UNIVERSITY OF ENGINEERING & MANAGEMENT,JAIPUR

Lecture-wise Plan

Subject Name: Metrology & Measurement — Subject Code-ME501

Year: 3rd Year — Semester: Fifth

Module Number	Topics	Number of Lectures
1	**Unit 1**	**5L**
	Definition and importance of Metrology Measurement	1L
	Methods of measurements – Direct, Indirect, Comparison, Substitution.	1L
	Methods of measurements – Transposition, Deflection and Null measurement.	1L
	Errors in measurement – Absolute, Relative, Parallax, Alignment, Loading, Dynamic and Calibration error; Units of measurements – SI base and derived units, SI prefixes of units.	2L
2	**Unit 2**	**8L**
	Linear Metrology: Vernier scale; Construction and use of Vernier calliper,	1L
	Angular Metrology: Constructional features and use of protractor, Vernier bevel protractor, angle gauges	1L
	Sine bar and Slip gauges and their use	2L
	Vernier Height and Depth Gauge, Micrometer; Slip gauge.	1L
	Measurements of : (i) Level using spirit-level; (ii) Flatness using straight edge, interferometry (Newton's rings) and surface plate	2L
	Parallelism, Cylindricity and Concentricity using dial indicator.	1L
3	**Unit 3**	**10L**
	Interchangeability of components.	2L
	Concept of Limits, Tolerances and Fits.	2L
	Hole basis and shaft basis system of fits	2L
	Types of fits and their significance	2L
	Goand No Go limit gauges-Plug, Ring, Snap, Thread, Radius and Filler gauges	2L
4	**Unit 4**	**4L**
	Definition, use and essential features of Comparators.	2L
	Working principle and application of Dial gauge and Cookoptical comparator,	1L
	Back pressure Bourdon gauge pneumatic comparator and Optical comparator-profile projector	1L
5	**Unit 5**	**5L**
	Measuring Instruments: Functional elements of an instrument – sensing, conversion & manipulation, data transmission and presentation element.	2L
	Characteristics – accuracy, precision, repeatability, sensitivity,	2L

	reproducibility, linearity, threshold.	
	Calibration, response, dynamic or measurement error; Transducers – definition, primary and secondary, activeand passive.	1L
6	**Unit 6**	**6L**
	Measurement of Surface Finish: Definition; Terminologies – geometrical surface, effective surface, surface roughness, roughness (primary texture).	1L
	Waviness (secondary texture), form, lay, sampling length average.	1L
	Numerical evaluation of surfaceroughness: peak-to-valley height (Rmax), centre line average (CLA, Ra), depth (Rm), smoothness value (G)	2L
	Semiconductors and Composites	2L
7	**Unit 7**	**7L**
	Principle of operation of a few measuring instruments: displacement by LVDT	2L
	Force by strain – gauge load cell and piezoelectric load cell.	1L
	Pressure by Bourdon – tube gauge; temperature by liquid--in-glass thermometer.	1L
	Thermocouples, Optical pyrometer; Liquid velocity by pitot tube	1L
	Water flow by orifice meter.	1L
	Principle of operation of a Talysurf.	1L
Total Number Of Hours = 45		

ASSIGNMENT – 1 MECHANICAL MEASUREMENT & METROLOGY

1. State and explain five basic elements of measuring system

2. Describe with net sketch International prototype meter (Material length standard) stating material composition and limitation

3. Differential line standard and end standard

4. Explain various types of Errors in measurement and state how they can take care of.

ASSIGNMENT – 2 LINEAR & ANGULAR MEASUREMENT

1. Explain construction , working and principle of following:

a. Vernier caliper

b. Vernier depth gauge

c. Vernier height gauge

d. Telescopic gauge

e. Combination square set

f. Slip gauge

g. Sigma comparator

h. Johansson mikrokator

i. Dial indicator

2. Explain with sketch the construction and working of micrometer. Explain how least count is found and reading is taken. What is zero error?

3. Explain construction , working and principle of following:

a. Vernier bevel protractor

b. Angle gauge

c. Angle dekkor

d. Sine bar and sine Centre

e. Autocollimator

f. Clinometers

ASSIGNMENT – 3 Measurement of Force, Torque and strain

1. Explain different types of load cell.

2. Explain absorption dynamometers.

3. Explain Mechanical strain gauge.

4. Explain bridge arrangement.

5. Explain gauge factor.

ASSIGNMENT – 4 Velocity and acceleration measurement

1. Explain working principle of Resistive potentiometer.

2. Explain Linear variable differential transducer.

3. Explain electric and photoelectric techometers.

4. Explain piezoelectric Accelerometer.

ASSIGNMENT – 5 Tempreature measurement

1. Explain the construction and working of a resistance thermometer and thermocouple with a neat sketch.

2. Compare advantages of thermocouple and thermistors.

3. Explain filled system thermometers.

4. Explain radiation and optical pyrometer.

5. List and explain with neat sketch types of expansion thermometer stating applications

ASSIGNMENT – 6 Gear and screw thread measurement

1. Explain with neat sketch three wire method of measuring effective diameter of screw thread.

2. What is an effective diameter of threads? State its significance. Explain with sketch Measurement of effective diameter by two wire method stating limitation.

3. Calculate the chord length and its distance below the tooth tip for gear of module 4 and 20 degree pressure angle.

4. Explain Parkinson gear tester with neat sketch.

5. Describe with sketch the construction and use of gear tooth vernier caliper. How is the gear tooth thickness at PCD measured?

ASSIGNMENT – 7 Measurement Of Surface Finish

1. Explain Surface Texture and Elements of surface Roughness.

2. With the help of a neat sketch explain the working of Tomlinson’s surface meter and Profilometer.

3. Explain alignment test for lathe machine.

4. Explain following terms used in surface finish:

a. Roughness

b. Waviness

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Lession- Plan

Subject Name: Heat Transfer — Subject Code-ME502

Year: 3rd Year — Semester: Fifth

Module Number	Topics	Number of Lectures
1	**Introduction:**	**2L**
	1. Introduction & Basic equations, Newton's law of cooling	2L
2	**Conduction:**	**5L/1T**
	1. Fourier's law & 1-D and 3- D heat conduction equations, Thermal conductivity	2L/1T
	2. 1-D conduction problem with & without heat generation	1L
	3. Critical thickness of insulation & Numerical , Definition of overall heat transfer coefficient	2L
3	**Fins:**	**5L/1T**
	1. Fins- rectangular and pin fins	1L/1T
	2. Fins working & d\Design, Conditions	2L
	3. Fin effectiveness and fin efficiency.	2L
4	**Transient Conduction:**	**6L**
	1. transient heat conduction, Lumped parameter approach,	2L
	2. Time constant, Biot number:	1L
	3. 1-D transient heat conduction solution without heat generation.	2L
	4. Numerical	1L
5	**Thermal Radiation-**	**7L/2T**
	Part:1 Basic Relations:	3L/1T
	1. Physical mechanism of thermal radiation, laws of radiation	1L
	2. Definition of black body, emissive power	1L
	3. intensity of radiation, emissivity, reflectivity, transmittivity, irradiation, radiosity	1L/1T
	Part:2 Radiation exchange between Surfaces:	4L/1T
	1. Radiation exchange between black bodies	2L
	2. Radiation exchange between GDI surfaces by radiation network	2L
	3. Radiation shielding	1T

6	**Heat Exchangers:**	**5L/1T**
	1. types of heat exchangers, parallel and counter flow types	2L
	2. Introduction to LMTD. Correction factors, fouling factor, efficiency and effectiveness	2L
	3. E- NTU method for heat exchangers.	1L/1T
7	**Non – dimensional quantities:**	**5L**
	1. Non – dimensional quantities in heat transfer,	2L
	2. Analysis for a flow over a flat plate, order of magnitude analysis.	3L
8	**Convection:**	**8L/2T**
	1. Convective heat transfer	1L
	2. Newton's law of cooling and significance of heat transfer coefficients	1L/1T
	3. Momentum and energy equation in 2-D. & Numerical	1L
	3. Natural convection over a vertical plate	1L
	4. 1-D solution for Coutte flow and Poiseullie flow	2L
	5. Hydrodynamic and thermal boundary layers	1L
	6. laminar boundary layer equations	1L/1T
Total Number Of Hours = 37L/7T(42H)		

Assignment:

UNIT-1,2,:

1. Explain briefly the various modes of heat transfer.
2. Derive general heat conduction equation in cylinder coordinates study state and considering internal energy source.
3. What is heat transfer coefficient? Derive Expressions for it.
4. What are the assumptions for lumped capacity analysis?

5. A 2cm thick steel slab heated to 525^0C is held in air system having a mean temperature of 25^0C. Estimate the time interval when the slab temperature would not depart from the mean value of 25^0C by more than 0.5^0C at any point in the slab. the steel plate has the following thermo-physical properties:

   ρ-7950kg/m^3: c_p=455J/kg –deg: k=46 W/m-deg: h= 36 W/m^2-deg
6. A plane wall of thickness $ has its surfaces maintained at temperature T_1 and T_2. The wall is made of a material whose thermal conductive varies with temperature according to the relation $K=K_0T^2$. Set up an expression to work out the steady state heat conduction through the wall. Further proceed to calculate the temperate at which mean thermal conductivity be evaluated so as to get the same heat flow by its substitution in the simplified Fourier relation.
7. A furnace wall consists of 200mm layer of refractory bricks, 6mm layer of steel plate and a 100mm layer of insulation bricks. The maximum temperature of the wall is 1150^0C on the furnace side and minimum temperature is 40^0C on the outermost side of the wall. An accurate energy balance over the furnace shows that the heat loss from the wall is 400W/m^2. It is knows that there is a thin layer of air b/w the layers of refractory bricks and Steel plate. Thermal conductivities for the layers are 1.52., 45 and 0.138 W/m^0C respectively, finds to

   a. How many mm of insulation brick is the air layer equivalent?

   b. What is the temperature of the outer surface of the steel plate?

UNIT-3:

1. Starting from the first principal show that the critical radius of insulation for a spherical shell with isothermal surface and constant value of k and ho is equal to 2K/ho.
2. A composite fin consists of cylindrical rod (3mm diameter and 100mm length) of one material, uniformly covered with another material forming outer diameter 10mm and 100mm. K(inner material)=15 W/m-0C; K(outer material)=45 W/m-0C; h(surface heat transfer

coefficient) =12 W/m2-0C. Determine the effectiveness of the composite fin. Assume no temperature gradient along the radial direction and end is insulated for the composite fin.

3. Derive expression for heat dissipation from a fin losing heat at the tip.
4. Two long rods of the same diameter, one made of brass (K=85 W/m-deg) and other made of copper (k=375 W/m-deg) have one of their end inserted into the furnace. Both of the rods are exposed to the same environment. At a distance 105mm away from the furnace end, the temperature of the brass rod is 120^0c. At what distance from the furnace end the same temperature would be reached in the copper rod?.

UNIT-5,6:

1. Define the following terms: (i) Total emissive power (E) (ii) Emissivity (iii) Intensity of radiation
2. What is a ‘black body’? How does it differ from a gray body?
3. For a hemispherical furnace, the flat floor is at 700K and has an emissivity of 0.5. The hemispherical roof is at 1000K and has emissivity of 0.25 find the net radiative heat transfer from roof to floor.
4. Derive an expression for the shape factor in case of radiation exchange between two surfaces.
5. Derive an expression for LMTD in the case of parallel flow heat exchanger?
6. A hot fluid at 2000C enters a heat exchanger at a mass flow rate of 104Kg/h. Its Sp. heat is 2000 j/Kg K. It is to be cooled by another fluid entering at 250C with a mass flow rate 2500 g/h and sp. Heat 400 j/Kg K. The overall heat transfer coefficient based on outside area of 20m2 is 250 W/m2 K. find the exit temp. Of the hot fluid when the fluids are in parallel flow. Two fluids A and B exchange heat in a counter-current heat exchanger. Fluid A enters at 4200C and has a mass flow rate of 1Kg/s. Fluid A enters at 200C and has a mass flow rate of 1Kg/s. effectiveness of heat exchanger is 75%. Determine: Heat transfer rate; the exit temperature of fluid B. Specific heat of fluid A is 1KJ/Kg K and that of fluid B is 4KJ/Kg K.

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COURSE DESCRIPTION

Subject Name: Design of Machine Elements   Subject Code-ME503
Year: 3rd Year   Semester: Fifth

Module Number	Topics	Number of Lectures
1	Introduction to machine design, definition, and design philosophy, Objective and scope of Mechanical Engineering Design	1
	Fundamental of machine design, General design considerations	1
2	Material selection, overview of engineering materials its properties and applications.	1
	overview of manufacturing processes; codes and standards	1
	Procedure of Machine Design.	1
	Overview of pure bending equation & torsion equation.	1
3	Stresses in machine elements, Modes of failure; Design/allowable stress; Factor of safety (F0S).	1
	Stress and deflection analysis, fits and tolerances	1
	Theories of failure – maximum normal stress theory	1
	Maximum shear stress theory, Distortion energy theory.	2
	Choice of Failure criteria; Design for stability : buckling analysis – Johnson and Euler columns	1
4	Fatigue in metals; S-N curve; Endurance limit and fatigue strength, Stress concentration factors – effect of discontinuity, fillets and notches, Effect of size, surface finish, stress concentration and degree of reliability on endurance limit	2
	Design for finite and infinite life; Goodman, modified Goodman and Soderberg diagrams with respect to fatigue failure under variable stresses; Cumulative fatigue damage – Miner's equation.	2
	Problem practice	2
5	Design of Cotter joint	1
	Knuckle joint	1
	Fillet Welded joint of brackets under different types of loading	2
6	Riveted joints : Unwin's formula; Brief discussion on single, double and triple row lap joints, butt joints with single or double strap / cover plate; simple strength design; joint efficiencies.	3
	Bolted joints : Metric thread, standard sizes, use of lock nuts an washers; Applications in structures including brackets, turn buckle; Pre-stressed bolts;	3
7	Solid and hollow shafts, strength design of shafts, design based on torsional rigidity	2
	Shaft coupling-rigid, pin-bush and geared flexible type, alignment of coupling	3

8	Belt drives-geometrical relations, derivation of torque and power transmission by flat and V-belt drives, selection of belt from manufacturers' catalogues, pulley	3
	Chain drives – roller chains, polygonal effect, power rating, sprocket wheel, silent chain	2

9	Transmission screw, Screw jack	3
	Helical compression spring - stress and deflection equations, stiffness, curvature effect : Wahl's factor, springs in parallel and series	3
	Multi-leaf springs : load-stress and load-deflection equations, Nipping	3
Total Number Of Hours = 47		

Assignment:

Module-1(Introduction):

1. Define Machine Design
2. What is Concurrent Engineering?
3. Distinguish between Design Synthesis And Analysis.
4. What is Preferred Numbers?
5. What are steps involved in design of a machine elements?
6. Find out Numbers of R10 basic series?
7. It is required to Standardize 11 speeds from 72 to 720 rpm for a machine tool. Specify the speeds.

Module-2(Engineering Materials):

1. What are the advantages and Disadvantages of cast iron from design consideration?
2. Define alloy steel. Advantages of alloy steel. What are important components made of alloy steel?
3. What are ceramics? Advantages and Drawbacks of ceramics. Application of ceramics.
4. What are plastics? Define thermoplastics and thermosetting plastics?
5. What is Teflon? Where do you see that?
6. Advantages and Disadvantages of Fibre Reinforced Plastics.
7. What is Creep? Explain the situation where Creep is a serious problem?

Module-3(Manufacturing considerations in Design):

1. What is Tolerance? Define unilateral and bilateral tolerance.

2. What if Fit? Define various types of Fit.
3. What are the advantages of the hole- basis system over the shaft-basis system?
4. How will you designate Fundamental Deviation?
5. What are guidelines for selection of Clearance Fits, Transition Fits, and Interference Fits? Give Examples.
6. Distinguish between interchangeable and Selective assembly.
7. Explain the symbol of Surface Roughness.
8. A thin cylindrical pressure Vessel of 500 ml inside diameter is subjected to internal pressure of 2 Mpa. If the thickness of the vessel is 20 mm, find the Hoop Stress and Longituidinal Stress.

Module-4(Design against Static load):

1. State Maximum Shear Stress Theory Of Failure.
2. Stresses induced at a critical point in a machine component made of Steel 45C8(σ_{yp}=380 N/mm^2) are as follows σ_x=100 N/mm^2 , σ_y=40 N/mm^2 and τ_{xy}=80 N/mm^2. Calculate FOS by
   - Maximum Normal Stress Theory
   - Maximum Shear Stress Theory.
3. What is Factor Of Safety? Define it for Brittle and Ductile Material.
4. It is required to design a Cotter Joint to connect two steel rods of equal diameter. Each rod is subjected to an axial tensile force of 50 kn. Design the Joint and Specify its main dimension
5. It is required to design a Knuckle Joint to connect two circular rods subjected to an axial tensile force of 50 kn. The rods are co-axial and a small amount of angular movement between their axes is permissible. Design the joint and specify the dimensions of its components.
6. What is surging of spring? How it can be eliminated?
7. Why is cotter provided with a taper? Why it is provided only on one side?
8. State Distortion Energy Theory of Failure.
9. Distinguish stress distribution in curved and straight beams.
10. Give example of mechanical components that fail by static deflection, general yielding And fracture.

Module-5(Design against Fluctuating Load):

1. What is Stress concentration and Stress concentration factor?
2. What is Endurance limit? Define Fatigue Life.
3. What is S-N curve?
4. Define surface finish factor, notch sensitivity, size factor, reliability factor.
5. Miner’s equation. Where do you use.
6. Explain the Modified Goodman diagram for bending stresses and shear stresses.
7. Difference between Gerber curve and Soderberg and Goodman line.

Module-6 (Welded and Riveted Joints):

1. Explain the methods used to make the riveted joints leak proof.

2. A steam boiler 1.2 meter in dia, generates steam at a gauge pressure of 0.7 N/mm^2. Assuming the efficiency of riveted joints as 75%, find the thickness of the shell. Given that ultimate tensile stress=385 Mpa and FOS=5.
3. Two mild steel tie bars for a bridge structure are to be joined means of a butt joints with double straps. The thickness of the bar is 12mm and carries a tensile load of 400kn. Design the joint completely taking allowable stress as f_t= 100 N/mm^2, f_s=75 N/mm^2, f_c= 150 N/mm^2.
4. Two round tie bars of a roof truss are connected by means of a coupling joint (Turnckle). The max pull in the rod is 50 kn. Assuming that the allowable stress in tension compression and shear as 70 N/mm^2; 80 N/mm^2; 30 N/mm^2. Design and draw the joint. How much would be the rods drawn together for one turn of the coupler?
5. Two flat plates are subjected to a tensile force P are connected together by means of double strap butt joints .the force P is 250 kn and the width of the plate is 200mm. The rivets and plates are made of the same material and the permissible stresses in tension, compression and shear are 70, 100, 60 N/mm^2. Calculate:-
   a) The diameter of the rivets
   b) The thickness of the plate
   c) The dimension of the seam, viz. p, pt, m
   d) The efficiency of the joint.

Module-7(Shaft and Belt Drives):

1. In a belt drive, for maximum power transmission, show that one-third of the the max tension in the belt is absorbed as centrifugal tension.
2. What is axle? How does it differ from a shaft?
3. A parallel key is used to connect a pulley to a 45mm dia. Shaft. The standard cross-section of the key is 14*9 mm. The key is made of commercial steel (σ_{yt}=230 N/mm^2) and FOS is 3. Determine the length of the key on the basis of shear and compression consideration, if 15 kw power at 360 rpm is illustrated through the keyed joint. For the key material the yield strength in compression can be assumed to be equal to the yield strength in tension.
4. What is slip? How is it related with speed of pulleys?
5. Design a shaft as per A.S.M.E based on the following data;
   a) Torque and bending moments applied are 400 n-m and 120 n-m respectively
   b) The load applied with light shock. For this case the combined shock and fatigue factor applied to the bending moment k_b=1.5 and the combined shock and fatigue factor applied to torsional moment k_t=1.0
   c) The shaft material is having ultimate strength of 480 N/mm^2, yield strength of 310 N/mm^2 and elastic limit of 250 N/mm^2. Max shear stress τ_{max}= 0.30 S_{yt} or 0.18 S_{ut}(whichever is min).
6. A solid steel shaft transmitting 15kw at 200 rpm is supported on two bearings 750mm apart and has two hears keyed to it. The pinion having 30 teeth of 5mm module is located 100 mm to the left of the right hand bearing and delivers power horizontally to

the right. The gear having 300 teeth of 5 mm module is located 150 mm to the right of the left hand bearing and receives power in a vertical direction from below. Using allowable stress of 54 Mpa in shear, determine the dia of the shaft.

Module-8 and 9 (Power screw and Spring):

1. Define self-locking and overhauling of screw.
2. A helical spring made of a wire of 6mm dia and has outside dia of 75mm. If the permissible shear stress is 350 Mpa and modulus of rigidity 84 kn?mm^2, find the axial load which the spring can carry and the deflection per active turn
3. A vertical two start square threaded screw of 100 mm mean dia and 20mm pitch supports a vertical load of 20kn. The axial thrust on the screw is taken by a collar bearing of 250mm outside dia and 100 mm inside dia. Find the force required at the end of a lever which is 400 mm long in order to left and lover the rod. The coefficient of friction between screw and the nut is 0.15 and for collar bearing is 0.20.

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Lecture-wise Plan

Subject Name: Dynamics of Machines Subject Code-ME504
Year: 3rd Year Semester: 5th

Module Number	Topics	Number of Lectures
1	**Introduction:**	**1L**
	What is Dynamics of Machine? Overview of subject. Areas and Application.	1L
2	**Governors**	**8L**
	Governors: Use and classification; Study and analysis of Porter.	1L
	Study and analysis of Proell governor	2L
	Study and analysis of Wilson-Hartnell governor.	2L
	Sensitiveness, stability, isochronism, hunting, effort and power of governors.	2L
	Effort and power of governors.	1L
3	**Dynamics force analysis and Turning moment Diagram**	**7L**
	Inertia force and inertia torque in reciprocating engine.	2L
	Equivalent dynamical system.	1L
	Correction couple (torque);	1L
	Turning moment diagram and flywheel design.	3L
4	**Balancing**	**7L**
	Balancing: Static balancing; Dynamic balancing of rotating masses	1L
	graphical method	2L
	analytical method	1L
	Balancing of inline single cylinder and four cylinder engine.	1L
	Swaying couple; Hammer blow.	2L

5	**Vibrations**	**12L**
	Definition & types of vibration	1L
	Natural frequency of free longitudinal vibration-Equilibrium method, Natural frequency of free longitudinal vibration-Equilibrium method; Effect of inertia in longitudinal vibration; Natural frequency of free transverse vibration of a beam due to point loads - Rayleigh's method.	4L
	Differential equations of vibratory motions (longitudinal & torsional)	1L
	Whirling of shaft, synchronous whirling.	1L
	Critical speed - Dunkerley's method.	1L
6	Free damped vibration.	1L
	Damping factor; Logarithmic decrement.	1L
	Forced vibration, concept of under damped,.	1L
	Dynamic magnifier (magnification factor), Vibration isolation and transmissibility.	1L
7	**Gyroscope**:	4L
	Gyroscopic couple and precessional motion.	1L
	Effect of gyroscopic couple on aeroplane and ship;	2L
	Stability of two wheel and four wheel vehicles taking turn.	1L
	Total lectures	**39L**

Assignments

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Lecture-wise Plan

Subject Name: Dynamics of Machines Subject Code-ME504

Year: 3rd Year Semester: 5th

Module-1

1. Differentiate between the kinematics of machine and dynamics machine with examples.
2. Write down the engineering application of dynamics of machines.

Module-2

1. What is a function of a governor? How does it differ from that of a flywheel?
2. Define (i) Hunting (ii) Sensitiveness (iii) Sleeve lift and (iv) Isochronism (v) stability for governor
3. Prove that a governor is stable if dF/dr> F/r, Where F is controlling force and r is corresponding radius of rotation.
4. Classify governors and prove for Watt governor, height of the governor h = 895/ N 2.where N is speed of rotation of sleeve.
5. Describe the function of a Proell governor with the help of a neat sketch. Establish a relation among various forces acting on the bent link.
6. A porter governor has equal arms 200mm long pivoted on the axis of rotation. The mass of each ball is 3 kg and the mass on the sleeve is15 kg. The ball path is 120 mm when the governor begins to lift and 160 mm at the maximum speed. Determine the range of speed. If the fraction at the sleeve is equivalent to a force of 10 N, find the coefficient of insensitiveness.
7. A Proell governor has equal arms of length 30 cm. The upper & lower ends of the arms are pivoted on the axis of the governor. The extension arms of the lower links are each 8 cm long and parallel to the axis when the radii of rotation of the balls are 15 cm and 20 cm. The mass of each ball is 10 kg and the mass of the central load is 100 kg. Determine the range of speed of the governor.
8. A Hartnell governor having a central sleeve spring and two right angled bell crank lever operates between 290 r.p.m. and 310 r.p.m. for a sleeve lift of 15mm. The sleeve arms and the ball arms are 80 mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis and mass of each ball is 2.5 kg. The ball arms are parallel to the governor axis at the lowest equilibrium speed. Determine stiffness of the spring.

Module-3

1. State and explain DAlembert's principle.
2. Draw and explain Klein's construction for determining the velocity and acceleration of the piston in a slider crank mechanism.
3. What is meant by dynamically equivalent system? State and prove conditions for it.
4. Explain dynamically equivalent two mass systems.
5. The lengths of crank and the connecting rod of a horizontal reciprocating engine are 300 mm and 1.5 m respectively. The crank is rotating at 120 r.p.m. clockwise .The mass of the reciprocating parts of the engine is 290 kg where as the mass of the connecting rod is 250 kg. The C.G. of the connecting rod is 475 mm from the crank pin Centre and the radius of gyration of the connecting rod about an axis

passing through the C.G. is 625 mm. Find the inertia torque on the crank shaft analytically, when $\theta = 40^0$.

6. In I.C .Engine Mechanism the Crank radius is 400 mm and Connecting rod is 950 mm long. The diameter of piston is 100 mm and net gas pressure acting on the piston is 15 MPa. Find (1) Thrust in connecting road (2) Piston side exhaust (3) Torque acting on Crankshaft (4) Radial force or load on main bearings when crank has made45° from TDC.
7. A single cylinder vertical engine has a bore of 150 mm and a stroke of 200 mm. The connecting rod is 350 mm long. The mass of piston is 1.6 kg and engine speed is 1800 r.p.m. On the expansion stroke with a crank at 300 from the top dead Centre, the gas pressure is 750 kN/m^2. Determine the net thrust on the engine.
8. The connecting rod of a reciprocating engine has a mass of 55 kg, distance between the bearing centers is 850 mm, diameter of small end bearing is 75mm, diameter of big end bearing is 100 mm, time of oscillation when the connecting rod is suspended from the small end is 1.83 s and time of oscillation when it is suspended from the big end is 1.68 s. Determine:(i) the radius of gyration of the connecting rod about an axis passing through the mass centre and perpendicular to the plane of oscillation, (ii)the moment of inertia of the connecting rod about an axis passing through its mass centre and (iii) the dynamically equivalent system of the connecting rod comprising two masses, one at the small end bearing centre.
9. What are turning moment diagrams? What information can be avail from them?
10. Draw and explain to the point turning moment diagram of a 4-Strokesingle cylinder Engine.
11. Derive a relationship for the coefficient of fluctuation of speed in terms of maximum fluctuation of energy and the kinetic energy of the flywheel at mean speed.
12. Explain in brief the working of flywheel in punching Press.
13. The mass of a flywheel is 5000 kg with radius of gyration 2 m and the mean speed of an engine is 240 rpm. If the fluctuation of energy is 100 kN-m, find the maximum and minimum speeds of the flywheel.
14. The turning moment diagram for a multi cylinder engine has been to drawn to a scale of 1 mm to 500 N.m torque and 1 mm to 6° of crank displacement. The intercepted areas between output torque curve and mean resistance line taken in order from one end in sq. mm are,-30,+410,-280,+320,-330,+250,-360,+280,-260 sq. mm when the engine is running at 800 RPM. The engine has a stroke of 300 mm and the fluctuation of speed is not to exceed 2% of the mean speed. Determine a suitable diameter and cross section of the Flywheel rim for a limiting value of the safe centrifugal stress of 7 MPa. The material density maybe assumed as 7200 Kg/m^3. The width of Rim is to be 5 times the thickness.

Module-4

1. Explain the methods of Static and Dynamic balancing using balancing machines in the industry.
2. How and why are reciprocating masses balanced in a piston-cylinder assembly? Why reciprocating masses are partially balanced?
3. For an uncoupled two cylinder locomotive engine, derive the expressions of ‘variation in tractive force’, ‘swaying couple’ and ‘hammer blow’.

4. Discuss the method of Balancing of V-engines and determine the expression for magnitude and direction of resultant primary force.
5. A circular disc mounted on a shaft carries three attached masses of 4 kg, 3 kg and 2.5 kg at radial distances of 75 mm, 85 mm and 50 mm and at the angular positions of 45°,135° and 240° respectively. The angular positions are measured counterclockwise from the reference line along the x-axis. Determine the amount of the countermass at a radial distance of 75 mm required for the static balance.
6. Four masses m1, m2, m3 and m4 are 200 kg, 300 kg, 240 kg and 260 kg respectively. The corresponding radii of rotation are 0.2 m, 0.15 m, 0.25 m and 0.3 m respectively and the angles between successive masses are 45°, 75° and 135°. Find the position and magnitude of the balance mass required, if its radius of rotation is 0.2 m.
7. A shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radii 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70° and C to D 120°. The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400 mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, find their magnitudes and angular positions.
8. A single cylinder reciprocating engine has speed 240 rpm, stroke 300 mm, mass of reciprocating parts 50 kg, mass of revolving parts at 150 mm radius 30 kg. If all the mass of revolving parts and two-third of the mass of reciprocating parts are to be balanced, find the balance mass required at radius of 400 mm and the residual unbalanced force when the crank has rotated 60 from IDC.

Module-5

1. What is vibration? Explain the phenomenon of vibration.
2. What are the causes of vibrations? How the effects of undesirable vibrations can be reduced?
3. Define the terms: Periodic motion, Time period, Frequency, Amplitude, Natural frequency, Fundamental mode of vibration, Degree of freedom, Simple harmonic motion, Phase difference, spring stiffness, Damping, Damping coefficient, & Resonance.
4. Define following terms: Free vibration, Undamped free vibration and natural frequency of vibration.
5. What are different approaches to get equations of motion of a vibratory system? Explain any one in brief. (Three methods: Equilibrium method, Energy method and Rayleigh's method)
6. A cantilever shaft of 50 mm diameter and 300 mm long has a disc of mass 100 Kg at its free end. The Young's modulus for the shaft material is 200 GPa. Determine the

frequency of longitudinal and transverse vibration of the shaft.

7. What is damped vibration? What are the different types of damping methods?
8. Derive an expression for critical speed of shaft?
9. Explain Rayleigh's and Dunkerley's methods for calculating Natural Frequency of Free Transverse Vibrations For a Shaft, Subjected to a Number of Point Loads.

10. Calculate the whirling speed of a shaft 20 mm diameter and 0.6 m long carrying a mass of 1 kg at its mid-point. The density of the shaft material is 40 Mg/m^3, and Young's modulus is 200 GN/m^2. Assume the shaft to be freely supported.

11. A shaft 50 mm diameter and 3 metres long is simply supported at the ends and carries three loads of 1000 N, 1500 N and 750 N at 1 m, 2 m and 2.5 m from the left support. The Young's modulus for shaft material is 200 GN/m^2. Find the frequency of transverse vibration.

Module-6

1. What is damped vibration? What are the different types of damping methods?
2. Derive an expression for the displacement of spring-mass-damper system in case of under damping, critical damping and over damping.
3. Define: logarithmic decrement, damping factor and critical damping coefficient.
4. Derive an expression for logarithmic decrement. What is the significance of logarithmic decrement?
5. A disc of torsion pendulum has a moment of inertia of 0.05 $kg\text{-}m^2$ is immersed in a viscous fluid. During vibration of pendulum, the observed amplitudes on the same side of the neutral axis for successive cycles are found to decay 50% of the initial value. Determine (i) Logarithmic decrement. (ii) Damping torque per unit velocity (iii) The periodic time of vibration. Assume $G = 4.5 \times 10^{10}$ N/m^2 for the material of shaft. For shaft d = 0.10 m and l = 0.50 m.
6. The electric motor is supported on a spring and a dashpot. The spring has the stiffness 6400 N/m and the dashpot offers resistance of 500 N at 4.0 m/sec. The unbalanced mass 0.5 kg rotates at 50 mm radius and the total mass of vibratory system is 20 kg. The motor runs at 400 r.p.m. Determine: damping factor, amplitude of vibration and phase angle, resonant speed and amplitude
7. In a single-degree damped vibration system, a suspended mass of 8 kg makes 30 oscillations in 18 seconds. The amplitude decreases to 0.25 of the initial value after 5 oscillations. Find (1) Spring stiffness, (2) Logarithmic decrement, (3) Damping factor and (4) Damping coefficient.
8. In a single degree viscously damped vibrating system, the suspended mass of 16 kg makes 45 oscillations in 27 seconds. The amplitude of natural vibration decreases to one fourth of initial value after 5 oscillations. Determine: (i) The logarithmic decrement (ii) The damping factor and damping coefficient (iii) The stiffness of the spring.

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Lecture-wise Plan

Subject Name: Dynamics of Machines — Subject Code-ME504

Year: 3rd Year — Semester: 5th

Module-7

1. What is gyroscopic couple? Explain the principle of gyroscopic action and determine the magnitude and direction of gyroscopic couple.
2. Explain gyroscopic effect in case of naval ships with a diagram. Show the terminologies used to indicate sides, front and back of ship. Explain effect of steering, pitching and rolling, assuming ship moves left and right direction sequentially.
3. Explain gyroscopic couple and discuss its effect on an aero plane taking turns when viewed from rear.
4. Explain the effect of the gyroscopic couple on the reaction of the four wheels of a vehicle negotiating a curve.
5. Derive an expression for angle of heel of a two wheeler taking turn.
6. The moment of inertia of an aero plane air screw is 20 kg.m^2 and the speed of rotation is 1250 rpm clockwise when viewed from the front. The speed of the flight is 200 km/hr. calculate the gyroscopic reaction of the air screw on the aeroplane when it makes a left hand turn on a path of 150 m radius. The turbine rotor of a ship has a mass of 2.2 tones and rotates at 1800 r.p.m. clockwise when viewed from the left. The radius of gyration of the rotor is 320mm. Determine the gyroscopic couple and its effect when (1) Ship turns right at a radius of 250 m. with a speed of 25 km/hr. (2) Ship pitches with the bow rising at an angular velocity of 0.8 rad/sec. (3) Ship rolls at an angular velocity of 0.1 rad/sec.
7. The turbine rotor of a ship has mass of 2000 kg and rotates at 25 r.p.s. clockwise when viewed from the stern. The radius of gyration of rotor is 0.30 meter. Determine gyroscopic couple and its effect when (i) the ship turns right at a radius of 250 m with a speed of 25 kmph. (ii) The ship rolls at an angular velocity of 0.1 rad/sec.
8. The turbine rotor of a ship has a mass of 3500 kg. It has a radius of gyration of 0.45 m and a speed of 3000 rpm clockwise when looking from stern. Determine the gyroscopic couple and its effect upon the ship: 1. when the ship is steering to left on a curve of 100 m radius at a speed of 36 km/h 2. When the ship is pitching in a simple harmonic motion, the bow falling with its maximum velocity. The period of pitching is 40 seconds and the total angular displacement between the two extreme positions of pitching is 12 degrees.
9. A car is of total mass 2200 kg has the track width 1.5 m. Each wheel having an effective diameter 0.66 m and the mass moment of inertia 2.4 kg m2.The mass moment of inertia of rotating parts of the engine is 1.2 kg m2.Theengine axis is parallel to the rear axle and the crankshaft rotates in the same sense as the road wheels. The gear ratio of the engine to the rear wheel is 3.The center of mass of the car is 0.55 m above the road level. If the car is rounding a curve of 80 m radius at a speed of 100 km/h, determine the load distribution on the inner and outer wheels.

10. A two wheeler motor vehicle and its rider weight 225 kg and their combined center of gravity is 600 mm above the ground level, when the vehicle is upright. Each road wheel is of 600 mm diameter and has a moment of inertia of 1 kgm2. The rotating parts of the engine have a moment of inertia of 0.175 kg m^2. The engine rotates at 5.5 times the speed of the road wheels and in the same sense. Determine the angle of heel necessary, when the vehicle is rounding a curve of30 m radius at a speed of 55 km/hr.

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Lession- Plan

Subject Name: Applied Fluid Mechanics Subject Code-ME506B
Year: 3rd Year Semester: V

Module/Unit Number	Topics	Number of Lectures
Unit :1	Specific energy, Hydraulic Jump Compressible Flow: speed of propagation of a small disturbance through a compressible fluid,	2L
	sonic velocity, Mach number, mach cone and Mach wave; isentropic flow,.	1L
	stagnation properties of a compressible flow, isentropic pressure,	1L
	temperature and density ratios; compressibility correction factor in the measurement of air speed;	1L
	area – velocity relationship for compressible flow through a variable area duct	1L
	, mass flow rate through a duct,	1L
	flow through convergent-divergent nozzle.	1L
	critical condition and choking;	1L
Unit :2	Ideal Fluid Flow: rotation of a fluid particle,	1L
	vorticity, rotational and irrotational motion;	1L
	velocity potential function, circulation,	1L
	stream function, flownet; governing equation for two dimensional irrotational motion	2L
	, simple two dimensional irrotational flows like uniform flow, plane source, plane sink etc;	1L
	superimposition of simple irrotational flows,	1L
	combination of a source and a sink	1L
Unit :3	Analysis of flow through propellers and windmills –	1L
	slip stream theory, actuated disc theory;	1L
	jet propulsion devices –	1L
	analysis of thrust and other performance parameters	1L
Unit :4	Similarity and model study in turbomachines:	1L
	dimensional analysis of incompressible flow turbomachines flow coefficient,	1L

	head coefficient and power coefficient;	1L
	non-dimensional plot of performance curves;	1L
	specific speed; Cordier diagram;	1L
	specific speed as a design parameter of imcompressible flow turbomachines;	2L
	unit quantities for hydroturbines	1L
Unit :5	Mechanical, hydraulic and volumetric loss in a turbo-pump;	1L
	different types of losses in a hydroturbine installation;	1L
	different efficiencies in turbomachines.	1L
	Interaction of a turbomachine with the pipeline system;	1L
	system head curve and point of operation,	1L
	series and parallel operation of pumps and fans.	1L
	surging,	1L
Unit :6	Testing of hydroturbines,	1L
	different performance characteristics of hydroturbines like operating characteristics, main characteristics,	2L
	Muschel curves; .	1L
	Torque converter and fluid coupling – function and performance	1L
	speed governing of hydroturbines – different methods.	1L
Total Number Of Hours = 42L(42H)		

Assignments

1. Write down the mathematical expressions for vorticity and angular velocity of a three dimensional ow.
2. What is a material derivative? Write down an equation for material derivative.
3. Write Reynolds transport equation by clearly mentioning meanings for each variable involved.
4. De_ne Kutta-Juokowskys law.
5. What is a potential ow? Write the equation governing a potential ow.
6. The complex ow potential for a ow is given as f(z) = U1e i_z. Wire down its velocity and identify the type of ow.
7. Write down the expanded form of N-S equation in polar coordinates.
8. Write down the momentum integral equation for ow over a at plate.

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9. De_ne Reynolds number.
10. Explain laminar ow separation.

Module- I-II

11. (a) The motion of a fluid is described by the following Lagrangian coordinates

$$x = x_0\left(1+\frac{t}{\tau}\right);\quad y = y_0\left(1+2\frac{t}{\tau}\right);\, z = z_0\left(1+\frac{t^2}{\tau^2}\right)$$

where τ is a constant. Find (i) the velocity field (ii) Find the position of the particle at $t = 3\tau$, having location (a, b, c) at $t = \tau$. (10 marks)

(b) Consider the motion of fluid with velocity and density $\vec{V} = k(x\hat{i} - y\hat{j})$ and $\rho = \rho_0 + Aye^{kt}$, respectively. Where k, ρ_0 and A are constants. Find out the rate of change of density of individual fluid particles? (10 marks)

12. (a) Find the Lagrangian coordinate functions for x, y and z corresponding to the Eulerian velocity field $u = -Ax$, $v = By$ and $w = 0$. Given that A and B are positive constants. (10 marks)

(b)Find the equation of stream lines for the flow given by $u = u_0$, $v = v_0 \sin \Omega t$, $w = w_0$, where u_0, v_0, w_0 and Ω are constants. (10 marks)

Module-III-IV

13. (a) Derive an equation for complex ow potential of a doublet ow. (10 marks)
(b) Write down the equation of complex ow potential for ow over a circular cylinder.
Hence derive the equation for radial and tangential components of velocity at any point in the _eld. (10 marks)
14. Using conformal transformations derive the complex ow potential for ow against a vertical at plate. (20 marks)
Module-III
15. Simplify the Navier-Stokes equation in polar cylindrical coordinates for the case of developed ow though a pipe by clearly mentioning the assumptions. Solve this equation and _nd out (i) the velocity distribution and (ii) wall shear stress (10+5+5 marks)
16. Derive an equation for friction factor in laminar ow through a pipe. (20 marks)

Module-V-VI

17. (a) Consider two-dimensional laminar boundary layer ow over a at plate aligned with the direction of a uniform oncoming free stream. The velocity pro_le in the boundary layer is approximated by the sinusoidal distribution u=U1 = sin(_ y=2_) for y lying between 0 and _ and u=U1 = 1 for y > _. Determine the variation of boundary layer thickness and the total skin-friction drag on a plate of length L and width W. (15 marks)
(b) Discuss any four characteristic features of turbulent ow. (5 marks)

18. (a) Derive general momentum integral equation involving pressure gradient. (10 marks)
(b) Derive an ordinary di_erential equation in terms of a similarity variable for boundary ow over a at plate. (10 marks)

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Lecture-wise Plan

Subject Name: Electric Machine **Subject Code-ME506A**
Year: 2nd Year **Semester: Forth**

Module Number	Topics	Number of Lectures
1	**Introduction**	**6L**
	1. Electromechanical Energy Conversion Principle, Singly Excited Magnetic System and Doubly Excited Magnetic system. Physical concept of torque production- Electromagnetic torque and Reluctance torque	2
	2. Concept of General terms pertaining to Rotating Machines: Electrical &Mechanical degree, Pole pitch, Coil, Generated EMF in full pitched coil, Generated EMF in a short pitched coil.	2
	3. Distribution factor, Pitch factor. MMF produced by Distributed Windings, MMF of a coil, MMF of single phase distributed Winding.	2
2	**DC Machines:**	**12L**
	1. EMF generated in the armature. Methods of Excitation, Armature reaction & its effect in the performance, Methods of decreasing the effects of Armature reaction, Effect of Brush shift.	3
	2. Commutation process, Resistance commutation, Delayed commutation, Voltage commutation, Improvement of Commutation.	2
	3. Operating Characteristics of DC Generators: Separately Excited generators, Shunt Generators, Series Generators and Compound Generators.	2
	4. Torque equation of D.C. motor, Operating Characteristics of Shunt, Series &Compound motors.	2
	5. Losses and efficiency of DC machines, Hopkinson's and Swinburne's test.	2
	6. D.C. Machine application: Generator application, Motor application.	1
3	**3-phase Induction motor:**	**9L**
	1. Types, construction, rotating magnetic field, principle of operation	2
	2. Development of equivalent circuit. Performance equations.	2
	3. Torque slip characteristics & power slip characteristics.	2
	4. Parameter estimation. Starting and speed control of Induction motors	2
	5. Flux and MMF phasors in Induction motors,	1
4	**3-phase Transformer:**	**11L**
	1. Determination of polarity and connections (star/star, star/delta, delta/star, star/zigzag, delta/zigzag, open-delta), Phasor groups.	3
	2. Effect of unbalanced loading, Production of Harmonics in Transformer and its suppression.	1
	3. 3-phase to 2-phase transformation, Scott connection, 3-phase	3

	to 6-phase connections, Double star and Double delta.	
	4. 3-winding transformer: Parameter estimation, application.	2
	5. Parallel operation of Transformers, Introduction to Tap changing transformer and its function.	2
Total Number Of Hours = 38		

Shubhajit Pal
Faculty In-Charge

Prof. Aniruddh Mukherjee
HOD, EE Dept.

Assignment:

Module-1(Introduction):

1. Explain the procedure by which a point charge experiences a force when placed inside an electrical flux field.
2. What is Distribution factor, Pitch factor? Explain the importance of these factors.

Module-2 (DC Machines):

1. What is the necessity of commutation process in case of DC generator operation? Also describe the process with appropriate diagram.
2. A 4-pole 350V DC long shunt compound generator supplies a load of 15KW at the rated voltage. The armature, series field and shunt field resistances are 0.2Ω, 0.25Ω, and 300Ω respectively. The armature is lap wound with 50 slots, each slot containing 6 conductors. If the flux per pole is 50mWb, calculate the speed of the generator.
3. Explain the term "Back e.m.f." and describe the concept of torque production in case of a DC motor.
4. A 580V series motor runs at 550r.p.m. taking a current of 55A. Calculate the speed and percentage change in torque if the load is reduced so that the motor is taking 40A. Total resistance of the armature and field circuits is 0.8Ω. Assume flux and field current to be proportional.
5. "A DC series motor is best suited for traction drive" – Explain the statement

Module-3 (3-Phase Transformer):

1. Derive the conditions that should be met in case of parallel operation of two transformers with the support of mathematical expressions.
2. Derive the relation between the number of turns of main transformer and teaser transformer in case of scott-connection if same magnitude of voltage is needed in two phases of its output terminal. Also note down the applications of this type of connection.
3. An ordinary 100KVA two winding transformer's voltage profile is defined as 11500/2300V. If an auto transformer is formed by connecting the windings of two winding transformer in series, what will be the probable voltage ratios and output?

Module-4 (3-Phase Induction Motor):

1. Explain the concept of slip power recovery in case of speed control of three phase induction motor?
2. Prove that when 3-ϕ windings displaced in space by 120° are supplied by 3-ϕ currents displaced in time by 120°, the resulting magnetic flux is rotating in nature.

3. A 6-pole, 50Hz, 3-ϕ induction motor develops a total torque of 160Nm while running on full load. The rotor frequency is 2.5Hz. Find a) Rotor input power, b) Rotor copper loss, and c) Efficiency

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Lab Manual

Title of Course: Applied Thermodynamics & Heat Transfer Lab
Course Code: ME592
L-T –P Scheme: 3P
Course Credits: 2

Introduction:
Heat Transfer laboratory provides fundamental and industrial knowledge about modes of heat transfer, like conduction, convection and radiation, and their application.

Objectives:
Heat Transfer is one of the important subjects which is commonly applied in renewable energy, industrial,
commercial and domestic systems. The experiments are designed to provide exposure of practical aspects
of the various theoretical concepts developed under the course, Heat and Mass Transfer. The laboratory consists of experiments on various conductive, convective, radiative, boiling and condensing mechanisms
of heat transfer.

Learning Outcomes:
At the successful completion of course, the student is able to:
1. Practically relate to concepts discussed in the Heat Transfer course.
2. Conduct various experiments to determine thermal conductivity and heat transfer coefficient in various materials.
3. Select appropriate materials & designs for improving effectiveness of heat transfer.
4. Conduct performance tests and thereby improve effectiveness of heat exchangers.
5. Conduct performance tests and thereby improve effectiveness of refrigeration and air conditioning systems.

Course Contents:

Exercises that must be done in this course are listed below:
1. Study and performance test of a single acting reciprocating air compressor.
2. Study of a shell and tube heat exchanger and determination of LMTD.
3. Determination of thermal conductivity of a metal rod.
4. Determination of ‘h’ for forced convection over a pin fins
5. Verification of emissivity of a plate.
6. Determination of thermal conductivity of an insulating powder/or an insulating plate.

Text Books:

1. Heat and Mass Transfer -by R k Rajput, S. chand publication.
2. Heat And Mass Transfer -by Dr. D. S. Kumar , Publisher: S K Kataria and Sons.
3. Engineering Heat Transfer by Gupta and Prakash.
4. Experimental Methods for Engineers - Mc Graw Hill Book company JP Holman.

Experiment No: 1

Aim: Study and performance test of a single acting reciprocating air compressor.

OBJECTIVE:

To conduct a test on two cylinder Two stage air compressor and to draw graphs of isothermal efficiency and volumetric efficiency at various delivery pressures.

DISCRIPTION:

Two stage compressor is reciprocating type driven by a prime mover AC motor through belt. The test rig consists of a base on which the tank (air reservoir) is mounted. The electrical safety valve & mechanical safety valves are provided. The suction side of low pressure cylinder is connected to the air tank with an orifice plate. The pressure drop across the orifice plate can be measured by water manometer. The out put of the motor is recorded by the swinging field arrangement. The input of the motor can be measured by an energy meter.

COMPRESSOR DETAILS & PARAMETERS:

Dia of LP Cylinder D = 70mm
Stroke l = 85mm

PROCEDURE:

1. Close the outlet valve.
2. Check the manometer connections. The manometer is filled with water up to the half level.
3. Start the compressor and note down initial energy meter reading and spring balance reading.
4. Read the tank pressure gauge for a particular pressure.
5. Note down the RPM of the compressor from the digital speed indicator.
6. Note down the manometer readings.
7. Note down the spring balance reading.
8. Note down the reading of energy meter for a given no of revolutions.

Repeat the experiment for various discharge pressures.

s. no.	Speed (rpm)	T1	T2	T3	T4	H (Manometric diff.)	Inlet pressure	Delivery pressure
1								
2								
3								

Reading Table: 1

CALCULATIONS:

1. **Actual volume flow rate of air :**

$V_a = C_d\ A\ V_A \times 3600\ m^3/hr$

$= C_d\ A \sqrt{2gh_a} \times 3600\ m^3/hr$

$= C_d\ A \sqrt{\dfrac{2gh_w}{1000} \times \dfrac{_w}{_a}} \times 3600\ m^3/hr$

where C_d is co-efficient of discharge = 0.62

A is Aera of orifice = $\dfrac{d^2}{4}\ m^2$

d = dia of orifice = 22 mm (0.022 m)

$_w$ = 1. 283 kg/m cu (density of air)
$_a$ = 1000 kg/ m cu (density of water)
h_w = pressure drop across orifice plate in mm of water

2 . SWEPT VOLUME = Vs (m^3/hr)

$Vs = \dfrac{D^2}{4} \times L \times \dfrac{Nc \times 60}{}$ in m^3/hr.

D is dia of piston = 70 mm = 0.07 m
L is stroke length = 85 mm = 0.085 m
Nc is speed of the compressor in RPM.

3. VOLUMETRIC EFFICIENCY IN %

$$vol = \frac{Va}{Vs} \times 100$$

4 . **Isothermal efficiency of the compressor**

$$iso = \frac{\ln p_2/p_1}{[n/(n-1)]\,[(p_2/p_1)^{n-1/n} - 1]} \quad \text{when} \quad \frac{p_2}{p_1} = \frac{\text{discharge pressure}}{\text{inlet Pressure}}$$

for air

5. (i) Out put power of the electrical motor is given by

$$BP = \frac{2\ N_m \times S \times r}{4500} \times 0.736\ kW$$

where N_m = Speed of the motor, rpm
S = spring balance reading, kgf
r = radius of the arm = 0.18m

(ii) Power input to the motor is found form the energy meter is provided.

6. Reading Table 2:

Readings are noted in the tabular column given below.

No	Discharge pressures		$\frac{p_2}{p_1} = \frac{p_2}{1}$	N_c	N_m	h_w, mm	vol	iso
	p_g	$p_2 = p_g + 1$						

7. Graphs :

Graphs of Volumetric efficiency and isothermal efficiency are drawn for various discharge pressures of air form the compressor.

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Experiment No: 2
Aim: - Study of a shell and tube heat exchanger and determination of LMTD.

SHELL AND TUBE HEAT EXCHANGER APPARATUS

Heat exchangers are the devices used to transfer heat from one fluid to another. Transfer of heat is needed for many applications. Commonly used types of heat exchangers are transfer type, storage type and direct contact type. In transfer type, both, hot and cold fluids pass simultaneously through the heat exchanger. The heat is transferred through the separating wall between them. Transfer type heat exchangers are simple for connections and installations, hence are used in many applications.

In transfer type heat exchangers, different type of flow arrangements are used, viz, parallel, counter or cross flow. The **'SCIENTIFIC'** shell and tube heat exchanger is one shell pass & two tube pass heat exchanger. The hot fluid is hot water obtained from water heater. The cold fluid is cold water. The schematic flow arrangement is shown in figure. Hot water enters the lower side of end box. Flows through the tubes in lower half of shell and comes to the other end of the shell. It reverses its direction, flows through tubes in upper half of the shell and leaves out. Cold water enters lower part of the shell passes over the tubes between the baffles and leaves out of the shell through the outlet at upper surface of shell.

SPECIFICATIONS:

1) Shell - 150 NB,750 m.m. long provided with end boxes.
   a) One end box with devider plate.
   b) 25% cut baffles -4Nos. in the shell.
2) Tubes - 4.5 I.D., 6.35 O.D.,750 mm. copper tubes with triangular pitch. (28 Nos.)
3) Instantaneous water heater, 3Kw capacity, to supply hot water
4) Thermometers for measuring the water temperature.

5) Valves to control hot and cold water flow.

SERVICES REQUIRED FROM CUSTOMER-

1) Water supply about 10 lit/min at constant head .
2) 1 PH, AC supply.
3) Floor space of about 1.5 mtr x 1mtr.
4) Suitable drain arrangements for water.

EXPERIMENTAL PROCEDURE -

1) Connect the water supply and start water flow, for hot water (tube side) keep flow rate above 2.5 Lit/min (maximum flow rate is 7 Lit/min),keep cold water (shell side) flow rate between 3 to 8 Lit/min.
2) Connect the main electric supply (250V,15 A) and switch 'ON' the water heater.

NEVER SWITCH ON THE HEATER BEFORE STARTING WATER SUPPLY.

3) Observe water inlet and outlet temperatures.
4) Wait till steady state is reached and note down the observation's.
5) Repeat the procedure by changing the water flow rates.

OBERVATIONS:

	HOT WATER			**COLD WATER**		
Sr. No	**Inlet temp. t_{hi} ^0c**	**Outlet temp. t_{ho} ^0c**	**Discharge Time for 1 ltrs of water. 't_h'**	**Inlet temp t_{ci} ^0c**	**Outlet temp t_{co} ^0c**	**Discharge Time for 1 ltrs of water. 't_c'**
1						
2						

DATA

1) Sp. heat of water = C_{pw} = 4.2 KJ/Kg K
2) Inside area of tubes = A_i = 4.5 x 10^{-3} x π x 0.75 x 28 = 0.296 m^2
3) Outside area of tubes = A_o= 6.35 x 10^{-3} x π x 0.75 x 28= 0.417 m^2
4) Density of water, ρ_w = 1000 Kg/m^3

CALCULATIONS ;-

1) Hot water inlet temp. T_{hi} = ^0c

Hot water outlet temp. T_{ho} = ^0c

Cold water inlet temp. T_{ci} = ^0c

Cold water outlet temp. T_{co} = ^0c

2) Mass flow rate -

Let time required for 1 ltrs. flow of water in measuring tank, for cold water be t_c and hot water be t_h

mass flow rate, $m_c = 1 / t_c$ kg/s

Similarly, for hot water , $m_h = 1 / t_h$ kg/s

3) Heat collected by cold water -

$$Q_c = m_c \times c_{pw} (t_{c\,o} - t_{ci}) \quad \text{watts}$$

Similarly,

Heat lost by hot water - $Q_h = m_h \times c_{pw} (T_{hi} - T_{ho})$ watts

4) Logarithmic mean temperature difference (LMTD),

For shell and tube heat exchanger,

$\Delta T = F \times LMTD_{cf}$ ^oc

where, $LMTD_{cf}$ = LMTD if the arrangement was counter flow ,

(for 1 - shell pass and 2 - tube pass, $LMTD_{cf}$ should be taken.)

$$LMTD_{cf} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln (T_{hi} - T_{co}) / (T_{ho} - T_{ci})}$$

and , F = correction factor

for finding out correction factor, values of R and S are required

$R = (T_{co} - T_{ci}) / (T_{hi} - T_{ho})$

$S = (T_{hi} - T_{ho}) / (T_{hi} - T_{ci})$

Find out value of F from graph attached using values of R and S.

F =

$\Delta T = F \times LMTD_{cf}$

5) Heat transfer coefficient ,

i) Inside heat transfer coefficient

$$U_i = Q_h / A_i . \Delta T$$

ii) Out side heat transfer coefficient,

$$U_o = Q_c / (A_o . \Delta T)$$

6) Effectiveness of the heat exchanger ,

$$\in = (T_{co} - T_{ci}) / (T_{hi} - T_{ci}) \text{ ------------- } (\text{if } m_c < m_h)$$

OR

$$\in = (T_{hi} - T_{ho}) / (T_{hi} - T_{ci}) \text{ ------------ } (\text{if } m_h < m_c)$$

RESULTS :-

Obs.. .No.	ΔT	U_i	U_o	$\in$

PRECAUTIONS :-

1) Start water supply before switching on the water heater. Put water heater OFF before closing the water supply.
2) Use all the controls and switches gently.
3) Keep the flow rates in the prescribed range, mentioned in experimental procedure. Too low flow rate for hot water may give very high water temperature, which may cause thermostat to put off the heater. Too high flow rate will not give appreciable temperature rise of water.
4) Use clean water for the experiment. Water containing impurities or floating particles may clog the tubes.

SHELL & TUBE HEAT EXCHANGER

SPECIMEN CALCULATIONS:

OBERVATIONS

	HOT WATER			COLD WATER		
Sr. No	Inlet temp. t_{hi} ^0c	Outlet temp. t_{ho} ^0c	Discharge Time for 1 ltrs of water.	Inlet temp t_{ci} ^0c	Outlet temp t_{co} ^0c	Discharge Time for 1 ltrs of water.
1	43	36	19.2	26	32	20.4
2						

DATA

1) Sp. heat of water = C_{pw} = 4.2 KJ/Kg K
2) Inside area of tubes = A_i = 4.5 x 10^{-3} x π x 0.75 x 36 = 0.3817 m^2
3) Outside area of tubes = A_o= 6.35 x 10^{-3} x π x 0.75 x 36= 0.54 m^2
4) Density of water, ρ_w = 1000 Kg/m^3

CALCULATIONS ;-

1) Hot water inlet temp. T_{hi} = 43 ^0c

   Hot water outlet temp. T_{ho} = 36 ^0c

   Cold water inlet temp. T_{ci} = 26 ^0c

   Cold water outlet temp. T_{co} = 32 ^0c

2) Mass flow rate -

   Mass flow rate, m_c = 0.049 Kg/s

   Similarly, for hot water , m_h = 0.052 Kg/s.

3) Heat collected by cold water -

$$Q_c = m_c \times c_{pw} (t_{co} - t_{ci})$$
$$= 0.049 \times 4.2 \times 10^3 \times (32 - 26)$$
$$= 1234.8 \text{ watts}$$

Heat lost by hot water -

$$Q_h = m_h \times c_{pw} (T_{hi} - T_{ho})$$
$$= 0.052 \times 4.2 \times 10^3 \times (43 - 36)$$
$$= 1528.8 \quad \text{watts}$$

4) Logarithmic mean temperature difference (LMTD),

For shell and tube heat exchanger,

$$\Delta T = F \times LMTD_{cf} \quad {}^oc$$

where, $LMTD_{cf}$ = LMTD if the arrangement was counter flow ,

(for 1 - shell pass and 2 - tube pass, $LMTD_{cf}$ should be taken.)

$$LMTD_{cf} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln (T_{hi} - T_{co}) / (T_{ho} - T_{ci})}$$

$$= \frac{(43 - 32) - (36 - 26)}{\ln (43 - 32) / (36 - 26)}$$

$$= 10.49 \ {}^0c$$

and , F = correction factor

for finding out correction factor, values of R and S are required

$$R = (T_{co} - T_{ci}) / (T_{hi} - T_{ho})$$
$$= (32 - 26) / (43 - 36)$$
$$= 0.86$$
$$S = (T_{hi} - T_{ho}) / (T_{hi} - T_{ci})$$
$$= (43 - 36) / (43 - 26)$$
$$= 0.41$$

Find out value of F from graph attached using values of R and S.

$$F = 0.94$$
$$\Delta T = F \times LMTD_{cf}$$
$$= 0.94 \times 10.49$$
$$= 9.8606$$

5) Heat transfer coefficient ,

i) Inside heat transfer coefficient

$U_i = Q_h / A_{i\,.}\,\Delta T$

$= 1528.8 / (0.3817 \times 9.8606)$

$= 406.18\ W/m^2 . k$

ii) Out side heat transfer coefficient,

$U_o = Q_c / (A_{o.}\,\Delta T)$

$= 1234.8 / (0.54 \times 9.8606)$

$= 231.9\ W/m^2 . k$

6) Effectiveness of the heat exchanger ,

$\in = (T_{co} - T_{ci}) / (T_{hi} - T_{ci})$ ------------- (if $m_c < m_h$)

OR

$\in = (T_{hi} - T_{ho}) / (T_{hi} - T_{ci})$ ------------ (if $m_h < m_c$)

as $m_c < m_h$ $= (32 - 26) / (43 - 26)$

$= 0.3529$

RESULTS :-

Ob. .No.	ΔT	U_i	U_o	$\in$
1	9.8606 C	406.18 $W/m^2 . k$	231.9 $W/m^2 . k$	0.3529

SAMPLE CALCULATIONS:

SHELL & TUBE HEAT EXCHANGER

OBERVATIONS

	HOT WATER			COLD WATER		
Sr. No	Inlet temp. t_{hi} ^0c	Outlet temp. t_{ho} ^0c	Discharge Time for 1 ltrs of water.	Inlet temp t_{ci} ^0c	Outlet temp t_{co} ^0c	Discharge Time for 1 ltrs of water.
1	43	33	6.17 Sec.	29	31	6.54Sec

DATA

1) Sp. heat of water = C_{pw} = 4.2 KJ/Kg K
2) Inside area of tubes = $A_i = 4.5 \times 10^{-3} \times \pi \times 0.75 \times 36 = 0.3817\ m^2$
3) Outside area of tubes = $A_o = 6.35 \times 10^{-3} \times \pi \times 0.75 \times 36 = 0.54\ m^2$
4) Density of water, ρ_w = 1000 Kg/m^3

CALCULATIONS ;-

1) Hot water inlet temp. T_{hi} = 43 ^0c

   Hot water outlet temp. T_{ho} = 33 ^0c

   Cold water inlet temp. T_{ci} = 29 ^0c

   Cold water outlet temp. T_{co} = 31 ^0c

2) Mass flow rate -

   Mass flow rate, m_c = 1/ 6.54 = 0.1529 Kg/s

   Similarly, for hot water , m_h = 1/6.17 = 0.162 Kg/s.

3) Heat collected by cold water -

$$Q_c = m_c \times c_{pw} (t_{c\,o} - t_{ci})$$
$$= 0.1529 \times 4.2 \times 10^3 \times (31 - 29)$$
$$= 1284.40 \quad \text{watts}$$

Heat lost by hot water -

$$Q_h = m_h \times c_{pw} (T_{hi} - T_{ho})$$

$$= 0.162 \times 4.2 \times 10^3 \times (43 - 33)$$

$$= 6807.13 \quad \text{watts}$$

4) Logarithmic mean temperature difference (LMTD),

For shell and tube heat exchanger,

$\Delta T = F \times LMTD_{cf} \quad {}^oc$

where, $LMTD_{cf}$ = LMTD if the arrangement was counter flow ,

(for 1 - shell pass and 2 - tube pass, $LMTD_{cf}$ should be taken.)

$$LMTD_{cf} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln (T_{hi} - T_{co}) / (T_{ho} - T_{ci})}$$

$$= \frac{(43 - 33) - (33 - 29)}{\ln (43 - 31) / (33 - 29)}$$

$$= 9.65 \ {}^0c$$

and , F = correction factor

for finding out correction factor, values of R and S are required

$R = (T_{co} - T_{ci}) / (T_{hi} - T_{ho})$
$= (31 - 29) / (43 - 33)$
$= 0.2$

$S = (T_{hi} - T_{ho}) / (T_{hi} - T_{ci})$

$= (43 - 33) / (43 - 29)$

$= 0.71$

Find out value of F from graph attached using values of R and S.

$F = 0.93$

$\Delta T = F \times LMTD_{cf}$

$= 0.93 \times 9.65$

$= 8.98$

5) Heat transfer coefficient ,

i) Inside heat transfer coefficient

$U_i = Q_h / A_i . \Delta T$

$= 6807.13 / (0.3817 \times 8.98)$

$= 1985.93\ W/m^2 . k$

ii) Out side heat transfer coefficient,

$U_o = Q_c / (A_o . \Delta T)$

$= 1284.40 / (0.54 \times 8.98)$

$= 264.86\ W/m^2 . k$

6) Effectiveness of the heat exchanger ,

$\in = (T_{co} - T_{ci}) / (T_{hi} - T_{ci})$ ------------- (if $m_c < m_h$)

OR

$\in = (T_{hi} - T_{ho}) / (T_{hi} - T_{ci})$ ------------ (if $m_h < m_c$)

as $m_c < m_h$ $= (31 - 29) / (43 - 29)$

$= 0.1428$

RESULTS :-

Ob. .No.	ΔT	U_i	U_o	$\in$
1	$5.077\ ^0C$	$3512.64\ W/m^2 . k$	$468.49 W/m^2 . k$	0.1428

****

Experiment No: 3
Aim: - Determination of thermal conductivity of a metal rod.

THERMAL CONDUCTIVITY OF METAL ROD

INTRODUCTION:

Thermal conductivity is the physical property of the material denoting the ease with which a particular substance can accomplish the transmission of thermal energy by molecular motion.
Thermal Conductivity of a material is found to depend on the chemical composition of the substance or substances of which it is a composed, the phase
(i.e. gas, liquid or solid) in which it exists, its crystalline structure if a solid, the temperature and pressure to which it is subjected, and whether or not it is a homogeneous material.
Tabel -1- lists the values of thermal conductivity of for some common metal:

Table -1 - THERMAL CONDUCTIVITY OF SOME MATERIALS

SOLIDS (Metals)	Thermal Conductivity w / m ^{0}C	STATE
Pure Copper	3 80	20 ^{0}C
Brass	110	.. do ..
Steel (0.5% C)	54	.. do ..
Stainless Steel	17	.. do ..

MECHANISM OF THERMAL ENERGY CONDUCTION IN METALS

Thermal energy can be conducted in solids by free electrons and by lattice vibrations. Large number of free electrons moves about in the lattice structure of the material, in good conductors. These electrons carry thermal energy from higher temperature region to lower temperature region, in a similar way they transport electric charge. In fact, these electrons are frequently referred as electron gas. Energy may also be transferred as vibrational energy in the lattice structure of the material. In general, however, this mode of energy transfer is not as large as electron transport and hence, good electrical conductors are always good heat conductors, e. g. copper, silver etc.

However, with increase in temperature, lattice vibrations come in the way of transport by free electrons and for most the metals thermal conductivity decreases with increase in temperature.

THE APPARATUS

The apparatus consists of a copper bar, one end of which is heated by an electric heater and the other end is cooled by a water circulated heat sink. The middle portion, i.e. test section of the bar is covered by a shell containing insulation. The bar temperature is measured at 8 different sections, while 2 thermocouples measure the temperatures at the shell. Two thermometers are provided to measure water inlet and outlet temperatures.

A dimmer is provided for the heater to control its input. Constant water flow is circulated through the heat sink. A gate valve provided, controls the water flow.

SPECIFICATIONS

1) Metal Bar : Copper, 25 mm O.D., approx. 430 mm long with insulation shell along the test length and water cooled heat sink at the other end.

2) Test length of the bar : 231 mm.

3) Thermocouples : Chromel / alumel -12 nos.

4) Band heater to heat the bar.

5) Dimmerstat to control the heater input..

6) Voltmeter and Ammeter to measure heater input.

7) Multichannel Digital temperature indicator, 0.1 ^{0}C least count, 0-200 ^{0}C with channel selector switch.

8) Measuring flask to measure water flow.

EXPERIMENTAL PROCEDURE:

1) Start the electric supply.
2) Start heating the bar by adjusting the heater input to, say, 80 volts or 100 volts.
3) Start cooling water supply through the heat sink and adjust it to around 350 - 400 ml per minute.
4) Bar temperature will start rising. Go on checking the temperatures at time intervals of 5 minutes.
5) when all the temperatures remain steady, note down all the observations and complete the observation table.

OBSERVATION TABLE -

Sr. No.	Test Bar Temperature^{0}C								Shell Temp. ^{0}C		Water Temp. ^{0}C		Water Flow Rate Lit / Sec.
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	

Using the temperatures of the bar at various points, plot the temperature distribution along the length of the bar and determine the slopes of the graph (i. e. temperature drop per unit length) dT/dx at the sections AA, BB and CC as shown in figure.

(Note: As the value of temperature goes on decreasing along the length of the bar, the value of the slope dT / dl is negative.)

CALCULATIONS -

Heat is flowing through the bar from heater end to water heat sink. When steady state is reached, heat passing through the section CC of the bar is heat taken by water.

1) Heat passing through section CC

- $q_{CC} = m \cdot C_P \cdot \Delta T$ watts.

where,

m = mass flow rate of cooling water, Kg / s.

C_p = Specific heat of water

= 4180 J/Kg^{0}C

ΔT = (Water outlet temp.) – (water inlet temp.) ^{0}C

$$\text{Now, } q_{CC} = - K_{CC} \cdot \left[\frac{dT}{dx}\right]_{CC} \cdot A$$

A = Cross sectional area of the bar = 0.00049 m^2

$\therefore K_{CC} =$ W / m ^{0}C

2) Heat passing through section BB

$q_{bb} = q_{cc}$ + Radial heat loss between CC & BB.

$$= q_{CC} + \frac{2\pi k \cdot L_1 (T_6 - T_{10})}{\log e \; (r_o / r_i)}$$

Where,

k = Thermal conductivity of insulation

= 0.35 W/m ^{0}C

L_1 = Length of insulation cylinder

= 0.066 m

r_o = outer radius

= 0.105 m.

r_i = inner radius

= 0.0125 m.

$$\therefore q_{bb} = - K_{bb} \cdot \left[\frac{dT}{dx}\right]_{bb} \cdot A$$

$\therefore K_{bb} =$ W / m ^{0}C

3) Similarly, heat passing through section AA,

$q_{aa} = q_{bb}$ + Radial heat loss between BB & AA.

$$= q_{bb} + \frac{2 \pi k L_2 (T_3 - T_9)}{\log e (r_0 / r_i)}$$

where,

$L_2 = 0.099$ m

$$q_{aa} = - K_{aa} . \left[\frac{dT}{dx} \right]_{AA} . A$$

$\therefore K_{aa} =$ W / m ^{0}C

RESULTS

1) Temperature of the bar decreases from hot end to cool end, which satisfies the Fourier law of heat conduction.
2) Thermal conductivity of bar at three different sections.

Kcc =

K_{bb} =

Kaa =

REFERENCES

1) Engineering Heat Transfer by Gupta and Prakash.

2) Experimental Methods for Engineers - Mc Graw Hill Book company JP Holman.

****

Experiment No: 4
Aim: - Determination of 'h' for forced convection over a pin fins

PIN FIN APPARATUS

Extended surfaces or fins are used to increase the heat transfer rates from a surface to the surrounding fluid wherever it is not possible to increase the value of the surface heat transfer coefficient or the temperature difference between the surface and the fluid. Fins are abricated in variety of forms. Fins around the air cooled engines are a common example.

As the fins extend from primary heat transfer surface, the temperature difference with the surrounding fluid diminishes towards the tip of the fin. The aim of the experiment is to study the temperature distribution and the effectiveness of the fin, which plays an important role in fin design.

The apparatus consists of a simple pin fin which is fitted in a rectangular duct. The duct is attached to suction end of a blower. One end of fin is heated by an electrical heater. Thermocouples are mounted along the length of fin and a thermocouple notes the duct fluid temperature. When top cover over the fin is opened and heating started, performance of fin with natural convection can be evaluated and with top cover closed & blower started, fin can be tested in forced convection.

SPECIFICATIONS -

1) Fins – 12.7 mm O.D., effective length 102 mm with 5 Nos. of thermocouple positions along the length, made of brass, mild steel and aluminum - one each.

Fin is screwed in heater block which is heated by a band heater.

2) Duct - 150 x 100 mm cross section, 1000 mm long connected to suction side of blower.

3) F.H.P. centrifugal blower with orifice and flow control valve on discharge side.

4) Orifice - dia. 22 mm, coefficient of discharge Cd = 0.64.

5) Measurements and controls-

a) Dimmerstat to control heater input, 0 - 230 V, 2 amp.

b) Voltmeter 0 - 250 V, for heater supply voltage.

c) Ammeter 0 - 2 amp. for heater current.

e) Multichannel digital temperature indicator.

f) Water manometer connected to orificemeter.

THEORY -

Let A = cross sectional area of the fin, m^2.

P = circumference of the fin, m.

L = length of the fin = 0.102 m.

T_1 = Base temperature of the fin.

T_f = Duct fluid temperature (channel No. 6 of temperature indicator)

$\varnothing$ = Temperature difference of fin and fluid temperature

= $T - T_f$.

h = heat transfer coefficient, $w / m^2\ ^oC$.

K_f = Thermal conductivity of fin material.

= 110 W / m K for brass.

= 46 W / m K for mild steel.

= 232 W / m K for aluminum.

Heat is conducted along the length of fin and also lost to surroundings. Applying first law of thermodynamics to a control volume along the length of fin at a station which is at length 'x' from the base,

$$\frac{d^2T}{dx^2} - \frac{h.P}{k_f . A} \varnothing = 0 \quad \text{----------- 1}$$

$$y\ \varnothing = (C_1 .\ e^{mx}) + (C_2 . e^{-mx}) \quad \text{-------- 2}$$

$$\text{where, } m = \sqrt{\frac{h . P}{k_f . A}} \quad \text{--------- 3}$$

with the boundary conditions of $\varnothing = \varnothing_1$ at $x = 0$.

$\varnothing_1 = T_1 - T_f$, assuming tip to be insulated.

$\frac{d\varnothing}{dx} = 0$ at $x = L$ results in obtaining equation (2) in the form

$$\frac{\varnothing}{\varnothing_1} = \frac{T - T_f}{T_1 - T_f} = \frac{\cosh m(L - x)}{\cosh m.L} \quad \text{------- } (4)$$

This is the equation for temperature distribution along the length of the fin. Temperatures T_1 and T_f will be known for the given situation and the value of 'h' depends upon mode of convection i.e. natural or forced.

EXPERIMENTAL PROCEDURE

A) NATURAL CONVECTION -

Open the duct cover over the fin. Ensure proper earthing to the unit and switch on the main supply. Adjust dimmerstat so that about 80 volts are supplied to the heater. The fin will start heating. When the temperatures remain steady, note down the temperatures of the fin and duct fluid temperature. Repeat the experiment at different inputs to heater.

OBSERVATIONS -

Sr. No.	Input		Fin Temperatures ^{0}c					Duct fluid temp. ^{0}c
	V	I	T_1	T_2	T_3	T_4	T_5	T_6

B) FORCED CONVECTION -

Close the duct cover over the fin. Start the blower. Adjust the dimmerstat so that about 100 - 110 volts are supplied to the heater. When the temperatures become steady, note down all the temperatures and the manometer difference.

Repeat the experiment at different inputs and at different air flow rates.

OBSERVATION TABLE -

Sr. No.	Manometer difference	Fin Temperatures ^{0}c					Duct fluid temp. ^{0}c
	H (m of water)	T_1	T_2	T_3	T_4	T_5	T_6

CALCULATIONS -

NOMENCLATURE -

T_m = Average fin temperature = $(T_1 + T_2 + T_3 + T_4 + T_5) / 5$

$\Delta T = T_m - T_f$

T_{mf} = mean film temperature = $(T_m + T_f) / 2$

ρ_a = Density of air, kgm / m^3

ρ_w = Density of water, kgm / m^3 = 1000 kgm / m^3

D = Diameter of pin fin = 12×10^{-3} m.

d = Diameter of orifice = 22 x 10^{-3} m.

Cd = coefficient of discharge of orifice = 0.64

μ = Dynamic viscosity of air, N-s /m^2.

Cp = Specific heat of air, kJ /kg ^{0}C.

ν = Kinematic viscosity, m^2 / s.

k_{air} = Thermal conductivity of air, w / m ^{0}C

β = volume expansion coefficient = $1 / (T_{mf} + 273)$

H = manometer difference, m of water.

V = velocity of air in duct, m /s.

Q = volume flow rate of air, m^3 /s.

V_{tmf} = velocity of air at mean film temperature.

All properties are to be evaluated at mean film temperature.

Natural Convection -

The fin under consideration is horizontal cylinder loosing heat by natural convection. For horizontal cylinder, Nusselt number,

$Nu = 1.10\ (Gr . Pr)^{1/6}$ ------- for $10^{-1} < Gr . Pr < 10^4$.

$Nu = 0.53\ (Gr . Pr)^{1/4}$ ------- for $10^4 < Gr . Pr < 10^9$.

$Nu = 0.13\ (Gr . Pr)^{1/3}$ ------- for $10^9 < Gr . Pr < 10^{12}$.

where, Gr = Grashof number,

$$= \frac{g \cdot \beta \cdot D^3 \cdot \Delta T}{\nu^2}$$

Pr = Prandtl number

$$= \frac{Cp \cdot \mu}{k_{air}}$$

Determine Nusselt number.

Now, $Nu = (h \cdot D) / k_{air}$.

y h =

From h, determine 'm' from equation (3)

Using h and m , determine temperature distribution in the fin from equation (4).

The rate of heat transfer from the fin can be calculated as

$$q = \sqrt{h \cdot P \cdot k_f \cdot A} \times (T_1 - T_f) \tanh mL \quad \text{-------} 5$$

and effectiveness of the fin can be calculated as,

$$\varepsilon = \frac{\tanh mL}{mL} \quad \text{-------} 6$$

Forced Convection -

As in natural convection, for horizontal cylinder loosing heat by forced convection,

$Nu = 0.615 \, (Re)^{0.466}$ ----- for $40 < Re < 4000$

$Nu = 0.174 \, (Re)^{0.618}$ ----- for $4000 < Re < 40000$

where,

$$Re = \frac{V_{tmf} \cdot D}{\nu}$$

$$V_{tmf} = \frac{V \cdot (T_{mf} + 273)}{(T_f + 273)}$$

Velocity of air is determined from air volume flow.

$$Q = Cd \frac{\pi}{4} d^2 \sqrt{2 . g . H (\rho_w / \rho_a)} \quad m^3 / s.$$

$$V = Q / \text{ Duct cross sectional area}$$

$$= Q / (0.15 \times 0.1) \quad m/s.$$

From Nusselt number, find out 'h' and from 'h', find out 'm'.

Now temperature distribution, heat transfer rate and effectiveness of the fin can be calculated using equations 4, 5 and 6 respectively.

CONCLUSION -

1) Comment on the observed temperature distribution and calculation by theory , it is expected that observed temperatures should be slightly less than their calculated values because of radiation and non-insulated tip.

2) Plot the graphs of temperature distribution in both natural and forced convection.

PRECAUTIONS -

1) Operate all the switches and controls gently.
2) Do not obstruct the suction of the duct or discharge pipe.
3) Open the duct cover over the fin for natural convection experiment.
4) Fill up water in the manometer and close duct cover for forced convection experiment.
5) Proper earthing to the unit is necessary.
6) While replacing the fins, be careful for fixing the thermocouples. Incorrectly fixed thermocouples may show erratic readings.

PROPERTIES OF AIR

T	°	**Cp**	**« x 10^6**	**k**	**Pr**	**v x 10^6**
^{0} C	kgm/m^3	kJ/kgm-K	N-Sec / m^2	W/m-K		m^2 /Sec
0	1.293	1.005	17.2	0.0244	0.707	13.28
10	1.247	1.005	17.7	0.0251	0.705	14.16
20	1.205	1.005	18.1	0.0259	0.703	15.06
30	1.165	1.005	18.6	0.0267	0.701	16.00
40	1.128	1.005	19.1	0.0276	0.699	16.96
50	1.093	1.005	19.6	0.0283	0.698	17.95
60	1.060	1.005	20.1	0.0290	0.696	18.97
70	1.029	1.009	20.6	0.0297	0.694	20.02
80	1.000	1.009	21.1	0.0305	0.692	21.09
90	0.972	1.009	21.5	0.0313	0.690	22.10
100	0.946	1.009	21.9	0.0321	0.688	23.13
120	0.898	1.009	22.9	0.0334	0.686	25.45
140	0.854	1.013	23.7	0.0349	0.684	27.80

****

Experiment No: 5
Aim: - Verification of emissivity of a plate.

EMISSIVITY MEASUREMENT APPARATUS

INTRODUCTION

All the bodies emit and absorb the thermal radiation to and from surroundings. The rate of thermal radiation depends upon the temperature of body. Thermal radiation's are electromagnetic waves and they do not require any medium for propagation.

When thermal radiation strikes a body, part of it is reflected, part of it is absorbed and part of it is transmitted through body.

The fraction of incident energy, reflected by the surface is called reflectivity (ρ) . The fraction of incident energy, absorbed by the surface is called absorptivity (α) and the fraction of incident energy transmitted through body is called transmissivity (τ)

The surface which absorbs all the incident radiation is called a black surface.

For a black surface , $\rho + \alpha + \tau = 1$

The radiant flux, emitted from the surface is called emissive power (e).

The emissivity of a surface is ratio of emissive power of a surface to that of black surface at the same temperature. Thus,

$$\varepsilon = \frac{e}{eb}$$

THE APPARATUS

The apparatus uses comparator method for determining the emissivity of test plate. It consists of two aluminum plates, of equal physical dimensions. Mica heaters are provided inside the plates. The plates are mounted in an enclosure to provide undisturbed surroundings.

One of the plates is blackened outside for use as a comparator (because black surface has $\varepsilon = 1$). Another plate is having natural surface finish. Input to heaters can be controlled by separate dimmerstats. Heater input is measured on common ammeter and voltmeter. One thermocouple is fitted on surface of each plate to measure the surface temperature with digital temperature indicator. By adjusting input to the heaters, both the plates are brought to same temperature, so that conduction and convection losses from both the plates are equal and difference in input is due to different emissivities.

Holes are provided at back side bottom and at the top of enclosure for natural circulation of air over the plates. The plate enclosure is provided with perspex acrylic sheet at the front.

EXPERIMENTAL PROCEDURE

1. Blacken one of the plates with the help of lamp black (Normally this is blackened at the works, but if blackening is wiped out, then blackening is necessary)
2. Keep both the dimmer knobs at ZERO position.
3. Insert the supply pin-top in the socket (which is properly earthed) and switch 'ON' the mains supply.
4. Switch ON the mains switch on the panel.
5. Keep the meter selector switch (toggle switch) at the black plate side position.
6. Adjust dimmer of black plate, so that around 110 - 120 volts are supplied to black plate.
7. Now, switch the meter selector switch on other side.
8. Adjust test plate voltage slightly less than that of black plate (say 100 -110 volts)
9. Check the temperatures (after, say 10 minutes) and adjust the dimmers so that temperatures of both the plates are equal and steady. Normally, very minor adjustments are required for this.
10. Note down the readings after the plate temperatures reach steady state.

OBSERVATIONS

Plate	I n put		Surface Temp. ^{0}C
	V	I	
Test Plate			T_1 =
Black plate			T_2 =

Enclosure temp. – T3 = ^{0}C

CALCULATIONS

1) Enclosure Temp.

$$TE = T_3 \ {}^0C$$
$$= (T_3 + 273.15) K$$

2) Plate surface temp.

$$T = T_1 = T_2 = \quad {}^0C$$
$$TS = (T + 273.15) K$$

3) Heat input to black plate,

Wb = V x I watts

4) Heat input to test plate,

WT = V x I watts

5) Surface area of plates

$$A = 2 \times \frac{\pi}{4} \cdot D^2 + [\pi \cdot D \cdot t]$$
$$= 0.0447 \ m^2$$

Where, D = dia. of plates = 0.16 m.

and , t = thickness of plates = 0.009 m.

6) For black plate,

Wb = WCVb + WCdb + WRb ------------ (i)

Where,

WCVb = Convection losses

WCdb = Conduction losses

WRb = Radiation losses

Similarly, for test plate,

$$WT = WCVT + WCDT + WRT \quad \text{-------------} \quad (ii)$$

as both plates are of same physical dimensions, same material & at same temperatures,

$$WCVb = WCVT \quad \& \quad WCDb = WCDT$$

Subtracting equation (ii) from (i) we get,

$$Wb - WT = WRb - WRT$$

$$= [\sigma \cdot A \cdot \varepsilon b \; (TS^4 - TE^4)] - [\sigma \cdot A \cdot \varepsilon T \; (TS^4 - TE^4)]$$

$$= \sigma \cdot A \cdot (TS^4 - TE^4) \; (\varepsilon b - \varepsilon)$$

as emissivity of black plate is 1,

$$Wb - WT = \sigma \cdot A \cdot (TS^4 - TE^4) \; (1 - \varepsilon)$$

where,

ε = Emissivity of test plate

σ = Stefan Boltzmann constant = 5.667×10^{-8} W/m^2 K^4

[Note - Emissivity of oxidized aluminum plate i.e. test plate is normally within the range of 0.3 to 0.7.]

CONCLUSION

The emissivity of test plate was found to be ------ at the temperature of ------ K .

PRECAUTIONS

1) Black plate should be perfectly blackened.
2) Never put your hand or papers over the holes provided at the top of enclosure.
3) Keep at least 200mm distance between the back side of unit and the wall.
4) Operate all the switches and knobs gently.

****

Experiment No: 6
Aim: - Determination of thermal conductivity of an insulating powder/or an insulating plate.

THERMAL CONDUCTIVITY OF INSULATING POWDER

Conduction of heat is flow of heat which occurs due to exchange of energy from one molecule to another without appreciable motion of molecules. In any heating process, heat is flowing outwards from heat generation point. In order to reduce losses of heat, various types of insulation's are used in practice. Various powders e.g. asbestos powder , plaster of paris etc. are also used for heat insulation. In order to determine the appropriate thickness of insulation, knowledge of thermal conductivity of insulating material is essential. The 'SCIENTIFIC INDIAN' make unit enables to determine the thermal conductivity of insulating powders, using 'sphere in sphere' method.

THE APPARATUS

The **'SCIENTIFIC INDIAN'** apparatus consists of a smaller (inner) sphere, inside which is fitted a mica electric heater. Smaller sphere is fitted at the center of outer sphere. The insulating powder, whose thermal conductivity is to be determined, is filled in the gap between the two spheres. The heat generated by heater flows through the powder to the outer sphere. The outer sphere loses heat to atmosphere. The input to the heater is controlled by a dimmerstat and is measured wattmeter. Six thermocouples are provided on the outer surface of inner sphere and six thermocouples are on the inner surface of outer sphere, which are connected to a multichannel digital temperature indicator. Average of outer & inner sphere temperatures give the temperature difference across the layer of powder.

SPECIFICATIONS -

1. INNER SPHERE - 100 mm O. D. , halved construction.
2. OUTER SPHERE - 200 mm I. D., halved construction.
3. HEATER - Mica flat heater, fitted inside inner sphere.
4. CONTROLS - a) Main switch - 30 A , DPDT Switch

   b) Dimmerstat - provided.

5. MEASUREMENTS -

   a) Watt meter

   b) Multichannel digital temperature indicator, calibrated for cr / A1 thermocouples.

EXPERIMENTAL PROCEDURE -

1. Keep dimmerstat knob at ZERO position and switch ON the equipment.
2. Slowly rotate the dimmerstat knob, so that wattmeter is applied across the heater. Let the temperatures rise.
3. Wait until steady state is reached.
4. Note down all the temperatures and input of heater .
5. Repeat the procedure for different heat inputs.

OBSERVATIONS

Sr. No.	TEMPERATURES ^{0}C												Watt meter Reading
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	

T H E O R Y

Consider the transfer of heat by heat conduction through the wall of a hollow sphere formed of insulating powder (Ref. fig.)

Let, r_i = radius of inner sphere, m.

r_0 = radius of outer sphere, m.

T_i = average inner sphere surface temp. ^{0}c.

T_o = average outer sphere surface. ^{0}c.

Consider a thin spherical layer of thickness dr at radius r & temperature difference of dT across the layer. Applying fourier law of heat conduction, heat transfer rate,

$$q = -k \cdot 4\pi \cdot r^2 \cdot [dT / dr]$$

where, k = thermal conductivity of insulating powder.

$$y \quad \frac{q}{4\pi k} \times \frac{dr}{r^2} = -dT$$

Integrating between , r_i to r_o and T_i to T_o, we get

$$\frac{q}{4\pi k} \int_{r_i}^{r_o} \frac{dr}{r^2} = -\int_{T_i}^{T_o} dT$$

$$\text{or} \quad \frac{q}{4\pi k} \times \left(\frac{1}{r_i} - \frac{1}{r_o} \right) = (T_i - T_o)$$

$$\text{or} \quad q = \frac{4\pi k \, r_i \, r_o \, (Ti - T_o)}{(r_o - r_i)}$$

From The measured values of q, Ti and To thermal conductivity of insulating powder can be determined as,

$$k = \frac{q \, (r_o - r_i)}{4\pi \cdot r_i \cdot r_o \cdot (Ti - T_o)}$$

CALCULATIONS-

1. Heater input = q = watts
2. Average inner sphere surface temperature

$$T_i = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6}{6} \; {}^oc$$

3. Average outer sphere surface temperature

$$T_o = \frac{T_7 + T_8 + T_9 \,.....\, + T_{12}}{6} \; {}^oc$$

4. Inner sphere radius = 50 mm = 0.05 m
5. Outer sphere radius = 100 mm = 0.1 m.

$$\text{now, } k = \frac{q \; (r_o - r_i)}{4\pi \cdot r_i \, . \, r_o \; (T_i - T_o)} \quad W / m.k$$

$$\text{at} \quad \frac{T_i + T_o}{2} \; {}^oc$$

PRECAUTIONS

1. Operate all the switches and controls gently.
2. If thermal conductivity of the powder other than supplied is to be determined, then gently dismantle the outer sphere and remove the powder, taking care that heater connections and thermocouples are not disturbed.
3. Earthing is essential for the unit.

Sample Calculations - (T.C. Of Insulating Powder)

OBSERVATIONS

Sr. No.	EMPERATURES ^0C										HEATER INPUT	
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	V o l t s	Amps
1	175	175	180	178	46	46	46	48	48	48	55	0.78

CALCULATIONS-

1. Heater input = q =55 x 0.78 = 42.9 watts

2. Average inner sphere surface temperature

$$T_i = \frac{175 + 175 + 180 + 178}{4}$$

$$= 177\ ^0C$$

3. Average outer sphere surface temperature

$$T_o = \frac{46 + 46 + 46 + 48 + 48 + 47}{6}$$

$$= 46.8\ ^0C$$

4. Inner sphere radius = 50 mm = 0.05 m
5. Outer sphere radius = 100 mm = 0.1 m.

$$\text{now, } k = \frac{42.9\ (0.1 - 0.05)}{4\pi \times 0.1 \times 0.05\ (177 - 46.8)}$$

$$= 0.26 \text{ Watts / m}^{2\,0}\text{C} \quad \text{at} \quad 111.9\ ^0\text{C}$$

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Course Description

Title of Course: Metrology & Measurement Lab **Course Code: ME591**
L-T –P Scheme: 2P **Course Credits: 2**

Introduction:
Heat Transfer laboratory provides fundamental and industrial knowledge about modes of heat transfer, like conduction, convection and radiation, and their application.

OBJECTIVES:

1. To provide Practical knowledge on various Metrological equipments available to measure the dimension of the components.
2. To provide Practical knowledge on the correct procedure to be adopted to measure the dimension of the components..
3. Very good knowledge about the all instrument for using measuring purpose
4. To demonstrate the theoretical concepts taught in Mechanical Measurements & Metrology.
5. To understand and use various measuring tools.
6. To understand calibration of various measuring devices

OUTCOMES:

- Upon completion of this course, the Students can demonstrate different measurement technologies and use of them in Industrial Components.

- Error can be easily calculated after performing this lab
- Calibration can easily done
- To demonstrate the theoretical concepts taught in Mechanical Measurements & Metrology.
- To understand and use various measuring tools.
- To understand calibration of various measuring devices.

Course Contents:

At least 6 experiments to be conducted from the following :
1. Taking measurements using following instruments :
(i) Vernier height & depth gauge, (ii) Dial micrometer, (iii) Thread gauge, (iv) Radius gauge, (v) Filler gauge, (vi) Slip gauge.
2. Measurement of angle of a component using :
(i) Vernier bevel protractor, (ii) angle gauges , (iii) Sine-bar and slip gauges.
3. Checking / measuring parallelism, cylindricity and concentricity of components using dial indicator.

4. Measurement of a specific dimension for a lot of components, and prepare a histogram from the data obtained.
5. Measurement of surface finish by a Talysurf instrument.
6. Measurement of micro feature of a product (eg. Thread of a bolt or saw etc.) in a profile projector.
7. Determine natural cooling characteristics of a heated object by using a thermocouple.
8. Measurement of air velocity across an air duct using anemometer.
9. Fixing a strain gauge on a cantilevered flat section of steel. Then calibration of it as a force dynamometer using a Wheatstone bridge
and loading arrangement.
(NB.: This experiment has to be done over two days– one day for fixing and second day for calibration).

Text Books:

1. Jain R.K. "Engineering Metrology", Khanna Publishers, 2005.
2. Gupta. I.C., "Engineering Metrology", Dhanpatrai Publications, 2005.

CALIBRATION OF PRESSURE GAUGE

Aim: To calibrate the given pressure gauge

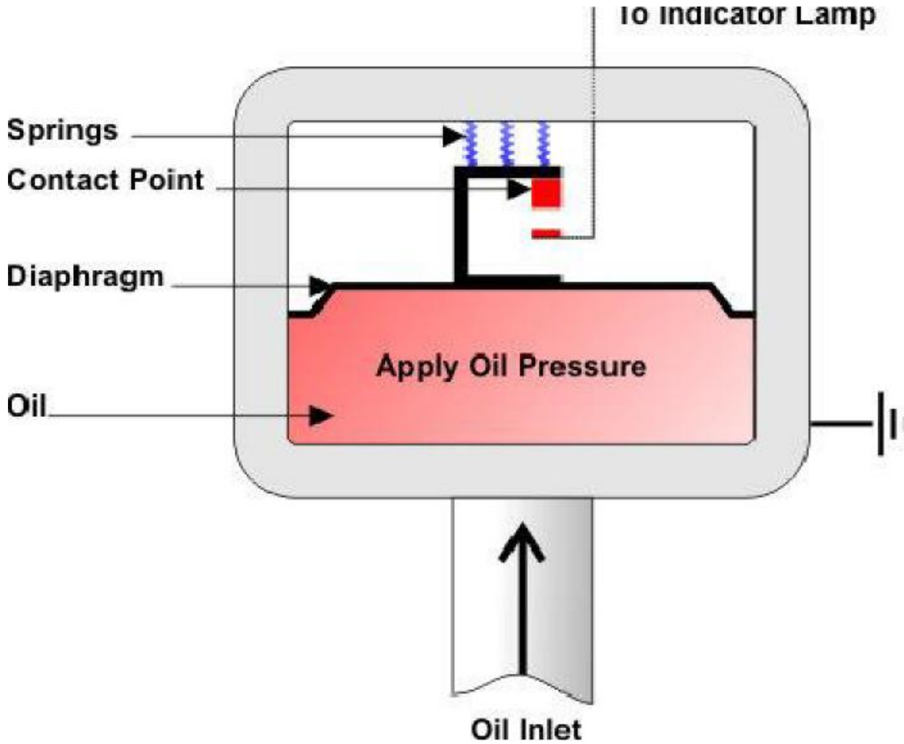
Apparatus: Pressure cell / sensor/ gauge, Dial type pressure cell indicator, Digital pressure Indicator

Theory: Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called **pressure gauges** or **vacuum gauges**. A '***manometer'*** is an instrument that uses a column of liquid to measure pressure, although the term is often used nowadays to mean any pressure measuring instrument. A **pressure sensor / gauges** measures pressure, typically of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area. A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed. Pressure sensors are used for control and monitoring in thousands of everyday applications. Pressure sensors can also be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude. Pressure sensors can alternatively be called **pressure transducers**, **pressure transmitters**, **pressure senders**, **pressure indicators**, **piezometers** and **manometers**, among other names.

Procedure:

1. Make sure that dead weight pressure tester is filled with oil. To fill oil, fill the oil fully in the oil cup provided. Move the plunger to and fro so that all the air inside the reservoir will be filled with oil completely.
2. Connect the pressure cell to the pressure indicator through given cable.
3. Connect the instrument to mains i.e., 230 volts power supply and switch on the instrument.

4. Check up the dead weight pressure tester plunger is to the extreme end so that there should not be any load or pressure on the piston.
5. Now adjust the zero point of the indicator, to indicate zero.
6. Apply the load of 10kg on the piston.
7. Move the plunger to apply pressure on the piston. When applied pressure reaches 10 kg/cm2, piston will start moving up.
8. Now read the pressure gauge reading and adjust the cal pot of the indicator to same pressure, as the analog reading. Now the given pressure cell is calculated.
9. Release the pressure fully by rotating the plunger.



SL No.	Actual Pressure (P_a) (kg/cm^2)	Pressure shown in digital indicator (P_i) (kg/cm^2)	Error $P_i - P_a$	% Error $\frac{Pi - Pa}{Pa}$ x 100
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

10. Load the piston by one kg; apply the pressure by rotating the plunger. At a Pressure of one kg /cm2, piston starts lifting up. Note down the reading.
11. Repeat the experiment for different loads on the piston step by step, and note down the readings of dial gauge and pressure indicator, simultaneously in every step.
12. Calculate the percentage error and plot the graph.

Calculation: % Error = Indicated Pressure – Actual Pressure X 100
Actual Pressure

Plot the Graphs as follows:

1. Indicated Pressure **v/s** Actual Pressure
2. Indicated Pressure **v/s** Percentage error

Applications:

Pressure gauges are used for variety of industrial and application-specific pressuremonitoring applications. Their uses include visual monitoring of air & gas pressure for compressors, vacuum equipment, process lines & specialty tank applications such as medical gas cylinders & fire extinguishers.

Fluid pressure industrial hydraulic circuits.

Measurement of steam pressure in power plants & boilers.

Measurement of pressure in large pumping stations/ water works/ or minor/major irrigations.

Results:
Finally the pressure gauge has been calibrated.

Experiment 2 : to be familiar with measuring measurements and also to study the random nature of product qualities, particularly in dimensions.

Equipment and materials:

1. vernier calipers
2. gage blocks
3. sine bar
4. micrometer
5. workpieces
6. crankshaft

Procedure:

1. Perform the measurements five times and take the average.
2. Repeat the measurements for the different parts.
3. Plot a histogram of frequency versus measured value.
4. Compute the mean and variance.

The items to be included in the report:

Course Description

1. Measured data
2. Plots of histogram if necessary
3. Mean and variance
4. Interference/Allowance information from the shafts and holes
5. Comments

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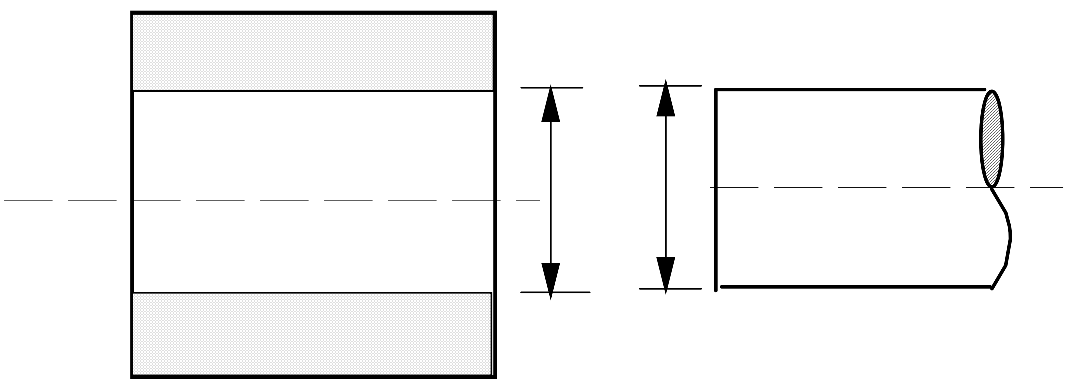
Course Description

EXAMPLE "A": Measurements of A Hole and Shaft



Hole Diameter	Shaft Diameter
1. ____________	1. ____________
2. ____________	2. ____________
3. ____________	3. ____________
4. ____________	4. ____________
5.	5.

6. ____________________

7. ____________________

8. ____________________

9. ____________________

10. ____________________

Nominal Size ____________________ ____________________

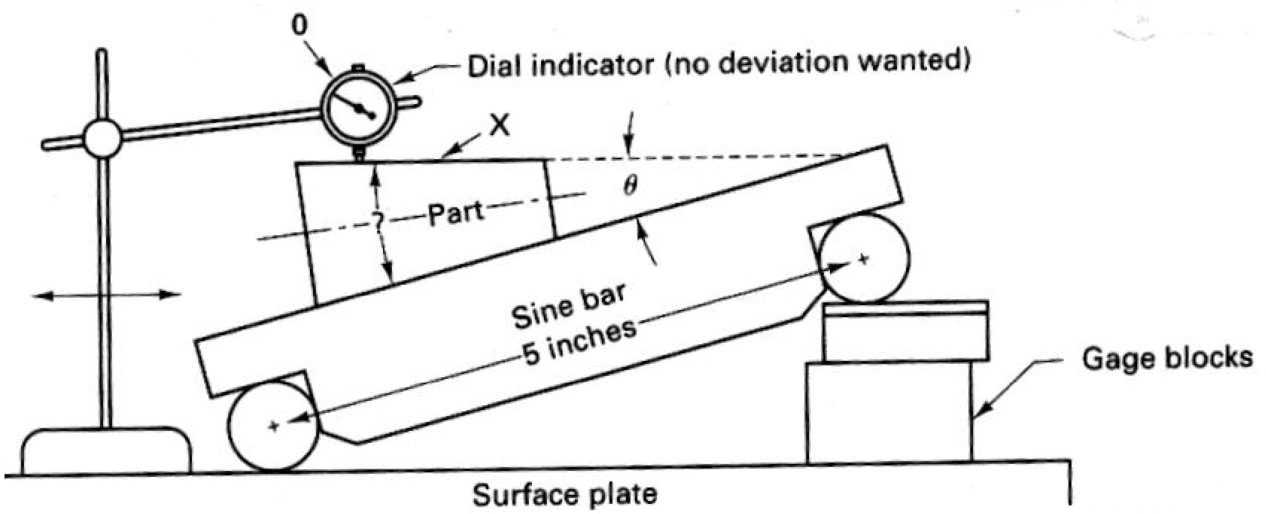
Basic Size ____________________ ____________________

Tolerance ____________________ ____________________

Allowance/Interference of **each** combination of shaft and hole ____________________

[BME#2]: MEASUREMENT EXPERIMENTS

EXAMPLE "B": Angular Measurements Using Sine Bar



Test Specimen	H_1	H_2	H_2-H_1	sinθ	θ°

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Course Description

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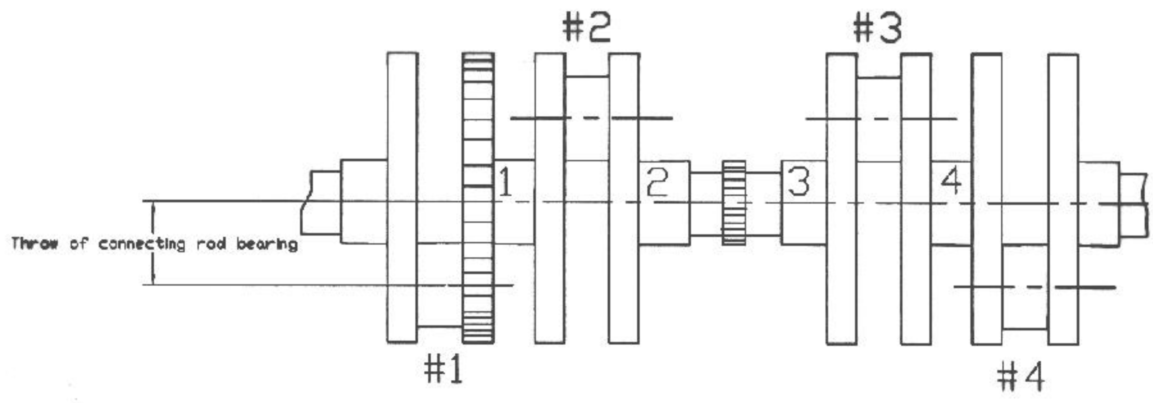
Course Description

EXAMPLE "C": Inspection of Crankshaft



1. Diameters of connecting rod bearing #1: ______________________________
2. Diameters of connecting rod bearing #2: ______________________________
3. Diameters of connecting rod bearing #3: ______________________________
4. Diameters of connecting rod bearing #4: ______________________________
5. Diameters of main bearing #1: ______________________________
6. Diameters of main bearing #2: ______________________________
7. Diameters of main bearing #3: ______________________________
8. Diameters of main bearing #4: ______________________________
9. Throw of connecting rod bearing #1: ______________________________
10. Throw of connecting rod bearing #2: ______________________________

11. Throw of connecting rod bearing #3: ____________________________

12. Throw of connecting rod bearing #4: ____________________________

Experiment 3 : to be familiar with surface roughness, hardness and coordinate measurements

Equipment and materials:

1. Taylor Hobson Surtronic 3+ surface profilometer
2. Brown & Sharp coordinate measuring machine
3. Mitutoyo Rockwell hardness tester
4. Aluminum specimens (turned and milled) for surface roughness measurement
5. Parts for CMM
6. Steel and aluminum specimens for hardness testing

The items to be included in the report:

1. Measured data and plots (roughness vs. feed)
2. AutoCAD drawings of the CMM results.
3. Straightness of surfaces A, B, C and D, out of roundness of holes E and F, parallelism. between A and B, and G and H, and perpendicularity between A and G (these have to be shown on the AutoCAD drawings).
4. Description on bearing area curve.
5. Hardness values in comparison with tensile strength data (available in handbooks)
6. Discussions and conclusions.

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Course Description

[AME #1] Surface Roughness Measurement

Procedure for surface roughness measurements:

1. Learn how to use the profilometer from the lab instructor.
2. Measure surface roughness of turned parts using cutoff lengths of 0.8 mm and 0.25 mm.
3. Rotate the part by 90^0 and repeat the measurement.
4. Generate Ra, Rq and bearing area curve.
6. Repeat 2 through 4 with a milled piece at three different locations: at the center of tool path (perpendicular to lay, position A), at the mid-point (approximately 45 degree to lay, position B) and at the outer point (approximately 60 degrees to lay, position C). See Figure 1.

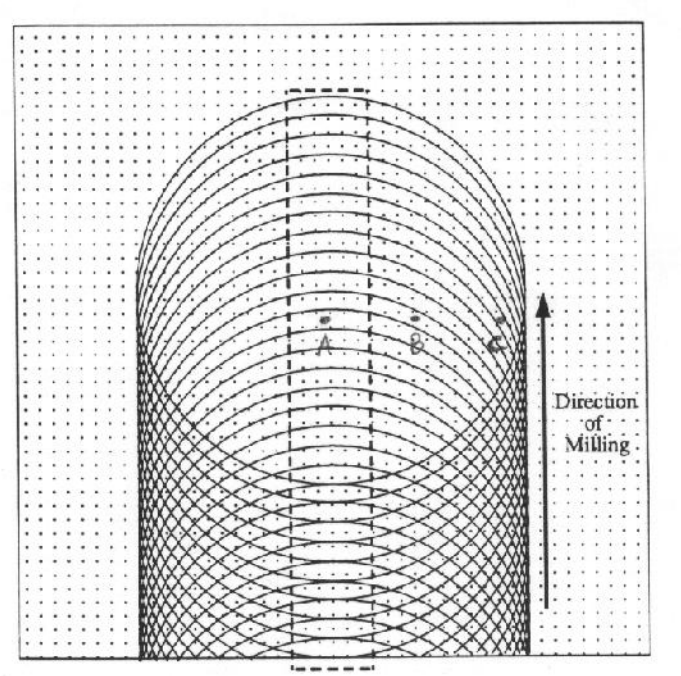

Figure 1 Measurement positions for the milled part.

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Course Description

Procedure for coordinate measurements

1. Position the tough trigger probe at the specified vertical location.
2. Perform the measurements on the specified points (see Figure 2)
3. Move the touch trigger probe in -z direction to the next specified vertical position.
4. Repeat 2.
5. Print out the measured data.
6. Calculate the center of the circles, parallelism of two surfaces of the slot, and the perpendicularity of the slot to the outside plane.
7. Generate AutoCAD drawings of the cross sectional views at three depths in z direction.

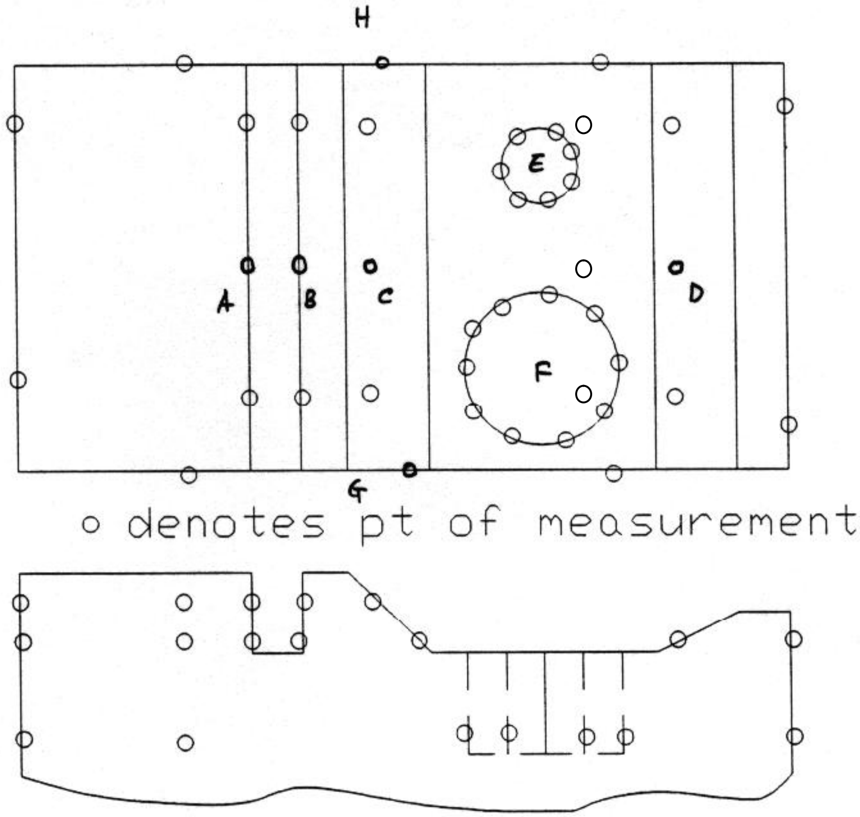

Figure 2: Measurement positions for the coordinate measurements.

[AME #3] Hardness Measurement

Procedure for hardness measurements

1. Learn how to use the hardness tester from the lab instructor.
2. Set the measurement scale to B for the aluminum and steel specimens.
3. After placing the specimen on the tester, ensure the minor load is set for the "R" scale.
4. Apply the major load of 100 kg for the aluminum specimen.
5. Record the hardness value.
6. Repeat steps 3 and 4 for the steel specimen with the major load of 100 kg.

Aim: To calibrate given load cell by actual load.
Apparatus: Load cell of (10 kg capacity), dead weights and digital load indicator.
Theory: Weighing load/force using spring deflection is widely accepted one. But the deflection of spring reading mechanically is very tedious and time consuming. One of the most effective & accurate method is using strain gauge based load cells. Using the principle of deflection of high tensile strength material when load is applied on it and converting it into proportional electrical signal by using strain gauges will give accurate way of measuring load. **Strain gauge**s are bonded on the columns of corrosion resistance super tough alloy of high tensile strength steel that deforms very minutely under load. This deformation is converted to electrical signal through strain gauges bonded on the column and connected to form a wheat stone bridge. This electrical output is proportional to the load acting on the columns. The output of the load cell is calibrated with reference to some standard i.e., primary standard i.e. dead weights.
Procedure:
1. Connect the load cell to digital indicator inserting the corresponding color codes.
2. Connect the digital indicator to mains and switch on the indicator.
3. Adjust the zero knob of the indicator to 0000.
4. Apply the weights up to 08 kg.
5. Apply the _Cal‘ knob of the indicator to read 78.48 N. i.e. (9 x 9.81 N).
6. Remove weights form the load cell.
7. Set the zero knob to zero and repeat the calibration.
8. Now instrument is ready for measurement
9. Keep the weights one by one and take down the indicator reading.
10. Calculate the correction, error and % error.

Tabular Column

Sl. No	Actual Load L_a in Kg	Indicated Load L_i in Kg	Error $L_i - L_a$	% Error $\frac{L_i - L_a}{L_a} \times 100$
1 2				
3				
4 5				

Calculation:

Error = Indicated Load - Actual Load

$$\% \text{ Error} = \frac{\text{Indicated Load} - \text{Actual Load}}{\text{Actual Load}} \times 100$$

Plot the Graphs:
1. Indicated Load **v/s** Actual Load.
2. Indicated Load **v/s** % Error.

Applications
1. Weighing systems are used in both static and dynamic applications.
2. In road and railway weigh bridges.
3. In electrical overhead travelling cranes.
4. Roll force measurement in steel plants/rolling mills.
5. Weigh bridges in conveyers & bunker

Result:
The given Load cell is calibrated by using actual loads.

Aim: To determine the taper angle of a given taper plug gauge/component by using sine centre.
Apparatus: Sine centre, Plug gauge, slips gauge, Surface Plate, Comparator with arrangement & cleaning agent with cotton.
Theory:

The sine centres are used to measure the angles very accurately or for locating any work to a given angle within much closed limits. Sine centre are made from High Carbon, High Chromium corrosion resistant steel, hardened, ground and stabilized.

A special type of sine bar is sine centre which is used for conical objects. It cannot measure the angle more than 45 degrees. Two cylinders of equal diameter are attached at the ends, the axis of these two cylinders are mutually parallel to each other and also parallel to and equal distance from the upper surface of the sine center. The distance between the axes of the two cylinders is exactly 50 or 100 in British system and 100, 200, 300, mm in Metric system. Some holes are drilled in the body of the bar to reduce the weight and to facilitate handling. Sine centre itself is not a complete measuring instrument. Another datum such as surface plate is used as well as auxiliary equipment notably slips gauges.

Sine centre is basically a sine bar with block holding centres which can be adjusted and rigidly clamped in any position. These are used for inspection of conical objects between centres. These are used up to inclination of 60°. Rollers are clamped firmly to the body without any play. This is a very useful device for testing the conical work cantered at each end. The principle of setting is same as of sine table.

Applications:

1. In workshops, assembly shops, precision machining.
2. Checking of existing machine components.
3. Precision machining in aerospace industries & quality control departments.
4. These are used in situations where it is difficult to mount the component on the sine bar.

Tabular Column

SL No	Taper length of the specimen 'l' mm	Height for one side of the work piece 'h1' mm	Height for another side of the work piece 'h2' mm	Diff. of height dh = (h2 - h1)	App. Ht. of slip gauge Read. Happ	Actual Ht. of slip gauge Read. Hact	Theoretical taper angle, θth	Actual taper angle, θact	Error
1									
2									

Calculations:

1) Height for one side of the work piece $'h_1' =$ -------------- mm
2) Height for another side of the work piece $'h_2' =$ -------------- mm
3) Difference in height dh $= (h_2 - h_1)$ = -------------- mm.
4) Approximate height of slip gauge used = $H_{app.}$

$$H_{app.} = \frac{dh \times L}{\sqrt{dh^2+l^2}} \text{ -------------- mm}$$

5) Theoretical taper angle, $\theta_{th} = \tan^{-1}\frac{(D - d)}{2l}$ = ------------- Degrees
6) Actual taper angle, $\theta_{act} = [\sin^{-1}(H_{act})]/L$ = ----------- Degrees
7) Error $\theta_{act} - \theta_{the}$ =--------------- Degrees

Procedure:

1. Note down the least count of the vernier calliper and dial gauge.
2. Measure the minimum, maximum diameter and axial length of taper plug gauge using Vernier calliper.
3. Calculate approximate height of slip gauge using formula.
4. Build up the height using M-87 set of cleaning the surface of slip gauge using acetone liquid and use wringing technique to build the height.
5. Place the slips below one of the cylinder of sine centre which is placed above the surface plate.
6. Keep the plug gauge in between the sin centre.
7. Use the dial gauge with assembling to check the deviation from one end to other end of plug gauge and note down the deviations.
8. Add or subtract the value of the deviation to difference in dial gauge Reading (dh) and repeat the step 7 until zero reading occur in dial gauge and rebuilt the slips repeatedly.
9. Calculate the actual angle of taper plug gauge using actual slip heights.

Results:

For a given component/ plug gauge , we found the theoretical taper angle is **_______** degrees & also actual taper angle is **__________** degrees.

Aim: To find out the taper angle of given work piece by using Bevel Protractor.

Apparatus: Surface Plate, Bevel Protractor, Tapered work piece.

Objectives:

Students will be able to know

- Understanddifferent parts of vernier bevel protractor,
- Know the use and working of bevel protractor,
- Understand the use of vernier bevel protractor.

Theory:

Main parts of bevel protractor are

1. Fixed Base blade and a circular body is attached to it.
2. Adjustable blade.
3. Blade clamp.
4. Scale magnifier lens.
5. Acute angle attachment.

Bevel protractor is used for measuring and lying out of angles accurately and precisely within 5 minutes. The protractor dial is slotted to hold a blade which can be rotated with the dial to the required angle and also independently adjusted to any desired length. The blade can be locked in any position.

It is the simplest instrument for measuring the angle between two faces of component. It consists of base plate attached to the main body and an adjustable blade which is attached to a circular plate containing vernier scale. The adjustable blade is capable of rotating freely about the centre of the main scale engraved on the body of the instrument and can be locked in the any position. It is capable of measuring from zero to 3600. The vernier scale has 24 divisions coinciding with 23 main scale divisions. Thus the least count of the instrument is 51. This instrument is most commonly used in work shop for angular measurements.

Note the reading, magnifying lens has been provided for easy reading of the instrument. Main scale is circular and is graduated in degrees on the circular body. Main scale graduations are all around the circular body which is attached to fixed base blade. Fixed base blade also called as stock is attached to circular body of bevel protractor as shown in figure. Once the reading is fixed, blade clamp fixes the reading. Blades are about 150 mm long or 300mm long, 13mm wide and 2mm thick. Its ends are bevelled at angles of 45 degree and 60 degree. Vernier scale is also marked on turret which can rotate all over the fixed body. Adjustable blade can pass through the slot provided in turret. So as the turret rotates, adjustable blade also rotates full 360 degrees. There are 12 graduations of Vernier scale starting from 0 to 60o on both sides of zero of Vernier scale as shown in figure.

$$\text{Least count of Vernier bevel protractor} = \frac{\text{smallest division on main scale}}{\text{Total no of divisions on Vernier scale}}$$

$$= 1^{\circ} \text{ (equal to 60') i.e. } \frac{60}{12}$$

$$= 5 \text{ minutes (written as 5')}$$

Observations:

Least count of the Bevel Protractor _________________ minutes

Tabular Column:

SL No.	Faces/Sides	Angles
1		
2		
3		
4		

Applications:

1. To measure the acute & obtuse angles in case of flat & circular objects with large radius.

2. In machining processes like production of flat surfaces.
3. For checking the ‗V‘ block, it is used.

Procedure:

1. Note down the least count of the Bevel Protractor.
2. Keep the work piece on the surface plate.
3. Fix the slide of Bevel Protractor to the Turret.
4. Keep one of the surfaces of the specimen on the working edge and rotate the turret. Remove the slide on to the other surface.
5. Fix the centre, after matching the both the faces and note down the reading.
6. Repeat the experiment for different faces

Results:

By using the bevel protractor, the taper angle of the given specimen is calculated.

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Title of Course: Applied Fluid Mechanics lab
Course Code: ME-596B
L-T-P scheme: 0-0-3 **Course Credit: 3**

The Applied Fluid Mechanics Lab focuses on using fundamental fluid mechanics principles integrated within an interdisciplinary framework for tackling problems in the areas of biomechanics, cardiovascular devices and renewable energy.

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:

At least 6 (six) of the following experiments to be conducted.
1. Study of cavitation characteristics of centrifugal pump.
2. Study of the characteristics of submerged jet.
3. Study of characteristics of hydraulic jump.
4. Study of cavitation phenomenon.
5. Verification of Stokes law.
6. Determination of loss through pipes and fittings.
7. Performance test of pumps in series & parallel.

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
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.

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FLUID MECHANICS AND MACHINERY LAB

1. Determination of the coefficient of discharge of given Orifice meter.
2. Determination of the coefficient of discharge of given Venturi meter.
3. Calculation of the rate of flow using Roto meter.
4. Determination of friction factor of given set of pipes.

5. Conducting experiments and drawing the characteristics curves of centrifugal pump/ submergible pump.

6. Conducting experiments and drawing the characteristics curves of reciprocating pump.

7. Conducting experiments and drawing the characteristics curves of Gear pump.

8. Conducting experiments and drawing the characteristics curves of Pelton wheel.

9. Conducting experiments and drawing the characteristics curves of Francis turbine.

10. Conducting experiments and drawing the characteristics curves of Kaplan turbine.

DETERMINATION OF THE CO-EFFICIENT OF DISCHARGE OF GIVEN ORIFICE METER

Exp No : 1

Date :

AIM:

To determine the co-efficient discharge through orifice meter

APPARATUS REQUIRED:

2. Differential U tube

3. Collecting tank

4. Stop watch

5. Scale

FORMULAE :

1. **ACTUAL DISCHARGE**:

$$Q_{act} = A \times h / t \qquad (m^3 / s)$$

2. **THEORTICAL DISCHARGE**:

$$Q_{th} = a_1 \times a_2 \times \sqrt{2gh} / \sqrt{a_1^2 - a_2^2} \qquad (m^3 / s)$$

Where:

A = Area of collecting tank in m^2

h = Height of collected water in tank = 10 cm

a_1 = Area of inlet pipe in, m^2

a_2 = Area of the throat in m^2

g = Specify gravity in m / s^2

t = Time taken for h cm rise of water

H = Orifice head in terms of flowing liquid

$= (H_1 \sim H_2) (s_{m} / s_{1} - 1)$

Where:

H1 = Manometric head in first limb

H2 = Manometric head in second limb

s_m = Specific gravity of Manometric liquid

(i.e.) Liquid mercury Hg = 13.6

s_1 = Specific gravity of flowing liquid water = 1

3. CO EFFICENT OF DISCHARGE:

Co- efficient of discharge = Q act / Q th (no units)

DESCRIPTION:

Orifice meter has two sections. First one is of area a_1, and second one of area a_2, it does not have throat like venturimeter but a small holes on a plate fixed along the diameter of pipe. The mercury level should not fluctuate because it would come out of manometer.

PROCEDURE:

1. The pipe is selected for doing experiments
2. The motor is switched on, as a result water will flow
3. According to the flow, the mercury level fluctuates in the U-tube manometer
4. The reading of H_1 and H_2 are noted
5. The time taken for 10 cm rise of water in the collecting tank is noted
6. The experiment is repeated for various flow in the same pipe
7. The co-efficient of discharge is calculated

RESULT:

The co efficient of discharge through orifice meter is ……… (no unit)

Exp No: 2

DETERMINATION OF THE CO EFFICIENT OF DISCHARGE OF GIVEN VENTURIMETER

S.no	Diameter in mm	Manometric reading		Manometric head H=(H1~H2)	Time taken for h cm rise of water t Sec	Actual discharge Q act x 10^{-3} m^3 / s	Theoretical discharge Qth x 10^{-3}	Co-efficient of discharge Cd (no unit)
		H1 cm of Hg	H2 cm of Hg					
Mean Cd =								

Date:

AIM:

To determine the coefficient of discharge for liquid flowing through venturimeter.

APPARATUS REQUIRED:

1. Venturimeter
2. Stop watch
3. Collecting tank
4. Differential U-tube
5. Manometer
6. Scale

FORMULAE:

1. **ACTUAL DISCHARGE:**

$Q_{act} = A \times h / t$ (m^3 / s)

2. **THEORTICAL DISCHARGE:**

$Q_{th} = a_1 \times a_2 \times \sqrt{2gh} / \sqrt{a_1^2 - a_2^2}$ (m^3 / s)

Where:

A = Area of collecting tank in m^2

h = Height of collected water in tank = 10 cm

a_1 = Area of inlet pipe in m^2

a_2 = Area of the throat in m^2

g = Specify gravity in m / s^2

t = Time taken for h cm rise of water

H = Orifice head in terms of flowing liquid

$= (H_1 \sim H_2)\ (s_m / s_1 - 1)$

Where:

H1 = Manometric head in first limb

H2 = Manometric head in second limb

s_m = Specific gravity of Manometric liquid

(i.e.) Liquid mercury Hg = 13.6

s_1 = Specific gravity of flowing liquid water = 1

3. **CO EFFICENT OF DISCHARGE:**

Co- efficient of discharge = Q act / Q th (no units)

DESCRIPTION:

Venturi meter has two sections. One divergent area and the other throat area. The former is represented as a_1 and the later is a_2 water or any other liquid flows through the Venturi meter and it passes to the throat area the value of discharge is same at a_1 and a_2 .

PROCEDURE:

1. The pipe is selected for doing experiments
2. The motor is switched on, as a result water will flow
3. According to the flow, the mercury level fluctuates in the U-tube manometer
4. The reading of H_1 and H_2 are noted
5. The time taken for 10 cm rise of water in the collecting tank is noted
6. The experiment is repeated for various flow in the same pipe
7. The co-efficient of discharge is calculated

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RESULT:

The co efficient of discharge through Venturimeter is ……… (no unit)

meter in mm	Manometric reading H1 cm of Hg	Manometric reading H2 cm of Hg	Manometric head H=(H1~H2)	Time taken for h cm rise of water t	Actual discharge Q act x 10^{-3} m^3 / s	Theoretical discharge Qth x 10^{-3}	Co-efficient of discharge Cd
						Mean Cd	

S.no					

CALCULATION OF THE RATE OF FLOW USING ROTOMETER

Exp No: 3

Date:

AIM:

To determine the percentage error in Rotometer with the actual flow rate.

APPARATUS REQUIRED:

1. Rotometer setup
2. Measuring scale
3. Stopwatch.

FORMULAE:

1. **ACTUAL DISCHARGE:**

$$Q_{act} = A \times h / t \qquad (m^3 / s)$$

Where:

A = Area of the collecting tank (m^2)

h= 10 cm rise of water level in the collecting tank (10^{-2} m).

t = Time taken for 10 cm rise of water level in collecting tank.

CONVERSION:

Actual flow rate (lit / min), Q_{act} = Qact x 1000 x 60 lit /min

$$\text{Percentage error of Rotometer} = \frac{\text{Rotometer reading} \sim \text{Actual} \times 100\ \%}{\text{Rotometer reading}}$$

$$= R \sim Qact / R \times 100\ \%$$

PROCEDURE:

1. Switch on the motor and the delivery valve is opened
2. Adjust the delivery valve to control the rate in the pipe
3. Set the flow rate in the Rotometer, for example say 50 litres per minute
4. Note down the time taken for 10 cm rise in collecting tank
5. Repeat the experiment for different set of Rotometer readings
6. Tabular column is drawn and readings are noted
7. Graph is drawn by ploting Rotometer reading Vs percentage error of the Rotometer

RESULT :

The percentage error of the Rotometer was found to be……. %

Time taken for 10cm rise of water In tank (t sec)	Actual discharge Q_{act} (lpm)	Percentage Error of Rotometer (%)

S.no	Rotometer Reading	Actual Discharge

DETERMINATION OF FRICTION FACTOR OF GIVEN SET OF PIPES

Exp No: 4

Date:

AIM:

To find the friction ‘f ’ for the given pipe.

APPARATUS REQUIRED:

1. A pipe provided with inlet and outlet and pressure tapping
2. Differential u-tube manometer
3. Collecting tank with piezometer
4. Stopwatch
5. Scale

FORMULAE:

1. FRICTION FACTOR (F):

$f = 2 \times g \times d \times h_f / l \times v^2$ (no unit)

Where,

g = Acceleration due to gravity (m / sec^2)

d = Diameter of the pipe (m)

l = Length of the pipe (m)

v = Velocity of liquid following in the pipe (m / s)

h_f = Loss of head due to friction (m)

$= h_1 \sim h_2$

Where

h_1 = Manometric head in the first limbs

h_2 = Manometric head in the second limbs

2. ACTUAL DISCHARGE:

$Q = A \times h / t$ (m^3 / sec)

Where

A = Area of the collecting tank (m^2)

h = Rise of water for 5 cm (m)

t = Time taken for 5 cm rise (sec)

3. VELOCITY:

$V = Q / a$ (m / sec)

Where

Q = Actual discharge (m^3/ sec)

A = Area of the pipe (m^2)

DESCRIPTION:

When liquid flows through a pipeline it is subjected to frictional resistance. The frictional resistance depends upon the roughness of the pipe. More the roughness of the pipe will be more the frictional resistance. The loss of head between selected lengths of the pipe is observed.

PROCEDURE :

1. The diameter of the pipe is measured and the internal dimensions of the collecting tank and the length of the pipe line is measured
2. Keeping the outlet valve closed and the inlet valve opened
3. The outlet valve is slightly opened and the manometer head on the limbs h_1 and h_2 are noted
4. The above procedure is repeated by gradually increasing the flow rate and then the corresponding readings are noted.

RESULT :

1.The frictional factor 'f ' for given pipe = x 10^{-2} (no unit)

2. The friction factor for given pipe by graphical method = …… x 10^{-2} (no unit)

Friction factor f x 10^{-2}						
V^2 m^2/s^2						

S.no	Diameter of pipe mm	Manometer readings h1 x 10^{-2}	Manometer readings h2 x 10^{-2}	Manometer readings hf = (h1-h2) x 10^{-2}	Time for 5cm rise of water	Actual discharge Qact x 10^{-3} m^3/s	Velocity V m/s

CHARACTERISTICS TEST ON CENTRIFUGAL PUMP

Exp No: 5

Date:

AIM :

To study the performance characteristics of a centrifugal pump and to determine the characteristics with maximum efficiency.

APPARATUS REQUIRED :

1. Centrifugal pump setup
2. Meter scale
3. Stop watch

FORMULAE :

1.ACTUAL DISCHARGE:

$Q_{act} = A \times y / t$ (m^3 / s)

Where:

A = Area of the collecting tank (m^2)

y = 10 cm rise of water level in the collecting tank

t = Time taken for 10 cm rise of water level in collecting tank.

2. TOTAL HEAD:

$H = Hd + Hs + Z$

Where:

Hd = Discharge head, meter

Hs = Suction head, meter

3.INPUT POWER:

$$I/P = (3600 \times N \times 1000) / (E \times T) \quad \text{(watts)}$$

Where,

N = Number of revolutions of energy meter disc

E = Energy meter constant (rev / Kw hr)

T = time taken for 'Nr' revolutions (seconds)

4. OUTPUT POWER:

$$Po = \rho \text{ x } g \text{ x } Q \text{ x } H / 1000 \quad \text{(watts)}$$

Where,

ρ = Density of water (kg / m^3)

g = Acceleration due to gravity (m / s^2)

H = Total head of water (m)

5.EFFICIENCY:

$$\eta_o = (\text{Output power o/p / input power I/p}) \times 100 \%$$

Where,

O/p = Output power kW

I/ p = Input power kW

DESCRIPTION:

PRIMING:

The operation of filling water in the suction pipe casing and a portion delivery pipe for the removal of air before starting is called priming.

After priming the impeller is rotated by a prime mover. The rotating vane gives a centrifugal head to the pump. When the pump attains a constant speed, the delivery valve is gradually opened. The water flows in a radially outward direction. Then, it leaves the vanes at the outer circumference with a high velocity and pressure. Now kinetic energy is gradually converted in to pressure energy. The high-pressure water is through the delivery pipe to the required height.

PROCEDURE:

1. Prime the pump close the delivery valve and switch on the unit
2. Open the delivery valve and maintain the required delivery head
3. Note down the reading and note the corresponding suction head reading
4. Close the drain valve and note down the time taken for 10 cm rise of water level in collecting tank
5. Measure the area of collecting tank
6. For different delivery tubes, repeat the experiment
7. For every set reading note down the time taken for 5 revolutions of energy meter disc.

GRAPHS:

1. Actual discharge Vs Total head
2. Actual discharge Vs Efficiency
3. Actual discharge Vs Input power
4. Actual discharge Vs Output power

RESULT:

Thus the performance characteristics of centrifugal pump was studied and the maximum efficiency was found to be ______________

S. no	Suction gauge Hs m of water	Suction head Hs m of water	Delivery Gauge Reading	Delivery Head (Hd) m of	Total Head (H) m of	Time taken for 'h' rise of water	Time taken for Nr revolutio n t S	Actual Discharge (Qact) $x10^{-3}$	Input Power (Pi) watt	Output Power (Po)	η %

CHARACTERISTICS CURVES OF SUBMERSIBLE PUMP

Date:

AIM :

To study the performance characteristics of a submersible pump.

APPARATUS REQUIRED :

1. Submersible pump
2. Meter scale
3. Stop watch

FORMULAE :

1**. ACTUAL DISCHARGE:**

$$Q_{act} = A \times h / t \qquad (m^3 / sec)$$

Where,

A = Area of the collecting tank (m^2)

h = Height of the water level collected (cm)

t = Time taken for 'h' rise of water (seconds)

x = Distance between the suction and delivery gauge

2. INPUT POWER:

$$P_i = (3600 \times N_r \times 1000) / (N_e \times t_e) \qquad (watts)$$

Where,

Nr = number of revolutions of energy meter disc

Ne = energy meter constant (rev / Kw hr)

te = time taken for 'Nr' revolutions (seconds)

3. OUTPUT POWER:

$P_o = W \times Q_{act} \times H$ (watts)

Where,

W = specific weight of water (N / m^3)

Qact = actual discharge (m^3 / s)

H = total head of water (m)

4. EFFICIENCY:

$\%\eta = (\text{Output power } P_o / \text{input power } P_i) \times 100$

DESCRIPTION:

In submergible pump electric motor and pump are coupled together and both are submerged in the water. The electric current is conducted through a waterproof cable. This is multi stage centrifugal pump with radial or mixed flow impellers.

The suction housing of the pump is fitted between the pump and motors are provided with a perforated strainer. The windings of the motor are insulated well and cooled by water. A gate valve, which is a non-return valve, is provided at the top of the pump to discharge water.

PROCEDURE:

1.The submersible pump is started

2. The delivery gauge reading is set to the required value by means of

Adjusting the gate-valve

3.The time taken for Nr revolutions in the energy meter disc is

Noted with the help of stop watch

4.The time taken for 'h' rise in water level in the collecting tank is

Found carefully. If the water flow is heavy reduce the 'h' value

5.The experiment is repeated for different delivery gauge readings

6.Finally the readings are tabulated and calculated

GRAPHS:

1. Actual discharge Vs Total head
2. Actual discharge Vs Input power
3. Actual discharge Vs Efficiency

RESULT:

The performance characteristic of the submersible pump is studied and the efficiency is calculated …………… %

CHARACTERISTICS CURVES OF RECIPROCATING PUMP

Exp No: 7

Date:

S.no	Delivery Gauge Reading	Delivery Head [Hd]x10	Total Head [Hd +2]	Time taken for 'h' rise Of water [t]	Time taken for Nr revolution	Actual Discharge [Qact]	Input Power [Pi]	Output Power [Po]	Efficiency ¦ %
								Mean =	

AIM:

To study the performance characteristics of a reciprocating pump and to determine the characteristic with maximum efficiency.

APPARATUS REQUIRED:

1. Reciprocating pump
2. Meter scale
3. Stop watch

FORMULAE:

1. **ACTUAL DISCHARGE:**

$$Q_{act} = A \times y / t \qquad (m^3 / s)$$

Where:

A = Area of the collecting tank (m^2)

y = 10 cm rise of water level in the collecting tank

t = Time taken for 10 cm rise of water level in collecting tank

2.TOTAL HEAD:

$$H = Hd + Hs + Z$$

Where:

Hd = Discharge head; Hd = Pd x 10, m

Hs = Suction head; Pd = Ps x 0.0136, m

Z = Datum head, m

Ps = Suction pressure gauge reading, mm of Hg

3.INPUT POWER:

$$P_i = (3600 \times N) / (E \times T) \quad (Kw)$$

Where,

N = Number of revolutions of energy meter disc

E = Energy meter constant (rev / Kw hr)

T = time taken for 'N' revolutions (seconds)

4. OUTPUT POWER:

$$Po = \rho \times g \times Q \times H / 1000 \quad (Kw)$$

Where,

ρ = Density of water (kg / m^3)

g = Acceleration due to gravity (m / s^2)

H = Total head of water (m)

Q = Discharge (m^3 / sec)

5.EFFICIENCY:

$$\eta_o = (\text{Output power po / input power pi}) \times 100\ \%$$

Where,

Po = Output power KW

Pi = Input power KW

PROCEDURE:

1. Close the delivery valve and switch on the unit
2. Open the delivery valve and maintain the required delivery head
3. Note down the reading and note the corresponding suction head reading
4. Close the drain valve and note down the time taken for 10 cm rise of water level in collecting tank
5. Measure the area of collecting tank
6. For different delivery tubes, repeat the experiment
7. For every set reading note down the time taken for 5 revolutions of energy meter disc.

GRAPHS:

1. Actual discharge Vs Total head
2. Actual discharge Vs Efficiency
3. Actual discharge Vs Input power
4. Actual discharge Vs Output power

RESULT:

The performance characteristic of the reciprocating pump is studied and the efficiency is calculated …………… %

S. no	Delivery pressure reading Pd kg / cm^2	Suction pressure reading Ps mm of Hg	Delivery head Hd=Pdx10.0	Suction head Hs = Ps x 0.0136	Datum head Z m	Total head H	Time taken for 10 cm of rise of water in tank t sec	Actual discharge Q_{act} m^3/s	Time taken for N rev of energy meter disc t sec	Input power Pi kw	Output power Po kw	
											Mean =	

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CHARACTERISTICS CURVES OF GEAR OIL PUMP

Exp No: 8

Date:

AIM:

To draw the characteristics curves of gear oil pump and also to determine efficiency of given gear oil pump.

APPARATUS REQUIRED:

1. Gear oil pump setup
2. Meter scale
3. Stop watch

FORMULAE:

1. ACTUAL DISCHARGE:

$Q_{act} = A \times y / t$ (m^3 / sec)

Where,

A = Area of the collecting tank (m^2)

y = Rise of oil level in collecting tank (cm)

t = Time taken for 'h' rise of oil in collecting tank (s)

2. TOTAL HEAD:

$H = Hd + Hs + Z$

Where

Hd = Discharge head; Hd = Pd x 12.5, m

Hs = Suction head; Pd = Ps x 0.0136, m

Z = Datum head, m

Pd = Pressure gauge reading, kg / cm^2

Ps = Suction pressure gauge reading, mm of Hg

3. INPUT POWER:

$Pi = (3600 \times N) / (E \times T)$ (kw)

Where,

Nr = Number of revolutions of energy meter disc

Ne = Energy meter constant (rev / Kw hr)

te = Time taken for 'Nr' revolutions (seconds)

4. OUTPUT POWER:

$Po = W \times Qact \times H /1000$ (watts)

Where,

W = Specific weight of oil (N / m^3)

Qact = Actual discharge (m³ / s)

h = Total head of oil (m)

5. EFFICIENCY:

$$\%\eta = (\text{Output power Po / input power Pi}) \times 100$$

DESCRIPTION:

The gear oil pump consists of two identical intermeshing spur wheels working with a fine clearance inside the casing. The wheels are so designed that they form a fluid tight joint at the point of contact. One of the wheels is keyed to driving shaft and the other revolves as the driven wheel.

The pump is first filled with the oil before it starts. As the gear rotates, the oil is trapped in between their teeth and is flown to the discharge end round the casing. The rotating gears build-up sufficient pressure to force the oil in to the delivery pipe.

PROCEDURE:

1. The gear oil pump is stated.
2. The delivery gauge reading is adjusted for the required value.
3. The corresponding suction gauge reading is noted.
4. The time taken for ‘N’ revolutions in the energy meter is noted with the help of a stopwatch.
5. The time taken for ‘h’ rise in oil level is also noted down after closing the gate valve.

6. With the help of the meter scale the distance between the suction and delivery gauge is noted.
7. For calculating the area of the collecting tank its dimensions are noted down.
8. The experiment is repeated for different delivery gauge readings.
9. Finally the readings are tabulated.

GRAPH:

1. Actual discharge Vs Total head
2. Actual discharge Vs Efficiency
3. Actual discharge Vs Input power
4. Actual discharge Vs Output power

RESULT:

Thus the performance characteristics of gear oil pump was studied and maximum efficiency was found to be. ………%.

S. no	Delivery pressure reading Pd kgf / cm^2	Suction pressure reading Ps mm of Hg	Delivery head Hd=Pdx12.5 m	Suction head Hs = Ps x 0.0136 m	Datum head Z m	Total head H m	Time taken for 10 cm of rise of water in tank t sec	Actual discharge Q_{act} m^3/s	Time taken for N rev of energy meter disc t sec	Input power Pi kw	Output power Po kw	%
											Mean =	

CHARACTERISTICS CURVES OF PELTON WHEEL

Exp No: 9

Date:

AIM:

To conduct load test on pelton wheel turbine and to study the characteristics of pelton wheel turbine.

APPARATUS REQUIRED :

1. Venturimeter
2. Stopwatch
3. Tachometer
4. Dead weight

FORMULAE:

1. **VENTURIMETER READING:**

$$h = (P1 \sim P2) \times 10 \qquad \text{(m of water)}$$

Where,

P1, P2 - venturimeter reading in Kg /cm^2

2. DISCHARGE:

$$Q = 0.0055 \times \sqrt{h} \qquad (m^3 / s)$$

3. BRAKE HORSE POWER:

$$BHP = (\pi \times D \times N \times T) / (60 \times 75) \quad (hp)$$

Where,

N = Speed of the turbine in (rpm)

D = Effective diameter of brake drum = 0.315 m

T = Torsion in To + T1 – T2 (Kg)

4. INDICATED HORSE POWER:

$$IHP = (1000 \times Q \times H) / 75 \quad (hp)$$

Where,

H = Total head (m)

5. PERCENTAGE EFFICIENCY:

$$\%\eta = (B.H.P / I.H.P \times 100) \quad (\%)$$

DESCRIPTION:

Pelton wheel turbine is an impulse turbine, which is used to act on high loads and for generating electricity. All the available heads are classified in to velocity energy by means of spear and nozzle arrangement. Position of the jet strikes the knife-edge of the buckets with least relative resistances and shocks. While passing along the buckets the velocity of the water is reduced and hence an impulse force is supplied to the cups which in turn are moved and hence shaft is rotated.

PROCEDURE:

1. The Pelton wheel turbine is started.
2. All the weight in the hanger is removed.

3. The pressure gauge reading is noted down and it is to be maintained constant for different loads.
4. The venturimeter readings are noted down.
5. The spring balance reading and speed of the turbine are also noted down.
6. A 5Kg load is put on the hanger, similarly all the corresponding readings are noted down.
7. The experiment is repeated for different loads and the readings are tabulated.

GRAPHS:

The following graphs are drawn.

1. BHP Vs IHP
2. BHP Vs speed
3. BHP Vs Efficiency

RESULT:

Thus the performance characteristics of the Pelton Wheel Turbine is done and the maximum efficiency of the turbine is ………. %

S.no	Pressure Gauge	Total Head [H]	Venturimeter reading		H= (P1-P2) x 10 m of water	Weight of hanger To	Speed of turbine N	Weigh of hanger [T1]	Spring Balance T2	Tension [T] Kg	Discharge Q $x10^{-3}$ m^3\sec	B.H.P hp	I.H.P hp	%
			P1	P2										
											Mean =			

CHARACTERISTICS CURVES OF FRANCIS TURBINE

Date:

AIM:

To conduct load test on franchis turbine and to study the characteristics of francis turbine.

APPARATUS REQUIRED:

1. Stop watch
2. Tachometer

FORMULAE:

1. VENTURIMETER READING:

$h = (p1 - p2) \times 10$ (m)

Where

P1, p2- venturimeter readings in kg / cm^2

2. DISCHARGE:

$Q = 0.011 \times \sqrt{h}$ (m^3 / s)

3. BRAKE HORSEPOWER:

$BHP = \pi \times D \times N \times T / 60 \times 75$ (h p)

Where

N = Speed of turbine in (rpm)

D = Effective diameter of brake drum = 0.315m

T = torsion in [kg]

4. INDICATED HORSEPOWER:

$HP = 1000 \times Q \times H / 75$ (hp)

Where

H – total head in (m)

5. PERCENTAGE EFFICIENCY:

$$\%\eta = B.H.P \times 100 / I.H.P \qquad (\%)$$

DESCRIPTION:

Modern Francis turbine in an inward mixed flow reaction turbine it is a medium head turbine. Hence it required medium quantity of water. The water under pressure from the penstock enters the squirrel casing. The casing completely surrounds the series of fixed vanes. The guides' vanes direct the water on to the runner. The water enters the runner of the turbine in the dial direction at outlet and leaves in the axial direction at the inlet of the runner. Thus it is a mixed flow turbine.

PROCEDURE:

1.The Francis turbine is started

2. All the weights in the hanger are removed

3.The pressure gauge reading is noted down and this is to be maintained constant for different loads

4. Pressure gauge reading is assended down

5. The venturimeter reading and speed of turbine are noted down

6.The experiment is repeated for different loads and the reading are tabulated.

GRAPHS :

The following graphs are drawn

1. BHP (vs.) IHP

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2. BHP (vs.) speed

3. BHP (vs.) % efficiency

RESULT :

Thus the performance charactertics of the Francis wheel turbine are done and the maximum efficiency of the turbine is …………. %

Weight of hanger To Kg	Speed of turbin e N	Weig h of hange r [T1]	Sprin g Balan ce T2	Tensi on [T] Kg	Disch arge Q x10^{-3} m^3\sec	B.H.P hp	I.H.P hp	%
Mean								

S.no	Pressure Gauge Reading		Total Head [H] m of water	Venturimeter reading $Kg\backslash cm^2$		H= (P1-P2) x 10 m of water

CHARACTERISTICS CURVES OF TRIANGULAR NOTCH

Exp No: 11

Date:

AIM:

To determine the co-efficient of discharge of flow through triangular notch.

APPARATUS REQUIRED:

1. Notch tank
2. Triangular notch
3. Hook gauge
4. Collecting tank
5. Stop watch
6. Piezo meter
7. Meter scale

FORMULAE:

1. ACTUAL DISCHARGE:

$Q_{act} = A \times h / t$ (m^3 / sec)

Where,

A = Area of the collecting tank (m^2)

h = Rise of water level in collecting tank (cm)

t = Time taken for 'h' rise of oil in collecting tank (s)

2. THEORETICAL DISCHARGE:

$Q_{the} = (8 / 15) \times (\tan \theta / 2) \sqrt{2 \times g} \times H^{5/2}$ (m^3 / s)

Where

H = Manometer height in m

g = Gravity in m / s

3. CO-EFFICIENT OF DISCHARGE:

$Cd = Q_{act} / Q_{the}$ (no unit)

DESCRIPTION:

1. The inlet valve is opened and water is allowed to rise up to the level of the triangular notch
2. The pointer of the manometer gauge is adjusted so that it coincides the water surface and note down reading
3. The inlet valve is opened so that the water flows over the notch at the same rate
4. The water level is noted by means of point gauge
5. The readings for H2 is noted
6. The time required for10 cm rise of water level is noted
7. The above procedure is repeated for different discharge

RESULT:

The co-efficient of discharge of triangular notch is Cd = ……(no unit)

Co efficient of discharge Cd (no unit)						

S.no	Manometric reading			Time taken for 10 cm of rise of water t sec	Actual discharge Q_{act} $\times 10^{-3}$	Theoretical discharge $Q_{the} \times 10^{-3}$
	H1 cm	H2 cm	H= H1~ H2 cm			
					Mean =	

KAPLAN TURBINE TEST RIG

Exp No: 12

Date:

AIM:

To study the characteristics of a Kaplan turbine

DESCRIPTION:

Kaplan turbine is an axial flow reaction turbine used in dams and reservoirs of low height to convert hydraulic energy into mechanical and electrical energy. They are best suited for low heads say from 10m to 5 m. the specific speed ranges from 200 to 1000

The turbine test rig consists of a 3.72 KW (5 Hp) turbine supplied with water from a suitable 20 Hp mixed flow pump through pipelines, sluice valve, and a flow measuring orifice meter. The turbine consists of a cast-iron body with a volute casing, and axial flow gunmetal runner with adjustable pitch vanes, a ring of adjustable guide vanes and draft tube. The runner consists of four numbers of adjustable vanes of aerofoil section. These vanes can be adjusted by means of a regulator, which changes the inlet and outlet angles of the runner vanes to suit the operating conditions. The marking at the outer end of the shaft indicates the amount of opening the vanes. The guide van can be rotated about their axis by means of hand wheel and the position indicated by a pair of dummy guide vanes fixed outside the turbine casing. A rope brake drum is mounted on the turbine shaft to absorb the power developed. Suitable dead weights and a hanger arrangement, a spring balance and cooling water arrangement is provided for the brake drum.

Water under pressure from pump enters through the volute casing and the guiding vanes into the runner while passing through the spiral casing and guide vanes a part of the pressure energy(potential energy) is converted into velocity energy(kinetic energy). Water thus enters the runner at a high velocity and as it passes through the runner vanes, the remaining potential energy is converted into kinetic energy due to curvature of the vanes the kinetic energy is transformed in to mechanical energy, i.e., the water head is converted into mechanical energy and hence the number rotates. The water from the runner is then discharged into the tailrace. Operating guide vane also can regulate the discharge through the runner.

The flow through the pipelines into the turbine is measured with the office meter fitted in the pipeline. A mercury manometer is used to measure the pressure difference across the orifice meter. The net pressure difference across the turbine output torque is measured with a pressure gauge and vacum gauge. The turbine output torque is determined with the rope brake drum. A tachometer is used to measure the rpm.

EXPERIMENTAL PROCEDURE:

1. Keep the runner vane at require opening
2. Keep the guide vanes at required opening
3. Prime the pump if necessary
4. Close the main sluice valve and them start the pump.
5. Open the sluice valve for the required discharge when the pump motor switches from star to delta mode.
6. Load the turbine by adding weights in the weight hanger. Open the brake drum cooling water gate valve for cooling the brake drum.
7. Measure the turbine rpm with tachometer
8. Note the pressure gauge and vacum gauge readings
9. Note the orifice meter pressure readings.

Repeat the experiments for other loads