/(1+x)$$

.

#### Algorithm:

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2.  $h = (x_2 - x_1)/2$
3.  $i = 2$
4.  $s_i = f(x_1) + f(x_2)$
5.  $s_2 = 0$
6.  $s_4 = f(x_1 + h)$
7.  $I_0 = 0$
8.  $I_n = (s + 4s_4).(h/3)$
9. Repeat
10.  $s_2 = s_2 + s_4$  {  $s_2$  stores already computed functional value and  $s_4$  the value computed in the new iteration }
11.  $s_4 = 0$
12.  $x = x_1 + h/2$
13. for  $j = 1$  to  $I$  do
14.  $s_4 = s_4 + f(x)$
15.  $x = x + h$
16.  $h = h/2$
17.  $i = 2i$
18.  $i_o = i_n$
19.  $i_n = (s_1 + 2s_2 + 4s_4) . (h/3)$
20. until  $|I_n - I_o| \leq \epsilon / i_n$
21. Write  $I_n, h, i$
22. STOP

**/\* Program to implement Simpson' s 1/3 rule. \*/**

```
#include<stdio.h>
#include<conio.h>
#include<math.h>
main()
{
    float h, a, b, n, x[20], y[20], sum = 0, itgl;
    int i;
    clrscr();
    printf("enter the values of a, b, n");
    scanf("%f%f%f", &a, &b, &n);
    printf("enter the values of x");
    for(i = 0; i <= n; i++)
    {
        scanf("%f", &x[i]);
    }
    printf("\n enter the values of y");
    for(i = 0; i <= n; i++)
    {
        scanf("%f", &y[i]);
    }
    h = (b - a)/n;
    a = x[0];
    b = x[n];
    for(i = 0; i <= (n-2); i++)
    {
        x[i] = x[i] + h;
        if(i % 2 == 0)
        {
            sum = sum + 4 * y[i];
        }
        else
        {
```

```

    }
}
itgl = sum * (h/3);
printf("integral value%f", itgl);
getch();
}

```

### OUTPUT :

enter the values of a, b, n

123

enter the value of x

4567

enter the values of y

8912

integral value is 5.555556

### Experiment No: 3(a)Gauss elimination.

**AIM: Write a C Program to implement Gauss elimination method.**

#### Description:

let us first consider the following three equations:

$$a_1x + b_1y + c_1z = d_1$$

$$a_2x + b_2y + c_2z = d_2$$

$$a_3x + b_3y + c_3z = d_3$$

Assuming  $a_1 \neq 0$ , x is eliminated from the second equation by subtracting  $(a_2/a_1)$  times the first equation from the second equation. In the same way, the C code presented here eliminates x from third equation by subtracting  $(a_3/a_1)$  times the first equation from the third equation.

Then we get the new equations as:

$$a_1x + b_1y + c_1z = d_1$$

$$b'_2y + c'_2z = d'_2$$

$$c''_3z = d''_3$$

The elimination procedure is continued until only one unknown remains in the last equation. After its value is determined, the procedure is stopped. Now, Gauss Elimination in C uses back substitution to get the values of x, y and z as:

$$z = d''_3 / c''_3$$

$$y = (d'_2 - c'_2z) / b'_2$$

$$x = (d_1 - c_1z - b_1y) / a_1.$$

#### Algorithm:

1. Start
2. Declare the variables and read the order of the matrix n.
3. Take the coefficients of the linear equation as:

Do for k=1 to n

Do for j=1 to n+1

Read a[k][j]

End for j

End for k

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4. Do for k=1 to n-1  
    Do for i=k+1 to n  
    Do for j=k+1 to n+1  
     $a[i][j] = a[i][j] - a[i][k] / a[k][k] * a[k][j]$   
    End for j  
    End for i  
    End for k
5. Compute  $x[n] = a[n][n+1] / a[n][n]$
6. Do for k=n-1 to 1  
    sum = 0  
    Do for j=k+1 to n  
    sum = sum +  $a[k][j] * x[j]$   
    End for j  
     $x[k] = 1 / a[k][k] * (a[k][n+1] - \text{sum})$   
    End for k
7. Display the result  $x[k]$
8. Stop

**/\* Program to implement Gauss elimination method \*/**

#include<stdio.h>

int main()

{

    int i,j,k,n;

    float A[20][20],c,x[10],sum=0.0;

    printf("\nEnter the order of matrix: ");

    scanf("%d",&n);

    printf("\nEnter the elements of augmented matrix row-wise:\n\n");

    for(i=1; i<=n; i++)

    {

        for(j=1; j<=(n+1); j++)

        {

            printf("A[%d][%d] : ", i,j);

            scanf("%f",&A[i][j]);

        }

    }

    for(j=1; j<=n; j++) /\* loop for the generation of upper triangular matrix\*/

    {

        for(i=1; i<=n; i++)

        {

            if(i>j)

            {

$c = A[i][j] / A[j][j];$

                for(k=1; k<=n+1; k++)

                {

$A[i][k] = A[i][k] - c * A[j][k];$

                }

            }

        }

    }

```

/* this loop is for backward substitution*/
for(i=n-1; i>=1; i--)
{
    sum=0;
    for(j=i+1; j<=n; j++)
    {
        sum=sum+A[i][j]*x[j];
    }
    x[i]=(A[i][n+1]-sum)/A[i][i];
}
printf("\nThe solution is: \n");
for(i=1; i<=n; i++)
{
    printf("\nx%d=%f\t",i,x[i]); /* x1, x2, x3 are the required solutions*/
}
return(0);

```

### OUTPUT :

```

No of Equations : 3
Enter Coefficients of Equation
4 3 -2
1 1 1
3 -2 1
Enter Constant value
5 3 2
Eliminated matrix as :-
4.00 3.00 -2.00 5.00
0.00 0.25 1.50 1.75
0.00 0.00 28.00 28.00
Solution :
X3 = 1.00
X2 = 1.00
X1 = 1.00

```

### Experiment No:3(b) Gauss-Seidel iterations.

**AIM: Write a C Program to implement Gauss-Seidel iterations method.**

#### Description:

The program for Gauss-Seidel method in C works by following the steps listed below:

When the program is executed, first of all it asks for the value of elements of the augmented matrix row wise.

Then, the program asks for allowed error and maximum number of iteration to which the calculations are to be done. The number of iterations required depends upon the degree of accuracy.

The program assumes initial or approximate solution as  $y=0$  and  $z=0$  and new value of  $x$  which is used to calculate new values of  $y$  and  $z$  using the following expressions:

$$x = 1/a_1 (d_1 - b_1y - c_1z)$$

$$y = 1/b_2 (d_2 - a_2x - c_2z)$$

$$z = 1/c_3 (d_3 - a_3x - b_3y)$$

#### Algorithm:

1. Start
2. Declare the variables and read the order of the matrix  $n$
3. Read the stopping criteria  $er$

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4. Read the coefficients aim as  
Do for i=1 to n  
Do for j=1 to n  
Read a[i][j]  
Repeat for j  
Repeat for i
5. Read the coefficients b[i] for i=1 to n
6. Initialize x0[i] = 0 for i=1 to n
7. Set key=0
8. For i=1 to n  
Set sum = b[i]  
For j=1 to n  
If (j not equal to i)  
Set sum = sum – a[i][j] \* x0[j]  
Repeat j  
x[i] = sum/a[i][i]  
If absolute value of ((x[i] – x0[i]) / x[i]) > er, then  
Set key = 1  
Set x0[i] = x[i]  
Repeat i
9. If key = 1, then  
Goto step 6  
Otherwise print results

.  
**/\* Program to implement Gauss-Seidel iterations method. \*/**

```
#include<stdio.h>
#include<math.h>
#define X 2
main()
{
    float x[X][X+1],a[X], ae, max,t,s,e;
    int i,j,r,mx;
    for(i=0;i<X;i++) a[i]=0;
    puts(" Enter the elements of augmented matrix rowwise\n");
    for(i=0;i<X;i++)
    {
        for(j=0;j<X+1;j++)
        {
            scanf("%f",&x[i][j]);
        }
    }
    printf(" Enter the allowed error and maximum number of iteration: ");
    scanf("%f%d",&ae,&mx);
    printf("Iteration\tx[1]\tx[2]\n");
    for(r=1;r<=mx;r++)
```

```

max=0;
for(i=0;i<X;i++)
{
    s=0;
    for(j=0;j<X;j++)
        if(j!=i) s+=x[i][j]*a[j];
    t=(x[i][X]-s)/x[i][i];
    e=fabs(a[i]-t);
    a[i]=t;
}
printf(" %5d\t",r);
for(i=0;i<X;i++)
    printf(" %9.4f\t",a[i]);
printf("\n");
if(max<ae)
{
    printf(" Converges in %3d iteration\n", r);
    for(i=0;i<X;i++)
        printf("a[%3d]=%7.4f\n", i+1,a[i]);
    return 0;
}
}
}

```

### OUTPUT :

Enter the number of equations: 3

Enter the co-efficients of the equations:

a[1][1]= 2

a[1][2]= 1

a[1][3]= 1

a[1][4]= 5

a[2][1]= 3

a[2][2]= 5

a[2][3]= 2

a[2][4]= 15

a[3][1]= 2

a[3][2]= 1

a[3][3]= 4

a[3][4]= 8

x[1] =2.500000

x[2] =1.500000

x[3] =0.375000

x[1] =1.562500

x[2] =1.912500

x[3] =0.740625

x[1] =1.173437

x[2] =1.999688

x[3] =0.913359

x[1] =1.043477

x[2] =2.008570

x[3] =0.976119



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x[2] = 2.004959  
x[3] = 0.994933

x[1] = 1.000054  
x[2] = 2.001995  
x[3] = 0.999474

converges to solution

x[1] = 1.000054  
x[2] = 2.001995  
x[3] = 0.999474

### **Experiment No: 4(a) Regular-falsi**

**AIM: Write a program to implement Regular-falsi method.**

#### **Description:**

The C Program for regula falsi method requires two initial guesses of opposite nature. Like the secant method, interpolation is done to find the new values for successive iterations, but in this method one interval always remains constant.

The programming effort for Regula Falsi or False Position Method in C language is simple and easy. The convergence is of first order and it is guaranteed. In manual approach, the method of false position may be slow, but it is found superior to the bisection method.

) tr – a counter which keeps track of the no. of iterations performed  
) maxmitr – maximum number of iterations to be performed  
) x0, x1 – the limits within which the root lies  
) x2 – the value of root at nth iteration  
) x3 – the value of root at (n+1)th iteration  
) allerr – allowed error  
) x – value of root at nth iteration in the regula function  
) f(x0), f(x1) – the values of f(x) at x0 and x1 respectively  
f(x) = cos(x) – x\*e^x

#### **Algorithm:**

1. Start
2. Read values of x0, x1 and e  
\*Here x0 and x1 are the two initial guesses  
e is the degree of accuracy or the absolute error i.e. the stopping criteria\*
3. Computer function values f(x0) and f(x1)
4. Check whether the product of f(x0) and f(x1) is negative or not.  
If it is positive take another initial guesses.  
If it is negative then goto step 5.
5. Determine:  
$$x = [x0*f(x1) - x1*f(x0)] / (f(x1) - f(x0))$$
6. Check whether the product of f(x1) and f(x) is negative or not.  
If it is negative, then assign x0 = x;  
If it is positive, assign x1 = x;

7. Check whether the value of  $f(x)$  is greater than 0.00001 or not.  
 If yes, goto step 5.  
 If no, goto step 8.  
 \*Here the value 0.00001 is the desired degree of accuracy, and hence the stopping criteria.\*
8. Display the root as x.
9. Stop
- 10.

```

/* Program to implement Regular-falsi method */
#include<stdio.h>
#include<math.h>
float f(float x)
{
    return cos(x) - x*exp(x);
}
void regula (float *x, float x0, float x1, float fx0, float fx1, int *itr)
{
    *x = x0 - ((x1 - x0) / (fx1 - fx0))*fx0;
    ++(*itr);
    printf("Iteration no. %3d X = %7.5f \n", *itr, *x);
}
void main ()
{
    int itr = 0, maxmitr;
    float x0,x1,x2,x3,allerr;
    printf("\nEnter the values of x0, x1, allowed error and maximum iterations:\n");
    scanf("%f %f %f %d", &x0, &x1, &allerr, &maxmitr);
    regula (&x2, x0, x1, f(x0), f(x1), &itr);
    do
    {
        if (f(x0)*f(x2) < 0)
            x1=x2;
        else
            x0=x2;
        regula (&x3, x0, x1, f(x0), f(x1), &itr);
        if (fabs(x3-x2) < allerr)
        {
            printf("After %d iterations, root = %6.4f\n", itr, x3);
            return 0;
        }
        x2=x3;
    }
    while (itr<maxmitr);
    printf("Solution does not converge or iterations not sufficient:\n");
    return 1;
}

```

#### OUTPUT :

Enter the value of x0: -1

Enter the value of x1: 1

---

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---

```
-1.000000 1.000000 0.513434 -4.540302 1.459698 -0.330761
0.513434 1.000000 0.603320 -0.330761 1.459698 -0.013497
0.603320 1.000000 0.606954 -0.013497 1.459698 -0.000527
0.606954 1.000000 0.607096 -0.000527 1.459698 -0.000021
```

---

App.root = 0.607096

### **Experiment No: 4(b) Newton Raphson methods**

**AIM: Write a program to implement Newton Raphson methods.**

#### **Algorithm:**

1. Start
2. Read x, e, n, d
  - \*x is the initial guess
  - e is the absolute error i.e the desired degree of accuracy
  - n is for operating loop
  - d is for checking slope\*
3. Do for i =1 to n in step of 2
4.  $f = f(x)$
5.  $f1 = f'(x)$
6. If (  $[f1] < d$  ), then display too small slope and goto 11.
  - \*[ ] is used as modulus sign\*
7.  $x1 = x - f/f1$
8. If (  $[(x1 - x)/x1] < e$  ), the display the root as x1 and goto 11.
  - \*[ ] is used as modulus sign\*
9.  $x = x1$  and end loop
10. Display method does not converge due to oscillation.
11. Stop

**/\* Program to implement Newton Raphson methods \*/**

```
#include<stdio.h>
#include<math.h>
float f(float x)
{
    return x*log10(x) - 1.2;
}
float df (float x)
{
    return log10(x) + 0.43429;
}
```

```

{
    int itr, maxmitr;
    float h, x0, x1, allerr;
    printf("\nEnter x0, allowed error and maximum iterations\n");
    scanf("%f %f %d", &x0, &allerr, &maxmitr);
    for (itr=1; itr<=maxmitr; itr++)
    {
        h=f(x0)/df(x0);
        x1=x0-h;
        printf(" At Iteration no. %3d, x = %9.6f\n", itr, x1);
        if (fabs(h) < allerr)
        {
            printf("After %3d iterations, root = %8.6f\n", itr, x1);
            return 0;
        }
        x0=x1;
    }
    printf(" The required solution does not converge or iterations are insufficient\n");
    return 1;
}

```

#### OUTPUT :

ENTER THE TOTAL NO. OF POWER:::: 3

$x^0:: -3$

$x^1:: -1$

$x^2:: 0$

$x^3:: 1$

THE POLYNOMIAL IS :::  $1x^3 - 0x^2 - 1x^1 - 3x^0$

INITIAL X1---->3

ITERATION	X1	FX1	F'X1
1	2.192	21.000	26.000
2	1.794	5.344	13.419
3	1.681	0.980	8.656
4	1.672	0.068	7.475
5	1.672	0.000	7.384

THE ROOT OF EQUATION IS 1.671700

#### Experiment No:5(a)Euler' s methods

**AIM: Write a program to simulate Euler' s method.**

#### Description:

Solving an ordinary differential equation or initial value problem means finding a clear expression for y in terms of a finite number of elementary functions of x. Euler's method is one of the simplest method for the numerical solution of such equation or problem. This **C program for Euler's method** considers an ordinary differential equations, and the initial values of x and y are known. Mathematically, here, the curve of solution is approximated by a sequence of short lines i.e. by the tangent line in each interval. Using these information, the value of the value of 'y<sub>n</sub>' corresponding to the value of 'x<sub>n</sub>' is to determined by dividing the length (x<sub>n</sub> - x) into n strips.

Therefore, strip width= (x<sub>n</sub> - x)/n and x<sub>n</sub>=x<sub>0</sub>+ nh.

Again, if m be the slope of the curve at point, y<sub>1</sub>= y<sub>0</sub> + m(x<sub>0</sub> , y<sub>0</sub>)h.

Similarly, values of all the intermediate y can be found out.

Below is a source code for **Euler's method in C** to solve the ordinary differential equation **dy/dx = x+y**. It asks for the value of x<sub>0</sub>, y<sub>0</sub>, x<sub>n</sub> and h. The value of slope at different points is calculated

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The values of y are calculated in while loop which runs till the initial value of x is not equal to the final value. All the values of 'y' at corresponding 'x' are shown in the output screen.

$$dy/dx = x+y$$

### **Algorithm:**

1. Start
2. Define function
3. Get the values of x0, y0, h and xn  
\*Here x0 and y0 are the initial conditions  
h is the interval  
xn is the required value
4.  $n = (x_n - x_0)/h + 1$
5. Start loop from i=1 to n
6.  $y = y_0 + h*f(x_0, y_0)$   
 $x = x + h$
7. Print values of y0 and x0
8. Check if  $x < x_n$   
If yes, assign  $x_0 = x$  and  $y_0 = y$   
If no, goto 9.
9. End loop i
10. Stop

**/\* Program to simulate Euler' s method \*/**

```
#include<stdio.h>
float fun(float x,float y)
{
    float f;
    f=x+y;
    return f;
}
main()
{
    float a,b,x,y,h,t,k;
    printf("\nEnter x0,y0,h,xn: ");
    scanf("%f%f%f%f",&a,&b,&h,&t);
    x=a;
    y=b;
    printf("\n x\t y\n");
    while(x<=t)
    {
        k=h*fun(x,y);
        y=y+k;
        x=x+h;
        printf("%.3f\t%.3f\n",x,y);
    }
}
```

### **OUTPUT :**

Enter the value of range: 1 1.5

Enter the h: 0.1

y1 = 5.000

x = 1.000 => y2 = 5.500

x = 1.100 => y3 = 6.105

x = 1.200 => y4 = 6.838

x = 1.300 => y5 = 7.726

x = 1.400 => y6 = 8.808

x = 1.500 => y7 = 10.129

### **Experiment No:5(b) Runge-Kutta methods**

**AIM: Write a program to simulate Runge-Kutta methods.**

**/\* Program to simulate Runge-Kutta methods\*/**

```
#include<stdio.h>
```

```
#include<math.h>
```

```
float f(float x,float y);
```

```
int main()
```

```
{
```

```
    float x0,y0,m1,m2,m3,m4,m,y,x,h,xn;
```

```
    printf("Enter x0,y0,xn,h:");
```

```
    scanf("%f %f %f %f",&x0,&y0,&xn,&h);
```

```
    x=x0;
```

```
    y=y0;
```

```
    printf("\n\nX\tY\n");
```

```
    while(x<xn)
```

```
    {
```

```
        m1=f(x0,y0);
```

```
        m2=f((x0+h/2.0),(y0+m1*h/2.0));
```

```
        m3=f((x0+h/2.0),(y0+m2*h/2.0));
```

```
        m4=f((x0+h),(y0+m3*h));
```

```
        m=((m1+2*m2+2*m3+m4)/6);
```

```
        y=y+m*h;
```

```
        x=x+h;
```

```
        printf("%f\t%f\n",x,y);
```

```
    }
```

```
}
```

```
float f(float x,float y)
```

```
{
```

```
    float m;
```

```
    m=(x-y)/(x+y);
```

```
    return m;
```

```
}
```

### **OUTPUT:**

Enter the value of x0: 0

Enter the value of y0: 2

Enter the value of h: 0.05

Enter the value of last point: 0.1

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$$k_2 = 0.1025$$

$$y(0.0500) = 2.101$$

$$k_1 = 0.1026$$

$$k_2 = 0.1052$$

$$y(0.1000) = 2.205$$

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**Title of Course: Fluid mechanics & Hydraulic Lab**

**L-T-P scheme: 0-0-3**

**Course Code: ME491**

**Course Credit: 2**

### **Objectives:**

1. To learn and understand basic principles of fluid mechanics, Fluid properties and fundamentals of Fluid statics and fluid flow
2. To know the application of fluid mechanics by the inclusion of fluid machinery.
3. To provide an understanding of the hydraulic machines design aspects and practical application.
4. To introduce the concepts of flow measurements and flow through pipes .

**Learning Outcomes:** The students will have a detailed knowledge of the concepts of Fluid mechanics. The purpose of this course is to learn the Fluid properties and fundamentals of Fluid statics and fluid flow and apply them to practical engineering system design and development. The purpose of this course is to learn the Fluid properties and fundamentals of Fluid statics and fluid flow. Student will learn the concepts of flow measurements and flow through pipes, knowledge of the pumps and turbines, knowledge of impact of jets.

. Upon the completion of Fluid mechanics & Hydraulic Lab, the student will be able to:

- ) **Understand** and implement basic concepts of fluid mechanics.
- ) Know the definitions of fundamental concepts of fluid mechanics including: continuum, velocity field; viscosity, surface tension and pressure (absolute and gage); flow visualization using timelines, pathlines, streaklines, and streamlines; flow regimes: laminar, turbulent and transitional flows; compressibility and incompressibility; viscous and inviscid.
- ) Apply the basic equation of fluid statics to determine forces on planar and curved surfaces that are submerged in a static fluid; to manometers; to the determination of buoyancy and stability; and to fluids in rigid-body motion.
- ) Ability to analyze fluid flow problems with the application of the momentum and energy equations.

### **Course Contents:**

Experiments that must be done in this course are listed below:

Experiment No.1: Determining coefficient of discharge for venturimeter.

Experiment No.2: Determining coefficient of discharge for orificemeter.

Experiment No.3: Experiment to verify Bernoulli's theorem.

Experiment No.4: Flow through pipes.

Experiment No.5: Reynold's experiments

Experiment No.6: Study of pressure measuring devices.

Experiment No.7: Determination of metacentric height of a floating vessel

Experiment No.8: Study of fluid machinery pumps & compressors.

Experiment No.9: Study of Francis turbine or Pelton turbine.

Experiment No.10: Friction in pipes.

### **Text books:**

1. Fluid Mechanics, Hydraulic and hydraulic machines by **Modi** and **Seth**, Standard book house.
2. Open channel flow by **K.Subramanya**, Tata Mc.Grawhill publishers.
3. Fluid mechanics & fluid machines by Narayana Pillai, Universities Press.

### **Reference Text Books:-**

1. Fluid Mechanics & fluid machines by Rajput, S.Chand & Co.
2. Fluid Mechanics and Machinery, CSP Ojha, Oxford Higher Education
3. Fluid Mechanics by Frank M. White (Tata Mc.Grawhill Pvt. Ltd.)
4. Fluid Mechanics by A.K. Mohanty, Prentice Hall of India Pvt. Ltd., New Delhi



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5. A text of Fluid mechanics and hydraulic machines by Dr. R.K. Bansal - Laxmi Pub.(P) Ltd., New Delhi.

6. Fluid Mechanics and Machinery by D. Ramdurgaia New Age Publications.

### **Recommended Equipments/Systems/Software Requirements:**

1. venturimeter., orificemeter, bernoulis apparatus, Reynold's apparatus, pitot tube.
2. Fluid pumps, fluid turbines.

### **Experiment No: 1 VENTURIMETER APPARATUS**

**Aim:** To Determine coefficient of discharge for venturimeter

**APPARATUS:-** Venturimeters are widely used for determination of flow of fluid. While using the venturi their calibration is important. The equipment enables to determine the coefficient of discharge of venturimeter.

### **SPECIFICATIONS: -**

1. Supply pipe of 21.5 mm (3/4") connected to inlet manifold.
2. Venturi meter size inlet 21.5 mm and throat 15.5 mm.
3. Differential mercury manometer tapping's provided at inlet and throat of venturimeter and orificemeter. Manometer size 30 cm height. Measuring tank size - 300 mm x 300 mm x 300 mm height.

### **EXPERIMENTAL PROCEDURE : -**

Before starting the experiment please see that;

- 1) Clean water in the sump tank is filled to approx.  $\frac{3}{4}$  of its height.
  - 2) The pressure relief valves above the manometer tubes are fully open.
  - 3) The pressure valves of both the meters are fully closed. The bypass gate valve, drain valve of the measuring tank is kept open. Now, start the flow.
  - 4) Let the water flow through the pressure relief valves above the manometer. Remove all the air bubbles and then close both the pressure relief cocks slowly and simultaneously so that mercury does not get lifted out from the manometer. Observe the mercury head difference in the manometer.
  - 5) Close the gate valve of measuring tank and measure the time required for 10 cm rise of the water in the measuring tank.
- Repeat the procedure by changing the discharge.

### **OBSERVATION TABLE : -**

Sr. No.	Manometer diff. h ( m )	Time for 10 cm rise in measuring tank. (sec)

### **DATA:-**

- \* Inlet diameter of Venturimeter = 21.5 mm = 0.0215 m
- \* Throat of venturimeter = 0.0155 m

### **CALCULATIONS :-**

$$0.3 \times 0.3 \times 0.1$$

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t

2) Let 'H' be the water head across manometer in, m.

... H = Manometer difference (Sp. gravity of Mercury - Sp. gravity of water)

or H = Manometer difference x ( 13.6 - 1 )

A = cross sectional area at inlet to venturimeter = 0.000363 m<sup>2</sup>

a = Cross sectional area at throat to venturimeter – 0.000188 m<sup>2</sup>

Theoretical Discharge,

$$Q_{th} = \frac{A \cdot a \cdot (2 \cdot g \cdot H)^{0.5}}{(A^2 - a^2)^{0.5}} \quad m^3 / s$$

Thus;

$$Q_{th} = 3.45 \times 10^{-3} \times (H)^{0.5}$$

3) Co-efficient of discharge  $C_d = \frac{Q_a}{Q_{th}}$

### **CONCLUSION: -**

1. Calibrated value of co-efficient of discharge for Venturimeter is.....

### **PRECAUTIONS: -**

- 1) Operate manometer valve gently while removal of air bubble so that mercury in manometer does not get lifted out from the manometer.
- 2) Drain all the water from the sump tank after completion of the experiment.

### **SAMPLE CALCULATIONS: -**

#### **FLOW MEASUREMENT BY VENTURI APPARATUS**

a) Observation Table (Venturimeter): -

Sr. No.	Manometer diff. h ( m )	Time for 10 liter water discharge t ( Sec.)
1	0.032	19

### **CALCULATION: -**

1) Actual discharge,  $Q_a = \frac{0.01}{19} = 5.26 \times 10^{-4} m^3 / s$

2)  $Q_{th} = 0.00318 \sqrt{h}$   
 $= 0.00318 \sqrt{0.032}$   
 $= 5.68 \times 10^{-4} m^3 / s$

3) Co-efficient of discharge  $C_d = \frac{Q_a}{Q_{th}}$   
 $= \frac{5.26 \times 10^{-4}}{5.68 \times 10^{-4}} = 0.926$

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**Sample calculations are only for reference purpose.**

### **Experiment No: 2 ORIFICEMETER APPARATUS**

**Aim:** To Determine coefficient of discharge for Orificemeter

**APPARATUS:-** Orificemeter are widely used for determination of flow of fluid. While using the Orifice their calibration is important. The equipment enables to determine the coefficient of discharge of venturimeter.

### **SPECIFICATIONS: -**

1. Supply pipe of 21.5 mm (3/4") connected to inlet manifold.
2. Orificemeter size inlet 21.5 mm and throat 14 mm.
3. Differential mercury manometer tapping's provided at inlet and throat of orificemeter. Manometer size 30 cm height. Measuring tank size - 300 mm x 300 mm x 300 mm height.

### **EXPERIMENTAL PROCEDURE : -**

Before starting the experiment please see that;

- 1) Clean water in the sump tank is filled to approx.  $\frac{3}{4}$  of its height.
- 2) The pressure relief valves above the manometer tubes are fully open.
- 3) The pressure valves of both the meters are fully closed. The bypass gate valve, drain valve of the measuring tank is kept open. Now, start the flow.
- 4) Let the water flow through the pressure relief valves above the manometer. Remove all the air bubbles and then close both the pressure relief cocks slowly and simultaneously so that mercury does not get lifted out from the manometer. Observe the mercury head difference in the manometer.
- 5) Close the gate valve of measuring tank and measure the time required for 10 cm rise of the water in the measuring tank.

Repeat the procedure by changing the discharge.

### **OBSERVATION TABLE: -**

Sr. No.	Manometer diff. h ( m )	Time for 10 cm rise in measuring tank. (sec)

### **DATA:-**

- \* Inlet diameter of Orificemeter = 21.5 mm = 0.0215 m
- \* Throat of Orificemeter= 0.014 m

### **CALCULATIONS:-**

1) Actual discharge,  $Q_a = \frac{0.3 \times 0.3 \times 0.1}{t}$

- 2) Let 'H' be the water head across manometer in, m.

... H = Manometer difference (Sp. gravity of Mercury - Sp. gravity of water)

or H = Manometer difference  $\times (13.6 - 1)$

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a = Cross sectional area at throat to Orificemeter -  $0.0001539 \text{ m}^2$

Theoretical Discharge,

$$Q_{th} = \frac{A \cdot a \cdot (2 \cdot g \cdot H)^{0.5}}{(A^2 - a^2)^{0.5}} \quad \text{m}^3 / \text{s}$$

Thus;

$$Q_{th} = 2.67 \times 10^{-3} \times (H)^{0.5}$$

3) Co-efficient of discharge  $C_d = \frac{Q_a}{Q_{th}}$

### **CONCLUSION: -**

1. Calibrated value of co-efficient of discharge for Venturimeter is.....

### **PRECAUTIONS: -**

- 2) Operate manometer valve gently while removal of air bubble so that mercury in manometer does not get lifted out from the manometer.
- 2) Drain all the water from the sump tank after completion of the experiment.

### **SAMPLE CALCULATIONS: -**

#### **FLOW MEASUREMENT BY VENTURI APPARATUS**

Observation Table ( Orificemeter ) : -

Sr. No.	Manometer diff. h ( m )	Time for 10 liter water discharge t ( Sec.)
1	0.088	18.72

**CALCULATION:-**

- 1) Actual discharge,  $Q_a = \frac{0.01}{18.72} = 5.34 \times 10^{-4} \text{ m}^3 / \text{s}$
- 2)  $Q_{th} = 0.002778 \sqrt{h}$   
 $= 0.002778 \sqrt{0.088} = 8.24 \times 10^{-4} \text{ m}^3 / \text{s}$
- 3) Co-efficient of discharge  $C_d = \frac{Q_a}{Q_{th}} = \frac{5.34 \times 10^{-4}}{8.24 \times 10^{-4}} = 0.64$

**Sample calculations are only for reference purpose.**

**Experiment No: 3 VERIFICATION OF BERNOULLI'S THEOREM APPARATUS**

**Aim:** To verify the bernoullis theorem.

**Theory:** When an incompressible fluid is flowing through a closed conduit, it may be subjected to various forces, which cause change of velocity, acceleration or energies involved. The major forces involved are pressure and body forces. Due to elevation of conduits, pressure may change or due to change of cross section, velocity of fluid may

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change. But, though there is change of velocity, pressure also changes accordingly. In other words, if velocity energy of fluid is raised, its pressure will drop, i.e. total energy of fluid is constant at any two points in the path of flow. The theorem is known as Bernoulli's theorem. Hence, when applied to steady irrotational flow of incompressible fluids,

$$\frac{P}{w} + \frac{V^2}{2g} + Z = C$$

where,

P = pressure

V = velocity at the point

Z = potential head from datum

### APPARATUS:

The apparatus consists of a rectangular flow channel, which is tapered along the length. Flow area at inlet is maximum and it goes on reducing towards outlet. Water is fed to flow channel through a supply tank. Outlet is direct collect in measuring tank.

### EXPERIMENTAL PROCEDURE:

1. Connect the water pipe to the inlet valve.
2. Reduce flow by inlet gate valve, so that there is only a small rise of water in the last pressure tapping.
3. Allow the levels to stabilize and note down the heads.
4. Close outlet valve of the measuring tank, and measure the time to raise water level by 10 cms.
5. Now, repeat the procedure by changing the discharge, and note the drop of head towards outlet for each observation.

### OBSERVATIONS -

Sr . No	Head in cms. Tappings 1, 2, 3, 4, -- -- -- -- -- -- -- -- -- -- -- --	Discharge time for 10 Cms of water flow)Sec.
14		

### CALCULATIONS:-

(Consider section at 1<sup>st</sup> tapping)

Area of flow channel, A =  $\frac{0.4 \times 0.21 \times 0.1}{m^2}$  ----- (refer table )

1) Discharge, Q =  $\frac{V}{t}$  m<sup>3</sup>/sec

2) Velocity of water,

$$V = \frac{Q}{A} \text{ m/sec}$$

Hence,

3) Velocity energy or head =  $\frac{V^2}{2g}$

4) Pressure head,

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$$H = \frac{w}{\dots}$$

$$\text{Or } H = h + h_1$$

Where,  $h$  = Water rise from top channel, m

$h_1$  = Distance from top of channel to its center (See chart)

5) Now, datum line is same at inlet and outlet.

Hence,  $Z_1 = Z_2 = Z_3 = 0$

According to Bernoulli's equation,

$$\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2$$

Or,

$$H_1 + \frac{V_1^2}{2g} + Z_1 = H_2 + \frac{V_2^2}{2g} + Z_2$$

As,  $Z_1 = Z_2$  for the channel,

$$H_1 + \frac{V_1^2}{2g} = H_2 + \frac{V_2^2}{2g} = C$$

Find out the value of  $C$  for each section (at same flow rate). It is approximately same for all sections.

**Note-** Practically, value of ' $C$ ' goes on changing slightly towards outlet, due to various factors which are not considered like friction, turbulence, etc.

### **CONCLUSION:-**

1. As value of ' $C$ ' is fairly constant, total energy of flow is same over the entire length.
2. As velocity of flow increases, pressure head drops.
3. Bernoulli's equation, i.e.

$$\frac{P}{w} + \frac{V^2}{2g} + Z = C \text{ is thus verified.}$$

### **PRECAUTIONS:-**

1. Note down the head readings after the level has been established.
2. After noting the discharge, drain the measuring tank.
3. After completion of experiment, drain all the water from the equipment.

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**TABLE**

Tapping Sr. No.	$h_1$ m	Area $m^2$
Inlet	-	0.001
1	0.0335	0.00084
2	0.0332	0.00068
3	0.0322	0.00054
4	0.0317	0.00044
5	0.0307	0.00032
6	0.0292	0.00026
7	0.0275	0.00022
8	0.0278	0.00024
9	0.0295	0.0003
10	0.0303	0.00038
11	0.0307	0.0005
12	0.0309	0.00062
13	0.031	0.00074
14	0.0313	0.0009
outlet	-	0.001

**TABLE**

Tapping Sr. No.	$h_1$ m	Area $m^2$
Inlet	-	$1 \times 10^{-3}$
1	0.0225	$9 \times 10^{-4}$
2	0.019	$7.6 \times 10^{-4}$
3	0.0155	$6.2 \times 10^{-4}$
4	0.0125	$5 \times 10^{-4}$
5	0.01	$4 \times 10^{-4}$
6	0.08	$3.2 \times 10^{-4}$
7	$6.5 \times 10^{-3}$	$2.6 \times 10^{-4}$
8	0.005	$2 \times 10^{-4}$
9	$6.5 \times 10^{-3}$	$2.2 \times 10^{-4}$
10	$7 \times 10^{-3}$	$2.8 \times 10^{-4}$
11	$11.5 \times 10^{-3}$	$4.6 \times 10^{-4}$
12	$12 \times 10^{-3}$	$4.8 \times 10^{-4}$
13	$16.5 \times 10^{-3}$	$6.6 \times 10^{-4}$
14	$21 \times 10^{-3}$	$8.4 \times 10^{-4}$
outlet		$1 \times 10^{-3}$

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### **Experiment 4: FLOW THROUGH PIPES IN SERIES**

**Aim:** To calculate the flow through pipes in series.

#### **Theory:**

Pipes in series or compound pipes are the pipes of different lengths and different diameters connected end to end (in series) to form a pipe line.

The apparatus consists of 3 pipes in series of diameters of 16 mm, 21 mm, & 27 mm and approx length of 300 mm each. The head loss of the pipes at entry and exit can be found out by the water head tapping made on the test section. Also equivalent pipe of dia. 27 mm is given to find out the equivalent length of series pipe.

Let,  $L_1, L_2, L_3$  = length of pipes 1, 2 & 3 respectively

$d_1, d_2, d_3$  = diameter of pipes 1, 2, & 3 respectively

$V_1, V_2, V_3$  = velocity of flow through pipes 1, 2, 3

$f_1, f_2, f_3$  = co-efficient of friction for pipes 1, 2, 3

$H$  = difference of water level in the two tanks,

The discharge passing through each pipe is same.

$$Q = A_1 V_1 = A_2 V_2 = A_3 V_3$$

The difference in liquid surface levels is equal to the sum of the total head loss in the pipes.

$$H = \frac{0.5 V_1^2}{2g} + \frac{4 f_1 L_1 V_1^2}{d_1 \times 2g} + \frac{0.5 V_2^2}{2g} + \frac{4 f_2 L_2 V_2^2}{2g} + \frac{(V_2 - V_3)^2}{2g} + \frac{4 f_3 L_3 V_3^2}{d_3 \times 2g} + \frac{V_2^2}{2g}$$

If minor losses are neglected, then above equation becomes as

$$H = \frac{4 f_1 L_1 V_1^2}{d_1 \times 2g} + \frac{4 f_2 L_2 V_2^2}{d_2 \times 2g} + \frac{4 f_3 L_3 V_3^2}{d_3 \times 2g}$$

If the co-efficient of friction is same for all pipes.

i.e.,  $f_1 = f_2 = f_3 = f$ , then equation becomes as

$$H = \frac{4 f L_1 V_1^2}{d_1 \times 2g} + \frac{4 f L_2 V_2^2}{d_2 \times 2g} + \frac{4 f L_3 V_3^2}{d_3 \times 2g}$$

$$H = \frac{4 f}{2g} \left[ \frac{L_1 V_1^2}{d_1} + \frac{L_2 V_2^2}{d_2} + \frac{L_3 V_3^2}{d_3} \right]$$

**SPECIFICATIONS: -**



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1. Test section: series pipe consist of dia.16 mm, dia. 21 mm and dia.27 mm length 300 mm each.
2. Equivalent pipe: dia. 27 mm lengths 1Mtr.
3. Sump tank: sufficient capacity
4. Measuring tank: 300 x 300 x 300 mm height.
5. Water head tapplings at entry and exit of test section and equivalent pipe.
6. Mono block pump of 0.5 H.P. capacity for water recirculation.

### **PROCEDURE: -**

1. Fill up sump tank at least 75% of its capacity with clean water.
2. Start the pump the water passes through the test section to the measuring tank and back to the sump tank and the vertical water tapping.
3. Adjust the water head of the '6 ' tapping's in the readable range with the help of bypass valve and the discharge valve at the end of test section.
4. Note down the readings at the respective water heads and time for 10 cm rise of water level in the measuring tank by closing the drain valve of the measuring tank.
5. Now, open the discharge gate valve of the 27 mm equivalent pipe containing 4 tapplings at equivalent distance of 0.56 m and approx at the same discharge.
6. Repeat the procedure at different flow rates and fill up the observation table.

### **OBSERVATION TABLE**

#### **A. TEST SECTION**

Sr. No.	Tapping Head Mtr.						Time for 10 cm water rise in 't ' sec.
	h1	h3	h3	h4	h5	h6	

#### **B. EQUIVALENT PIPE**

Sr. No.	Tapping Head Mtr.				Time for 10 cm water rise in 't ' sec.
	h7	h8	h8	h9	

### **DATA**

Pipe dia d1 = 27 mm = 0.027 m., Area =  $5.72 \times 10^{-4} \text{ m}^2$  & Length = 0.5 m.

Pipe dia d2 = 21 mm = 0.021 m., Area =  $3.46 \times 10^{-4} \text{ m}^2$  & Length = 0.5 m.

Pipe dia d3 = 16 mm = 0.016 m., Area =  $2.01 \times 10^{-4} \text{ m}^2$  & Length = 0.5 m.

### **CALCULATIONS:**

1. Flow rate

$$Q = \frac{0.3 \times 0.3 \times 0.1}{t} \text{ m}^3 / \text{Sec.}$$

Where 't' is the required for 10 cm. rise of water in the measuring tank.

It V1, V2 & V3 are the velocity of water in the 3 pipes respectively

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$$V_1 = \frac{Q}{A}$$

$$V_2 = \frac{Q}{A} \quad \&$$

$$V_3 = \frac{Q}{A}$$

Let 'f' be the co-efficient of friction of pipe material with the water then,  
We have,

Head loss within the test section i.e.  $H = [(h_1 - h_2) + (h_3 - h_4) + (h_5 - h_6)]$  m

$$\text{Also, } H = \frac{4f}{2g} \left[ \frac{L_1 V_1^2}{d_1} + \frac{L_2 V_2^2}{d_2} + \frac{L_3 V_3^2}{d_3} \right]$$

Here we have  $L = L_1 = L_2 = L_3 = 0.5$  m.

$$H = \frac{4f}{4g} \left[ \frac{V_1^2}{d_1} + \frac{V_2^2}{d_2} + \frac{V_3^2}{d_3} \right] \text{ m}$$

$$f = \frac{gH}{\left[ \frac{V_1^2}{d_1} + \frac{V_2^2}{d_2} + \frac{V_3^2}{d_3} \right]} \quad \text{----- (1)}$$

3. Head loss in equivalent pipe.

$$\text{Head loss 'He' = } \frac{4 \times 16 Q^2 f}{3.142 \times 2 \times g} \times \left[ \frac{L_e}{d^5} \right] \quad \text{----- (2)}$$

The value of 'f' from the equation ( 1 ) can be used in the equation ( 2 ) The discharge of both the readings one done.

**GRAPH:** Draw graph of the head V/s length of the head of equivalent pipes the test section at equal discharge.

### **PRECAUTION:**

1. Use clean water for the experiment.
2. Operate the control valves and cocks gently.
3. After completion of experiment drain all the water.

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**Aim:** - To find critical Reynolds number for a pipe flow.

**Apparatus Used:-** Flow condition inlet supply, elliptical belt type arrangement for coloured fluid with regulating valve, collecting tank.

**Formula Used:-** Reynolds No = Inertia force/Viscous force

### **Theory:-**

Whenever a fluid is flowing through a pipe, the flow is either laminar or turbulent. When fluid is flowing in parallel layers or laminae, sliding past adjacent laminae, it is called laminar flow. When the fluid does not flow in parallel layers and there is intermingling of fluid particles then the flow is said to be turbulent. Existence of these two types was first demonstrated by OSBORN REYNOLDS in 1883.

The apparatus consists of a constant head supply tank supplied with water. This tank is provided with a bell mouth outlet to which a transparent tube is fitted. At outlet of the tube a regulating valve is providing. A dye tank containing colored dye is fitted above the supply tank the water flows through pipe and dye is injected at the center of the pipe. When the velocity of flow is low, (i.e. flow is laminar) then dye remains in the form of straight filament. As the velocity of water (i.e. flow of water) is increased, a state is reached when the dye filament becomes irregular and water. With further increase of velocity of water through the tube, dye filament becomes more and more irregular and ultimately the dye diffuses over the entire cross section of the tube.

The velocity at which the flow changes from laminar to turbulent for the case of a given fluid at given temperature and in a given pipe is known as critical velocity. The state of flow between these two types of flow is known as 'transition state' or flow in transition.

The occurrence of laminar and turbulent flow is governed by relative magnitudes of inertia and viscous forces. Reynolds related the inertia to viscous forces and arrived at a dimensionless parameter now called Reynolds number.

### **EXPERIMENTAL PROCEDURE**

1. Fill up water in sump tank fully & dye vessel to half of its height and add 0.5 gm of potassium per magnet to the dye vessel.
2. Open the brass cock behind the supply tank. Start the pump. Fill up the water in the supply tank fully. Stop the pump. Allow the water to become steady without disturbing it for about 5 minutes.
3. Open the gate valve slightly and start the flow. Also open slightly the valve below the dye vessel. Wait for some time. A steady line of the dye will be observed. Take the time required for 0.5 liter discharge.
4. Slowly increase the water flow. At a particular flow rate, a wavy dye line will be observed. Again take the time required for 0.5 liter discharge.
5. Again go on increasing the flow. The disturbances of dye line will go on increasing and at certain flow; the dye line diffuses over the entire cross section. Again note down the time required for 0.5 liter discharge.
6. Slightly increase the flow and then slowly reduce the flow. Note the flow at which diffused dye tends to become steady, (begining of transition zone while reducing velocity.)
7. Further reduce the flow and note the flow at which dye line becomes straight and steady.

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### **OBSERATION TABLE -**

Sr. NO.	Flow Type	Time / 0.5 lit ( sec. )

### **CALCULATIONS**

1. I. D. of pipe = 20 mm, cross sectional area of pipe

$$A = 3.14 \times 10^{-4} \text{ m}^2$$

Let time required for 0.5 liters in measuring tank be 't' sec.

$$\text{Then, flow, } Q = \frac{0.0005}{t} \quad \text{m}^3 / \text{sec}$$

$$\text{Velocity, } V = \frac{Q}{A} \quad \text{m /sec}$$

Then, Reynolds number,

$$\text{Re} = \frac{\rho \cdot V \cdot D}{\mu}$$
$$= \frac{V \cdot D}{\nu}$$
$$\Rightarrow$$

Where,  $V$  = Velocity, m / sec

$L$  = Characteristic linear dimension

$D$  = diameter of the pipe = 0.02 m.

$\Rightarrow$  Kinematic viscosity of fluid =  $0.805 \times 10^{-6} \text{ m}^2 / \text{s}$

$$\dots \text{Re} = V \times 24844.7$$

While increasing the velocity, laminar flow is disturbed at slightly higher velocity. But at the time of reducing the velocity, the flow does not turn to laminar at this velocity, but becomes laminar at still lower velocity is called lower critical

Reynolds number flow is always laminar and above upper critical Reynolds number flow is always turbulent. Practically, upper critical Reynolds, number lies between 2700 - 4000 and lower critical Reynolds, number is approximately 2000. Between Reynolds number 2000 and 4000 the transition region exists.

### **OBSERATIONS**

1. Increasing velocity
  - a) Flow at beginning of transition
  - b) Flow at beginning of turbulence.
2. Decreasing velocity
  - a) Flow at beginning of transition
  - b) Flow at beginning of laminar region.

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**Aim:** To study of pressure measuring devices.

### **Theory:**

Pressure is defined as the force exerted over the unit area. Measurement of pressure is essential at many places, e.g. given fluid flowing through pipe, boiler etc. Depending upon the pressure and accuracy of measurement required various devices are used for pressure measurement. Unit shows measurement of pressure using following devices -

- 1] Pressure Gauge.
- 2] Vacuum Gauge.
- 3] U - Tube manometer.
- 4] Differential manometer.

### **EXPERIMENTAL PROCEDURE:-**

- 1) Water supply pipe connect to inlet of the piping.
- 2) Open the gate valve (exhaust) completely.
- 3) See that mercury is filled in the manometers & bypass cocks are open.
- 4) now, remove the air bubbles and observe the observations of manometer and gauges as follows-

#### **1) Vacuum gauge-**

Vacuum gauges are used for measurement of pressures below atmospheric , i.e. negative pressure. Negative pressure is created at suction side of pump. The vacuum gauge used is bourdon tube type. All the vacuum gauges are available in 0 to 760 mm: of Hg range. (Take the supply for vacuum gauge from suction section of the pump.)

#### **[2] Pressure gauge: -**

When the pressure is above atmospheric, bourdon tube type pressure gauge is the simplest way of pressure measurement, because it gives direct reading of pressure. Pressure gauges are available in various ranges, e.g. 0 to 1.05 Kg/cm<sup>2</sup> (15 psig ), 0 to 2.1 , 10.5 , 21.2 Kg/cm<sup>2</sup> etc. and in various dial sizes, like 65 mm, 100mm, 150mm. etc. For observation of pressure, close the connection to all other devices (at the back side) and slowly go on closing the gate valve. As the gate valve is being closed, & pressure will go on rising, which will be indicated on the pressure gauge. Observe the pressure gauge reading while closing the valve.

#### **[3] U - Tube Manometer: -**

See that mercury is filled in the U - tube. Now open the inlet cocks slowly, observing the mercury (sudden opening of the cock may cause mercury to be forced out of tube). By operating the cock provided at the "T" remove the air between water and mercury and note the rise of mercury level in the limb which is open to atmosphere. The difference in the mercury levels in the two limbs is the pressure of water at the tapping. Pressure, if measured in terms of mercury head, can be directly expressed in cms of Hg. If it is to be measured in kg / cm<sup>2</sup>, 760 mm. of equal to one atmosphere i.e. 1.0332 kg/cm<sup>2</sup>. (1.014 bar)

$$P = h (S_2 - S_1) \cdot W \quad \text{N/m}^2$$

Where,

P = Pressure to be measure.

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$S_2$  = Specific gravity of mercury = 13.6.

$h$  = Manometer difference Mtr.

$W$  = Specific weight of water  $9810 \text{ N/m}^3$  ,

### **[4] Differential manometer.** -

Fill up sufficient mercury in the manometer. Follow the same procedure as for U - Tube manometer, for opening the cocks and observe the difference in the mercury levels. The differential manometer is used for measuring the difference of pressure at two points. The two limbs of the manometer are connected at inlet and outlet of an orifice, so that the manometer directly shows the pressure drop across the orifice, in terms of mercury head.

-----

### **Experiment No.7 Determination of metacentric height of a floating vessel.**

**Aim:** - To determine the Meta-centric height of a floating body.

**Apparatus Used:** - Take tank 2/3 full of water, floating vessel or pontoon fitted with a pointed pointer moving on a graduated scale, with weights adjusted on a horizontal beam.

**Theory:** - Consider a floating body which is partially immersed in the liquid, when such a body is tilted, the center of buoyancy shifts from its original position 'B' to 'B' (The point of application of buoyant force or upward force is known as center of G which may be below or above the center of buoyancy remain same and couple acts on the body. Due to this couple the body remains stable. At rest both the points G and B also  $F_b \times W_c$  act through the same vertical line but in opposite direction. For small change ( ) B shifted to B. The point of intersection M of original vertical line through B and G with the new vertical, line passing through 'B' is known as metacenter. The distance between G and M is known as metacentric height which is measure of static stability.

**Formula Used:** -  $GM = W_m \cdot X_d$

$(W_c + W_m) \tan$

Where: -

$W_m$  is unbalanced mass or weight.

$W_c$  is weight of pontoon or anybody.

$X_d$  is the distance from the center of pointer to striper or unbalanced weight.

is angle of tilt or heel.

### **Procedure:** -

1. Note down the dimensions of the collecting tank, mass density of water.
2. Note down the water level when pontoon is outside the tank.
3. Note down the water level when pontoon is inside the tank and their difference.
4. Fix the strips at equal distance from the center.
5. Put the weight on one of the hanger which gives the unbalanced mass.
6. Take the reading of the distance from center and angle made by pointer on arc.
7. The procedure can be repeated for other positioned and values of unbalanced mass.

### **Observation Table:-**

Length of the tank =

Width of the tank =

Area of the tank =

Initial level of the water without pontoon =

Final level of the water without pontoon =

Difference in height of water(X) =  $X_2 - X_1$  =

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Height of water In tank with Pontoon (X2) (m)	Difference in Height $X = X_2 - X_1$ (m)	Weight of Pontoon $W_c = XA$ (kg)	Unbalanced Mass, $W_m$ (kg)	Q	G M = Metacentric Height (m)	$X_d$ (m)

**Result:** - Meta centric height of the pontoon is measured with different positions and weights.

**Precautions:** -

1. The reading taking carefully without parallax error.
2. Put the weight on the hanger one by one.
3. Wait for pontoon to be stable before taking readings.
4. Strips should be placed at equal distance from the centre.

-----

### **Experiment No.8: Study of fluid machinery pumps.**

**Aim:** Study of hydraulic pumps.

Introduction:

#### ***Hydraulic Pump***

The combined pumping and driving motor unit is known as hydraulic pump. The hydraulic pump takes hydraulic fluid (mostly some oil) from the storage tank and delivers it to the rest of the hydraulic circuit. In general, the speed of pump is constant and the pump delivers an equal volume of oil in each revolution. The amount and direction of fluid flow is controlled by some external mechanisms. In some cases, the hydraulic pump itself is operated by a servo controlled motor but it makes the system complex. The hydraulic pumps are characterized by its flow rate capacity, power consumption, drive speed, pressure delivered at the outlet and efficiency of the pump. The pumps are not 100% efficient. The efficiency of a pump can be specified by two ways. One is the volumetric efficiency which is the ratio of actual volume of fluid delivered to the maximum theoretical volume possible. Second is power efficiency which is the ratio of output hydraulic power to the input mechanical/electrical power. The typical efficiency of pumps varies from 90-98%.

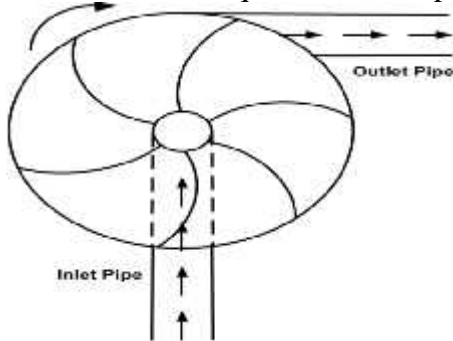
The hydraulic pumps can be of two types:

- Centrifugal pump
- Reciprocating pump

#### **Centrifugal pump**

Centrifugal pump uses rotational kinetic energy to deliver the fluid. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis, accelerates in the propeller and flung out to the periphery by centrifugal force as shown in figure. In centrifugal pump the delivery is not constant and varies according to the outlet pressure. These pumps are not suitable for high pressure

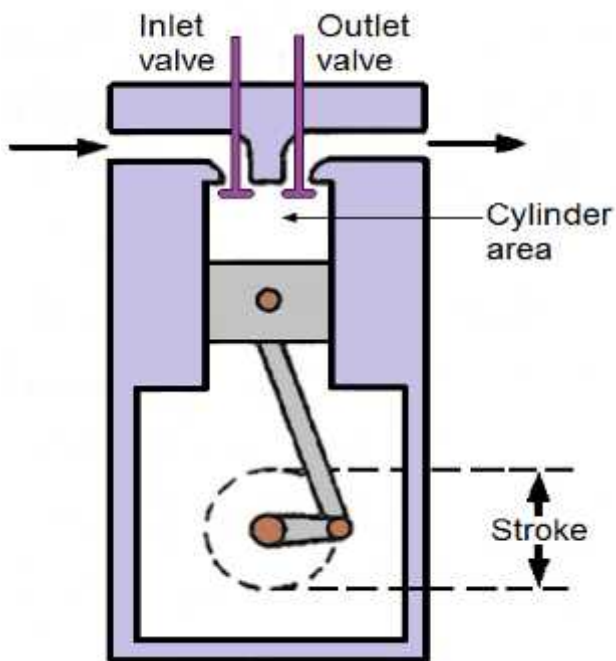
The maximum pressure capacity is limited to 20-30 bars and the specific speed ranges from 500 to 10000. Most of the centrifugal pumps are not self-priming and the pump casing needs to be filled with liquid before the pump is started.



Centrifugal pump

### **Reciprocating pump**

The reciprocating pump is a positive plunger pump. It is also known as positive displacement pump or piston pump. It is often used where relatively small quantity is to be handled and the delivery pressure is quite large. The construction of these pumps is similar to the four stroke engine as shown in figure. The crank is driven by some external rotating motor. The piston of pump reciprocates due to crank rotation. The piston moves down in one half of crank rotation, the inlet valve opens and fluid enters into the cylinder. In second half crank rotation the piston moves up, the outlet valve opens and the fluid moves out from the outlet. At a time, only one valve is opened and another is closed so there is no fluid leakage. Depending on the area of cylinder the pump delivers constant volume of fluid in each cycle independent to the pressure at the output port.



Reciprocating or positive displacement pump

### ***1. Classification of Hydraulic Pumps***

These are mainly classified into two categories:

- A. Non-positive displacement pumps
- B. Positive displacement pumps.



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### **A. Non-Positive Displacement Pumps**

These pumps are also known as hydro-dynamic pumps. In these pumps the fluid is pressurized by the rotation of the propeller and the fluid pressure is proportional to the rotor speed. These pumps can not withstand high pressures and generally used for low-pressure and high-volume flow applications. The fluid pressure and flow generated due to inertia effect of the fluid. The fluid motion is generated due to rotating propeller. These pumps provide a smooth and continuous flow but the flow output decreases with increase in system resistance (load). The flow output decreases because some of the fluid slip back at higher resistance. The fluid flow is completely stopped at very large system resistance and thus the volumetric efficiency will become zero. Therefore, the flow rate not only depends on the rotational speed but also on the resistance provided by the system. The important advantages of non-positive displacement pumps are lower initial cost, less operating maintenance because of less moving parts, simplicity of operation, higher reliability and suitability with wide range of fluid etc. These pumps are primarily used for transporting fluids and find little use in the hydraulic or fluid power industries. Centrifugal pump is the common example of non-positive displacement pumps.

### **B. Positive displacement pump**

These pumps deliver a constant volume of fluid in a cycle. The discharge quantity per revolution is fixed in these pumps and they produce fluid flow proportional to their displacement and rotor speed. These pumps are used in most of the industrial fluid power applications. The output fluid flow is constant and is independent of the system pressure (load). The important advantage associated with these pumps is that the high-pressure and low-pressure areas (means input and output region) are separated and hence the fluid cannot leak back due to higher pressure at the outlets. These features make the positive displacement pump most suited and universally accepted for hydraulic systems. The important advantages of positive displacement pumps over non-positive displacement pumps include capability to generate high pressures, high volumetric efficiency, high power to weight ratio, change in efficiency throughout the pressure range is small and wider operating range pressure and speed. The fluid flow rate of these pumps ranges from 0.1 and 15,000 gpm, the pressure head ranges between 10 and 100,000 psi and specific speed is less than 500.

It is important to note that the positive displacement pumps do not produce pressure but they only produce fluid flow. The resistance to output fluid flow generates the pressure. It means that if the discharge port (output) of a positive displacement pump is opened to the atmosphere, then fluid flow will not generate any output pressure above atmospheric pressure. But, if the discharge port is partially blocked, then the pressure will rise due to the increase in fluid flow resistance. If the discharge port of the pump is completely blocked, then an infinite resistance will be generated. This will result in the breakage of the weakest component in the circuit. Therefore, the safety valves are provided in the hydraulic circuits along with positive displacement pumps. Important positive displacement pumps are gears pumps, vane pumps and piston pumps.

### **2. Gear Pumps**

Gear pump is a robust and simple positive displacement pump. It has two meshed gears revolving about their respective axes. These gears are the only moving parts in the pump. They are compact, relatively inexpensive and have few moving parts. The rigid design of the gears and houses allow for very high pressures and the ability to pump highly viscous fluids. They are suitable for a wide range of fluids and offer self-priming performance. Sometimes gear pumps are designed to function as either a motor or a pump. These pump

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to Roots blowers (commonly used as superchargers), and mechanical designs that allow the stacking of pumps. Based upon the design, the gear pumps are classified as:

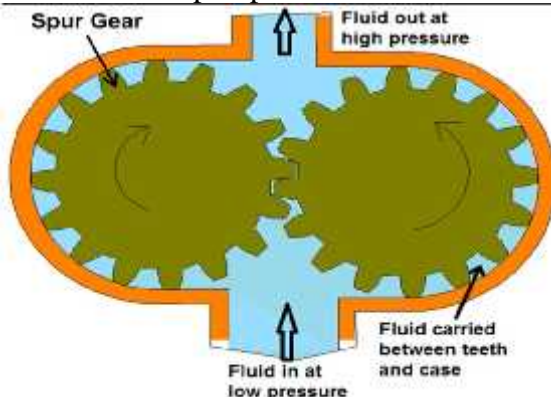
- External gear pumps
- Lobe pumps
- Internal gear pumps
- Gerotor pumps

Generally gear pumps are used to pump:

- Petrochemicals: Pure or filled bitumen, pitch, diesel oil, crude oil, lube oil etc.
- Chemicals: Sodium silicate, acids, plastics, mixed chemicals, isocyanates etc.
- Paint and ink
- Resins and adhesives
- Pulp and paper: acid, soap, lye, black liquor, kaolin, lime, latex, sludge etc.
- Food: Chocolate, cacao butter, fillers, sugar, vegetable fats and oils, molasses, animal food etc.

### **2.1 External gear pump**

The external gear pump consists of externally meshed two gears housed in a pump case as shown in figure. One of the gears is coupled with a prime mover and is called as driving gear and another is called as driven gear. The rotating gear carries the fluid from the tank to the outlet pipe. The suction side is towards the portion where the gear teeth come out of the mesh. When the gears rotate, volume of the chamber expands leading to pressure drop below atmospheric value. Therefore the vacuum is created and the fluid is pushed into the void due to atmospheric pressure. The fluid is trapped between housing and rotating teeth of the gears. The discharge side of pump is towards the portion where the gear teeth run into the mesh and the volume decreases between meshing teeth. The pump has a positive internal seal against leakage; therefore, the fluid is forced into the outlet port. The gear pumps are often equipped with the side wear plate to avoid the leakage. The clearance between gear teeth and housing and between side plate and gear face is very important and plays an important role in preventing leakage. In general, the gap distance is less than 10 micrometers. The amount of fluid discharge is determined by the number of gear teeth, the volume of fluid between each pair of teeth and the speed of rotation. The important drawback of external gear pump is the unbalanced side load on its bearings. It is caused due to high pressure at the outlet and low pressure at the inlet which results in slower speeds and lower pressure ratings in addition to reducing the bearing life. Gear pumps are most commonly used for the hydraulic fluid power applications and are widely used in chemical installations to pump fluid with a certain viscosity.

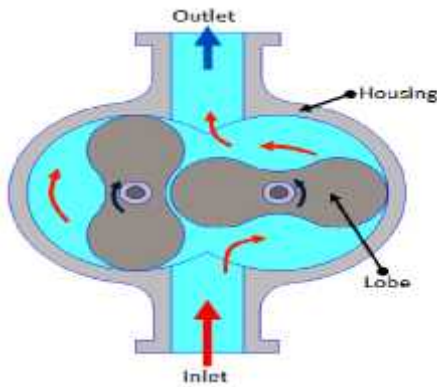


### **Gear pump**

### **2.2 Lobe Pump**

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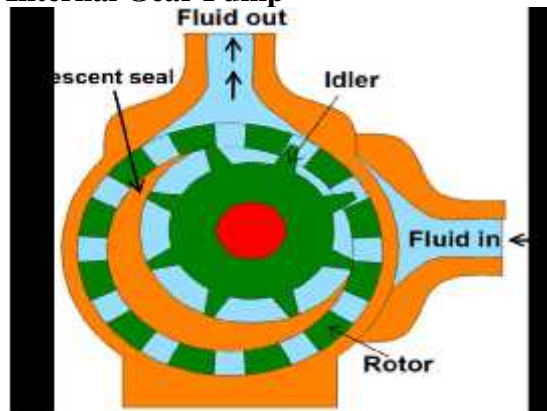


Lobe pumps work on the similar principle of working as that of external gear pumps. However in Lobe pumps, the lobes do not make any contact like external gear pump (see Figure). Lobe contact is prevented by external timing gears located in the gearbox. Similar to the external gear pump, the lobes rotate to create expanding volume at the inlet. Now, the fluid flows into the cavity and is trapped by the lobes. Fluid travels around the interior of casing in the pockets between the lobes and the casing. Finally, the meshing of the lobes forces liquid to pass through the outlet port. The bearings are placed out of the pumped liquid. Therefore the pressure is limited by the bearing location and shaft deflection.

Because of superb sanitary qualities, high efficiency, reliability, corrosion resistance and good clean-in-place and steam-in-place (CIP/SIP) characteristics, Lobe pumps are widely used in industries such as pulp and paper, chemical, food, beverage, pharmaceutical and biotechnology etc. These pumps can handle solids (e.g., cherries and olives), slurries, pastes, and a variety of liquids. A gentle pumping action minimizes product degradation. They also offer continuous and intermittent reversible flows. Flow is relatively independent of changes in process pressure and therefore, the output is constant and continuous.

Lobe pumps are frequently used in food applications because they handle solids without damaging the product. Large sized particles can be pumped much effectively than in other positive displacement types. As the lobes do not make any direct contact therefore, the clearance is not as close as in other Positive displacement pumps. This specific design of pump makes it suitable to handle low viscosity fluids with diminished performance.

### **2.3 Internal Gear Pump**



Internal gear pumps are exceptionally versatile. They are often used for low or medium viscosity fluids such as solvents and fuel oil and wide range of temperature. This is non-pulsing, self-priming and can run dry for short periods. It is a variation of the basic gear pump.

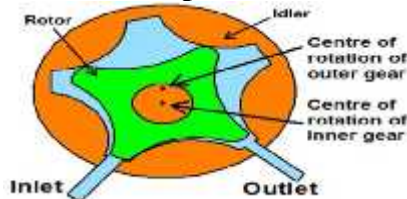
It comprises of an internal gear, a regular spur gear, a crescent-shaped seal and an external housing. The schematic of internal gear pump is shown in figure. Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth. Liquid is then forced through the crescent-shaped seal and exits through the outlet port. Compared to the liquid hand

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acts as a seal between the suction and discharge ports. When the teeth mesh on the side opposite to the crescent seal, the fluid is forced out through the discharge port of the pump. This clearance between gears can be adjusted to accommodate high temperature, to handle high viscosity fluids and to accommodate the wear. These pumps are bi-rotational so that they can be used to load and unload the vessels. As these pumps have only two moving parts and one stuffing box, therefore they are reliable, simple to operate and easy to maintain. However, these pumps are not suitable for high speed and high pressure applications. Only one bearing is used in the pump therefore overhung load on shaft bearing reduces the life of the bearing.

### **2.4 Gerotor Pump**



Gerotor is a positive displacement pump. The name Gerotor is derived from "Generated Rotor". At the most basic level, a Gerotor is essentially one that is moved via fluid power. Originally this fluid was water; today the wider use is in hydraulic devices. The schematic of Gerotor pump is shown in figure. Gerotor pump is an internal gear pump without the crescent. It consists of two rotors viz. inner and outer rotor. The inner rotor has  $N$  teeth, and the outer rotor has  $N+1$  teeth. The inner rotor is located off-center and both rotors rotate. The geometry of the two rotors partitions the volume between them into  $N$  different dynamically-changing volumes. During the rotation, volume of each partition changes continuously. Therefore, any given volume first increases, and then decreases. An increase in volume creates vacuum. This vacuum creates suction, and thus, this part of the cycle sucks the fluid. As the volume decreases, compression occurs. During this compression period, fluids can be pumped, or compressed (if they are gaseous fluids).

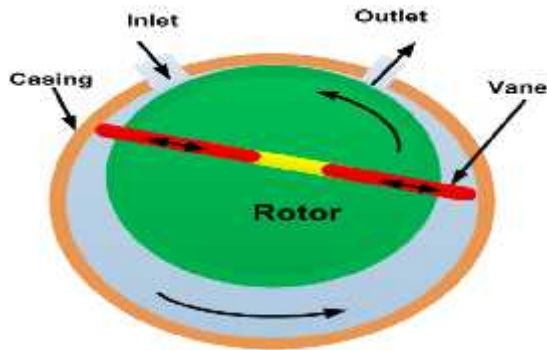
The close tolerance between the gears acts as a seal between the suction and discharge ports. Rotor and idler teeth mesh completely to form a seal equidistant from the discharge and suction ports. This seal forces the liquid out of the discharge port. The flow output is uniform and constant at the outlets.

The important advantages of the pumps are high speed operation, constant discharge in all pressure conditions, bidirectional operation, less sound in running condition and less maintenance due to only two moving parts and one stuffing box etc. However, the pump is having some limitations such as medium pressure operating range, clearance is fixed, solids can't be pumped and overhung load on the shaft bearing etc.

### **Vane Pumps:**

In the hydraulic pumps we have studied the gear pumps. These pumps have a disadvantage of small leakage due to gap between gear teeth and the pump housing. This limitation is overcome in vane pumps. The leakage is reduced by using spring or hydraulically loaded vanes placed in the slots of driven rotor. Capacity and pressure ratings of a vane pump are generally lower than the gear pumps, but reduced leakage gives an improved volumetric efficiency of around 95%.

Vane pumps are available in a number of vane configurations including sliding vane, flexible vane, swinging vane, rolling vane, and external vane etc. Each type of vane pump has its own advantages. For example, external vane pumps can handle large solids. Flexible vane pumps can handle only the small solids but create good vacuum. Sliding vane pumps can run dry for short periods of time and can handle small amounts of vapor. The vane pumps are known for their dry priming, ease of maintenance, and good suction.



The schematic of vane pump working principle is shown in figure. Vane pumps generate a pumping action by tracking of vanes along the casing wall. The vane pumps generally consist of a rotor, vanes, ring and a port plate with inlet and outlet ports. The rotor in a vane pump is connected to the prime mover through a shaft. The vanes are located on the slotted rotor. The rotor is eccentrically placed inside a cam ring as shown in the figure. The rotor is sealed into the cam by two side plates. When the prime mover rotates the rotor, the vanes are thrown outward due to centrifugal force. The vanes track along the ring. It provides a tight hydraulic seal to the fluid which is more at the higher rotation speed due to higher centrifugal force. This produces a suction cavity in the ring as the rotor rotates. It creates vacuum at the inlet and therefore, the fluid is pushed into the pump through the inlet. The fluid is carried around to the outlet by the vanes whose retraction causes the fluid to be expelled. The capacity of the pump depends upon the eccentricity, expansion of vanes, and width of vanes and speed of the rotor. It can be noted that the fluid flow will not occur when the eccentricity is zero. These pumps can handle thin liquids (low viscosity) at relatively higher pressure. These pumps can be run dry for a small duration without any failure. These pumps develop good vacuum due to negligible leakage. However, these pumps are not suitable for high speed applications and for the high viscosity fluids or fluids carrying some abrasive particles. The maintenance cost is also higher due to many moving parts. These pumps have various applications for the pumping of following fluids:

- ) □ Aerosol and Propellants
- ) Aviation Service - Fuel Transfer, Deicing
- ) Auto Industry - Fuels, Lubes, Refrigeration Coolants
- ) Bulk Transfer of LPG and NH<sub>3</sub>
- ) LPG Cylinder Filling
- ) Alcohols
- ) Refrigeration - Freons, Ammonia
- ) Solvents
- ) Aqueous solutions

### ***Piston pumps***

Piston pumps are meant for the high-pressure applications. These pumps have high-efficiency and simple design and needs lower maintenance. These pumps convert the rotary motion of the input shaft to the reciprocating motion of the piston. These pumps work similar to the four stroke engines. They work on the principle that a reciprocating piston draws fluid inside the cylinder when the piston retracts in a cylinder bore and discharge the fluid when it extends. Generally, these pumps have fixed inclined plate or variable degree of angle plate known as swash plate. When the piston barrel assembly rotates, the swash plate in contact with the piston slippers slides along its surface. The stroke length (axial displacement) depends on the inclination angle of the swash plate. When the swash plate is vertical, the reciprocating motion does not occur and hence pumping of the fluid does not



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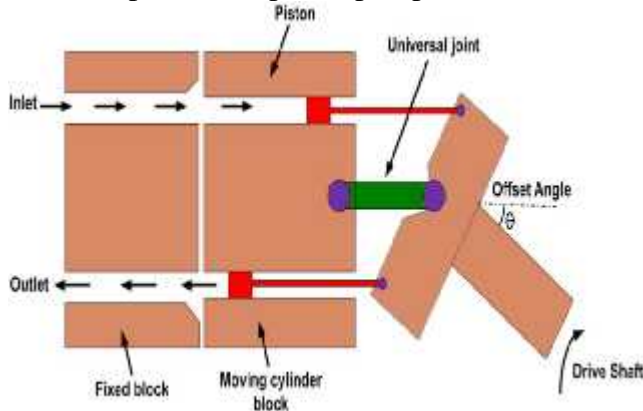
barrel. The stroke length increases with increase in the swash plate angle and therefore volume of pumping fluid increases. During one half of the rotation cycle, the pistons move out of the cylinder barrel and the volume of the barrel increases. During another half of the rotation, the pistons move into the cylinder barrel and the barrel volume decreases. This phenomenon is responsible for drawing the fluid in and pumping it out. These pumps are positive displacement pump and can be used for both liquids and gases. Piston pumps are basically of two types:

- i. Axial piston pumps
- ii. Radial piston pumps

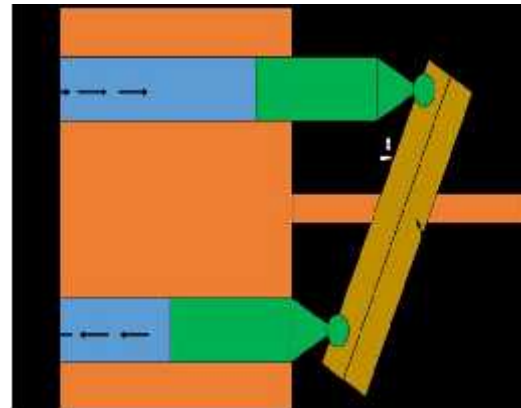
### **Axial Piston Pump**

Axial piston pumps are positive displacement pumps which convert rotary motion of the input shaft into an axial reciprocating motion of the pistons. These pumps have a number of pistons (usually an odd number) in a circular array within a housing which is commonly referred to as a cylinder block, rotor or barrel. These pumps are used in jet aircraft. They are also used in small earthmoving plants such as skid loader machines. Another use is to drive the screws of torpedoes. In general, these systems have a maximum operating temperature of about 120 °C. Therefore, the leakage between cylinder housing and body block is used for cooling and lubrication of the rotating parts. This cylinder block rotates by an integral shaft aligned with the pistons. These pumps have sub-types as:

- a. Bent axis piston pumps
- b. Swash plate axial piston pump

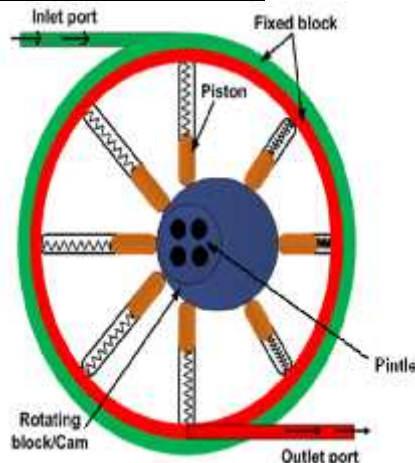


**Bent axis piston pump**



**Swash plate piston pump**

### **Radial Piston Pump**



**Radial piston pump**

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The typical construction of radial piston pump is shown in Figure. The piston pump has pistons aligned radially in a cylindrical block. It consists of a pintle, a cylinder barrel with pistons and a rotor containing a reaction ring. The pintle directs the fluid in and out of the cylinder. Pistons are placed in radial bores around the rotor. The piston shoes ride on an eccentric ring which causes them to reciprocate as they rotate. The eccentricity determines the stroke of the pumping piston. Each piston is connected to inlet port when it starts extending while it is connected to the outlet port when start retracting. This connection to the inlet and outlet port is performed by the timed porting arrangement in the pintle. For initiating a pumping action, the reaction ring is moved eccentrically with respect to the pintle or shaft axis. As the cylinder barrel rotates, the pistons on one side travel outward. This draws the fluid in as the cylinder passes the suction port of the pintle. It is continued till the maximum eccentricity is reached. When the piston passes the maximum eccentricity, pintle is forced inwards by the reaction ring. This forces the fluid to flow out of the cylinder and enter in the discharge (outlet) port of the pintle.

The radial piston pump works on high pressure (up to 1000 bar). It is possible to use the pump with various hydraulic fluids like mineral oil, biodegradable oil, HFA (oil in water), HFC (water-glycol), HFD (synthetic ester) or cutting emulsion. This is because the parts are hydrostatically balanced. It makes the pump suitable for the many applications such as machine tools (displace of cutting emulsion, supply for hydraulic equipment like cylinders), high pressure units (overload protection of presses), test rigs, automotive sector (automatic transmission, hydraulic suspension control in upper-class cars), plastic (powder injection molding) and wind energy etc.

**In general the applications of Hydraulic Pumps can be summarized as,**

- Hydraulic pumps are used to transfer power via hydraulic liquid. These pumps have a number of applications in automobiles, material handling systems, automatic transmissions, controllers, compressors and household items.
- The hand operated hydraulic pump is used in a hydraulic jack where many strokes of the pump apply hydraulic pressure to lift the ram.
- A backhoe uses an engine driven hydraulic pump to drive the articulating parts of the mechanical hoe.
- The hydraulic pumps are commonly used in the automotive vehicles especially in power steering systems.
- The lift system of tractor is operated by the hydraulic pumps. These are used in automatic transmissions and material handling systems in industries.
- Many precise controllers are developed by using hydraulic pumps. The commonly used compressor is operated by reciprocating pumps.
- The hydraulic pumps are also used in routine household systems like power lift and air-conditions. Therefore, it can be said that the hydraulic pumps have significant applications in industries as well as ones routine life.

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### **Experiment No.9: Study of francis turbine or pelton turbine.**

Aim: Study of francis turbine or pelton turbine.

#### **Introduction:**

- Hydraulic turbines may be defined as prime movers that transform the kinetic energy of the falling water into mechanical energy of rotation and whose primary function is to drive a electric generator.
- A cubic meter of water can give about 9800 Joules of mechanical energy for every meter it descends and a flow of a cubic meter per second in a fall of 1 meter can provide 9800 W of

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- Hydro-power is essentially a controlled method of water descent usefully utilized to generate power.
- Hydroelectric plants utilize the energy of water falling through a head that may vary from a few meters to ~1500 or even 2000 m. To manage this wide range of heads, many different kinds of turbines are employed, which differ in their working components.
- The main components of a hydroelectric system may be classified into two groups:
  - The **hydraulic system** components that include the turbine, the associated conduits-like penstocks, tunnel and surge tank-and its control system, and
  - The **electric system** components formed by the synchronous generator and its control system.

### **Classification of Hydraulic Turbines**

Hydraulic turbines are generally classified as

Impulse Turbine – Pelton, Turgo turbine

Reaction Turbine – Francis, Kaplan and Propeller turbine

Based on flow direction, they are further classified as:

Tangential Flow

Radial Flow

Axial Flow

Mixed Flow

### **Impulse and Reaction Turbines:**

- ) The flow energy to the impulse turbines is completely converted to kinetic energy before transformation in the runner.
- ) The impulse forces being transferred by the direction changes of the flow velocity vectors when passing the buckets create the energy converted to mechanical energy on the turbine shaft.
- ) The flow enters the runner from jets spaced around the rim of the runners. The jet hits momentarily only a part of the circumference of the runner.
- ) In the reaction turbines two effects cause the energy transfer from the flow to the mechanical energy on the turbine shaft:
  - ✓ Firstly, it follows from a drop in pressure from inlet to outlet of the runner. This is denoted as the *reaction part* of the energy conversion.
  - ✓ Secondly, the changes in the directions of the flow velocity vectors through the runner blade channels transfer impulse forces. This is denoted as the *impulse part* of the energy conversion.
- ) The pressure from inlet to outlet of the runners is obtained because the drop runners are completely filled with water.

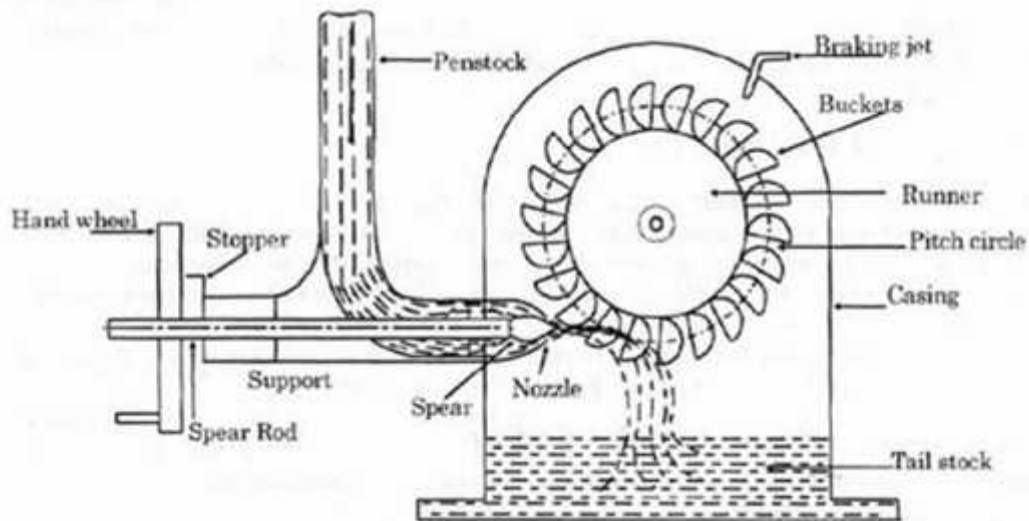
### **Pelton Turbine**

- ) Invented by Pelton in 1890.
- ) The Pelton turbine is a tangential flow impulse turbine.
- ) The Pelton wheel is most efficient in high head applications.
- ) Power plants with net heads ranging from 200 to 1,500 m.
- ) The largest units can be up to 200 Megawatts.
- ) Pelton turbines are best suited for high head and low flow sites.
- ) Depending on water flow and design, Pelton wheels can operate with heads as small as 15 meters and as high as 1800 meters.
- ) As the height of fall increases, less volume of water can generate same power.



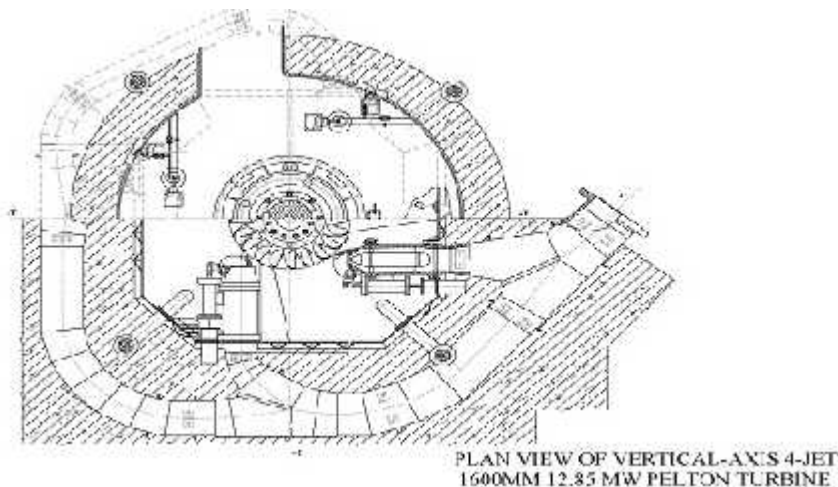
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### **Horizontal Arrangement of a Pelton Turbine**

Horizontal arrangement is found only in medium and small sized turbines with usually one or two jets. In some designs, up to four jets have been used. The flow passes through the inlet bend to the nozzle outlet, where it flows out as a compact through atmospheric air on to the heel buckets from the outlet of jet through wheel buckets. Outlet the buckets the water falls through the pit down into the tail water canal.



### **Vertical Arrangement of a Pelton Turbine**

Large Pelton turbines with many jets are normally arranged with vertical shaft. The jets are symmetrically distributed around the runner to balance the jet forces. The figure shows the vertical and horizontal sections of the arrangement of a six jet vertical Pelton turbine.

### **Parts of a Pelton Turbine**

The Pelton runners may be designed either for casting of the disc and buckets in one piece, i.e. monocast, or the disc and each of the buckets are casted in separate pieces.

The shape of the buckets is decisive for the efficiency of the turbines. Limitations however is that bucket shape always will be a compromise between a hydraulically ideal and a structural optimum design.

The runner disc is fastened to the shaft by bolts and nuts.

The turbine shaft of vertical Pelton turbines is made of forged steel with an integral flange at both ends. A hole is drilled centrally through the whole length of the shaft. An oil

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Journal and thrust bearings are provided with circulating oil to carry the heat dissipated by the shaft and bearings.

The distributor pipe is designed to provide an acceleration of the water flow through the bifurcation towards each of the main injectors. This design is advantageous, because it contributes in keeping a uniform velocity profile of the flow.

The injector is operated hydraulically by servo motors.

### **Material of Pelton Turbine**

Case: fabricated carbon steel to BS EN 10025:1993 S275JR

Runner: cast Stainless BS3100 Grade 425 C11

Shaft seal: cast gunmetal labyrinth type seal

Bearings: rolling element or sleeve type

Spear : stainless steel internal components housed in a carbon Needle valve steel fabricated or cast branch pipe

Deflector: stainless steel plate

The material of the runner and buckets are chosen according to the head, stresses, content of sand in the water and other strain factors. For the large turbines the main strain factors are cavitation, sand erosion and cycle fatigue

### **Pelton Turbine Specifications:**

Dixence, Switzerland

Gross head: 1748 m

Net head: 1625 m

Jet velocity: 177 m/s

Power: 18.6 MW

Speed: 500

Jet diameter: 94.2 mm

Pitch diameter of the wheel: 3.319m

### **Francis Turbine:**

- The Francis turbine is a reaction turbine, which means that the working fluid changes pressure as it moves through the turbine, giving up its energy.
- The inlet is spiral shaped. The guide vanes direct the water tangentially to the runner causing the runner to spin.

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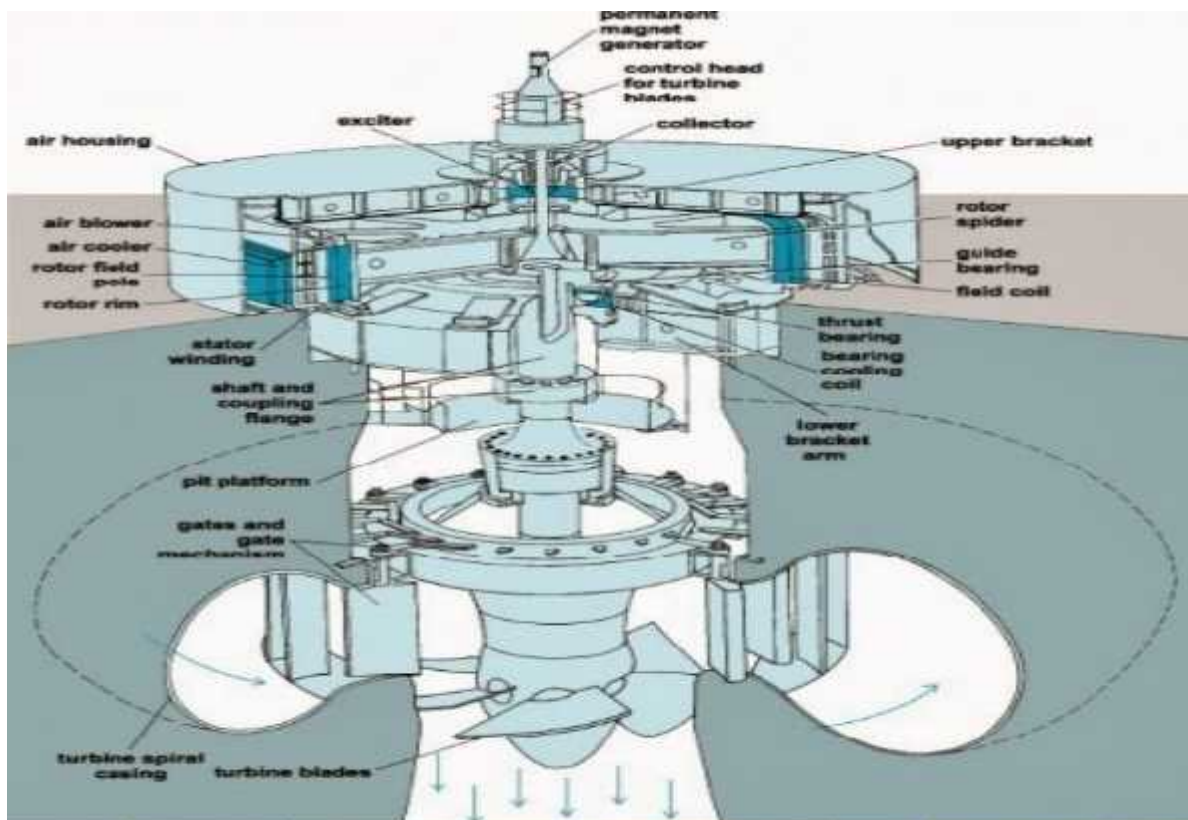
- The guide vanes (or wicket gate) may be adjustable to allow efficient turbine operation for a range of water flow conditions.
- Power plants with net heads ranging from 20 to 750 m.

The water from the penstock is conducted through the scroll casing and distributed around the stay ring and the complete circumference of the guide vane cascade. The scroll casings are normally welded steel plate constructions for turbines at low, medium as well as high heads.

The openings of the guide vanes are adjustable by the regulating ring, the links and levers. The vanes are shaped according to hydraulic design specifications and given a smooth surface finish. The bearings of the guide vane shafts are lubricated with oil or grease.

Casing covers are bolted to the stay ring of the scroll casing. They are designed for high stiffness to keep the deformations caused by the water pressure at a minimum. This is of great importance for achieving a minimal clearance gap between the guide vane ends and the facing plates of the covers. Between the runner and the covers the clearance is also made as small as possible.

The turbine shaft is steel forged and has forged flanges at both ends. The turbine and generator shafts are connected by a flanged joint. This joint may be a bolted reamed or friction coupling where the torque is transferred by means of shear or friction.



**Regulating Mechanism for Francis Turbine:**

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The guide vane mechanism along with the governors provides the regulation of the turbine output.

The turbine governor controls the servomotor which transfers its force through a rod to the regulating ring. This ring transfers the movement to the guide vanes through a rod, lever and link construction.

The guide vane exit area flow varied by an equal rotation of each of the guide vanes.

### **Material of Francis Turbine**

Case: Fabricated carbon steel to BS EN 10025:1993 S275JR

Runner: Cast Stainless BS3100 Grade 425 C11 or Aluminium

Bronze BS 1400 Gr. AB2C

Draft tube: Fabricated carbon steel

Bearings: Rolling element or sleeve type

Guide vanes: Stainless steel or Aluminium Bronze

Operating ring: Fabricated steel BS 10025:1993 S275 JR

Deflector: Stainless steel plate

Francis Turbine-Specification

### **Fionnay, Switzerland**

Head: 454 m

Power: 47.1 MW

Speed: 750 rpm

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### **Experiment N0. 10: LOSSES IN PIPE FRICTION**

Aim: To calculate the losses in pipe friction

**THEORY:** WHEN A FLUID IS FLOWING THROUGH THE PIPE, IT IS SUBJECTED TO RESISTANCE TO FLOW DUE TO SHEAR FORCES BETWEEN THE PIPE WALL AND FLUID PARTICLES AND BETWEEN THE FLUID PARTICLES ALSO. THIS RESISTANCE IS GENERALLY CALLED FRICTIONAL RESISTANCE. THIS RESISTANCE DEPENDS UPON THE VELOCITY OF FLOW AND AREA OF SURFACE IN CONTACT. IT ALSO DEPENDS UPON THE TYPE OF FLOW, I.E. LAMINAR OR

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TURBULENT. THIS FRICTIONAL RESISTANCE CAUSES LOSS OF PRESSURE IN THE DIRECTION OF FLOW.

**THE APPARATUS:-** THE APPARATUS CONSIST OF THREE PIPES WITH I. D.'S, 27 MM. G.I. PIPE, 14 MM G. I. PIPE AND 14 MM COPPER PIPE, SO THAT LOSS OF HEAD CAN BE COMPARED FOR DIFFERENT DIAMETERS AND DIFFERENT MATERIALS. A FLOW CONTROL VALVE IS PROVIDED AT OUTLET OF PIPES. WHICH ENABLES EXPERIMENTS TO BE CONDUCTED AT DIFFERENT FLOW RATES, I.E. AT DIFFERENT VELOCITY'S.

TAPPINGS ARE PROVIDED ALONG THE LENGTH OF PIPES, SO THAT DROP OF HEAD CAN BE VISUALIZED ALONG THE LENGTH OF PIPE. EACH PIPE IS PROVIDED WITH VALVE AT OUTLET, WHICH ENABLES HEADS TO BE CONTROLLED.

### **EXPERIMENTAL PROCEDURE :-**

1. FILL UP WATER IN THE SUMP TANK.(THIS WATER SHOULD BE FREE OF ANY OIL CONTENT.)
2. OPEN ALL THE OUTLET VALVES AND START THE PUMP.
3. CHECK FOR LEAKAGE'S BY CLOSING THREE OF OUTLET VALVES ONE BY ONE FOR EACH PIPE, AND CORRECT THE LEAKS IF ANY.
4. OPEN THE OUTLET VALVES OF THE PIPE TO BE TESTED.
5. REMOVE ALL THE AIR BUBBLES FROM MANOMETER AND CONNECTING PIPES.
6. REDUCE THE FLOW. ADJUST OUTLET VALVES, SO THAT WATER HEADS IN MANOMETER ARE TO THE READABLE HEIGHT.
7. NOTE DOWN THE HEADS AND FLOW RATE.

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8. NOW, INCREASE THE FLOW AND ACCORDINGLY ADJUST THE OUTLET VALVE, SO THAT WATER WILL NOT OVERFLOW. NOTE DOWN HEADS AND FLOW.

9. REPEAT THE PROCEDURE FOR OTHER PIPES.

### **OBSERVATION TABLE: -**

SR. NO.	PIPE TYPE	HEAD DROP H (M)	FLOW RATE 'T 'SEC (TIME FOR 5 CM RISE IN SEC.).

### **CALCULATIONS :-**

1] 27 MM. G.I. PIPE : -

$$\text{AREA OF PIPE, } A = \pi/4 \times D^2 \quad M^2$$

$\Leftrightarrow$

$$= \frac{\pi}{4} \times (0.027)^2 \quad M^2 = 0.000572 \quad M^2$$

4

$$0.3 \times 0.3 \times 0.05$$

$$\text{DISCHARGE, } Q = \frac{\text{-----}}{T} \quad M^2 / S.$$

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Q

VELOCITY OF WATER,  $V = \frac{Q}{A}$  M / SEC.

A

LET, 'F' BE THE COEFFICIENT OF FRICTION. TEST LENGTH OF PIPE IS 1 METER.

FOR 1 METER LENGTH, DROP OF HEAD,  $H_F$

..  $H_F$  = MANOMETER DIFFERENCE.

ACCORDING TO DARCY 'S-WEISH BACH EQUATION, HEAD LOSS DUE TO FRICTION.

$$4 \cdot F \cdot L \cdot V^2$$

$$H_F = \frac{4 \cdot F \cdot L \cdot V^2}{2 \cdot G \cdot D}$$

$$2 \cdot G \cdot D$$

WHERE, F = COEFFICIENT OF FRICTION.

L = LENGTH OF PIPE = 1 M

V = VELOCITY OF WATER M / SEC.

G = GRAVITATIONAL ACCELERATION = 9.81 M/S<sup>2</sup>

D = INSIDE DIAMETER OF PIPE, M

THEN,

$$H_F \cdot G \cdot D$$

$$F = \frac{H_F \cdot G \cdot D}{2 \cdot L \cdot V^2}$$

$$2 \cdot L \cdot V^2$$

THE VALUE OF COEFFICIENT OF FRICTION IS NOT CONSTANT AND DEPENDS UPON ROUGHNESS OF PIPE INSIDE SURFACE AND REYNOLDS'S NUMBER. ANY OIL CONTENT IN WATER ALSO AFFECTS VALUE OF 'F'

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[REPEAT THE SAME PROCEDURE FOR OTHER PIPES. ]

### **CONCLUSIONS: -**

1] LOSS OF HEAD DUE TO FRICTION IS PROPORTIONAL TO LENGTH OF PIPE AND SQUARE OF VELOCITY.

2] LOSS OF HEAD IS INVERSELY PROPORTIONAL TO INSIDE DIAMETER OF PIPE.

3] AVERAGE VALUE OF 'F' FOR -

A] 27 MM. G.I. PIPE.-

B] 14 MM. G.I. PIPE.-

C] 14 MM. COPPER PIPE -

### SAMPLE CALCULATIONS

#### **LOSSES IN PIPE FRICTION**

### **OBSERVATIONS :-**

SR. NO.	TYPE OF PIPE		HEAD DROP 'H' CM	TIME FOR 10 LIT. DISCHARGE OF WATER. 'T' SEC
1	G.I.	21 MM	8.0	21.19
2	CU	14 MM	56.0	25.53
4	G.I.	17 MM	43.5	24.72

( 21 MM. G.I. PIPE)

⇔

⇔

1) AREA OF PIPE, A = ----- X D<sup>2</sup> = ----- X (0.021)<sup>2</sup>

4

4



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$$= 0.000346 \text{ m}^2$$

$$\frac{0.01}{0.01}$$

2) DISCHARGE,  $Q = \frac{\text{Volume}}{\text{Time}} = \frac{0.01}{21.19}$

$$= 4.72 \times 10^{-4} \text{ m}^3 / \text{SEC.}$$

$$Q = 4.72 \times 10^{-4}$$

3) VELOCITY OF WATER,  $V = \frac{Q}{A} = \frac{4.72 \times 10^{-4}}{3.46 \times 10^{-4}} = 1.36 \text{ m/s}$

$$A = 3.46 \times 10^{-4}$$

4) ACCORDING TO DARCY- WEISBACH EQUATION,

$$2 \cdot H_f \cdot G \cdot D = 2 \times 0.08 \times 9.81 \times 0.021$$

$$F = \frac{2 \cdot H_f \cdot G \cdot D}{L \cdot V^2} = \frac{2 \times 0.08 \times 9.81 \times 0.021}{1 \times 1.36^2} = 0.0178$$

$$L \cdot V^2 = 1 \times 1.36^2$$

**NOTE: - SAMPLE CALCULATIONS ARE ONLY FOR REFERENCE PURPOSE.**

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## Lab manual

**Title of Course: Manufacturing Technology Lab**  
**L-T-P scheme: 0-0-3**

**Course Code: ME492**  
**Course Credit: 2**

### **Objectives:**

1. The objective of the laboratory is learning. The experiments are designed to illustrate phenomena in different areas of Workshop and to expose you to uses of instruments.
2. To provide an understanding of the design aspects of machines.
3. To provide an efficient understanding of the equipments and their functioning.

**Learning Outcomes:** The students will have a detailed knowledge of the concepts of process of workshop equipments and their use in various areas of mechanical engineering. Upon the completion of practical course, the student will be able to:

- ) **Understand** and implement basic services and functionalities of the machines using tools and equipments.
- ) **Use** modern manufacturing technology to understand outlined process of production.
- ) **Understand** the benefits of newly manufactured parts and designs.
- ) **Analyze** the dimensions of job and measurements to be taken in account.
- ) **Implement** the manufacturing processes in competition of different jobs.
- ) **Understand** the concepts of different operations conducted on milling, shaper and working in smithy and forging.

### **Course Contents:**

**Exercises that must be done in this course are listed below:**

- Exercise No.1: Smithy & Forging operation
- Exercise No. 2: Operation on Shaper machine
- Exercise No. 3: Operation on Drilling machine
- Exercise No. 4: Operation on grinding machine
- Exercise No. 5: Machining spur gear

### **Text Book:**

1. Hazra Choudhary, Media Promoters & Publishers Pvt Ltd.
2. Ashish Dutt Sharma, S. Chand

## **EXPERIMENT NO. 1**

### **SMITHY AND FORGING**

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### **Aim: Study of Smithy & Forging Operation**

The smithy and forging is a process of heating the metal to a plastic state and then shaping it with a hand hammer or power hammer. The smithying is an oldest form of forging and is largely used where heating them in an open fire or hearth shapes small parts. It is also called hand forging and is done by the blacksmith.

The forging is a process of heating the metal in a closed furnace to a desired temp. in order to acquire sufficient plasticity and shaping it in dies under the pressure of heavy hammers, forging machines and presses.

**FORGEABLE MATERIALS:** - Any metal or alloy, which can be brought into plastic stage through heating, can be forged. The extent to which a material can be forged is governed by its composition as well as temp. of forging. The selection of forging material depends upon certain desirable mechanical properties such as strength, malleability, durability, machinability etc.

**FORGING PROCESS:** The forging process, according to the method used, is classified in to the following two groups....

1. Flat die forging
2. Closed die forging

### **SMITH FORGING OPERATIONS:**

**1.UPSETTING:-** It consists of increasing the c/s of a bar at the expense of its length. In this process first of all the work is heated to the required temp. and then heavy blow is given by hand hammer. The swelling of work takes place at the heating portion. The position and the nature of upsetting depend upon the heating and upon the type of blow delivered.

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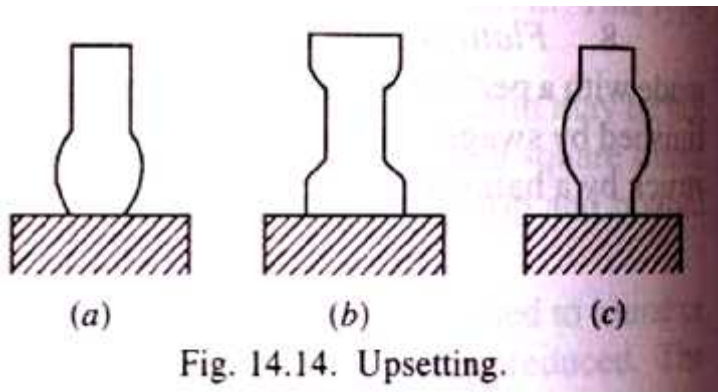


Fig. 14.14. Upsetting.

**2.DRAWING DOWN:-** It is the process of reducing the c/s of a bar and increasing its length. The operation is carried out in following two steps.

- ) First of all the hammering is done with a straight pin hammer by keeping the work at the edge or beak of the anvils.
- ) Now the curved top of the work is leveled off with the set hammer and finally finished with the flatter.

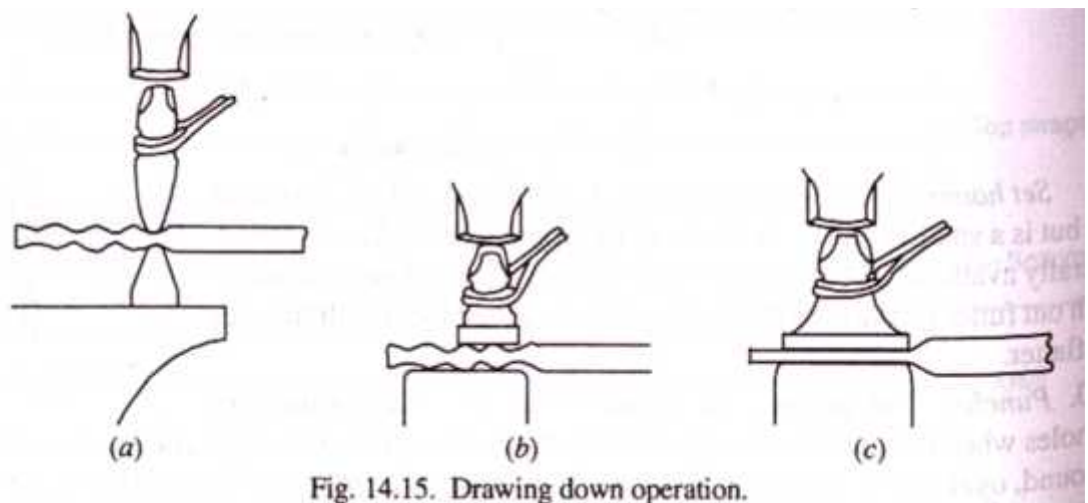
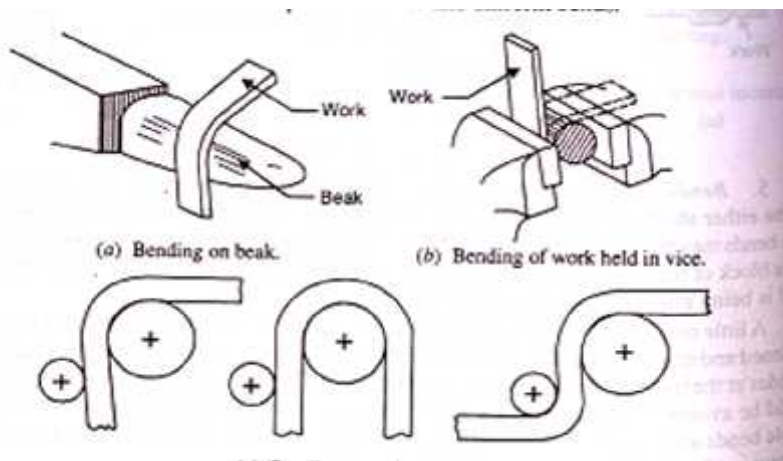
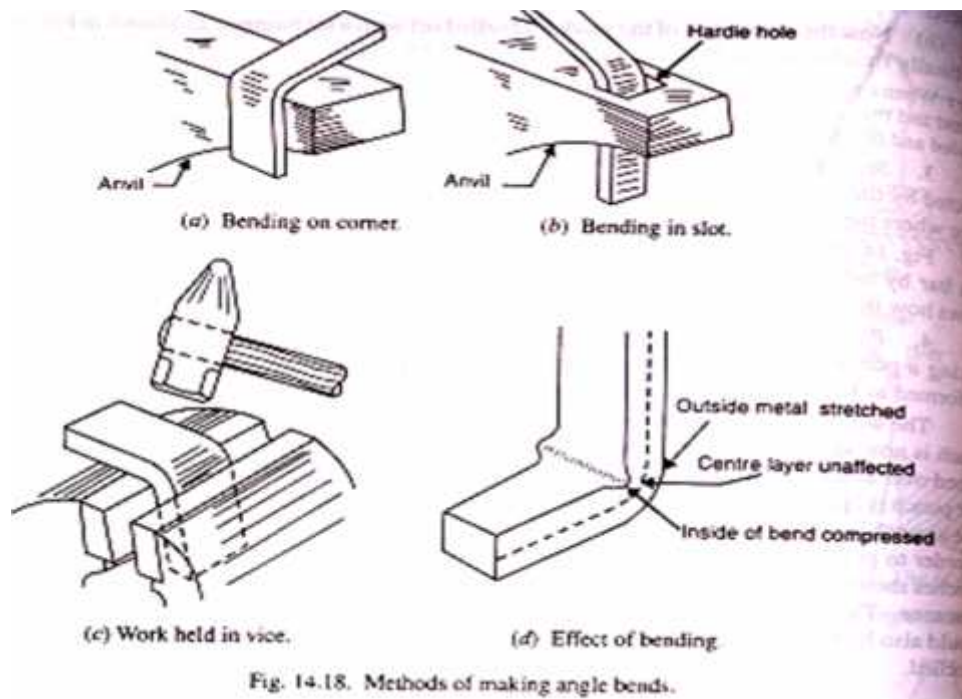


Fig. 14.15. Drawing down operation.

**3. BENDING:** It is an imp. Process in forging and is frequently used. The bend may be either sharp cornered angle bends or they may be composed of a more gradual curve .the angle bends may be made by hammering the metal over the edge of the anvil.

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4. WELDING: It is the process of joining the two surface of metal after they are heated to the correct temp. The correct temp. Of wrought iron is about 1350 deg. C whereas for mild steel the temp. is little lower than this .it may be noted that if the temp. is low it will not cause the weld to take place .on the other hand if the temp. is too high, it will ruin the metal by burning it .

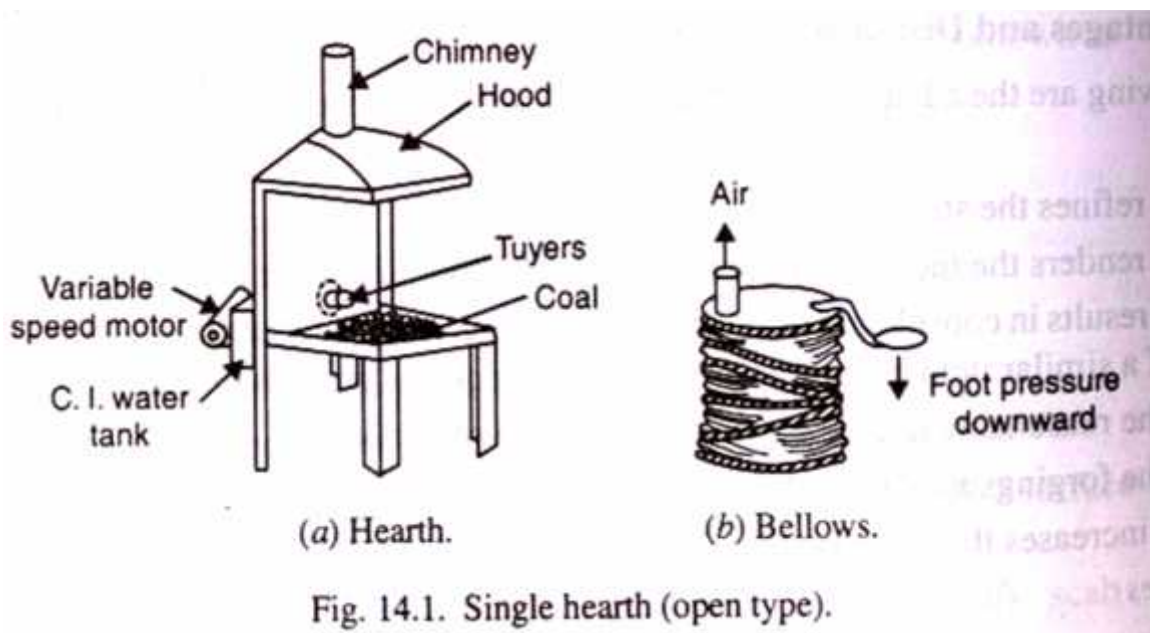
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### TOOLS AND EQUIPMENTS USE IN HAND FORGING

#### Smith's forge or hearth:

- ) it has a robust cast iron or steel structure consisting of 4 leg support, an iron bottom known as hearth, a hood at the top and tuyere opening into the hearth either from the rear or from the bottom.
- ) The hearth carries the coal and is, therefore, provided with firebricks lining to withstand the extensive heat produced due to the combustion of coal.
- ) Air under pressure, is supplied by the blower, suitably placed somewhere near the forge, through the tuyere opening in the hearth.
- ) The chimney provided at the top enable an easy escape of smoke and gases produced due to the burning of coal.
- ) They prove to be very efficient furnaces but have a disadvantage that they are not portable the amount of heat developed in the fire largely depends upon the supply of air and with due increase in air blast it can be raised up to white heat.
- ) Care should be exercised in keeping the job in the fire so that the air blast does not impinge on to the metal surface directly.
- ) A glowing fire with minimum amount of smoke will be best suited for heating the job efficiently for forging work.



#### Open fire and stock fire:

- ) Two types of fires are prepared in a smith's forge for heating the metal. They are known as open fire and stock fire.
- ) An open fire is prepared by converging the previously burnt coal by fresh coal in front of the tuyere.

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- ) The stock fire is prepared for prolonged heating, i.e., to last for a long period, as may be required for heating relatively large components.
- ) It is prepared by stacking the coal around a prepared wooden block placed opposite to the tuyere.

### Anvil:

- ) Its body is generally made of cast steel, wrought iron or mild steel provided with a hardened top, about 20 to 25 mm thick.
- ) This hardened plate is welded to the body on the top.
- ) The horn or beak is used in bending the metal or forming curved shapes.
- ) The flat step provided, between the top and the horn, is used to support jobs during cutting and is known as chipping block.
- ) The flat projecting piece at the back of the anvil is known as tail. It carries a square hole to accommodate the square shank of the bottom part of various hand tools like swages, fullers, Pick iron and hardies. It is called a hardie hole.
- ) The circular hole provided near the hardie hole is known as pritchel hole. The anvil is supported either on an iron base, wooden construction or mass.

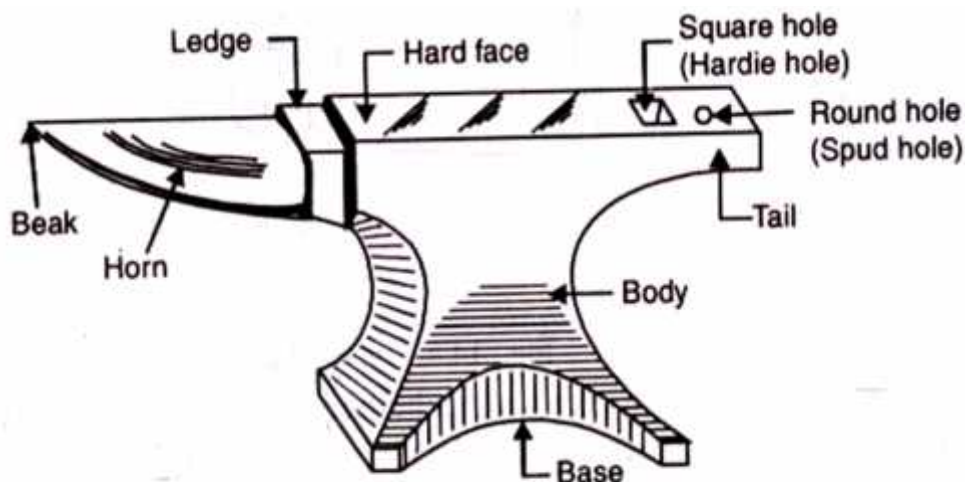


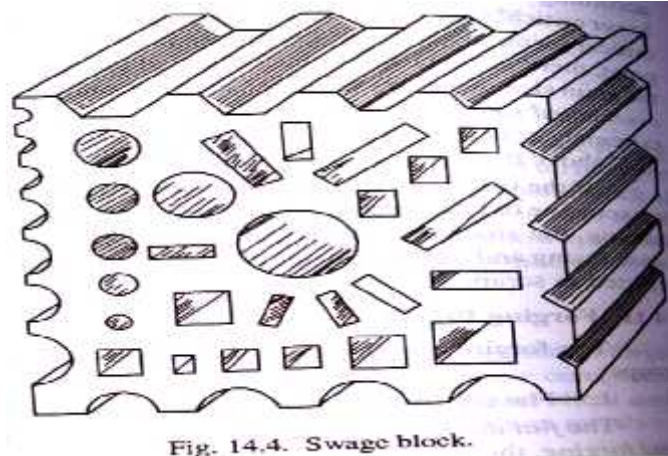
Fig. 14.3. Anvil.

### Swage block:

- ) It is usually block of cast steel or cast iron carrying a number of slots different shapes and sizes along its four side faces and through holes from its top face to bottom face, which also vary in shapes and sizes.
- ) This is used as a support in punching holes and forming different shapes

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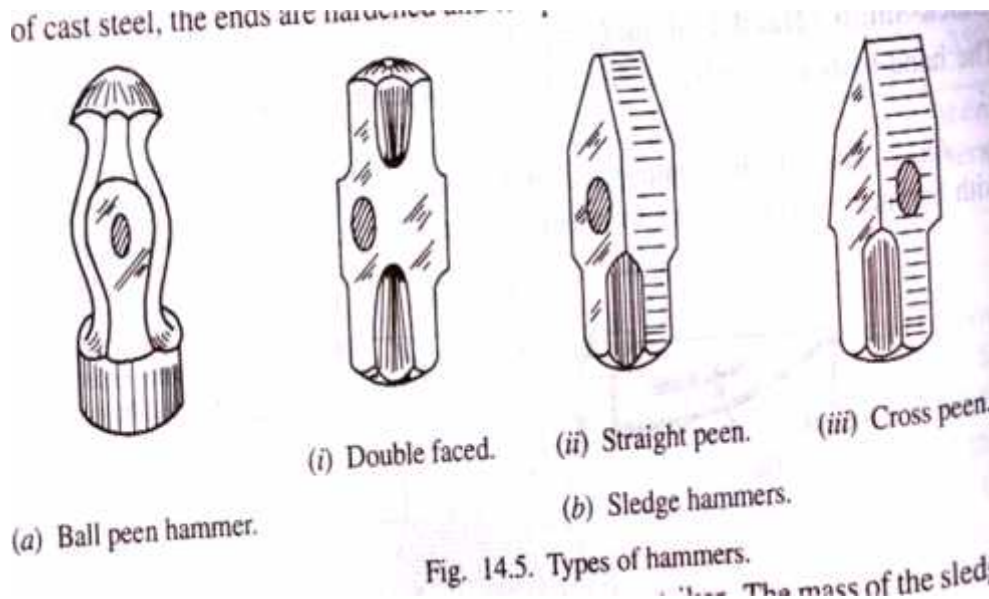
### Hammers:

- ) The top portion is given the shape of a ball and the portion between this ball and the cheeks reduced in size, by fullering, it gets a particular form known as ball peen hammer.
- ) Sledgehammers are comparatively 3 to 4 times heavier than the hand hammers. They are available in varying sizes and weights from 3 kg to 8 kg. They are employed when heavy blows are needed in forging and other operations done on heavy jobs.
- ) Sledge hammers can be of straight peen, cross peen or double faced type as shown in fig.
- ) The straight peen hammer is one which carries the peen formed parallel to the axis of the eye at one end and a flat face at the other end.
- ) Cross peen hammer is similar in construction to the former except that the peen runs at right angles to the axis of the eye.
- ) If the hammer has no peen formation and instead carries flat faces at both ends, it is known as a double face hammer.



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### Tongs:

- ) Tongs are usually named after the inside shapes of the jaws.
- ) Flat tongs are used for gripping thin sections and small flat pieces.
- ) Round hollow tongs, with curved surface inside, are used for holding round work.
- ) Hollow tongs with square jaws are used to hold square or hexagonal work.
- ) Pick up tongs have their jaws so shaped that even small sections can be easily picked up, they are not used for holding the work.
- ) Similarly, the jaws can be made to have different types of shapes so as to suit the varying shapes of the jobs. Tongs, which are in very common use, are shown in fig.

### Chisels hardie and gouges:

- ) Chisels are used to cut metal in hot or cold state.
- ) Those, which are used for cutting the metal in hot state are termed as hot chisels or hot set and the others used for cutting in cold state are known as cold chisels or cold set.
- ) The main difference between these chisels is in the included angle at the cutting edge

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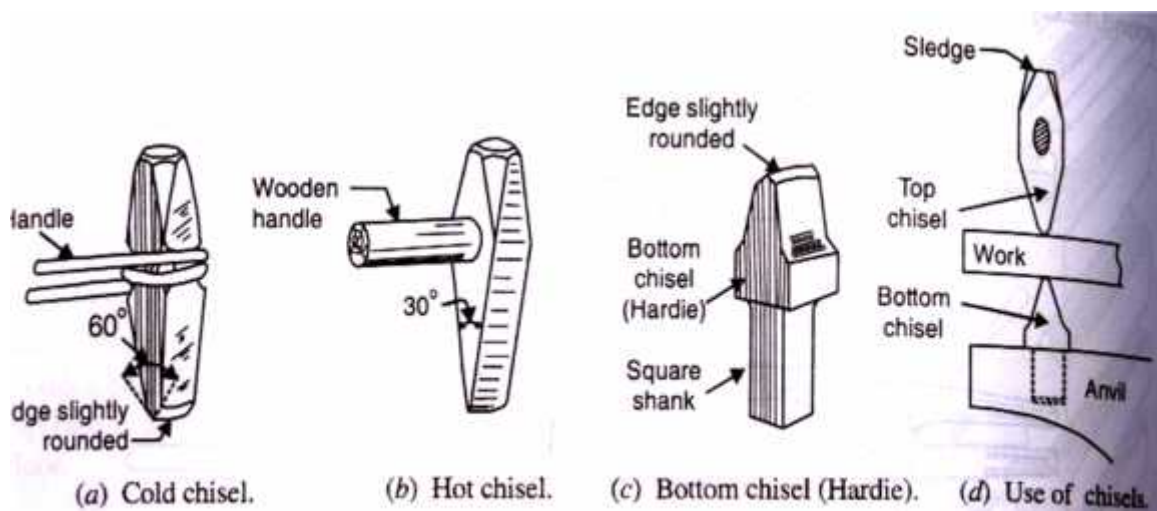
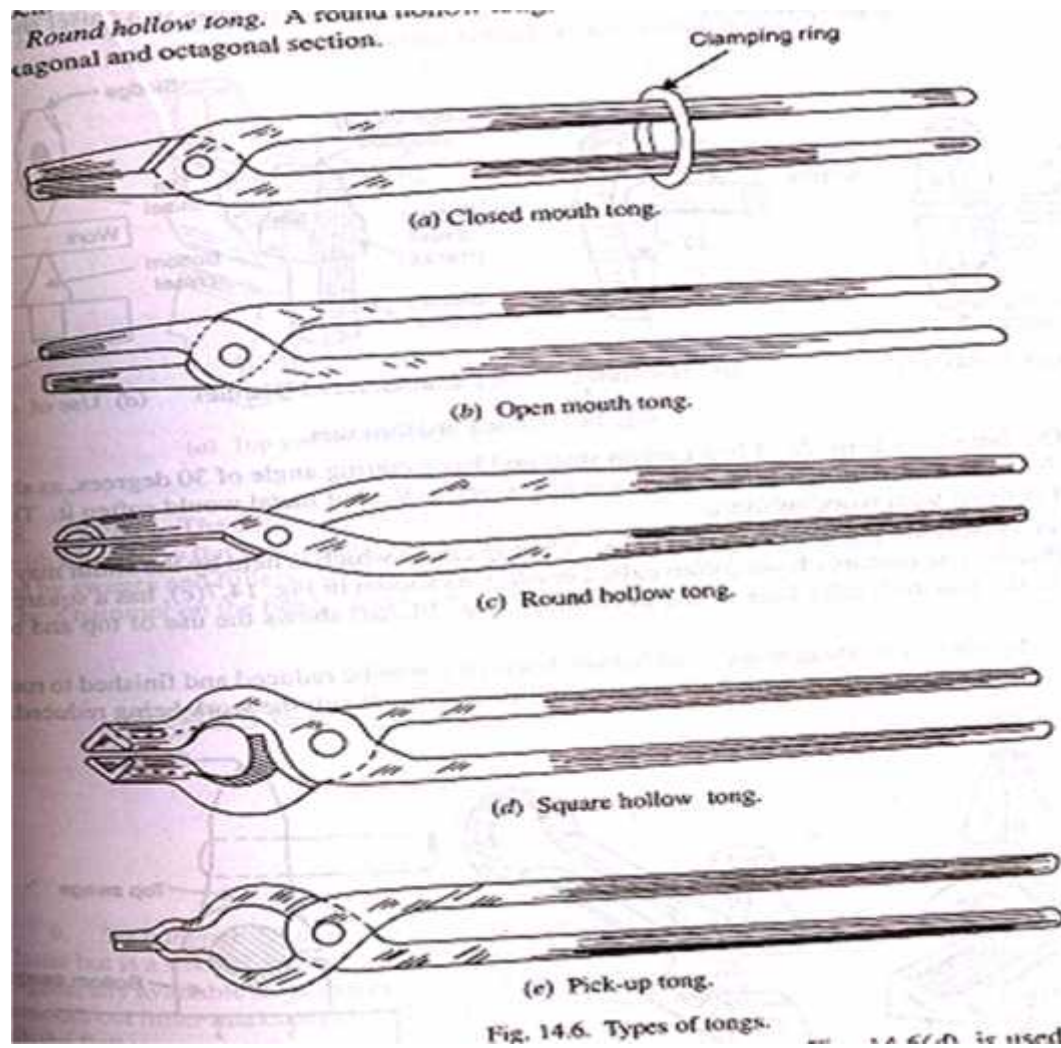
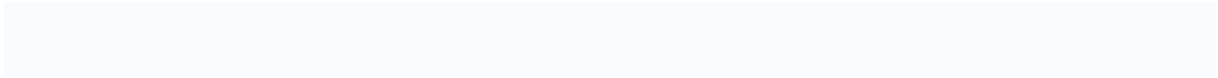


Fig. 14.7. Chisels and their uses.

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### **EXPERIMENT-2**

**AIM:-** To study shaper machine, its mechanism and calculate quick return ratio.

### **INTRODUCTION:-**

The shaper machine is a reciprocating type of machine tool which is used to produce flat, horizontal, vertical and inclined surfaces by means of a single point cutting tool (similar to a lathe tool) cut with a perpendicular feed.

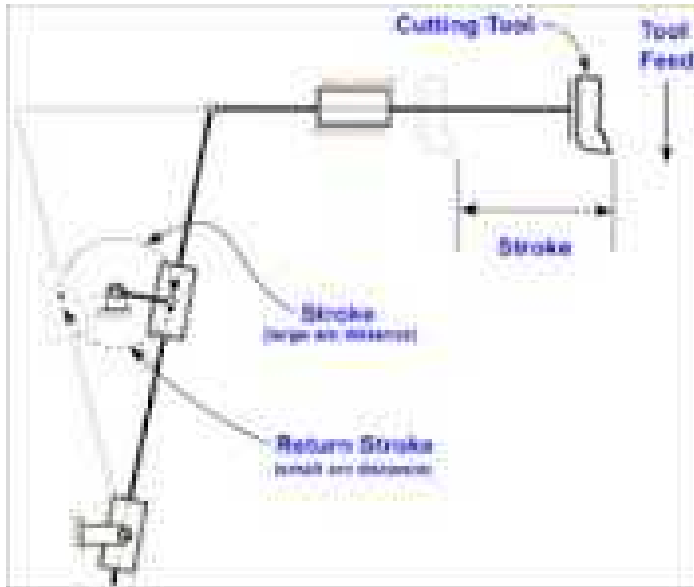
### **WORKING PRINCIPLE:-**

The tool held in the tool holder mounted on the ram moves forward and backward in a straight line over the work piece rigidly held in a vice clamped over the work table. Each time the tool moves forward to cut metal from the work-piece and moves backward by lifting the tool clear of the work-piece. Regular feed is obtained by moving the work table

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automatically at right angles to the direction of cutting tool and the tool head gives downward feed at right angles to the regular feed or any other angle as desired.

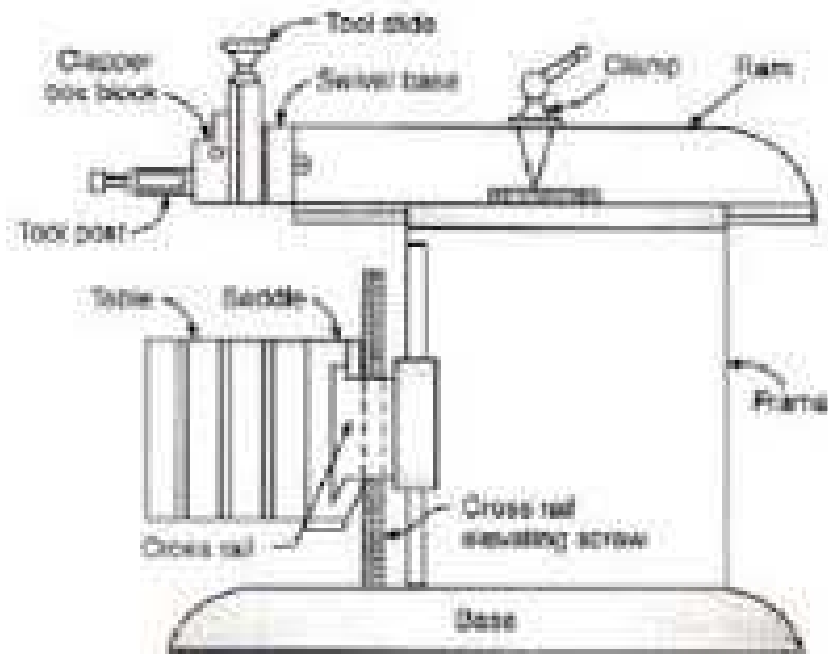


### MAIN PARTS OF THE SHAPER:

- ) Base
- ) Column
- ) Cross rail
- ) Saddle
- ) Work table
- ) Ram
- ) Tool head

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### **SHAPER MECHANISM (QUICK RETURN MECHANISM):**

In a shaper, circular moment of the drive is converted into reciprocating movement by the mechanism. In a standard shaper, metal is removed in a forward cutting stroke while the return stroke goes idle and no metal is removed. To reduce the total machining time it is necessary to reduce the time taken by the return stroke.

Thus, the shaper machine is so designed that it allows the ram to move slower during the forward cutting stroke and faster during the return stroke to reduce the idle return time. This mechanism is known as quick return mechanism.

### **SHAPER OPERATIONS:**

Horizontal cutting  
Vertical or groove cutting  
Angular cutting  
Irregular cutting

**HORIZONTAL CUTTING:** It Is the most common operation performed on a shaper machine to obtain the flat surfaces. The work is fed in horizontal direction under the reciprocating tool and the surfaced produce is horizontal and flat .

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**VERTICAL CUTTING:** The tool is fed downwards in vertical cutting to make grooves , keyways , parting of and squaring of the ends shoulders by rotating the down feed screw by hand at the end of the return stroke .

**ANGULAR CUTTING:** This operation employed, machining inclined surfaces, beveled surfaces and dovetails .Here again the down feed screw is rotated to feed the tool. For shaping angular faces, the swivel head is set to the required angle.

**IRREGULAR CUTTING:** A form tool is used for machining a narrow irregular surface .A round nose tool is used for machining irregular surfaces.

### **QUICK RETURN RATIO:**

To calculate quick return ratio,

**QUICK RETURN RATIO= FORWARD STROKE/BACKWARD STROKE**

### **PRECAUTIONS:**

1. One should not stand in front of the ram.
2. Set the stroke length before starting the machine.
3. Always use sharp tools.

## **EXPERIMENT NO. 3**

### **DRILLING**

**Aim:** Study of Drilling operation

Various types of drilling machines:

- ) Portable drilling machine
- ) Bench-type Drilling machine
- ) Sensitive drilling machine
- ) Upright drilling machine
  - o Plane drilling machine

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- Turret drilling machine
- ) Radial drilling machine
- ) Multiple-spindle Drilling machine
- ) Deep hole Drilling machine
- ) Gang drilling machine
- ) Automatic drilling machines

### Drilling Operation:

- ) Drilling
- ) Counter boring
- ) Boring
- ) Countersinking
- ) Spot facing
- ) Tapping



### EXPERIMENT NO. 4

#### Grinding machine

**Aim:** Study of grinding machine

A **grinding machine** is a machine tool used for producing very fine finishes or making very light cuts, using an abrasive wheel as the cutting device. This wheel can be made up of various sizes and types of stones, diamonds or of inorganic materials. For machines used to reduce particle size in materials processing see grinding.

#### Construction

The grinding machine consists of a power driven grinding wheel spinning at the required speed (which is determined by the wheel's diameter and manufacturer's rating, usually by a

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formula) and a bed with a fixture to guide and hold the work-piece. The grinding head can be controlled to travel across a fixed work piece or the workpiece can be moved whilst the grind head stays in a fixed position

A **bench grinder** or **pedestal grinder** is a machine used to drive an abrasive wheel (or wheels).

Depending on the grade of the grinding wheel it may be used for sharpening cutting tools such as lathe tools or drill bits. Alternatively it may be used to roughly shape metal prior to welding or fitting.

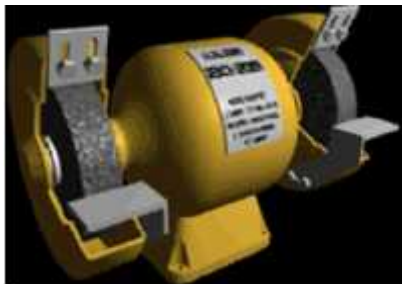
Wire brush or buffing wheels are often mounted in place of the grinding wheels and are used to clean or polish work-pieces.

### Safety issues

Goggles or safety glasses need to be worn to protect the operator's eyes from the sparks and metal filings that result. Depending on the work piece and time of exposure, hearing protection may also be required; the dust produced is also potentially hazardous.

The tool rest (or work rest) should be mounted slightly below the center of the grinding wheel with less than 3 mm clearance from the wheel. This prevents the work from jamming between the tool rest and the wheel.

Grinding wheels designed for steel should not be used for grinding softer metals, like aluminum. The soft metal gets lodged in the pores of the wheel and expands with the heat of grinding. This can dislodge pieces of the grinding wheel





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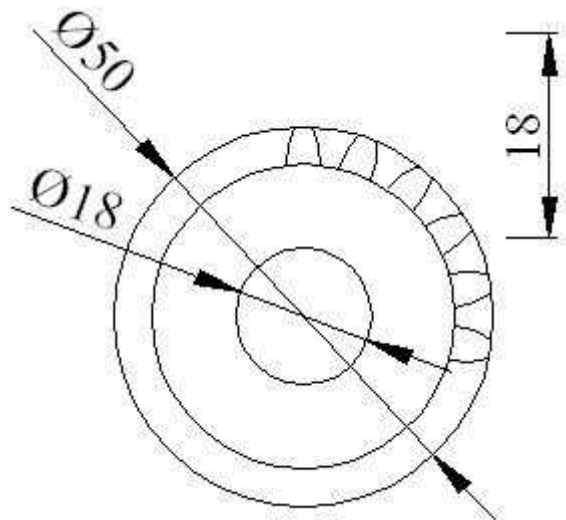
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### **EXPERIMENT NO. 5**

#### **AIM :**

To machine a spur gear to the given module and number of teeth in the given workpiece

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**TOOLS AND EQUIPMENTS REQUIRED :**

Milling machine, Vernier caliper, Mandrel

**PROCEDURE :**

1. Calculate the gear tooth proportions.

$$\begin{aligned}\text{Blank diameter} &= (Z + 2) m \\ \text{Tooth depth} &= 2.25 m \\ \text{Tooth width} &= 1.5708 m\end{aligned}$$

where,

$$\begin{aligned}Z &= \text{Number of teeth required} \\ m &= \text{module}\end{aligned}$$

2. Indexing calculation  
Index crank movement =  $40 / Z$
3. The dividing head and the tail stock are bolted on the machine table. Their axis must be set parallel to the machine table.
4. The gear blank is held between the dividing head and tailstock using a mandrel. The mandrel is connected with the spindle of dividing head by a carrier and catch plate.
5. The cutter is mounted on the arbor. The cutter is centred accurately with the gear blank.
6. Set the speed and feed for machining.
7. For giving depth of cut, the table is raised till the periphery of the gear blank just touches the cutter.
8. The micrometer dial of vertical feed screw is set to zero in this position.

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9. Then the table is raised further to give the required depth of cut.
10. The machine is started and feed is given to the table to cut the first groove of the blank.
11. After the cut, the table is brought back to the starting position.
12. Then the gear blank is indexed for the next tooth space.
13. This is continued till all the gear teeth are cut.

### **CALCULATION :**

$$Z = \text{No. of teeth} = 23$$

$$m = \text{module} = 2 \text{ mm}$$

$$\begin{aligned} \text{Blank Diameter} &= (Z + 2) m \\ &= (23 + 2) 2 \\ &= 50 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Tooth Depth} &= 2.25 m \\ &= 2.25 * 2 \\ &= 4.5 \text{ mm} \end{aligned}$$

$$\begin{aligned} \text{Indexing Calculation} &= 40 / Z \\ &= 40 / 23 \\ &= 1 \frac{17}{23} \end{aligned}$$

### **RESULT :**

Thus the required gear is machined using the milling machine to the required number of teeth.

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## **Lab Manual**

**Title of Course: MATERIAL TESTING LAB**  
**L-T-P scheme: 0-0-3**

**Course Code: ME493**  
**Course Credit: 2**

### **Objectives:**

1. The objective of this course is to understand the characteristics and behavior of mechanical engineering materials.
2. Students will learn standard principles and procedure to design prepare and/or test materials.
3. Know how to select materials based on their properties and their proper use for a particular facility under prevailing loads and environmental conditions.
4. Students will have exposure to practical applications including writing of a technical report related to each experiment.
5. To investigate the conventional heat treatment procedures, such as quenching and annealing, used to alter the properties of steels.

**Learning Outcomes:** The Students will learn standard principles and procedure to design prepare and/or test materials. Know how to select materials based on their properties and their proper use for a particular facility under prevailing loads and environmental conditions

The purpose of this course is to learn the mechanical properties and fundamentals of material testing.

Upon the completion of material testing lab, the student will be able to:

- ) **Understand** the characteristics and behavior of mechanical engineering materials. .
- ) Interpret and quantitatively determine standard mechanical properties.
- ) Conduct a meaningful hardness, tensile, and impact test and report the test results in a clear and useful manner.
- ) Determine appropriate tests to be employed to determine given mechanical properties using both destructive and non-destructive techniques.
- ) Assess and describe the mechanisms leading to failure when provided with a failure example with an unknown cause.
- ) Ability to analyze heat treatment of carbon steels under different rates of cooling including quenching, and change in hardness and observing its microstructural changes through metallographic studies.

### **Course Contents:**

Experiments that must be done in this course are listed below:

Experiment No.1: Izod impact test.

Experiment No.2: Charpy impact test.

Experiment No 3: Test for drawability of sheet-metals through cupping test.

Experiment No.4: Fatigue test of a typical sample.

Experiment No.5: Sample preparation and etching of ferrous and non-ferrous metals and alloys for metallographic observation

Experiment No.6: Study of heat treatment Processes.

Experiment No.7: Study of non-destructive techniques, such as dye penetration (DP) Test, ultrasonic or eddy-current test.

**Text books:**

- [1] Materials science and engineering: an introduction (7th edition), William D. Callister, Jr., John Wiley and Sons, (2007).
- [2] Chandler, H., Heat Treater's Guide, 2nd ed., ASM International, Metals Park, OH, 1995..
- [3] Materials Science and Engineering: by Raghavan V.
- [4] Dieter, G.E., *Mechanical metallurgy*, 1988, SI metric edition, McGraw-Hill,

**Recommended Equipments/Systems/Software Requirements:**

- 1. Impact testing machine, MS Specimen, cupping test apparatus.
- 2. Microscope, fatigue test apparatus

**EXPERIMENT NO: 1 IZOD IMPACT TEST**

**Aim:** To determine the Impact strength (Specific impact factor) through Izod test.

**Principle:** Static tests are not satisfactory in determining the resistance to shock or impact loads such as automobile parts are subjected to shock loads, and in the impact test a notched specimen of the material is fractured by a single blow from a heavy hammer, the energy required being a measure of the resistance to impact.

**Materials and equipments required**

Impact testing machine, MS Specimen

**Theory**

**IZOD Impact Test:**

A pendulum type single blow impact test in which the specimen, usually notched, is fixed at one end and free at other end. Specimen is broken by a falling pendulum. The energy absorbed as measured by the subsequent rise of the pendulum is a measure of impact strength or notch toughness.

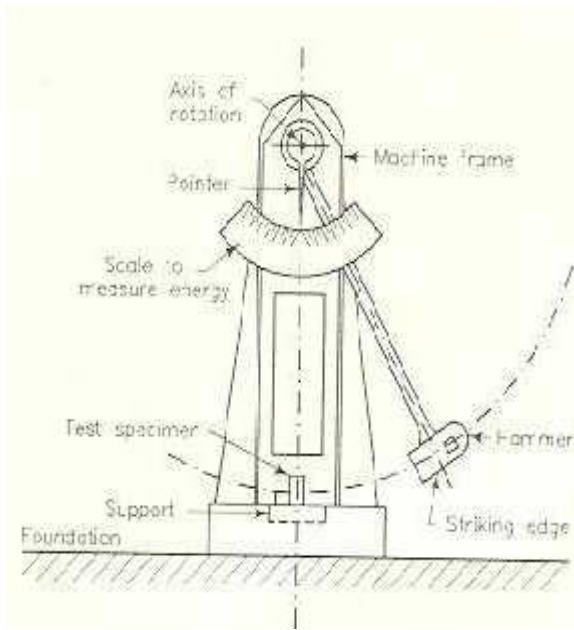
**Notch:** A slot or groove of specified characteristics intentionally cut in a test piece so as to concentrate the stress localizing the rupture.

**Notch Toughness:** The high resistance of the material to fracture under suddenly applied loads at any Stress raiser such as notch.

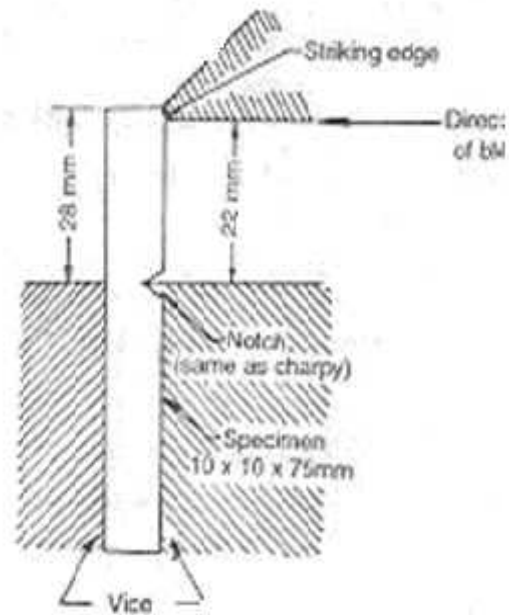
**Toughness:** The ability of the material to absorb energy and deform plastically before fracture. It is usually measured by the energy absorbed in a notched impact test like Charpy and Izod tests. The area under the stress - strain curve in a tensile test is also a measure of toughness and as such is proportional to the combined effects of tensile strength and ductility.

The Izod impact energy (I) i.e, the energy required to break the specimen is obtained directly from the test. The depth below the notch and the breadth of the specimen is measured (i.e d and b). The effective cross-sectional area below the notch is obtained ( $A=bd \text{ mm}^2$ ) hence, specific Impact factor= $I_f=I/A \text{ Joules /mm}^2$

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**Fig: Izod Impact testing equipment**



**Fig: Position of specimen for Izod test**

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**Tabular Column:**

Sl. No.	Specimen	Trials	Initial Reading K1 in J	Final Reading K2 in J	Izod Impact Value $K=K1-K2$ J	Izod impact Strength $I=K/A$ (J/Cm <sup>2</sup> )
1	MS	1				
2	MS	2				

### **Specification**

Specimen size= 75\*10\*10

Type of notch = V- Notch

Angle of notch= 45°

Depth of notch= 2mm -4mm

### **Procedure**

1. Fix the izod striker in its respective position; place the izod test specimen on supports.
2. Align the centre at the specimen notch with respect to centre of support by means of setting gauge.
3. Touch the striker to the test specimen and adjust the indicating pointer to 170J.
4. Lift the pendulum till it gets latched in its position at 900 from its vertical axis.
5. Allow the pendulum to swing freely and break the specimen.
6. After rupture apply the break to the pendulum slowly by operating break lever.
7. Note down the reading at observed energy directly on the dial as indicated by the indicating pointer.
8. Before proceeding for next test, remove the broken piece of the tested specimen and bring indicating pointer, striker to its original position at 170J.

### **Results and Conclusion**

Average impact value of Mild Steel = -----Joules

Average impact strength = -----Joules/cm<sup>2</sup>

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## **EXPERIMENT NO: 2 CHARPY IMPACT TEST**

**Aim:** To determine the Impact strength (Specific impact factor) through Charpy test.

### **Principle:**

The Charpy Impact Test is similar in principle to the Izod, but the notched specimen is supported at each end as a beam and struck by the hammer in the centre.

### **Materials and equipments required:**

Impact testing machine, MS Specimen

### **Theory**

In an impact test a specially prepared notched specimen is fractured by a single blow from a

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produced by a swinging of an impact weight (hammer) from a height. Release of the weight from the height swings the weight through the arc of a circle, which strikes the specimen to fracture at the notch. Here it is interesting to note that height through which hammer drops determines the velocity and height and mass of a hammer combined determine the energy. Energy used can be measured from the scale given. The difference between potential energies is the fracture energy. In test machine this value indicated by the pointer on the scale. This energy value called impact toughness or impact value, which will be measured, per unit area at the notch.

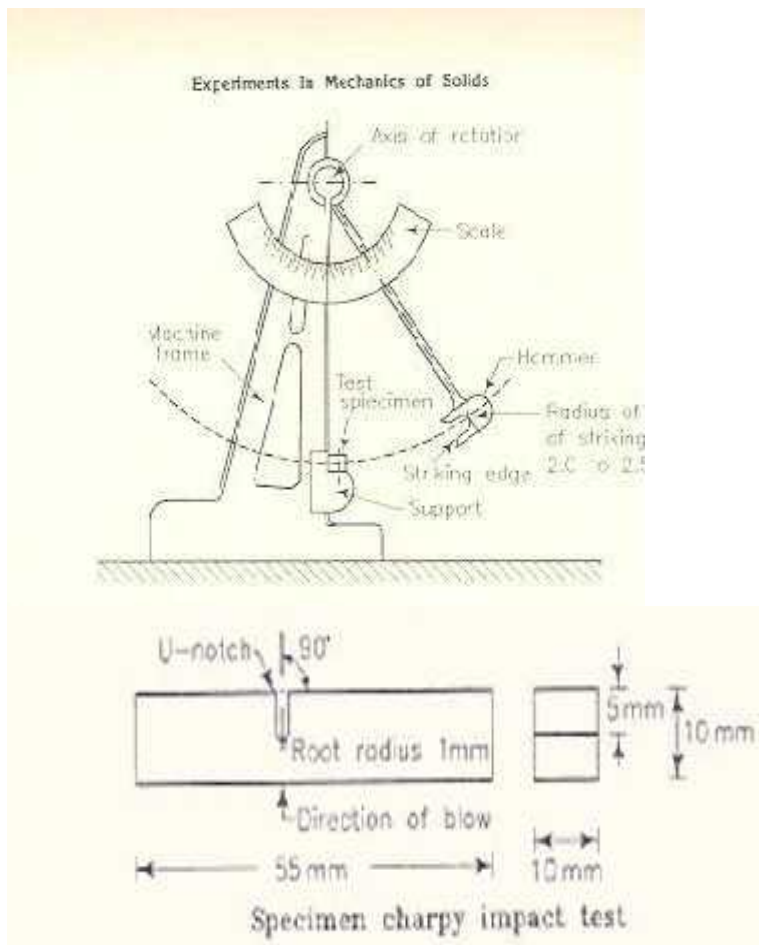
### **Specification**

Specimen size=  $55 \times 10 \times 10$

Type of notch = U - Notch

Angle of notch=  $45^\circ$

Depth of notch= 2mm-5mm



**Fig: Charpy impact testing equipment**  
**Charpy test**

**Fig: Specimen for**  
**Charpy test**



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**Tabular Column:**

Sl. No.	Specimen	Trials	Initial Reading K1 in J	Final Reading K2 in J	Charpy Impact Value $K=K1-K2$ J	Charpy impact Strength $I=K/A$ (J/Cm <sup>2</sup> )
1	MS	1				
2	MS	2				

### **Procedure**

1. Fix the charpy striker in its respective position; place the charpy test specimen on supports.
2. Align the centre at the specimen notch with respect to centre of support by means of setting gauge.
3. Touch the striker to the test specimen and adjust the indicating pointer to 300J.
4. Lift the pendulum till it gets latched in its position at 1400 from its vertical axis.
5. Allow the pendulum to swing freely and break the specimen.
6. After rupture apply the break to the pendulum slowly by operating break lever.
7. Note down the reading at observed energy directly on the dial as indicated by the indicating pointer.
8. Before proceeding for next test, remove the broken piece of the tested specimen and bring indicating pointer, striker to its original position at 300J.

### **Results and Conclusion**

Average impact value of Mild Steel = -----Joules

Average impact strength = -----Joules/cm<sup>2</sup>

---

### **EXPERIMENT NO: 4 Test for drawability of sheet-metals through cupping test**

**Aim:** Test for drawability of sheet-metals through cupping test.

#### **Theory:**

##### ***1.1 Limiting draw ratio:***

In deep drawing, the longitudinal tensile stress on the cup leads to thinning and tearing.

There is a maximum size of the blank which can be drawn out without tearing. The limiting draw ratio (LDR) is defined as the highest value of the ratio of the blank diameter

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$$\text{LDR} = (D_0/D_p)_{\max} = e^{\eta} \quad \dots\dots 1.1$$

Where  $\eta$  is the efficiency of drawing.

The maximum LDR for efficiency =100% is equal to 2.7. The above can be proved as followed:

Consider the deep drawing of a cup. The maximum true strain of the blank during deep drawing is:

$$\epsilon_{\max} = \ln \left( \frac{D_0}{D_p} \right)$$

For ideal drawing we can write the draw stress = Y

For maximum or limiting draw, we can equate the draw stress to yield strength of the material.

$$Y = \text{draw stress} = y_{\max}$$

From which we get:

$$\epsilon_{\max} = \ln \left( \frac{D_0}{D_p} \right) = 1 \quad \dots\dots 1.3$$

$$\text{From the above we get } \frac{D_0}{D_p} = e = 2.7 \quad \dots\dots 1.4$$

If we assume an efficiency of 70% the maximum LDR is about 2. That means the maximum reduction possible in single deep drawing step is 50%.

LDR is affected by the punch dia, lubrication, the hold down pressure, and clearance. LDR is also affected anisotropy of the material of the blank. One way of increasing the drawability of sheets is to impart anisotropy through grain texturing. Anisotropic behavior refers to direction dependency of mechanical properties. Normal anisotropy or plastic anisotropy of a sheet metal is given by the ratio of the width strain to thickness strain.

$$R = \frac{\ln (w_0/w_f)}{\ln (t_0/t_f)} \quad \dots\dots\dots 1.5$$

Subscript f denotes final dimension.

If the true strain along width is equal to that along thickness direction  $R = 1$ . That is the case of isotropic material. On the other hand, if R is very less or higher than unity it indicates considerable anisotropy.

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The thickness strains are very difficult to measure. Therefore we may write R using length, applying volume constancy as:

$$R = \frac{l_1 (w_0/w_f)}{l_1 (w_0/w_f)} \dots\dots\dots 1.6$$

For rolled sheets, we can consider planar anisotropy, which means the orientation of the test specimen with respect to rolling direction will decide the properties. Planar anisotropy taken at different angles with respect to rolling direction, averaged out is defined as:

$$\bar{R} = \frac{R_0 + 2 R_{45} + R_{90}}{4} \dots\dots\dots 1.7$$

The average normal anisotropy value depends on the material structure, grain size, etc. Typically, for HCP R values are high. Similarly, finer the grains lower is the value of average anisotropy.

Material	$\bar{R}$
Hot rolled steel	0.8 to 1
Stainless steels	0.9 to 1.2
Aluminium alloys	0.6 to 0.8
Copper	0.6 to 0.9

It has been demonstrated experimentally that as the average normal anisotropy increases, the LDR also increases, almost linearly. It is shown in figure below:

Planar anisotropy of a sheet metal can be given by:

$$R = \frac{R_0 + 2 R_{45} + R_{90}}{4} \dots\dots\dots 1.8$$

A low value of planar anisotropy enhances the LDR.

LDR in crystalline materials can be controlled through anisotropy. Anisotropy can be controlled through grain texture. Texture can be imparted through rolling or other thermo-mechanical processing. In plane strain stressing of the cup wall, if textured structure can improve the normal anisotropy, LDR will have increased – meaning that drawability has been enhanced. Planar anisotropy sometimes causes a type of defect in drawn cups called earing. Ears are fold like structures that form along the cup length.

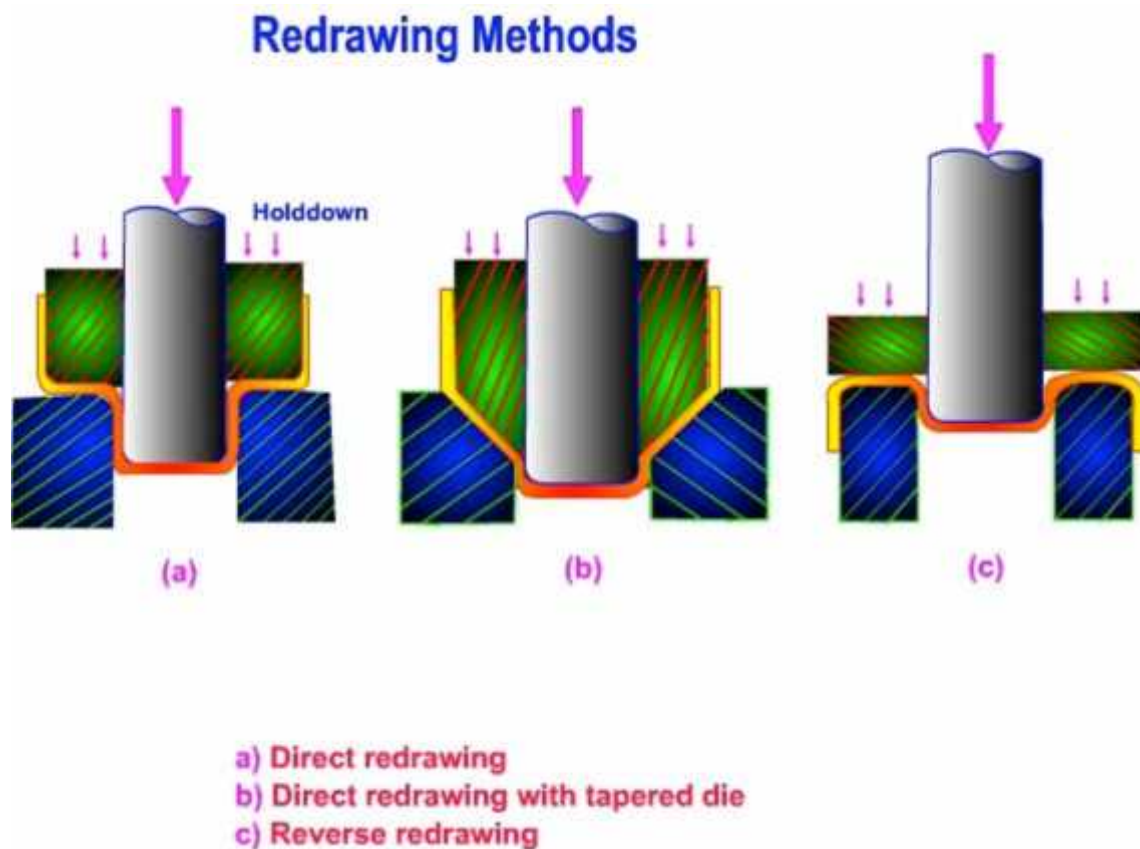
### ***1.2 Redrawing:***

Redrawing is reduction in diameter and increase in length of a cup which has been drawn to a certain draw ratio. In case of materials which are difficult to draw in one step, redrawing is performed. Generally, during the first stage upto 40% reduction is achieved. In the first redrawing after drawing, maximum of 30% reduction can be set. In

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the second redrawing stage, 16% reduction is set. In direct redrawing process, the angle of bending undergone by the cup is less than  $90^\circ$ , thereby reducing the draw force. In reverse redrawing, the outside surface of the drawn cup becomes the inner surface during redrawing. Wrinkling is controlled to a good extent in this process. Friction is higher in redrawing. Therefore larger reductions cannot be affected in redrawing.



**Fig. Redrawing**

### ***1.3 Formability of sheet metals:***

Formability of sheet metal is the ability of the sheet metal to undergo forming to the desired shape and dimensions, without failure. Sheet metal operations are very complex. Therefore, simple tensile or compressive tests may not be sufficient to evaluate the formability. We can determine the ductility, anisotropy and other parameters from the uniaxial tensile test. A number of other tests have been devised to determine formability of sheet metals. Cupping tests: In order to reflect the biaxial state of stress involved in drawing, a few tests have been devised to obtain the drawability. In Erichsen test a sheet metal is placed on the die cavity and clamped with 1000 kg load. A spherical ball of 20 mm diameter is pressed into the sheet using hydraulic force. The test is terminated at the point of maximum load or until a crack forms on the sheet. Erichsen number is the

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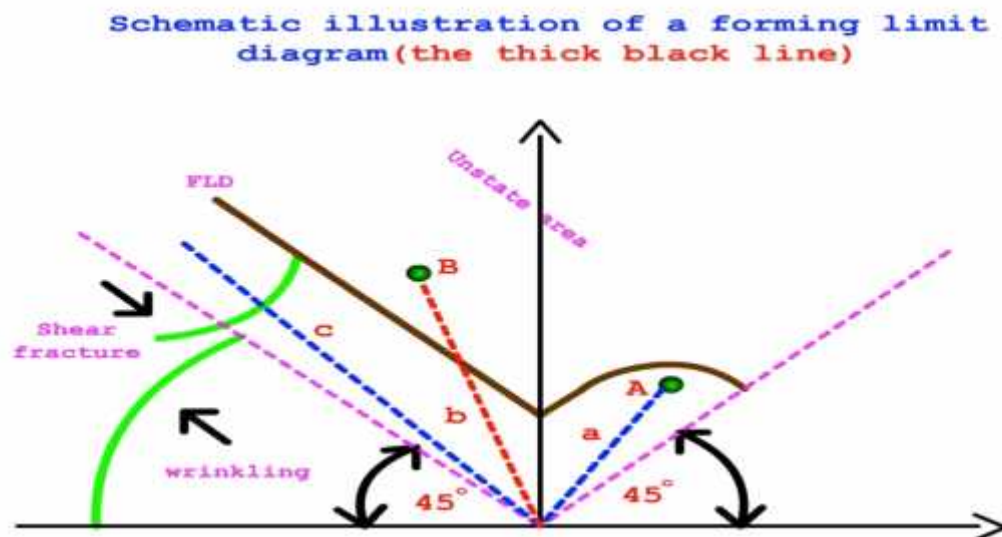
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distance through which the sheet has stretched. Bulge test: A sheet metal clamped around its periphery, is bulged by hydraulic pressure. The depth of penetration before failure is taken to be a measure of formability. This test is also done to study effective stress-effective strain curve for biaxial stress.

Swift test involves pure drawing, while Fukui test combines drawing and stretching, by using a hemispherical punch which produces a conical cup.

### ***1.4 Forming limit diagram (FLD):***

Prediction of failure during drawing is possible by construction forming limit diagrams. Circles of a specific pattern are etched on the surface of the sheet metal, by chemical etching or photo printing. The circles may be 2.5 to 5 mm in diameter. Then the blank is subjected to stretching using suitable punch and draw bead. The deformations of the circles in regions where necking has happened are measured. Lubrication may be used if needed. Major and minor strains on the circles are found from the deformed circle. Circles get deformed into ellipse. If we take a wide rubber plate, draw a circle at the centre and stretch the rubber along longitudinal direction. We can see that the circle now gets stretched to an ellipse. On the other hand, if a circle is drawn on the surface of a spherical balloon and the balloon expanded, the circle becomes a larger circle. This means that both minor and major axes have undergone equal strain.



**Fig. A typical forming limit diagram**

Length of major axis of the stretched circle minus dia of original circle divided by original dia of circle gives the major strain (engineering strain). Similarly engineering minor strain

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is negative strain. By comparing the deformed circles, with original circled we can also predict if the sheet has undergone thinning or not. A larger ellipse is an indication of thinning. After a number of such tests, the forming limit diagram is drawn, between major strain and minor strain. The boundary between safe and failed regions is represented in the forming limit diagram. Any strain represented on the diagram by a point lying above the curve indicates failure. The strain path can be varied by varying the width of the sheet. Different materials have different forming limit diagrams. The higher the position of the curve greater is the formability.

A typical formability limit diagram is known as Keeler-Goodwin diagram. The curves shift upward if the sheet thickness is increased – indicating increase in forming limit. In this diagram, a few straight lines indicating the strain paths are also shown. The vertical line at the center (zero minor strain) represents plane strain. In biaxial strain, both strains are equal. This is represented by the inclined line on right side of the diagram. Simple uniaxial tension is represented on the left side by a line with slope 2:1. This is due to the fact that Poisson's ratio for plastic deformation is  $\frac{1}{2}$ . Negative minor strain means there is shrinkage. It is better to have negative minor strain because; the major strain for failure will be higher with negative minor strain. Some of the factors which affect the forming limit of a material are: strain rate sensitivity, anisotropy, thickness of the sheet, strain hardening etc. The forming limit curve will be shifted upwards for a thicker sheet.

### ***1.5 Hydroforming of sheet metals:***

Forming of sheet metals using hydrostatic pressure of a fluid has immense potential for automotive and aerospace applications. Sheet metal products meant for these applications can be formed using hydroforming. Hydrostatic pressure enhances the ductility. Further, it also enhances the LDR. There are two methods of hydrostatic forming of sheet metals, namely hydro-mechanical forming and hydroforming.

#### ***1.5.1 Hydro-mechanical forming:***

In this method of cup drawing, an oil or water chamber underneath the cup contains high pressure fluid. The fluid pressure exerted on the bottom side of the cup ensures that the blank is pressed against the punch, thereby reducing neck formation. The hydraulic pressure also enhances the lubrication between die and blank. This better lubrication improves LDR. If pressurized fluid is supplied onto the edges of the blank, the drawability is further enhanced through reduced friction. Reverse redrawing or redrawing can also be carried out by this process.

#### ***1.5.2 Hydro-forming:***

In hydroforming the fluid pressure is directly utilized for deforming the material. Bulging of tubes is one example for hydroforming. In this process, the high pressure fluid held inside the tube expands the tube at the section where there is no restraint.

### ***1.6 Defects in sheet metal formed products:***

One of the major defects in drawing of sheet metals is thinning or localized necking, which leads to crack formation or tearing. During cup drawing, material near the punch radius is subjected to maximum thinning and therefore, the bottom of the cup gets separated. Providing large radius on the punch or reducing the punch load may eliminate this defect. Radial cracks in the flange of the cup are an indication of poor ductility of the material. Buckling of the flange material due to high compressive stress leads to wrinkling. The critical circumferential compressive load is lower for thin sheets. We may imagine that each circumferential element of the metal acts like a column subjected to buckling. Increasing the hold down pressure will eliminate wrinkling. Large grain size of sheet metals results in poor surface finish and the surface develops orange peel effect, which is surface roughness. This defect can be prevented using fine grained material for drawing. Surface defects called stretcher strains occur on low carbon steel sheets due to yielding. Depressions form on the surface oriented along directions of maximum shear, namely, 45 degrees. They merge and form rough surface. The entire surface is covered by stretcher strains. Temper rolling or skin rolling treatment given at room temperature will eliminate stretcher strains. In temper rolling, a small cold reduction of 1 to 2% is given to the sheet. Formation of wavy edge on top of the cup, called earing, happens due to anisotropy of the material, especially planar anisotropy. Primarily, preferred orientation of grains is responsible for this defect.

**Example 1:** A sheet is subjected to tensile stretching during which it undergoes a stretching of 25% and also undergoes decrease in thickness of 12%. What is its limiting draw ratio?

Solution: The limiting draw ratio can be found from the relation between R and LDR.

$$R = \text{width strain/thickness strain} = \frac{L_f (w_0/w_f)}{L_f (t_0/t_f)}$$

$$\text{We are given } L_f/L_0 - 1 = 0.25 \text{ or } L_f/L_0 = 1.25$$

$$\text{Also, } 1 - t_f/t_0 = 0.12, \text{ Or } t_f/t_0 = 0.88$$

$$\text{From volume constancy, } L_0 t_0 w_0 = L_f t_f w_f$$

$$w_0/w_f = L_f t_f / L_0 t_0 = 1.25 \times 0.88 = 1.1$$

$$\text{Therefore, } R = 0.746$$

From the graph between R and LDR, we get the LDR for R=0.746, assuming planar anisotropy. LDR = 2.25

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#### **EXPERIMENT NO: 4 FATIGUE TEST**

**Aim:** To determine the fatigue failure of a given specimen.

**Apparatus:** fatigue testing machine, specimen

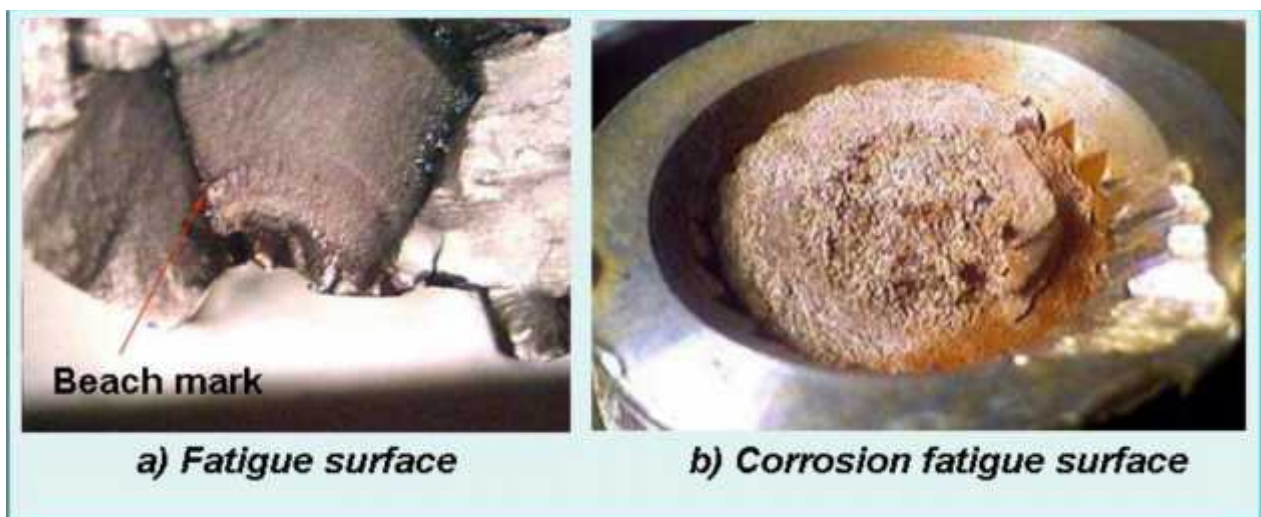
**Theory:**



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Characteristics of fatigue failure Most engineering failures are mainly due to fatigue in which the components are subjected to fluctuating or cyclic loading such as suspended bridges, rails, or airplane wings. Though the fluctuating load is normally less than the yield strength of the materials, it results in fracture behaviour which is more severe than that achieved from static loading. Fatigue failures are therefore unpredictable, and provide high-risk situations, if the operators are not aware of material behaviour when subjected to fatigue loading. Fatigue failures can be easily observed from its unique characteristics of fracture surfaces, revealing as a beach mark pattern as shown in figure 1 (a). Fatigue failures are also driven by severe environment. For example, corrosion fatigue is a combined situation of fatigue loading in a corrosive environment as illustrated in figure 1 (b).



***Figure 1: Fatigue surfaces.***

### ***1.2 Stress cycles and the S-N curve***

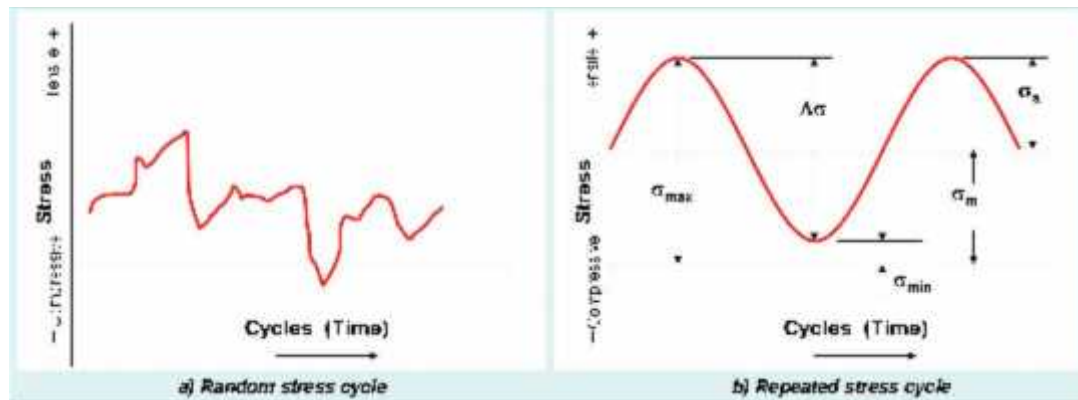
Cyclic loading in general has no repeated patterns or in situations where overloading occurs as seen in figure 2 (a). However, in order to investigate the fatigue behaviour according to engineering purposes, a simple relation between stress and number of cycles to failure (time) can be expressed in a sinusoidal curve as illustrated in figure 2 (b). Fatigue behaviour of materials can thus be practically described according to the parameters given as follows;

- Maximum stress (  $\sigma_{max}$  )
- Minimum stress (  $\sigma_{min}$  )
- Stress range (  $\Delta\sigma$  ) =  $\sigma_{max} - \sigma_{min}$
- Mean stress =  $(\sigma_{max} + \sigma_{min})/2$
- Stress amplitude =  $(\sigma_{max} - \sigma_{min})/2$
- Stress ratio =  $\sigma_{min} / \sigma_{max}$



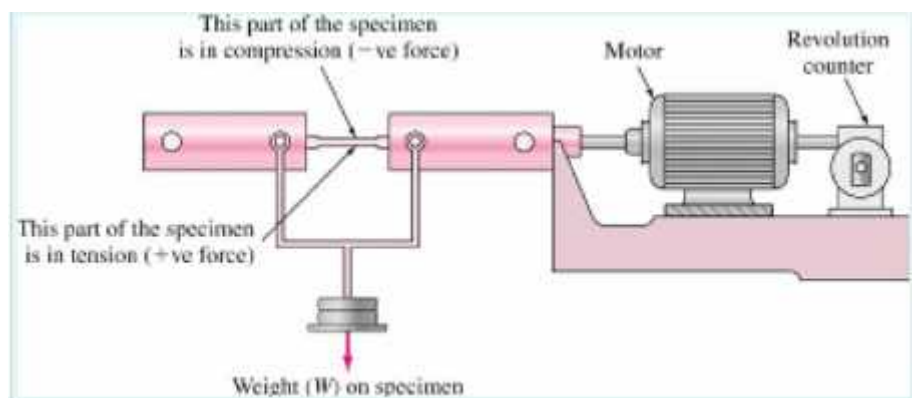
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**Figure 2:** Relationships between stress and time or no. of cycles.

These parameters significantly affect the fatigue behaviours of the materials. This is for example, increasing in the maximum stress as well as mean stress and stress range leads to more severe fatigue conditions. If the maximum and minimum stresses are tensile, they are considered to be more dangerous than compressive stresses as the tensile stresses will open up the fatigue crack. Furthermore, if the maximum and minimum stresses are in similar amounts but having the opposite signs (tensile and compressive stresses), the stresses in this case is called completely reversed cyclic stresses in which the stress ratio equals -1. For instance, a rotating-beam fatigue machine as shown in figure 3, fitted with a fatigue specimen hung by a weight in the middle. Specimen rotating action is driven by a motor on the right results in tensile stress in the lower fibrous and compressive stress in the upper fibrous of the specimen gauge length. Therefore, along the gauge length, specimen will be subjected to alternating tensile and compressive stresses similar to the reversed cyclic loading. The specimen will be fatigue loaded until failure. The number of cycles to failure according to the cyclic stress applied will then be recorded.



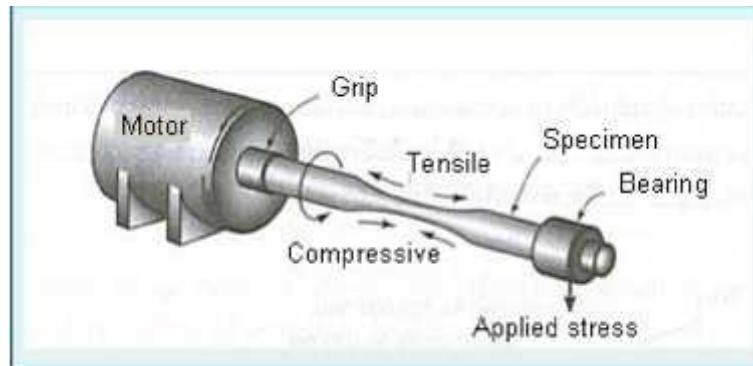
**Figure 3:** Rotating-beam fatigue testing machine [2].

The fatigue testing can also be conducted using an instrument as shown in figure 4. The fatigue specimen is gripped on to a motor at one end to provide the rotational motion whereas the other end is attached to a bearing and also subjected to a load or stress. When

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specimen gauge length are subjected to tensile and compressive stresses respectively. Therefore, stress varies sinusoidally at any point on the specimen surface. The test proceeds until specimen failure takes place. The revolution counter is used to obtain the number of cycles to failures corresponding to the stress applied.



***Figure 4: Fatigue testing machine [3].***

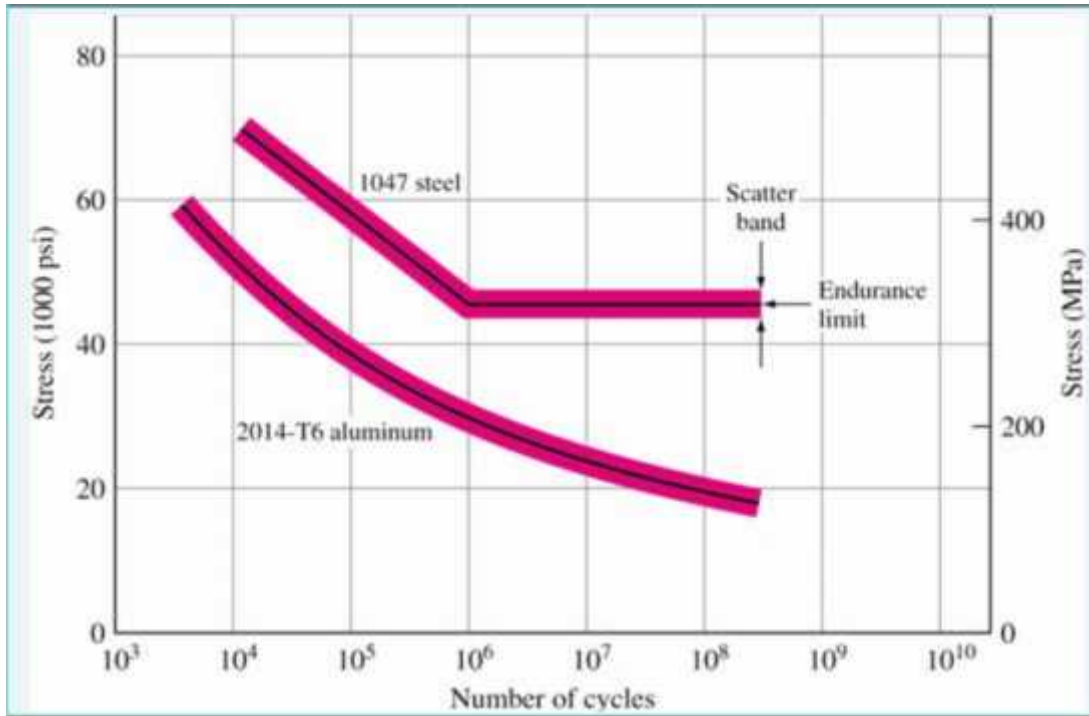
Increasing of the weight applied to the fatigue specimen results in a reduction in number of cycles to failure. We can then use the experimental results to construct an S-N curve as illustrated in figure 5. The fatigue test is normally conducted using at least 8-12 specimens in order to provide sufficient information for the interpretation of fatigue behaviour of the tested material. The S-N curve shows a relationship between the applied stress and the number of cycles to failure, which can be used to determine the fatigue life of the material subjected to cyclic loading. High applied cyclic stress results in a low number of cycles to failure. For example, the fatigue testing of a 1047 steel provides a small number of cycles to failure at a high cyclic stress. As the cyclic stress reduces, the number of cycles to failure increases. At the fatigue endurance limit, there will be a certain value of the cyclic stress where specimen failure will not occur. This cyclic stress level is called the fatigue strength. According to figure 4, the fatigue strength of 1047 steel is approximately 320 MPa. However, nonferrous alloys such as some alloys of aluminium, magnesium and copper will not normally show the fatigue endurance limit. The slope can be found gradually downwards with increasing number of cycles to failure and shows no horizontal line. In such a case, the fatigue strength will be defined at a stress level where the number of cycles to failure reaches  $10^7$  or  $10^8$  cycles.

The fatigue strength of engineering materials is in general lower than their tensile strength. A ratio of the fatigue strength to the tensile strength as described in equation 1 is called the fatigue ratio. It is normally observed that, in the case of steels, the fatigue strength increases in proportional to the tensile stress. Therefore, improving the tensile strength by hardening or other heat treatments normally increases the fatigue strength of the material. However for nonferrous metals such as aluminium an alloy, the fatigue ratio is found approximately 0.3 and the improvement of the tensile strength do not necessary increases the fatigue strength of the material.

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$$\text{Fatigue ratio} = \frac{F}{T} \frac{S_i}{S_i} \frac{h}{h} \quad (1)$$



**Figure 5:** S-N curves of 1047 steel and 2014-T6 aluminium alloy [2].

The fatigue S-N curve are generally considered in 2 cases, which are high cycle fatigue and low cycle fatigue. The study of high cycle fatigue concerns about fatigue behaviour of the materials which is controlled by the applied load or stress and where the gross deformation taking place is elastic. However highly localized plastic deformation can also be observed for example at the crack tip. The number of cycles to failure in this case is normally determined at higher than 10<sup>5</sup> cycles. The S-N curve in the high cycle fatigue region can be expressed using the Basquin equation as follow;

$$N_a p = C \quad \dots(2)$$

where  $a$  is Stress amplitude

$p$  and  $C$  is Empirical constants

In the case of low cycle fatigue, the fatigue behaviour is controlled by elastic and plastic strains and the number of cycles leading to failure is lower than 10<sup>4</sup> or 10<sup>5</sup> cycles. Gross plastic deformation is due to high levels of the applied stresses and leads to difficulties for stress interpretation. The low cycle fatigue data is generally presented as a relationship between plastic strain ( $\epsilon_p$ ) and the number of cycles to failure ( $N$ ) as illustrated in figure 6. When plotted in a log-log scale, the relationship can be expressed following the Coffin-Manson relationship

$$\epsilon_p/2 = f(2N)^c$$

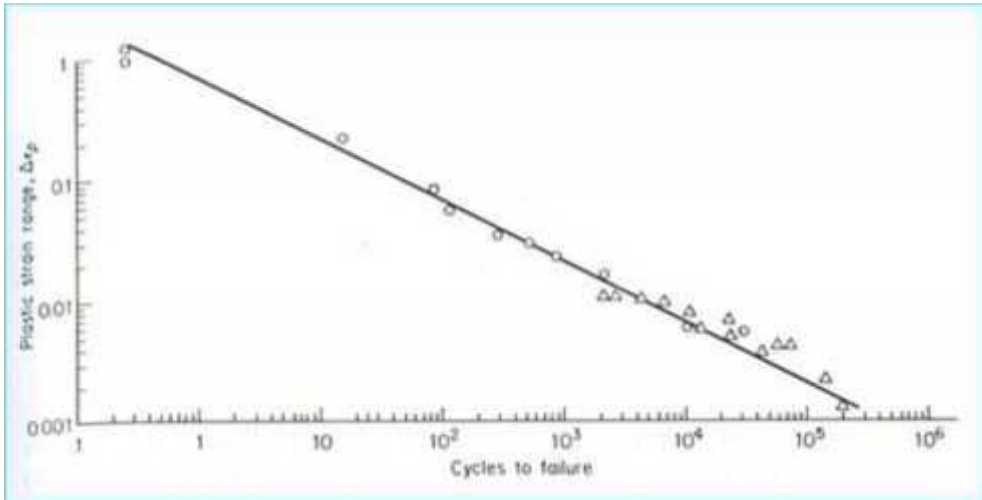
where  $\epsilon_p/2$  is Plastic strain amplitude

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2N is Strain reversal to failure, whereby 1 cycle equals 2 reversals

C is Fatigue ductility exponent, having the values ranging from -0.5 to 0.7.



**Figure 6:** Low cycle fatigue curve ( $\Delta_p$  vs  $N$ ) 347 stainless steel [1].

### 1.3 Cyclic stress-strain curve

Materials response differently to static and cyclic loading as illustrated from stress-strain relationship. If we first consider figure 7 (a), which shows the stress-strain loop under controlled strain (at constant strain amplitude), the stress-strain relation follows the OAB line when subjected to tensile loading passing the yield point. On unloading, the stress-strain relation follows BC line and goes into the compressive region having a negative strain. It is noticed that the compressive yield is somewhat smaller than that obtained from the tensile yielding. This phenomenon is called the Baushinger effect. Reloading results in a hysteresis loop and gives a total strain  $\Delta = \Delta_e + \Delta_p$  where  $\Delta_e$  is the elastic strain range and  $\Delta_p$  is the plastic strain range as shown in figure 7 (a).

Furthermore, plastic deformation taking place during cyclic loading causes microstructural changes such as structure and density of dislocations. Therefore, after every cycle applied the material responses slightly differently to the cyclic loading. The material will experience either cyclic hardening or cyclic softening, and both change the shape of the hysteresis loop as illustrated in figure 8. The hysteresis loop generally stabilizes after being cyclic loaded about 100 cycles. Figure 7 (b) demonstrates how materials response differently to static loading and cyclic loading. The former shows a monotonic  $\sigma$  -  $\epsilon$  curve whereas the latter provides a cyclic  $\sigma$  -  $\epsilon$  curve. This cyclic  $\sigma$  -  $\epsilon$  curve is constructed by connecting the tip of the stabilized hysteresis loops obtained from a number of fatigue tests at different controlled strain amplitude. Moreover, the cyclic  $\sigma$  -  $\epsilon$  curve can also be expressed in a power curve analogy to that obtained from static loading as shown in equation 4.

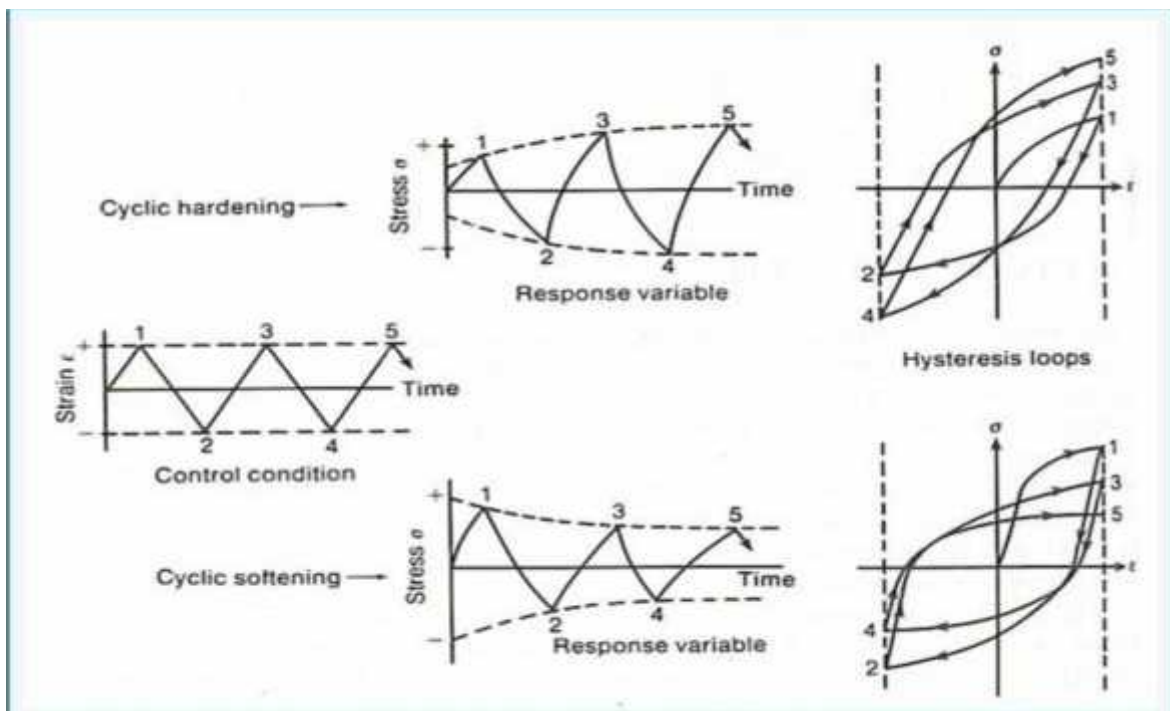
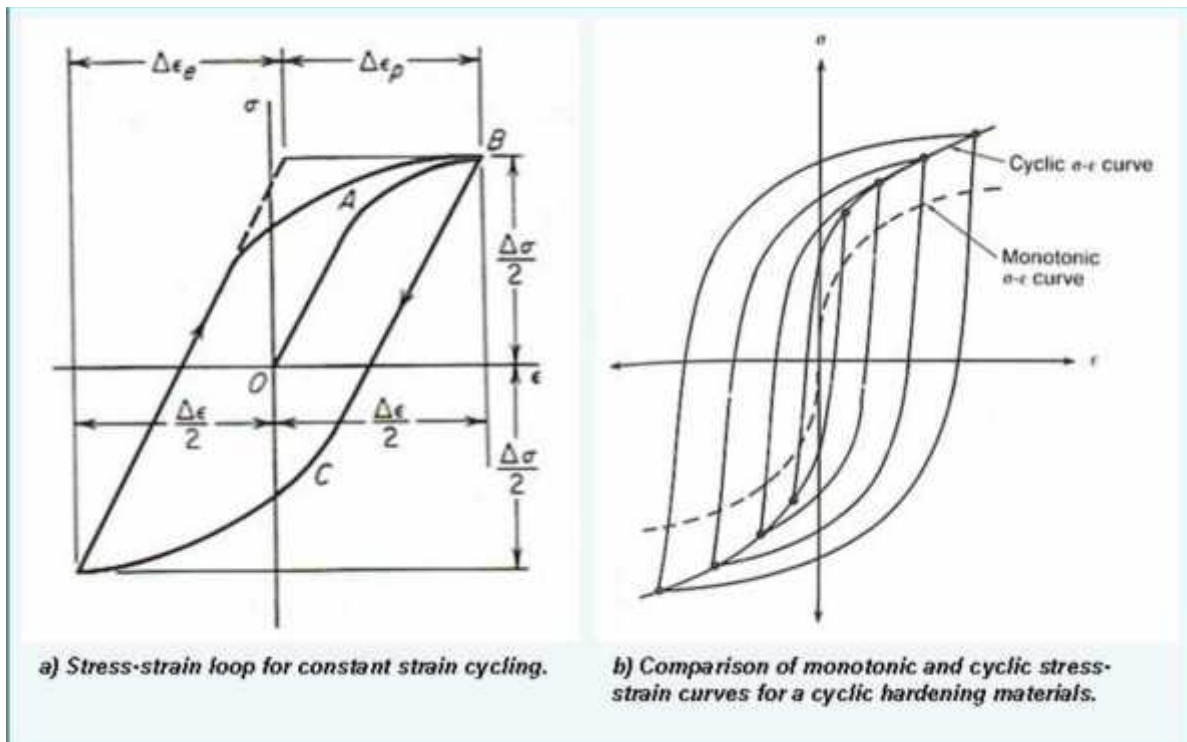
$$\Delta = K (\Delta_p)^n$$

where  $n$  is the cyclic strain hardening exponent

$K$  is the cyclic strength coefficient

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**Figure 8:** Responses of metals to cyclic strain cycles [1].

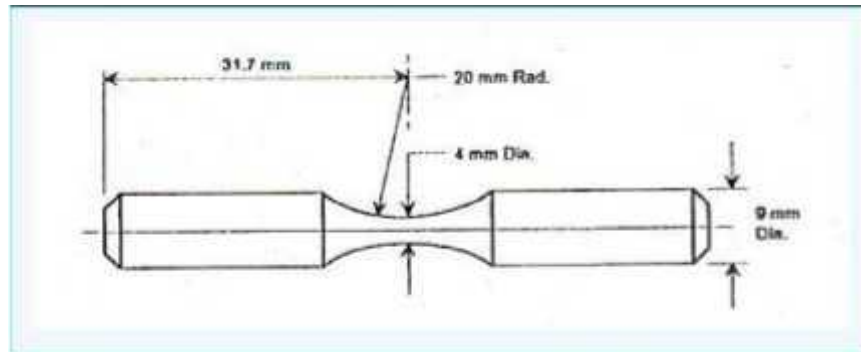
*Factors influencing fatigue properties of materials:*

As mentioned previously, characteristics of the applied stresses such as maximum stress, mean stress and stress ratio significantly affects the fatigue behaviour of the materials. However, there are a range of factors which are also found to significantly influence the fatigue properties of engineering materials. These are for example, stress concentration, size effect, surface effect, combined stresses, cumulative fatigue and sequence effect, metallurgical variables, corrosion and temperature. Generally the fatigue crack initiations

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concentration which accounts for further fatigue crack propagation and eventually lead to global failure. Corrosive environment and high service temperatures are reckoned to have negative effects on fatigue properties of the materials as they accelerate faster rates of both fatigue initiation and propagation.



*Fatigue specimen*

### **Materials and equipment**

1. Fatigue specimens
- 2 Micrometer or vernier calliper
- 3 Permanent pen
- 4 Fatigue testing machine

### **Experimental Procedure**

Measure dimensions of brass and steel specimens provided and record in tables 1 and 2. If the distance from the load end to the minimum diameter of the specimen is 125.7 mm, the bending stress,  $\sigma$ , can be calculated the bending stress for a load  $P$  (N) is shown in equation  $\sigma = 125.7 \sqrt{32 P / (\pi \times D^3)}$

Conduct the fatigue test at room temperature using the fatigue testing machine as shown in figure. Fit one end of the specimen to a motor and fit the other end to a bearing hung with a known weight, indicating the stress applied to the specimen. Start the motor to rotate the specimen at a constant speed. The revolution counter is used to record the number of cycles to which the specimen fails. Record the result in table 1.

Change the weights used and follow the experiment. Again, record the results in tables 1.

Construct the S-N curves of the steel specimens.

Investigate fracture surfaces of broken fatigue specimen and sketch the result in tables 1.

Analyze, discuss the obtained results. Give conclusions.

### **4. Results**

Details	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
---------	------------	------------	------------	------------	------------

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Specimen diameter (mm)					
Cross-sectional areas (mm <sup>2</sup> )					
Weight (kg)					
Maximum stress (MPa)					
Frequency (Hz)					
No. of cycles to failure (cycles)					
Fracture surfaces					

*Table 1: Fatigue data of steel specimens.*

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### **EXPERIMENT NO: 5 Sample preparation and etching of ferrous and non-ferrous metals and alloys for metallographic observation.**

**Aim:** To prepare Sample and etching of ferrous and non-ferrous metals and alloys for metallographic observation

**Introduction:**

- ) The credit for originating Metallographic examination goes to Alloys Beck Von Widmanstatten (between 1808 & 1840).
- ) Microscope was employed for the purpose in 1841, when Paul Annosow used the instrument to examine the etched surfaces of oriental steel blades.
- ) It was around 1890 when metallographic technique received general recognition, largely as a result of the work of Professor Henry C. Sorby in England.
- ) *Metallography* is the general study of metals and their behavior, with particular reference to their microstructure and macrostructure.
- ) *Microstructure* is the characteristic appearance and physical arrangement of metal molecules as observed with a microscope.
- ) *Macrostructure* is the appearance and physical arrangement as observed with the naked eye.
- ) *Metallurgical Microscope* is by far the most important tool of the metallurgist from both the scientific and technical stand point. It helps determining:
  - a) Grain size and shape.
  - b) Size, shape and distribution of various phases and inclusion.
  - c) Mechanical and thermal treatment of the alloys.

Preparation of Specimen:

Preparation of specimen is necessary to study its microstructure, because the metallurgical

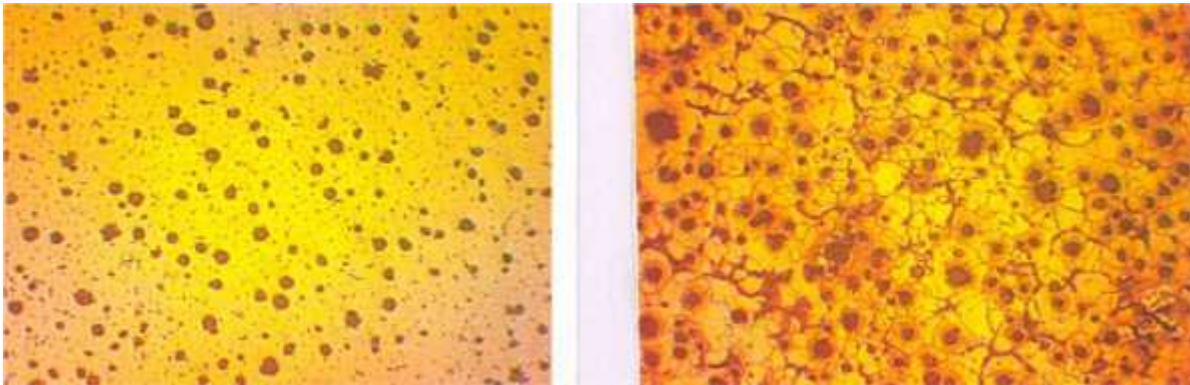


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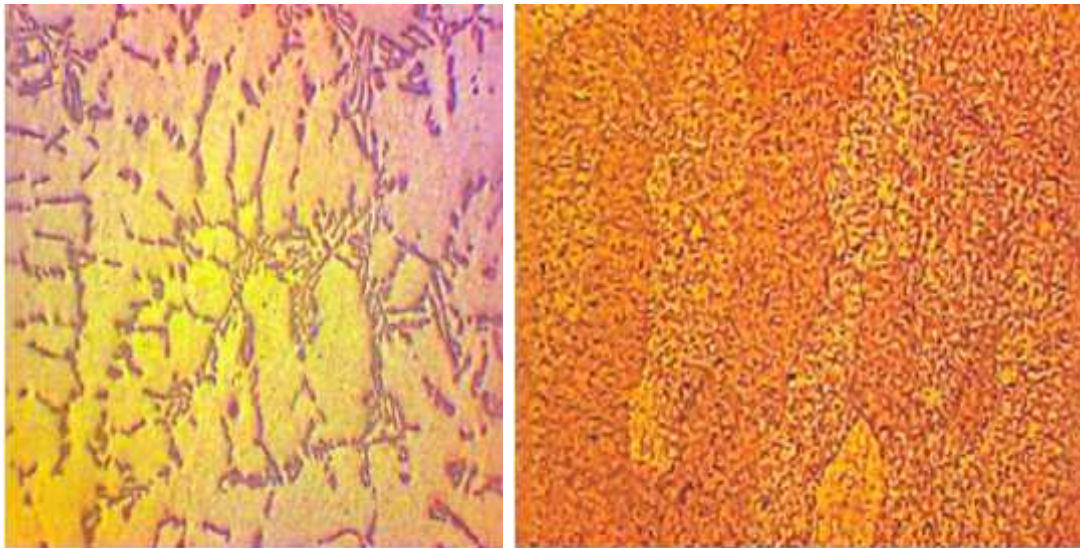
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specimen to obtain the final image of the metal structure. Following are the steps involved in the preparation of specimen:

- 1) *Selection of specimen:* When investigating the properties of a metal or alloy, it is essential that the specimen should be selected from that area (of the alloy plate or casting) which can be taken as representative of the whole mass.
- 2) *Cutting of the specimen:* After selecting a particular area in the whole mass, the specimen may be removed with the help of appropriate cutting tools.



**S G Iron**



**Aluminium Alloy**

**Copper Alloy**

- 3) *Mounting the specimen:* If the specimen is too small to be held in hand for further processing, it should be mounted on a thermoplastic resin disc or some other low melting point alloy.
- 4) *Obtaining flat specimen surface:* It is first necessary to obtain a reasonably flat surface on the specimen. This is achieved by using a fairly coarse file or machining or grinding.
- 5) *Intermediate and Fine Grinding:* Intermediate and fine grinding is carried out using emery papers of progressively finer grade.



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**6) Rough polishing:** A very small quantity of diamond powder (particle size about 6 microns) carried in a paste that is oil-soluble is placed on the nylon cloth-covered surface of a rotating polishing wheel. The specimen is pressed against the cloth of the rotating wheel with considerable pressure and is moved around the wheel in the direction opposite to rotation of the wheel to ensure a more uniform action.

**7) Fine polishing:** The polishing compound used is alumina ( $\text{Al}_2\text{O}_3$ ) powder placed on a cloth covered rotating wheel. Distilled water is used as a lubricant. Fine polishing removes fine scratches and very thin distorted layer remaining from the rough polishing stage.

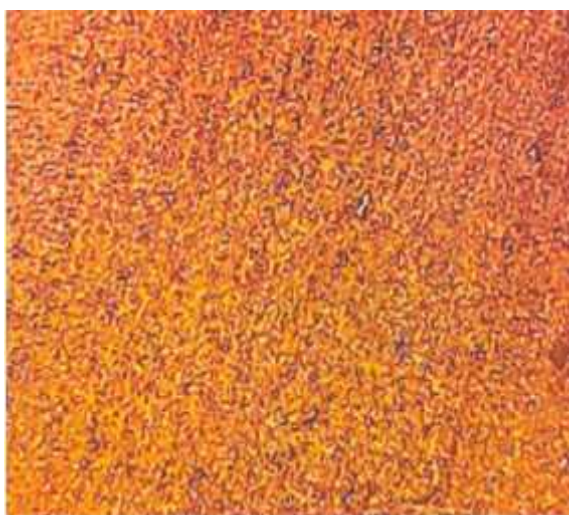
### **8) Etching:**

**Necessity-**Even after fine polishing, the granular structure in a specimen usually cannot be seen under the microscope; because grain boundaries in a metal have a thickness of the order of a few atom diameters at best, and the resolving power of a microscope is much too low to reveal their presence. In order to make the grain boundaries visible, after polishing the metal specimens are usually etched. Etching imparts unlike appearances to the metal constituents and thus makes metal structure apparent under the microscope.

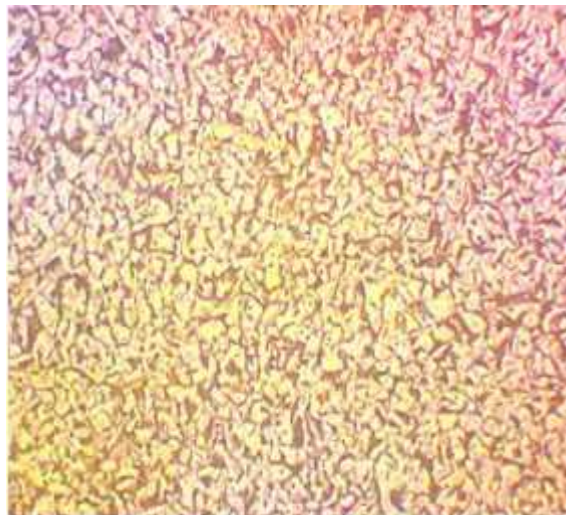
**Method-** Before etching, the polished specimen is thoroughly washed in running water. Then, the etching is done either by,

- (i) Immersing the polished surface of the specimen in the etching reagent or by
- (ii) Rubbing the polished surface gently with a cotton swab wetted with the etching reagent.

After etching, the specimen is again washed thoroughly and dried. Now, the specimen can be studied under the microscope.



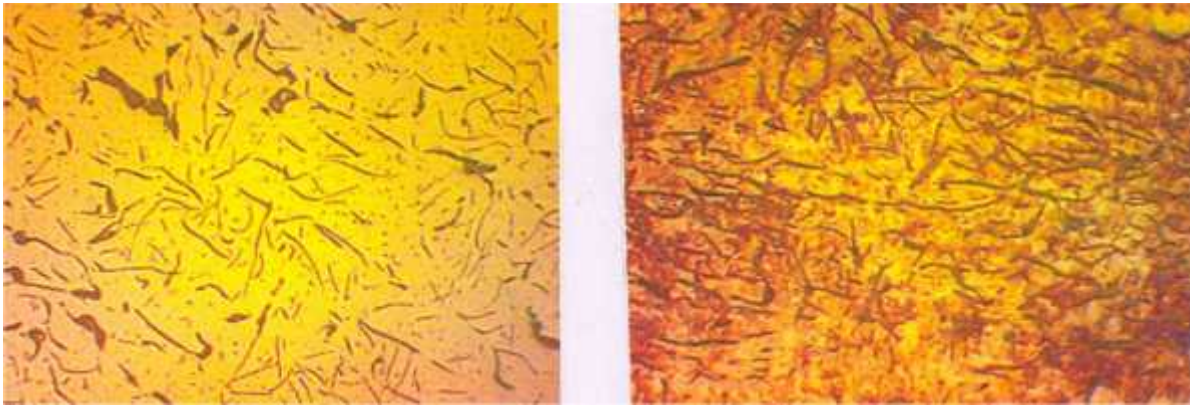
**Mild Steel**



**High Speed Steel**

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**Grey Cast Iron**

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### **EXPERIMENT NO: 6 Study of heat treatment process.**

**Aim: Study of heat treatment process.**

#### **Theory:**

#### **HEAT TREATMENT PROCESSES**

In general, heat treatment can be defined as an operation, or the combination of operations that involve heating and cooling of a metal in solid phase to obtain certain required properties. The ferrous materials can be heated to above transformation temperature and can be heat – treated to obtain different structure. The different heat treatment processes are based on heating the material to certain temperature and employing different cooling rates. In this process, heating temperature and rate of cooling adopted plays an important role.

*The different processes are:*

- ) Annealing
- ) Stress-relief annealing.
- ) Process annealing.
- ) Spheroidising.
- ) Full annealing.
- ) Normalizing
- ) Hardening
- ) Tempering

#### **Annealing:**

Annealing primarily is the process of *heating* a metal which is in a metastable or distorted structural state, to a temperature which will remove the instability or distortion and then *cooling* it to the room temperature so that the structure is stable and/or *strain free*.

#### ***Purpose of Annealing:***

1. Removal of residual stress.
2. Refining and homogenizing the structure and to give a coarse pearlite structure.

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3. Improving machinability.
4. Improving cold working characteristics for facilitating further cold work.
5. Producing desired microstructure.
6. Removing residual stresses.
7. Improving mechanical, physical, electrical and magnetic properties.
8. Reducing hardness.

### **Normalizing:**

This process involves heating the metal above the transformation temperature up to 900° C and cooling from that temperature adopting the required rate of cooling.

This process involves:

- ) Heating the metal to around 900° C so that the metal transforms completely into austenite.
- ) Holding at that temperature for some times (3minutes / mm of thickness)
- ) Cooling at a rate of 80° C to 90° C per hour up to 700°C
- ) Then air – cooled from 700° C to room temperature.

### ***Purpose of Normalizing:***

- ) Refining the grain structure and giving a fine pearlite structure.
- ) Producing a uniform structure.
- ) Achieving the required strength and ductility in a steel that is too soft and ductile for machining.
- ) Improving structures in welds.
- ) In general, improving engineering properties of steels.

### **Hardening: (By Quenching)**

Hardening is performed on metals to obtain desired hardness and structure. It involves:

- ) Heating the metal above transformation temperature, around 900°C.
- ) Holding at that temperature for 15 to 30 minutes per 25mm of cross-section.
- ) Quenching it immediately in a suitable cold medium (brine solution, water, oil etc.)

Hardness obtained will depend upon the Composition of the material, nature and properties of quenching medium and quenching temperature.

### **Properties obtained by hardening are:**

- ) Desired hardness can be obtained.
- ) Strength of material is increased.
- ) Wear resistance is increased.

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### **Tempering:**

Hardening of metal produces Martensite structure with some retained austenite. The Martensite structure makes the metal very hard and brittle. The retained austenite is unstable and it will change with time. This transformation of retained austenite even at room temperature leads to distortion of metal. Due to these factors the hardened metal cannot be used as it is. Hence tempering is carried out on the metals.

### **Tempering treatment involves:**

Heating the metal just above Martensite structure temperature (50 O C), Holding it at that temperature for some time and then cooling either rapidly or slowly. The purpose of tempering is to remove brittleness and improve ductility in the material.

*The Properties obtained after Tempering are:*

- ) Improvement in ductility and toughness.
  - ) Slight reduction in hardness.
  - ) Increase in tensile strength.
  - ) Reduction in internal stress.
- 

### **EXPERIMENT NO: 7 Study of non-destructive techniques, such as dye penetration (DP) Test, ultrasonic or eddy-current test.**

**Aim:** Study of non-destructive techniques, such as dye penetration (DP) Test, ultrasonic or eddy-current test.

### **Theory: Introduction**

Up to this point we have learnt various testing methods that somehow destruct the test specimens. These were, tensile testing, hardness testing, etc. In certain applications, the evaluation of engineering materials or structures without impairing their properties is very important, such as the quality control of the products, failure analysis or prevention of the engineered systems in service.

This kind of evaluations can be carried out with Non destructive test (NDT) methods. It is possible to inspect and/or measure the materials or structures without destroying their surface texture, product integrity and future usefulness.

The field of NDT is a very broad, interdisciplinary field that plays a critical role in inspecting that structural component and systems perform their function in a reliable fashion. Certain standards has been also implemented to assure the reliability of the NDT tests and prevent certain errors due to either the fault in the equipment used, the miss-application of the methods or the skill and the knowledge of the inspectors.

Successful NDT tests allow locating and characterizing material conditions and flaws that might otherwise cause planes to crash, reactors to fail, trains to derail, pipelines to burst, and variety of less visible, but equally troubling events. However, these techniques generally require considerable operator skill and interpreting test results accurately may be difficult because the results can be subjective.

These methods can be performed on metals, plastics, ceramics, composites, cermets, and coatings in order to detect cracks, internal voids, surface cavities, delamination, incomplete defective welds and any type of flaw that could lead to premature failure.

Commonly used NDT test methods can be seen in table 1. These are universal NDT methods; however, very special tests have been developed for specific applications.

Table 1 Commonly used NDT techniques

Technique	Capabilities	Limitations
Visual Inspection	Macroscopic surface flaws	Small flaws are difficult to detect, no subsurface flaws.

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Microscopy	Small surface flaws	Not applicable to larger structures; no subsurface flaws
Radiography	Subsurface flaws	Smallest defect detectable is 2% of the thickness; radiation protection. No subsurface flaws not for porous materials
Dye penetrate	Surface flaws	No subsurface flaws not for porous materials
Ultrasonic	Subsurface flaws	Material must be good conductor of sound
Eddy Current	Surface and near surface flaws	Difficult to interpret in some applications; only for metals.
Acoustic emission	Can analyze entire structure	Difficult to interpret, expensive equipments
Magnetic Particle	Surface / near surface and layer flaws	Limited subsurface capability, only for ferromagnetic materials.

### Visual inspection:

VI is particularly effective detecting macroscopic flaws, such as poor welds. Many welding flaws are macroscopic: crater cracking, undercutting, slag inclusion, incomplete penetration welds, and the like. Likewise, VI is also suitable for detecting flaws in composite structures and piping of all types. Essentially, visual inspection should be performed the way that one would inspect a new car prior to delivery, etc. Bad welds or joints, missing fasteners or components, poor fits, wrong dimensions, improper surface finish, delaminations in coatings, large cracks, cavities, dents, inadequate size, wrong parts, lack of code approval stamps and similar proofs of testing.

### Radiography:

Radiography has an advantage over some of the other processes in that the radiography provides a permanent reference for the internal soundness of the object that is radiographed. The x-ray emitted from a source has an ability to penetrate metals as a function of the accelerating voltage in the x-ray emitting tube. If a void present in the object being radiographed, more x-rays will pass in that area and the film under the part in turn will have more exposure than in the non-void areas. The sensitivity of x-rays is nominally 2% of the materials thickness. Thus for a piece of steel with a 25mm thickness, the smallest void that could be detected would be 0.5mm in dimension. For this reason, parts are often radiographed in different planes. A thin crack does not show up unless the x-rays ran parallel to the plane of the crack. Gamma radiography is identical to x-ray radiography in function. The difference is the source of the penetrating electromagnetic radiation which is a radioactive material such as  $^{60}\text{Co}$ . However this method is less popular because of the hazards of handling radioactive materials.

### Liquid (Dye) penetrate method:

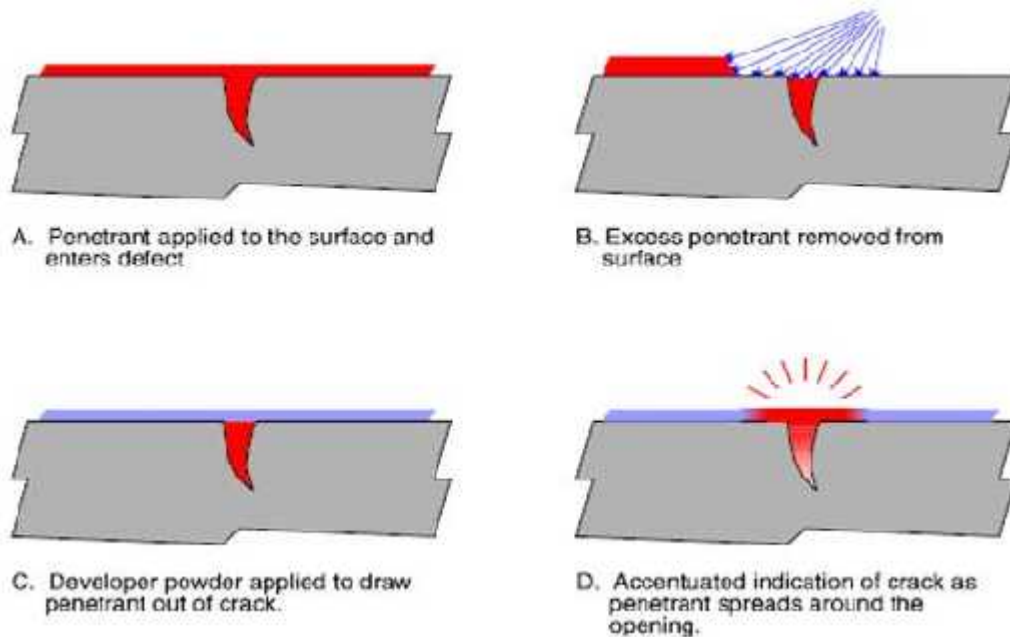
Liquid penetrate inspection (LPI) is one of the most widely used non-destructive evaluation (NDE) methods. Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. The technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action.

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This method is an inexpensive and convenient technique for surface defect inspection. The limitations of the liquid penetrate technique include the inability to inspect subsurface flaws and a loss of resolution on porous materials. Liquid penetrate testing is largely used on nonmagnetic materials for which magnetic particle inspection is not possible.

Materials that are commonly inspected using LPI include the following; metals (aluminum, copper, steel, titanium, etc.), glass, many ceramic materials, rubber, plastics. Liquid penetrate inspection is used to inspect of flaws that break the surface of the sample. Some of these flaws are listed below; fatigue cracks, quench cracks grinding cracks, overload and impact fractures, porosity, laps seams, pin holes in welds, lack of fusion or braising along the edge of the bond line.



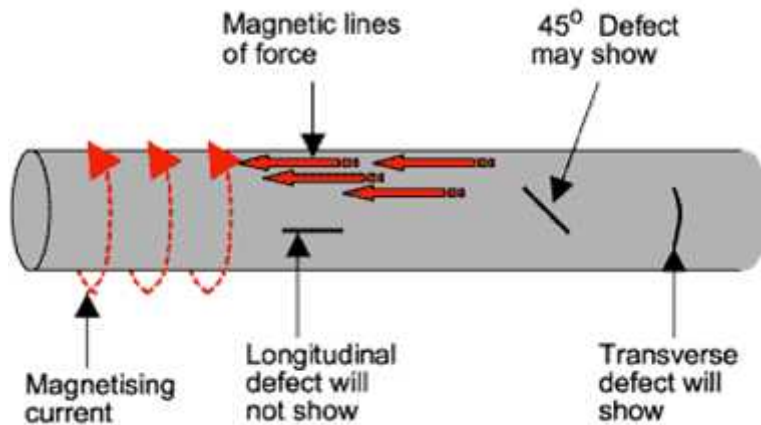
Magnetic particles:

Magnetic particle inspection is one of the simple, fast and traditional non-destructive testing methods widely used because of its convenience and low cost. This method uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components. The only requirement from an inspect ability standpoint is that the component being inspected must be made of a ferromagnetic material such iron, nickel, cobalt, or some of their alloys, since these materials are materials that can be magnetized to a level that will allow the inspection to be effective. On the other hand, an enormous volume of structural steels used in engineering is magnetic. In its simplest application, an electromagnet yoke is placed on the surface of the part to be examined, a kerosene-iron filling suspension is poured on the surface and the electromagnet is energized. If there is a discontinuity such as a crack or a flaw on the surface of the part, magnetic flux will be broken and a new south and north pole will form at each edge of the discontinuity. Then just like if iron particles are scattered on a cracked magnet, the particles will be attracted to and cluster at the pole ends of the magnet, the iron particles will also be attracted at the edges of the crack behaving poles of the magnet. This cluster of particles is much easier to see than the actual crack and this is the basis for magnetic particle inspection. For the best sensitivity, the lines of magnetic force should be perpendicular to the defect.



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Eddy current testing:

Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, such as copper wire, a magnetic field develops in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero. If another electrical conductor is brought into the close proximity to this changing magnetic field, current will be induced in this second conductor. These currents are influenced by the nature of the material such as voids, cracks, changes in grain size, as well as physical distance between coil and material. These currents form an impedance on a second coil which is used to as a sensor.

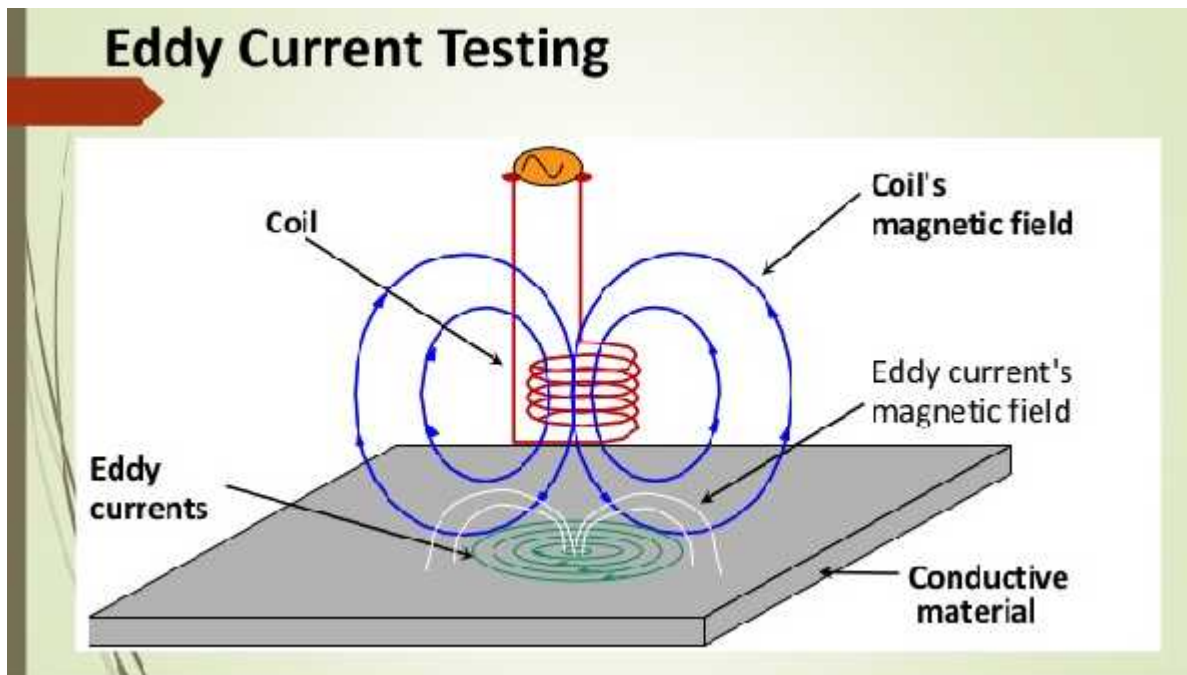
In practice a probe is placed on the surface of the part to be inspected, and electronic equipment monitors the eddy current in the work piece through the same probe. The sensing circuit is a part of the sending coil.

Eddy currents can be used for crack detection, material thickness measurements, coating thickness measurements, conductivity measurements for material identification, heat damage detection, case depth determination, heat treatment monitoring. Some of the advantages of eddy current inspection include; sensitivity to small cracks and other defects, ability to detect surface and near surface defects, immediate results, portable equipment, suitability for many different applications, minimum part preparation, no necessity to contact the part under inspection, ability to inspect complex shapes and sizes of conductive materials.

Some limitation of eddy current inspection; applicability just on conductive materials, necessity for an accessible surface to the probe, skillful and trained personal, possible interference of surface finish and roughness, necessity for reference standards for setup, limited depth of penetration, inability to detect of the flaws lying parallel to the probe coil winding and probe scan direction.

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### **Ultrasonic Inspection:**

Ultrasonic Testing (UT) uses a high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection evaluation, dimensional measurements, material characterization, and more. A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulse. Driven by the pulser, the transducer of various types and shapes generates high frequency ultrasonic energy operating based on the piezoelectricity technology with using quartz, lithium sulfate, or various ceramics. Most inspections are carried out in the frequency rang of 1 to 25MHz. Couplants are used to transmit the ultrasonic waves from the transducer to the test piece; typical couplants are water, oil, glycerin and grease.

The sound energy is introduced and propagates through the materials in the form of waves and reflected from the opposing surface. An internal defect such as crack or void interrupts the waves' propagation and reflects back a portion of the ultrasonic wave. The amplitude of the energy and the time required for return indicate the presence and location of any flaws in the work-piece.

The ultrasonic inspection method has high penetrating power and sensitivity. It can be used from various directions to inspect flaws in large parts, such as rail road wheels pressure vessels and die blocks. This method requires experienced personnel to properly conduct the inspection and to correctly interpret the results.

As a very useful and versatile NDT method, ultrasonic inspection method has the following advantages; sensitivity to both surface and subsurface discontinuities, superior depth of penetration for flaw detection or measurement, ability to single sided access for pulse-echo technique, high accuracy in determining reflector position and estimating size and shape, minimal part preparation, instantaneous results with electronic equipment, detailed imaging with automated systems, possibility for other uses such as thickness measurements.

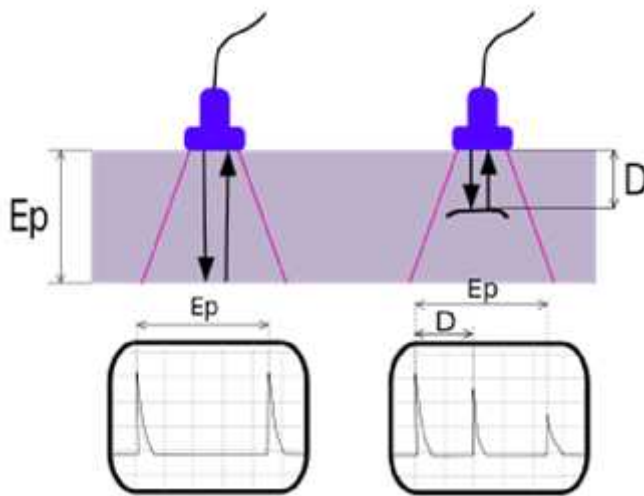
Its limitations; necessity for an accessible surface to transmit ultrasound, extensive skill and training, requirement for a coupling medium to promote transfer of sound energy into test specimen, limits for roughness, shape irregularity, smallness, thickness or not homogeneity, difficulty to inspect of coarse grained materials due to low sound transmission and high signal noise, necessity for the linear defects to be oriented parallel to the sound beam,



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necessity for reference standards for both equipment calibration, and characterization of flaws.

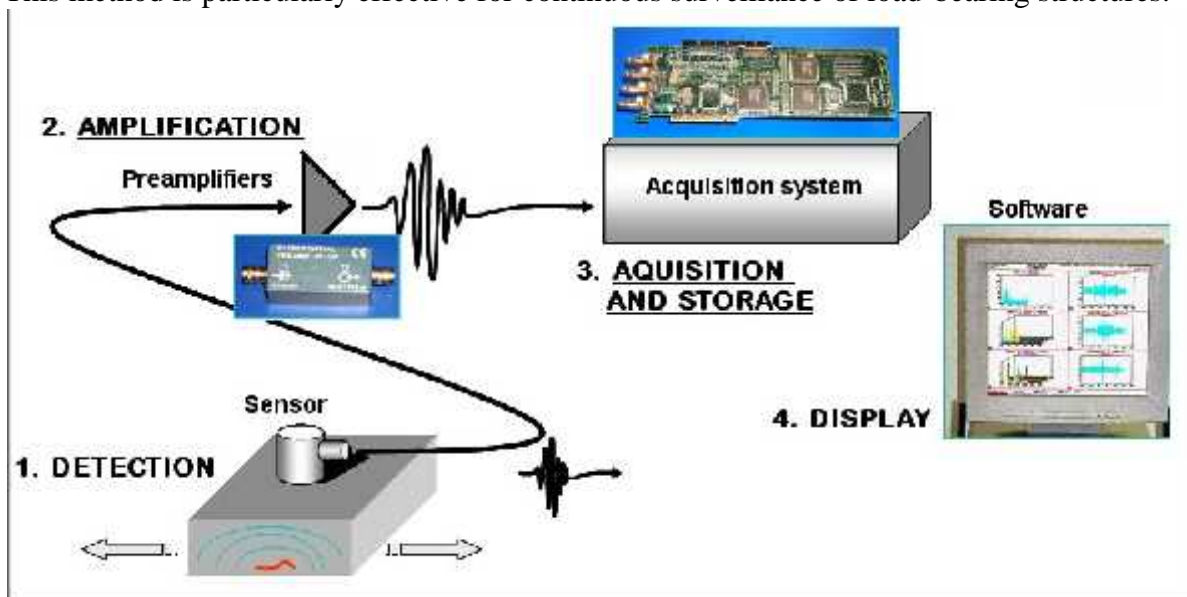


### **Acoustic Method:**

There are two different kind of acoustic methods: (a) acoustic emission; (b) acoustic impact technique.

#### **Acoustic emission:**

This technique is typically performed by elastically stressing the part or structure, for example, bending a beam, applying torque to a shaft, or pressurizing a vessel and monitoring the acoustic responses emitted from the material. During the structural changes the material such as plastic deformation, crack initiation, and propagation, phase transformation, abrupt reorientation of grain boundaries, bubble formation during boiling in cavitation, friction and wear of sliding interfaces, are the source of acoustic signals. Acoustic emissions are detected with sensors consisting of piezoelectric ceramic elements. This method is particularly effective for continuous surveillance of load-bearing structures.



#### **Acoustic impact technique:**

This technique consists of tapping the surface of an object and listening to and analyzing the signals to detect discontinuities and flaws. The principle is basically the same as when one taps walls, desktops or countertops in various locations with a finger or a hammer and listens to the sound emitted. Vitrified grinding wheels are tested in a similar manner to detect cracks in the wheel that may not be visible to the naked eye. This technique is easy to

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perform and can be instrumented and automated. However, the results depend on the geometry and mass of the part so a reference standard is necessary for identifying flaws.

### **Procedure**

#### **Liquid penetrate method:**

In this method the surfaces to be inspected should be free from any coatings, paint, grease, dirt, dust, etc.; therefore, should be cleaned with an appropriate way. Special care should be taken not to give additional damage to the surface to be inspected during the cleaning process. Otherwise, the original nature of surface could be disturbed and the results could be erroneous with the additional interferences of the surface features formed during the cleaning process.

Surface cleaning can be performed with alcohol. Special chemicals like cleaner remover can also be applied if needed. In the experiment, only cleaner-remover will be sufficient. Subsequent to surface cleaning, the surface is let to dry for 2 minutes. Commercially available cans of liquid penetrate dyes with different colors are used to reveal the surface defects.

#### ***Steps used in the experiment:***

1. Clean the surface with alcohol and let surface dry for 5 min.
2. Apply the liquid penetrate spray (red can) to the surface and brush for further penetration. Then, wait for 20 min.
3. Wipe the surface with a clean textile and subsequently apply remover spray (blue can) to remove excess residues on the surface and wait for a few min.
4. Apply the developer spray (yellow can) at a distance of about 30cm from the surface. The developer will absorb the penetrate that infiltrated to the surface features such as cracks, splits, etc., and then reacted with it to form a geometric shape which is the negative of the geometry of the surface features from which the penetrate is sucked.
5. The polymerized material may be collected on a sticky paper for future evaluation and related documentation, if needed.

#### **Magnetic particle:**

In this experiment, commercially available magnetic powder manufactured for NDT inspection will be used. A strong U shape magnet will be used to provide the necessary magnetic field at the inspected area.

*The following steps are applied during the experiment;*

1. The surface of the specimen will be roughly cleaned wiping with a piece of textile.
2. The fluorescent magnetic spray will be applied on the surface being inspected.
3. Magnetic field will be applied with a strong magnet to the location of interest.
4. The spots where the fluorescent magnetic particles accumulated will be inspected under UV light.

#### **Eddy current inspection:**

For this experiment, Magnefest ED-51 0 type unit will be used. A pencil type prop will be used for the inspections. The inspection is performed with 2 MHz frequency and at the related calibration settings. The test blocks were previously prepared for this experiment. Any coatings or paints on the surface of inspected specimens should be treated with special procedures.

*The following steps should be applied during the experiment:*

1. Inspection area should be clean, smooth, free from any irregular or uneven paint, dirt, grease, etc.
2. There shouldn't be any visible damage or discontinuity.

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3. During the inspection procedure the probe will be positioned near the inspection area, on the compensation point and lift off and zero will be adjusted if necessary.
4. The inspection will be carried out by using probe scans. The probe tip will be always at a right angle the inspection surface.
5. Any indication with indicator deflection to the right should be evaluated. All evaluated indications should be measured.
6. After this procedure, all evaluated indications with indicator deflections, will be classified as cracks and be recorded.

### Ultrasonic inspection:

For this experiment, USM-2 type ultrasonic unit will be used. The props used supports to work at frequency of 5 MHz. Echo techniques will be employed to find the cracks. Instrument will be tuned to a frequency of 5 MHz. An appropriate couplant used should not cause corrosion or other damage. During the inspection the calibration will be done on the reference standard, if needed. Two different test blocks will be employed in this test, sufficient amount of couplant will be applied to the transducer scan areas on the forward and after sides of the support fitting. The display will be monitored for crack indications. A crack signal will be similar to the following:

*The following steps should be applied during the experiment:*

1. The couplant should be applied on the inspected area.
2. For the circular test specimen, the prop will be placed in the corresponding space in the supporting fitting tool. Enough couplant should be used between the probe and tool.
3. For the flat specimen, no tool is needed, couplant only applied between the inspected surface and the probe.
4. Special attention should be paid on the location where possible cracks exist.
5. A discontinuity like a crack produces a peak on the screen.
6. Attention should also be given to the movement of the possible peak caused by the cracks on the specimen.

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **LAB Manual**

**Subject Name:-Machine Drawing Lab**  
**Year: Second Year**

**Subject Code:-ME494**  
**Semester: - IV**

### **Introduction:**

Technical Graphics is used to communicate the necessary technical information required for manufacture and assembly of machine components. These drawings follow rules laid down in national and International Organizations for Standards (ISO).

Hence the knowledge of the different standards is very essential. Students have to be familiar with industrial drafting practices and thorough understanding of production drawings to make themselves fit in industries. The following topics have been covered to fulfill the above objectives.

### **Objectives:**

Student will get methodically and well thought out presentation that covers fundamental issues common to almost all areas of machine drawing.

1. Students have an ability to apply knowledge of Modeling, science & engineering.
2. Student can model this drawing even in CAD/CAM software by applying the basic knowledge of machine drawing.
3. Students will able to demonstrate an ability to design and conduct experiments, analyze and interpret data and assembly and disassembly drawings knowledge will be provided.

### **Learning Outcomes:**

**At the successful completion of course, the student is able to:**

1. Analysis of complex design systems related to mechanical Engineering.
2. Making use of appropriate laboratory tools and design innovative methods.
3. To motivate students to develop new innovative methods for measuring product Characteristics.
4. To enhance the ability of students to work as teams.
5. Improving skills to adopt modern methods in mechanical engineering as continuous improvement
1. The broad education necessary to understand the impact of engineering solutions in a global, economic, environment and societal context.

### **Course Contents:**

UNIT: 1

Assembly and detailed drawings of a mechanical assembly, such as a simple gear box, flange coupling, Knuckle joint, Engine parts etc.

UNIT: 2

Practicing AutoCAD or similar graphics softwares and making orthographic and isometric projections of different components.

### **Text Books:**

1. Machine Drawing by N.D. Bhatt.
2. Machine Drawing by P.S. Gill.

Faculty In-Charge

HOD, ME Dept.

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **LAB Manual**

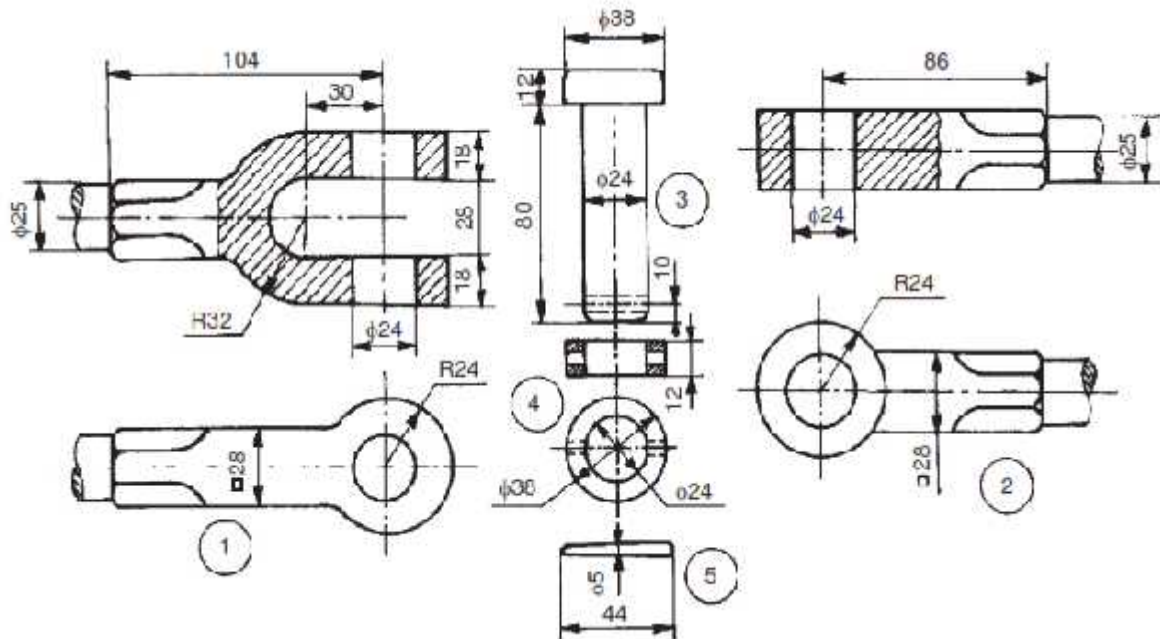
**Subject Name:-Machine Drawing Lab**  
**Year: Second Year**

**Subject Code:-ME494**  
**Semester: - IV**

### Exercise: 1

Lecturer Contact Hours: 02

**Aim:** Draw an assembly and detailed drawings of Gear box cover.



Parts list

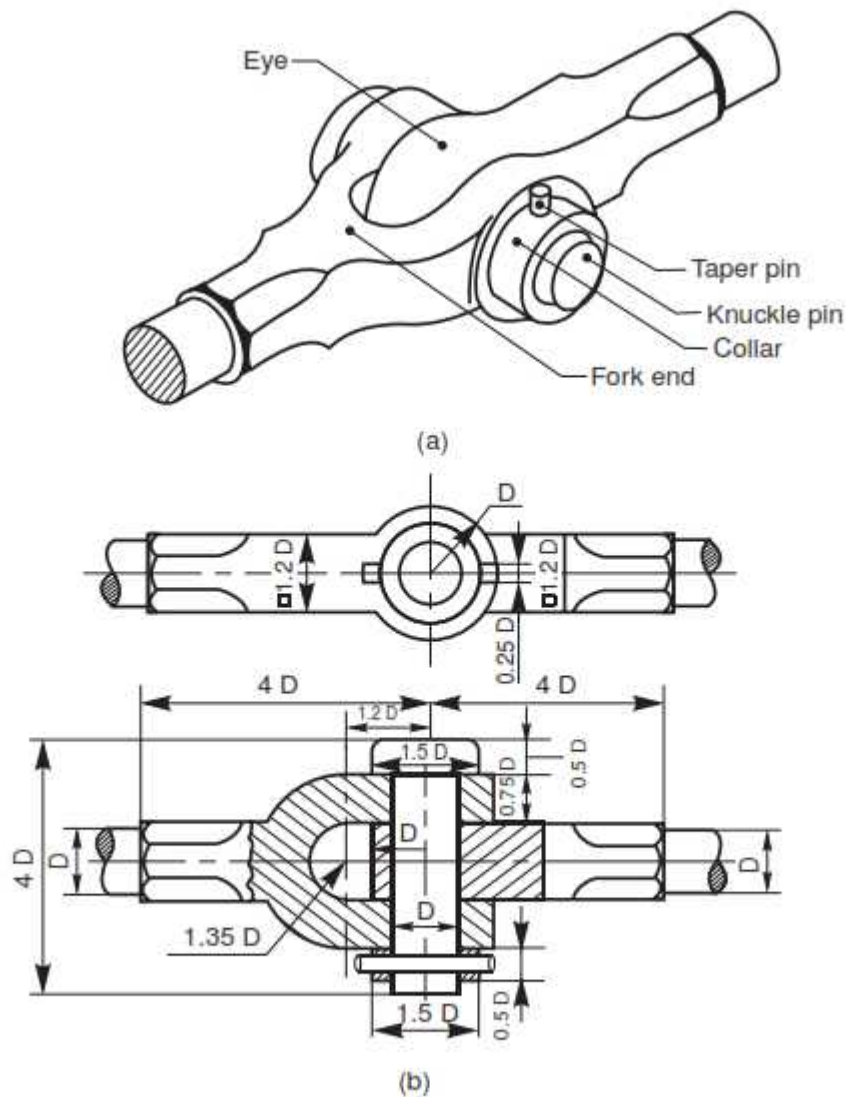
Sl. No.	Name	Matl.	Qty.
1	Fork end	Forged steel	1
2	Eye end	Forged steel	1
3	Pin	Mild steel	1
4	Collar	Mild steel	1
5	Taper pin	Mild steel	1

Fig. 18.40 Knuckle joint

**Exercise: 2**

**Lecturer Contact Hours: 01**

**Aim: Draw a detailed drawing of Knuckle joint.**

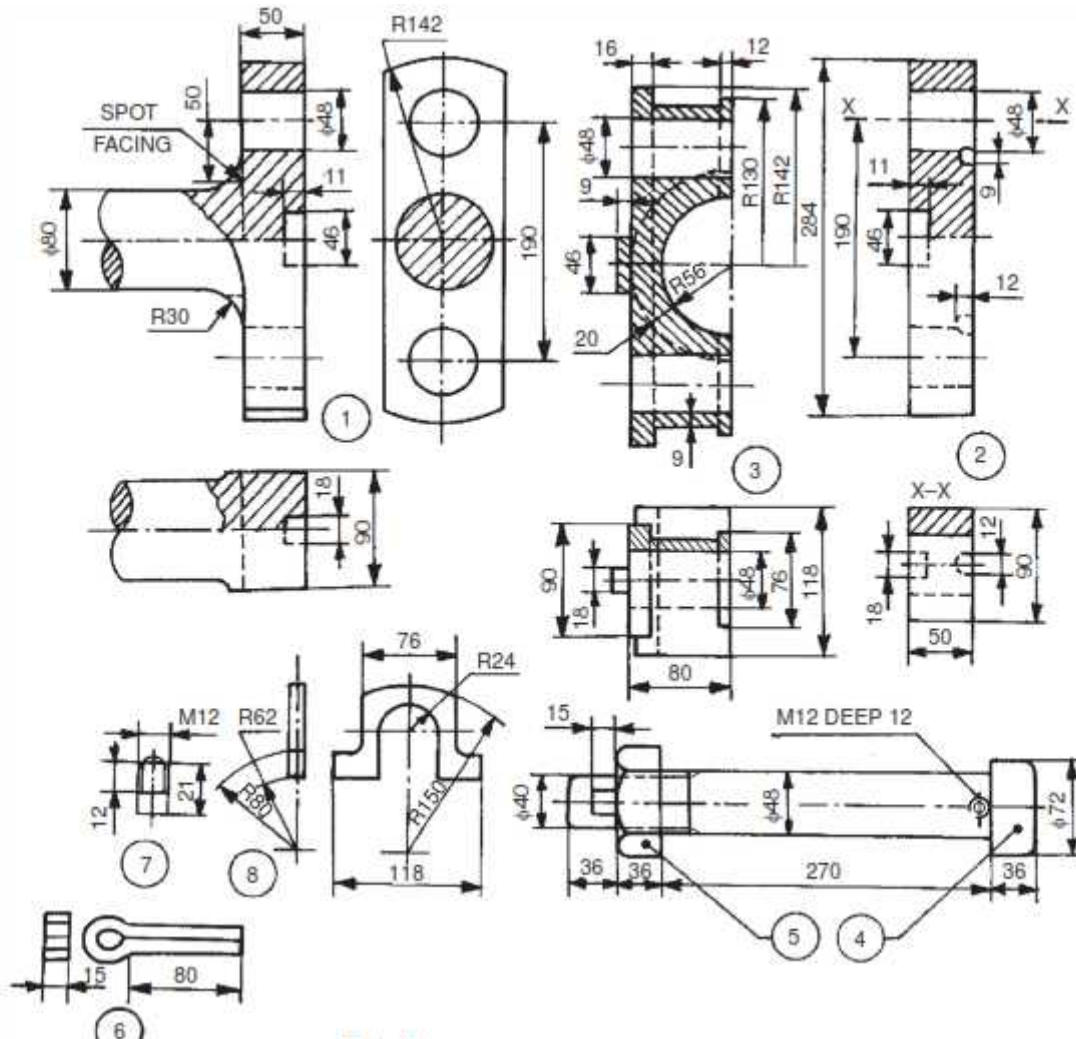


**Fig. 6.15 Knuckle joint**

**Exercise: 3**

**Lecturer Contact Hours: 02**

**Aim:** Draw an assembly and detailed drawings of engine connecting rod end.



Parts list

Sl. No.	Name	Matl.	Qty.
1	Rod end	FS	1
2	Cover end	FS	1
3	Bearing brass	GM	2
4	Bolt	MS	2
5	Nut	MS	2
6	Split cotter	MS	2
7	Snug	MS	2
8	Leather packing	—	2

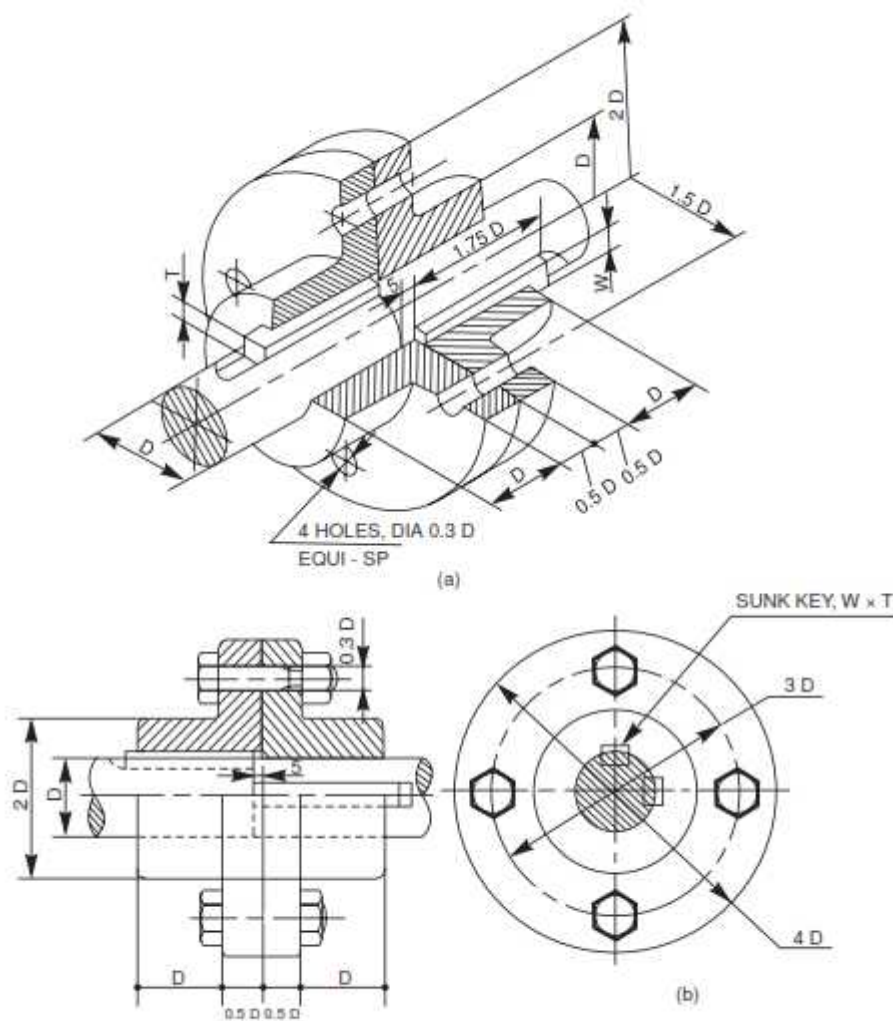
**Fig. 18.5** Marine engine connecting rod end



**Exercise: 4**

**Lecturer Contact Hours: 02**

**Aim:** Draw a detailed drawing of flange coupling.



**Fig. 7.4** Flanged coupling

# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **LAB Manual**

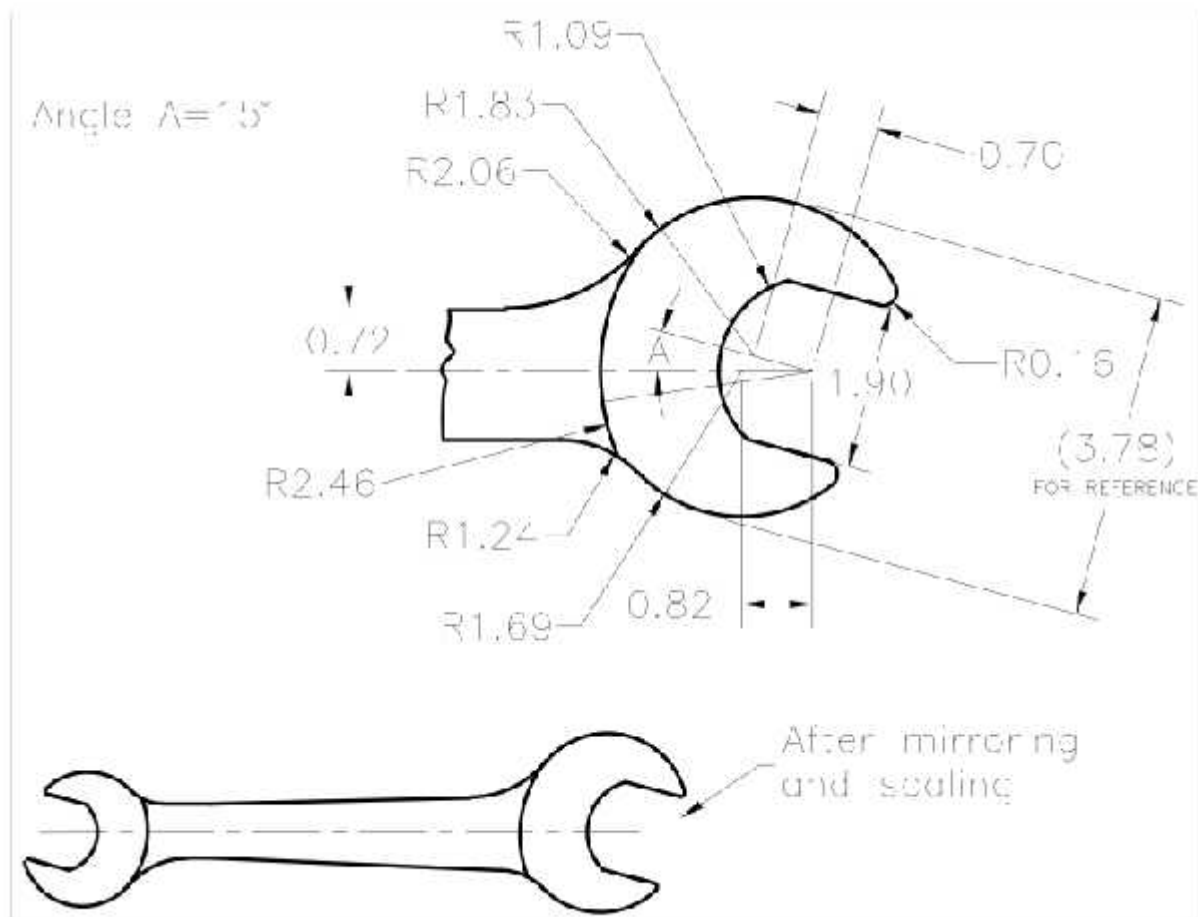
**Subject Name:-Machine Drawing Lab**  
**Year: Second Year**

**Subject Code:-ME494**  
**Semester: - IV**

**AUTO CAD Practice sheet: 1**

**Lecturer Contact Hours: 03**

**Aim:** Draw given drawing by help of AutoCAD Software.



# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **LAB Manual**

**Subject Name:-Machine Drawing Lab**

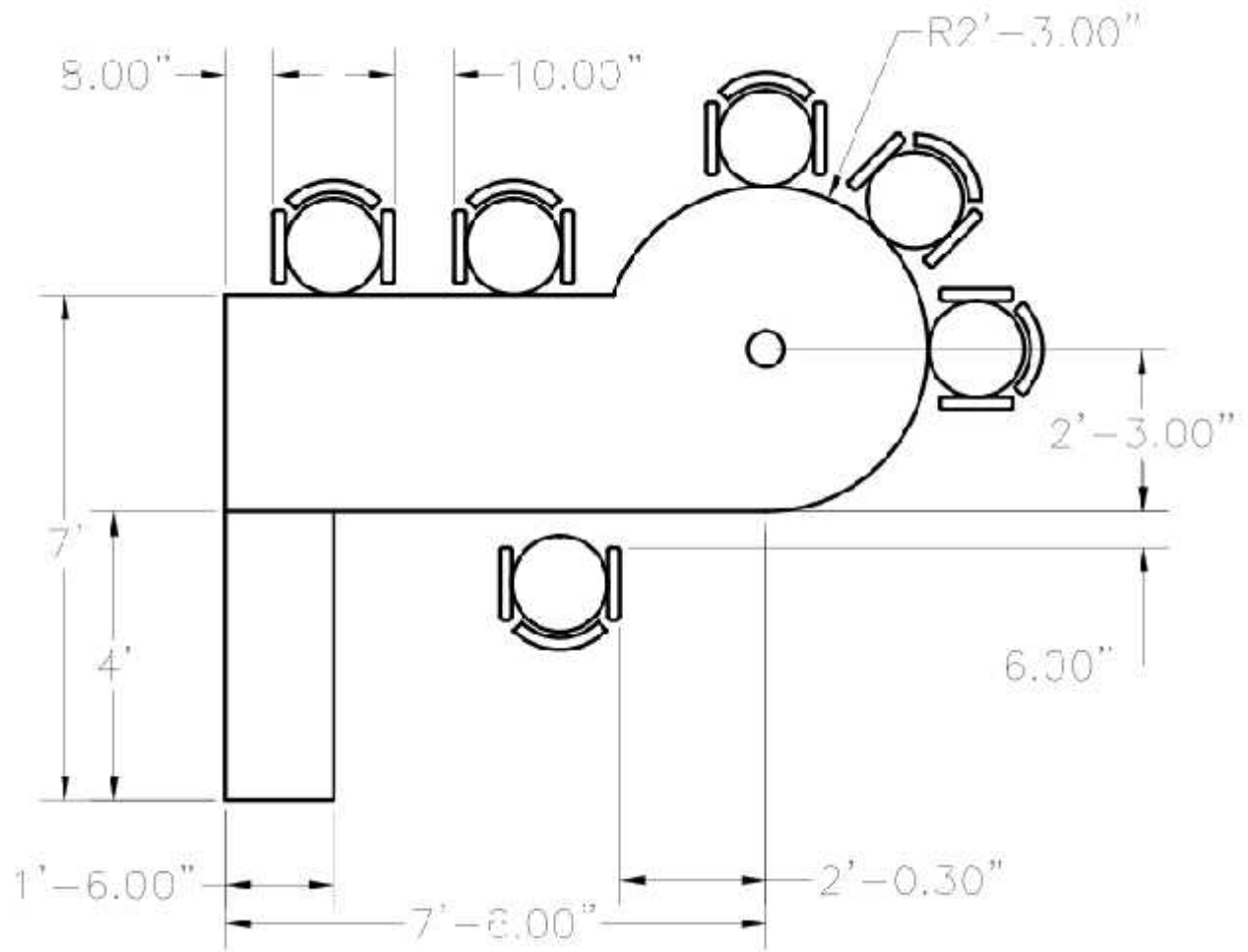
**Year: Second Year**  
**AUTO CAD Practice sheet: 2**

**Subject Code:-ME494**

**Semester: - IV**

**Lecturer Contact Hours: 03**

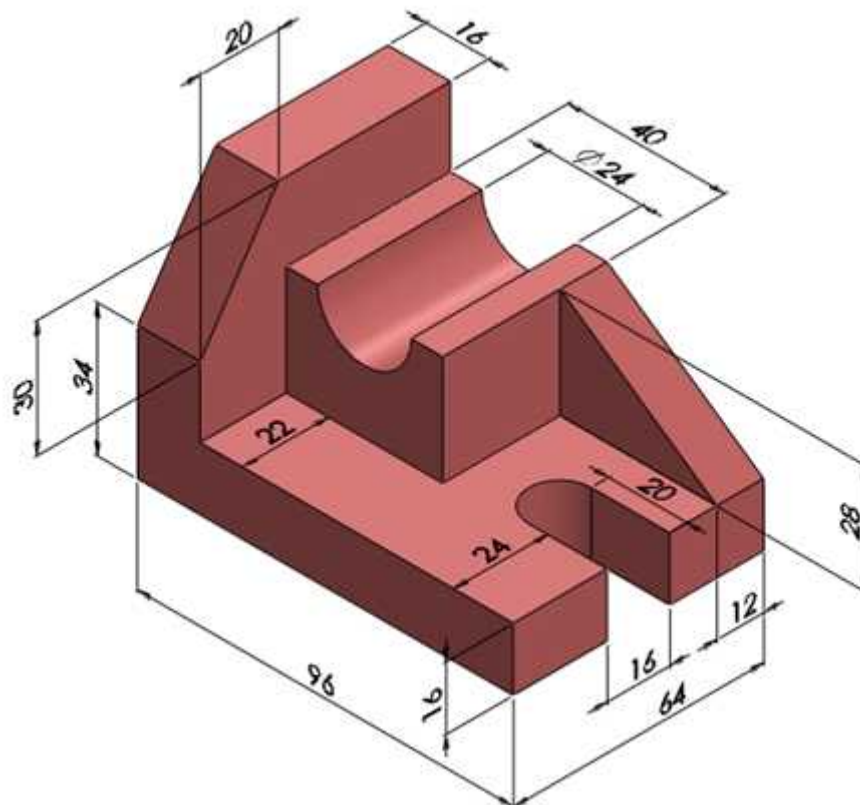
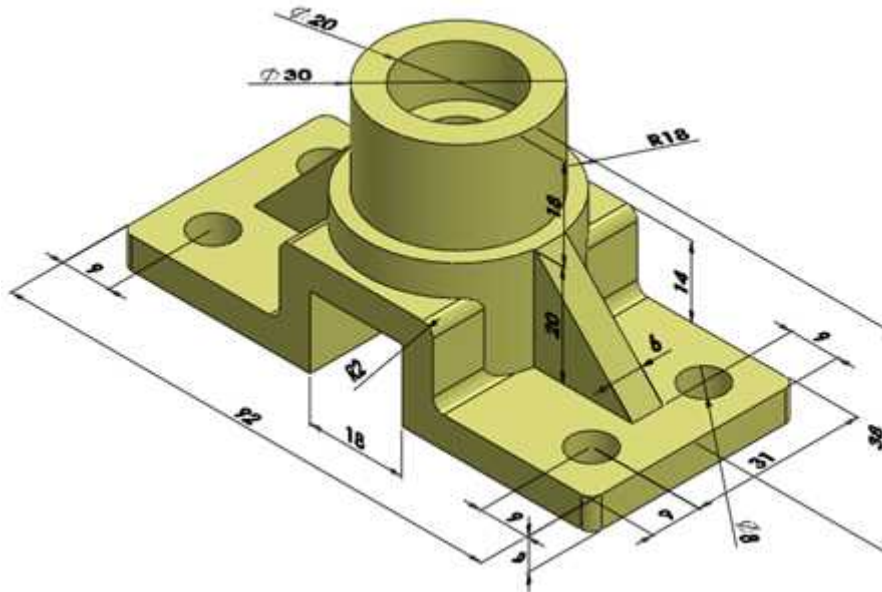
**Aim:** Draw given drawing by help of AutoCAD Software



## LAB Manual

**Subject Code:-ME494**  
**Semester: - IV**

**Aim:** Draw orthographic projections of given.



# **UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR**

## **LAB Manual**

**Subject Name:-Machine Drawing Lab**

**Year: Second Year**

**Subject Code:-ME494**

**Semester: - IV**

**AUTO CAD Practice sheet: 4**

**Lecturer Contact Hours: 02**

**Aim:** Draw orthographic projections of given.

