UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: IC Engine & Gas Turbine Subject Code-ME601
Year: 3rd Year Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	Classification and working of basic engine.	**1L**
	types: 2-stroke, 4- stroke,	1L
	C.I., S.I., etc	1L
Unit :2	Analysis of air standard cycles	**1L**
	fuel- air cycles	1L
	and actual cycles	1L
Unit :3	Fuels: classification and desirable characteristics of I.C. engine fuels,	**1L**
	Rating of S.I. and C.I. engine fuels,	1L
	Alternative fuels (liquid, gaseous, etc.),	1L
	Analysis of combustion product	1L
	, HCV and LCV of the fuels.	1L
Unit :4	Combustion of fuels in I.C. engines,	1L
	Combustion in S.I and C.I engines,	1L
	Parameter influencing combustion	1L
	, Detonation and knocking in S.I. and C.I. engines and their preventions	1L
	, Combustion chamber types,	1L
	Basic principles of combustion chamber in I.C. engines	1L
Unit :5	Fuel- air mixing in S.I. engines,	**1L**
	Working principle of a carburetor,	1L
	Analysis of simple carburetor,	1L
	Mechanical and electronic fuel injection system and their control in S.I. engines	2L
	. Basic principles of MPFI in SI engines,	1L
Unit :6	Fuel-oil injection in C.I. engines,	**1L**
	Fuel injection systems,	1L
	Working principles,	1L
	Injection pumps and nozzles	1L
Unit :7	Ignition: ignition systems in I.C. engines (Battery, magneto and electronic),	**2L**
	ignition timing and spark advance	1L
Unit :8	Supercharging and scavenging of I.C. engines,	**1L**
	supercharging limits,	1L
	Turbo charging, Scavenging - ideal and actual,	1L

	scavenging parameters,	1L
	and scavenging pumps	1L
Unit :9	Principles of lubrication in I.C. engines,	**1L**
	Properties of lubricating oil	1L
Unit :10	Air and liquid cooling of I.C. engines,	**1L**
	Principles and systems	1L

Total – 39 Lecture

Assignment No- 1

1. For the Air Standard Brayton cycle, express the net work in terms of the compressor pressure ratio, *r*, and the turbine-to-compressor inlet temperature ratio, $T3/T1$. Nondimensionalize the net work with $cpT1$, and derive an expression for the pressure ratio that maximizes the net work for a given value of $T3/T1$.

2. For a Brayton Air Standard cycle, work out an expression for the maximum possible compressor pressure ratio for a given turbine-to-compressor inlet temperature 215 ratio. Draw and label the cycle on a T-s diagram. What is the magnitude of the net work for this cycle? Explain.

3. For a calorically perfect gas, write an expression for the temperature difference, $T2$. $T1$, on an isentrope between two lines of constant pressure in terms of the initial temperature $T1$ and the pressure ratio $p2/p1$. Sketch a T-s diagram showing two different isentropes between the two pressure levels. Explain how your expression demonstrates that the work of an isentropic turbomachine operating between given pressure levels increases with temperature.
4. Derive an expression for the enthalpy difference, $h2$. $h1$, along a calorically perfect gas isentrope spanning two fixed pressure levels, $p2$ and $p1$, in terms of the discharge temperature $T2$. Note that as $T2$ increases, the enthalpy difference also increases.

Assignment No- 2

1. A simple-cycle stationary gas turbine has compressor and turbine efficiencies of 0.85 and 0.9, respectively, and a compressor pressure ratio of 20. Determine the work of the compressor and the turbine, the net work, the turbine exit temperature, and the thermal efficiency for 80°F ambient and 1900°F turbine inlet temperatures.
2. A simple-cycle stationary gas turbine has compressor and turbine efficiencies of 0.85 and 0.9, respectively, and a compressor pressure ratio of 20. Determine the work of the compressor and the turbine, the net work, the turbine exit temperature, and the thermal efficiency for 20°C ambient and 1200°C turbine inlet temperatures.
3. A regenerative-cycle stationary gas turbine has compressor and turbine isentropic efficiencies of 0.85 and 0.9, respectively, a regenerator effectiveness of 0.8, and a compressor pressure ratio of 5. Determine the work of the compressor and the turbine, the net work, the turbine and regenerator exit temperatures, and the thermal efficiency for 80°F ambient and 1900°F turbine inlet temperatures. Compare the efficiency of the cycle with the corresponding simple-cycle efficiency.

4. A regenerative-cycle stationary gas turbine has compressor and turbine isentropic efficiencies of 0.85 and 0.9, respectively, a regenerator effectiveness of 0.8, and a compressor pressure ratio of 5. Determine the work of the compressor and the turbine, the net work, the turbine and regenerator exit temperatures, and the thermal efficiency for 20°C ambient and 1200°C turbine inlet temperatures. Compare the efficiency of the cycle with the corresponding simple-cycle efficiency.

Assignment No- 3

1. A two-shaft stationary gas turbine has isentropic efficiencies of 0.85, 0.88, and 0.9216 for the compressor, gas generator turbine, and power turbine, respectively, and a compressor pressure ratio of 20.
   (a) Determine the compressor work and net work, the gas generator turbine exit temperature, and the thermal efficiency for 80°F ambient and 1900°F compressorturbine inlet temperatures.
   (b) Calculate and discuss the effects of adding reheat to 1900°F ahead of the power turbine.

2. A two-shaft stationary gas turbine with an intercooler and reheater has efficiencies of 0.85, 0.88, and 0.9 for the compressor, gas-generator turbine, and power turbine, respectively, and a compressor pressure ratio of 5.
(a) Determine the compressor work and net work, the gas generator turbine exit temperature, and the thermal efficiency for 80°F ambient and 1900°F turbine inlet temperatures.
(b) Calculate and discuss the effect on thermal efficiency, exhaust temperature, and net work of adding a regenerator with an effectiveness of 75%.

3. A two-shaft stationary gas turbine with an intercooler and reheater has efficiencies of 0.85, 0.88, and 0.9 for the compressor, gas-generator turbine, and powe turbine, respectively, and a compressor pressure ratio of 5.
(a) Determine the compressor work and net work, the gas generator turbine exit temperature, and the thermal efficiency for 20°C ambient and 1200°C turbine inlet temperatures.
(b) Calculate and discuss the effect on thermal efficiency, exhaust temperature, and net work of adding a regenerator with an effectiveness of 75%.

4. A two-shaft stationary gas turbine has isentropic efficiencies of 0.85, 0.88, and 0.9 for the compressor, gas generator turbine, and power turbine, respectively, and a compressor pressure ratio of 20.
(a) Determine the compressor work and net work, the gas generator turbine exit temperature, and the thermal efficiency for 20°C ambient and 1200°C compressorturbine inlet temperatures.
(b) Calculate and discuss the effects of adding reheat to 1200°C ahead of the power turbine.

Assignment No- 4

1. Consider a pulverized-coal-burning, single-shaft gas turbine in which the combustion chamber is downstream of the turbine to avoid turbine blade erosion and corrosion. The combustion gases leaving the burner heat the compressor discharge air through the intervening walls of a high temperature ceramic heat exchanger.
(a) Sketch the flow and T-s diagrams for this gas turbine, showing the influence of pressure drops through the combustor and the heat exchanger. The ambient, turbine inlet, and combustor exhaust temperatures are 80°F, 1900°F, and 3000°F, respectively. The compressor pressure ratio is 5. Assume perfect turbomachinery.
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(b) For zero pressure drops, determine the net work, the thermal efficiency, and the heat exchanger exhaust temperature.
(c) If the coal has a heating value of 14,000 Btu/lbm, what is the coal consumption rate, in tons per hour, for a 50-MW plant?

2. Consider a pulverized-coal-burning, single-shaft gas turbine in which the combustion chamber is downstream of the turbine to avoid turbine blade erosion and corrosion. The combustion gases leaving the burner heat the compressor discharge air through the intervening walls of a high-temperature ceramic heat exchanger.
(a) Sketch the flow and T-s diagrams for this gas turbine, showing the influence of pressure drops through the combustor and the heat exchanger. The ambient, turbine inlet, and combustor exhaust temperatures are 20°C, 1200°C, and 2000°C, respectively. The compressor pressure ratio is 5. Assume perfect turbomachinery.
(b) For zero pressure drops, determine the net work, the thermal efficiency, and the heat exchanger exhaust temperature.
(c) If the coal has a heating value of 25,000 kJ/kg, what is the coal consumption rate, in tons per hour, for a 50-MW plant?

3. A stationary gas turbine used to supply compressed air to a factory operates with zero external shaft load. Derive an equation for the fraction of the compressor inlet air that can be extracted ahead of the combustion chamber for process use in terms of the compressor pressure ratio, the ratio of turbine-to-compressor inlet temperatures, and the turbomachinery efficiencies. Plot the compressor mass extraction ratio as a function of compressor pressure ratio for temperature ratios of 3 and 5, perfect turbomachinery, and identical high- and low-temperature heat capacities.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lecture-wise Plan

Subject Machining Principles & Machine Tools **Subject Code-ME602**
Year: 3rd Year **Semester: Sixth**

Module Number	Topics	Number of Lectures
1	**Introduction to Machining Principles & Machine Tools:**	**3L**
	Recapitulation of various manufacturing processes	1
	Machining: Basic principle, purpose, definition and requirements	1
	Advantages & disadvatages of machining process over other manufacturing process	1
2	**Geometry of cutting tools:**	**6L**
	Definition of tool Geometry of single point turning & its importance	1
	Geometry of single point turning in ASA	1
	Geometry of single point turning in ASA	1
	Geometry of single point turning in ORS	1
	Conversion of tool angles one system to another	1
	Numericals	1
3.	**Mechanism of machining:**	**6L**
	Introduction to Chip formation mechanism & its classifications	1
	yielding and brittle fracture, chip reduction coefficient, cutting ratio,	1
	Shear angle and cutting strain	1
	Built-up edge formation, cause, type and effects	1
	Difference between Orthogonal cutting and oblique cutting	1
	Machining chips: types and conditions, chip formation in Drilling and Milling	1
4	**Mechanics of machining:**	**5L**
	Purposes of determination of cutting forces and basic two approaches	1
	Cutting force components in ORS and Merchant's circle diagram	1
	Determination of cutting forces, analytical methods & its measurement and numericals on it.	1
	Dynamometers, construction and working principles of strain gauge type	1
	Piezoelectric crystalsType turning drilling, milling and grinding dynamometers	1
5	**Cutting temperature**	**5L**
	Heat generators and cutting zone temperature, sources, courses and effects on job and cutting tools	1
	Role of variation of the machining parameters on cutting temperature	1
	Determination of cutting temperature by analytical and experimental methods.	1
	Control of cutting temperature and application of Cutting fluid	1

	Cutting fluids (purpose, essential properties, selection and methods of application)	1
6	**Cutting tools-failure, life and materials:**	**5L**
	Methods of failure of cutting tools mechanisms, geometry and assessment of tool wear-	1
	Tool life, definition, assessment and measurement	1
	Taylor's tool life equation and it's Applications	1
	Cutting tool materials, essential properties, characteristics applications of HSS,carbide(uncoated/coated), ceramic, diamond and CBN tools	1
	Applications of HSS,carbide(uncoated/coated), ceramic, diamond and CBN tools	1
7	**Broaching and grinding:**	**2L**
	Concept of Grinding forces, surface roughness and wheel life,Grinding machines and its applications	1
	Working prinples of Broaching machine its applications	1
8	**Machinability and machining economics:**	**1L**
	Machinability (and grindability), definition, assessment, improvement and evaluation of optimum cutting velocity and tool life.	1
9	**Machine tools – Introduction :**	**2L**
	Purpose of use , definition and general features of machine tools, classifications	1
	Generatrix and Directrix and tool – work motions in different operations of conventional machine tools	1
10	**General constructions function of machine tools :**	**2L**
	Major components and their functions in lathes ; shaping , planning and slotting machines	1
	Working of Drilling machines and Milling machines and its applications	1
11	**Automation and classification :**	1
	Purposes, degree, type and economy of machine tool automation ; broad classification of machine tools	1
12	**Kinematic structure of machine tools :**	**3L**
	Kinematic structure of drilling (column /radial) and milling machines	1
	Kinematic structure Capstan lathe, Turret lathes	1
	Kinematic structure of single spindle automatic lathe, by hydraulically driven machine tools , hobbing machine and gear shaping machine	1
	Control of speed and feed machine tools :	**3L**
	Need of wide ranges of speeds and feeds , and machine tool drive	1

13	Design of speed, gear box, speed layout, gear layout, ray diagrams , gears and spindle	1
	Control (selection and change) of feed in centre lathes and by hydraulically driven machine tools	1
14	**Machining time :**	**1L**
	Estimation of time required for various operations like turning , drilling , shaping , milling and gear teeth generation	1
15	**Introduction to Computer numerical controlled machine tools :**	**2L**
	NC and CNC system ; purpose, principle , advantages , limitations and application in machine tools	1
	Basic features and characteristics of CNC , lathes , milling machines etc, machining centres and FMS with reference to construction, advantages and applications.	1
Total Number Of Hours = 47		

Faculty In-Charge

Prof. Iqbal Ahmad

HOD, ME Dept.

Prof. Kulbhusan Bhagat

Assignments

Module-1

1. Define machining processes with examples.
2 Define manufacturing process with example.
3. Define non –conventional machining process with examples.
4. Define the term MRR with formula.
5. Write down the five advantages of machining process.
6. What is machine tool? How it differs from machine? Give the classification of Machine tools in detail.
7. What should be the aims and objectives in manufacturing of any product?
8. Justify “Machining is a value addition process”.

Module-2

1. Explain tool geometry of a single point cutting tool with neat diagrams in ASA system.
2. What do you understand by tool reference system? Explain various types of tools reference systems.
3. Explain with diagram concept of positive, negative and zero rake angles and discuss its significance.
4. Why the value of relief angle is always positive? Justify.
5. How do you classify cutting tool? Brief them.
6. Draw a neat diagram of right hand and left hand single point cutting tool showing various angles.
7. The following tool signature is specified for a single-point cutting tool in American system: 10, 12, 8, 6, 15, 20, 3.What does the angle 12 represent?

   (a) Side cutting-edge angle (b) Side rake angle (c) Back rake angle(d) Side clearance angle

8. 4. Tool geometry of a single point cutting tool is specified by the following elements:

1. Back rake angle 2.Side rake angle 3.End cutting edge angle 4.Side cutting edge angle 5.Side relief angle 6.End relief angle7. Nose radius

The correct sequence of these tool elements used for correctly specifying the tool geometry in ASA system

(a) 1,2,3,6,5,4,7 (b) 1,2,6,5,3,4,7 (c) 1,2,5,6,3,4,7 (d) 1, 2, 6, 3, 5, 4,7

Module-3

1. Differentiate orthogonal cutting and oblique cutting.

2. Derive the formula for stress developed in shearing zone for orthogonal cutting.

3 .Explain briefly about chip breakers, what are the common methods of chip breaking and what are the means for the same.

4. Discuss the various types of chips produced in metal cutting.

5. What is meant by Built-up Edge ? Explain conditions which promote the growth of built-up edge along with its consequences.

6. Explain the possible disadvantages of a cutting operation in which the type of chips produced is discontinuous.

7. What are the conditions that would allow a continuous chip to be formed in metal cutting?

8. Determine the value of shear strain for an orthogonal machining process having shear angle 45˚ and bake rake angle 0˚.

9. Why are discontinuous type chips preferred over the continuous type ?

10.Details pertaining to an orthogonal metal cutting process are given below.

Chip thickness ratio =0.4,Un -deformed thickness= 0.6mm ,α =10º,

Cutting speed= 2.5m/s, dy = 25 microns Calculate the shear strain rate ($\dot{\varepsilon}$).

Module-4

1. Derive the expressions for chip reduction coefficient in single point tool. State the assumptions made.

10. Discuss the various forces encountered in metal cutting.

11. Show schematically Merchant's force circle in orthogonal cutting. Derive the equations for shear and friction forces in terms of the material properties and cutting process parameters and also Give in detail the assumptions made while arriving at the final equations.

12. Prove the following relations for orthogonal machining process.

Cutting ratio(r) = $t_0/t_c = l_c/l_0 = V_c/V_0$,

Where all the parameter has their usual meanings

13. In orthogonal cutting test following observations were made:

Cutting force (F_H) =1200 N, Thrust force (F_V) = 200N

t_o=0.5 mm, t_c= 0.7 mm, Cutting speed = 20 m/min,Width of cut= 5 mm

Applying Merchant's theory, determine the following:

(a) Shear angle (b) Shear strain (c) Coefficient of friction at the tool- chip interface

14. The rake angel of a cutting tool is 15 , shear angel 45 and cutting velocity 35 m/min. What is the velocity of chip along the tool face ?
15. Orthogonal machining of a steel work-piece is done with a HSS tool of a zero rake angel . The ratio of a cutting force and the thrust force on the tool is 1:0.372. The length of cut chip is 4.71 mm while the uncut chip length is10 mm. What are the shear plane angle ϕ and friction angel β in deg. ? Use merchat's theory.
16. In orthogonal cutting test with a tool of rake angle 10º, the following observations were made: Chip thickness ratio= 0.3 , F_H =1290 N, F_V =1650 N. Using the merchant's theory , calculate the various components of the cutting forces, co-efficient friction and percentage error.

Module-5

1. Write short notes on sources of heat generation.
2. Explain Role of variation of the machining parameters on cutting temperature.
3. Discuss the method of Determination of cutting temperature by analytical and experimental methods.
4. What are functions of a cutting fluid? Discuss various methods of applying cutting fluid.
5. Most of the metal cutting heat goes into the........

   (a) Moving chip (b) Cutting tool (c) Work material (d) Machine tool

Module-6

1. Discuss important properties of cutting tool, what are the essential criteria for a cutting tool to give maximum production?
2. What are the types of tool materials used in metal cutting? Discuss their importance.
3. What are the desirable characteristics of a cutting tool material? Explain how these are satisfied in the case of high speed steel tools.

4. What is tool life? What is the significance of tool life to an engineer who is interested in productivity?
5. Discuss the forms of tool life equations generally used with their applicability.
6. Discus Taylor's relationship for cutting speed tool life.`
7. While machining a mild steel bar with H.S.S tool the Cutting speed is 32m/min, tool life is 50 min, If cutting speed is increased by 50%, how tool life is affected. Take n=0.2.
8. In a machining experiment, tool life was found to be varying with the cutting speed in following manner.

Cutting speed, V (m/min)	Tool life , T (in minute)
60	81
90	36

i. For the above relation find the value of exponent (n) and constant (C) of the Taylor's tool life equation.
ii. What will be the percentage increase in tool life when the cutting speed is halved?
9. Discuss various types of tool wear, Why tool wear is important in metal cutting?

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lecture-wise Plan

Module-7

1. Why are grinding operations necessary for part that have been machined by other processes?
2. What is an abrasive?
3.Describe any four types of bonds for bonded abrasives on a grinding wheel
4. What are the advantages of the vitrified bond?
5. How are grinding wheels specified? Take 3 suitable example and explain what the different terms in specification of a wheel by international standard.
6 How are grinding wheels specified? Clearly differentiate between grade and structure of a grinding wheel.
7 Explain why there are so many different types and sizes of grinding wheels.
8. Discuss the wear mechanism of grinding wheel.
9.Explain three different ways in which the wear of grinding.
wheel can take place. What can be done to prevent them.
10. What decides the hardness of the grinding wheel? Distinguish between dressing and truing of grinding wheel.
11 Discuss briefly dressing and truing of grinding wheel.
12.What is the classification method that could be used forgrinding machines? Give the applications of each variety of grinding machines.
13 What is surface grinding? Explain with neat sketch? Also list out its advantages and disadvantages.
15 What is external cylindrical grinding? Explain with proper sketch.
16 Explain centre-less grinding with neat sketch. Also write down its advantages and limitations.
17.What are the main difference between cylindrical and centre-less grinding
18 Write short notes on following ;
Lapping process b) Honing Process c) Super finishing
19. with neat diagram explain the working principle of a broaching machine.

Module-8

1. Define machinability index. What are the variables affecting machinability? / Explain how it is influenced by various factors?
2. Explain the methods of representing the machinability.

Module-9

1. Explain how various types of machine tools are classified.
2. Explain the concept of generatrix and directrix for various work and tool motions.

Module-10

1. Discuss how lathe machine are specified?
2. a) Give in detail classification of lathe.b) Why lathe beds are made of cast iron? Explain.
3. Why are engine lathes called by that name? What are the basic parts of an engine lathe with neat diagram? Discuss the function of head stock.
4. With neat diagram differentiate between the shaper, planar and slotting machine.
5. with neat diagram working principle of drilling machine.
6. with neat diagram working principle of milling machine.
7. Define milling. What are the various used in milling. Explain their relative applications And disadvantages. How do you classify the milling machine ?
8. What is a universal milling machine ? Draw at least one port which cannot be machined on a horizontal milling machine. List various types of milling cutters available and draw any two.
9. Why are bed milling machines preferred over column and knee types for production milling ?
10. How does face milling differ basically from peripheral milling ?
11. What type of milling (up or down) do you think uses the least power ? Explain.

12. Distinguish between up-milling and down-milling.
13. When might it be advantageous to use conventional milling ?
14. What is the function of indexing head as a milling machine attachment ? Giving example, explain its working.
15. What are the various types of drilling machines? Explain their usage in the workshop.
16. How a drilling machine is specified?
17. Define the operation of drilling.
18. With the help of a suitable sketch, describe the twist drill and also explain, how drill sizes are specified.
19. Explain what are the following operations :
(i) Boring (ii) Reaming (iii) Tapping (iv) Counter boring (v) Sinking (vi) Countersinking

Module-11

1. What do you mean by automation ? and write its types and also write the advantages of using automation.

Module-12

1. What are the basic differences between a tail stock and a turret in a lathe?
2. Compare Turret and capstan lathe? Write specification of Turret and capstan lathes?
3. Write down the advantages of capstan and turret lathe over the general purpose lathe.

Module-13

1. Explain need of wide ranges of speeds and feeds .
2. What are the various types drives employed for operation of machine tools? Discuss their relative merits.
3. What are the requirements to be satisfied for design of gears for gear box?
4. How the speed boxes for machine tools can be classified according to general layout and method of changing speed?
5. Distinguish between a ray diagram and speed diagram.

Module-14

1. Derive the formula for Estimation of time required for various operations like turning , drilling , shaping , milling and gear teeth generation.
2. **A rod of 150 mm long and having diameter 15 mm is reduced to 14mm diameters in one pass of the turning. Find the *MRR* & machining time when spindle speed is 400 rpm and feed 200 mm/ min.**
3. **A hollow work- piece of 50 mm diameter and 200 mm long is to be turned all over in 4 passes. If approach length is 20 mm, over travel 10 mm, feed 0.8 mm/ rev and cutting speed is 30 m/min , determine the machining time.**

Module-15

1. **Differentiate between the NC & CNC machines and writes its advantages and disadvantages.**
2. **Write short notes on FMS.**
3. **Explain working principle of NC & CNC machines.**

Prepared By: Prof. Iqbal Ahmad

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lecture-wise Plan

Subject Name: Machine Design II Subject Code-ME603
Year: 3rd Year Semester: Sixth

Module Number	Topics	Number of Lectures
1	***Clutches***	**6**
	Function, types; Friction clutches – torque capacity based on uniform pressure and uniform wear theory for disc, Friction materials, Considerations for heat dissipation.	2
	Cone clutch	2
	Centrifugal clutch	2
2	***Brakes***	**7**
	Function, types; Brake lining materials; Thermal considerations during braking, Energy equation for braking time calculation	1
	Internal expanding shoe brake, self energizing and self locking	2
	Pivoted block brake (single and double block brakes), block brake	2
	Magnetic and hydraulic thruster operated fail-safe	1
	Band brake-simple and differential	1
3	***Gears:***	**7**
	Design objectives, types, terminologies, conjugate action and involute tooth profile, tooth systems, standard modules; Gear materials.	2
	Spur Gear : Strength design, static and dynamic considerations in strength design, Lewis formula, Lewis form factor, beam strength, Buckingham equation for dynamic tooth load; Endurance strength and wear strength; Designing a pinion based on above considerations	3
	Helical Gear: Helix angle, minimum face width, virtual number of teeth; Strength design, Buckingham formulae for checking dynamic load and wear load.	2
4	***Bevel Gear:*** Terminologies, formative number of teeth; Lewis equation, dynamic load, endurance strength and wear strength checking.	**2**
	Worm- worm wheel: Terminologies and their inter-relation; Preferred combination of various parameters; Efficiency; Materials.	2
5	***Pressure vessels:***	**8**
	Thin cylinder, thick cylinder,category, Industrial Code	2
	Lame's equation, Clavarino's equation, Birnie's equation, Autofrettage	2
	Compound cylinders, End Covers, Opening in pressure vessel	2
	Area compensation method, Fired and unfired vessels	2
6	***Flywheel:***	**3**
	Design for application to: (i) Punching press; (ii) 2-stroke engine; (iii) 4-stroke engine, Torque analysis,	1
	Solid disc and rimmed flywheel	2

7	***Sliding contact bearings***	**6**
	Bearing types and materials; Stribeck Curve, Petroff equation, Hydrodynamic lubrication theory - pressure development;	3
	Tower experiment, Reynolds equation, Finite bearings – Raimondi- Boyd charts, Design factors/variables, Heat generation & dissipation; Hydrostatic bearing; Plummer block.	3
8	***Rolling contact bearings***	**5**
	Bearing types, nature of load; Static and dynamic load capacity, Stribeck equation, Load - Life relation	3
	Bearing selection from manufacturers' catalogues; Methods of lubrication; Bearing mounting on journal and bearing block	2
Total Number Of Hours = 44		

Assignments:

Unit 1 :(Clutches)

1. What id difference between clutch and flange coupling?
2. Difference between clutch and brake.
3. Advantages and drawbacks of centrifugal clutch.
4. Where do you use single plate clutch and multi plate clutch?
5. What are the drawbacks of asbestos friction materials?
6. Advantages of cone clutch. Also what are drawbacks of cone clutch?
7. Why heat dissipation is necessary in clutches?
8. An automotive single plate clutch consists of two pairs of contacting surfaces. The outer dia of the friction disk is 270mm. the coefficient of friction is 0.3 and max intensity of pressure is 0.3 N/mm^2. The clutch is transmitting a torque of 531 N-m. Assuming uniform wear theory calculate:
    - The inner dia of the friction disk;
    - Spring force required to keep the clutch engaged

Unit 2: (Brakes)

1. What is block brake with short shoe? Where do you use it? Write down its disadvantages.
2. What are the condition of self-locking block brake?
3. What is internal expanding shoe brake? Where do you use it?
4. What is differential band brake? Advantages of band brake.
5. What is the condition of self-locking in differential band brake? What is the remedy?
6. A double block brake consists of two symmetrical pivoted shoes. The dia of the brake drum is 300 mm and the angle of wrap (2Θ) for each shoe is 90°. The pivot of the shoe is located in

such a way as to avoid the couple due to frictional force. Determine the distance of pivot from the axis of the brake drum.

Unit 3:(Gears)

1. What is a herringbone gear?
2. What is pitting and scoring?
3. Advantages and disadvantages of internal gears.
4. What is hunting tooth?
5. Advantages of in volute and cycloidal teeth gears.
6. Where do you use grease and oil as a gear lubricant?
7. A pinion with 25 teeth and rotating at 1200 rpm drives a gear which rotates at 200 rpm. The module is 4 mm. calculate the centre distance between the gears.
8. A pair of spur gears with a center distance of 495mm. is used for a speed reduction of 4.5:1. The module is 6mm. calculate the number of teeth on the pinion and the gear.
9. What is a zerol bevel gear?
10. What is crown and miter gear?
11. What is virtual of formative bevel gear?
12. A pair of straight bevel gears is mounted on shafts, which is intersecting at right angles. The gears are made of steel and surface hardness is 300 BHN. The number of teeth on the pinion and gear are 40 and 65 respectively. The module at the outside dia is 3 mm, while the face width of thr tooth is 35mm. calculate the wear strength of the tooth.

Unit 4 :(Worm-worm Wheel)

1. What are the advantages and disadvantages of worm gear drives?
2. What is the material of worm wheel? Why?
3. Why the efficiency of worm gear drive is low?
4. A pair of worm gears is designated as 1/40/10/4. The input speed of the worm shaft is 1000 rpm. The worm wheel is made of case-hardened carbon steel 10C4. Determine the power transmitting capacity based on beam strength.
5. Assume the previous data of example determine the power transmitting capacity based on wear strength.
6. Why are worm gear reduction units not preferred over other types of gear boxes for transmitting large powers?

Unit 5 :(Pressure vessels)

1. What is class 1, class 2 and class 3 cylinders?
2. What is autofrettage?
3. Where do you use hemispherical head for cylindrical pressure vessel?
4. What do you understand by the term hydrostatic test pressure in pressure vessel?
5. What is the function of gasket?
6. What are the types of end closure for cylindrical pressure vessel?

7. A gas cylinder with internal dia of 200mm is subjected to an operating pressure of 10MPa. Its made of plain carbon steel FeE230 and FOS is 3. Calculate the cylinder wall thickness assuming it to be a thin cylinder and neglecting the effect of welded joints.

Unit 6: (Flywheel)

1. What are the applications of flywheel?
2. Why flywheels are used in presses?
3. What is the coefficient of speed fluctuation?
4. What is the coefficient of fluctuation of energy?
5. What is the function of flywheel?
6. What is the cooling stress?
7. What is the coefficient of steadiness?

Unit 7 :(Rolling contact Bearings)

1. Define the rating life of bearing?
2. Why ball and roller bearings are called Antifriction bearings?
3. What is L_{10} and L_{50} Life?
4. Name the various types of ball and roller bearings?
5. Where do use needle roller bearings?
6. What is the criterion for static load carrying capacity of ball bearing?
7. A cylindrical roller bearings with bore dia of 40mm is subjected to a radial force of 25kn. The coefficient of friction is 0.0012 and the speed of rotation is 1440 rpm. Calculate the power lost in friction.
8. A ball bearing is subjected to a radial force of 2500N and an axial force of 1000N. The dynamic load carrying capacity of the bearing is 7350N. The values of X and Y factors are 0.5 and 1.5 respectively. The shaft is rotating at 720 rpm. Calculate the life of bearing.

Unit 8 :(Sliding contact Bearing)

1. What is SAE, Doped oil, Hydrostatic lubrication, hydrodynamic lubrication?
2. Define conformability, embeddability.
3. What is viscosity index? Why does viscosity decrease with increase of temperature?
4. Write down petroff's equation
5. What is 2T oil? Where do you use them? Define grease.
6. Grease is thixotropic. What does it mean?
7. The following data is given for the hydrostatic step bearing of a vertical turbo generator:

Thrust load=450kn
Shaft dia=400mm
Recess dia=250mm
Shaft speed=750rpm
Viscosity of lubricant=30cP

Draw a neat sketch showing the effect of film thickness on energy losses. Calculate the optimum film thickness for min power loss.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lecture-wise Plan

Subject Name: Machine Design II | Subject Code-ME603

Year: 3^{rd} Year | Semester: Sixth

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Production & Operation Management Subject Code-ME604
Year: 3rd Year Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	**Operations Management:** An Overview -	**1L**
	Systems concepts in Operations Management, Objectives in Operations Management .	1L
	, Operations management Decisions, Productivity concepts and measurement,	1L
	Types of Production Systems.	1L
	Aggregate planning and master scheduling Objectives of Aggregate planning Methods,	1L
	Master Scheduling, Objectives,	1L
	Master Scheduling Methods.	1L
Unit :2	Forecasting Demand: **Forecasting Objectives and uses,**	**1L**
	Qualities & Quantities methods of Forecasting,	1L
	Opinion and Judgmental Methods Time Series Methods,	1L
	Exponential Smoothing, Regression and Correlation Methods,	1L
	Time Series Analysis, Application and Control of Forecasts.	1L
	Capacity Planning: Capacity Strategy, aspects of Capacity Planning,	1L
	Determination of Capacity Requirement,	1L
	Types of capacity, Evaluation of Alternative plant size,	1L
	Traditional Economic Analysis, Cost-Volume Profit Analysis	1T
Unit :3	Materials Management: Scope of Materials Management,	**1L**
	Purchase system and procedure, purpose of Inventories,.	1L
	Classification of inventory, factors effecting inventory, inventory models,	1L
	probabilistic models, inventory systems classification, selective inventory control, stores management,	1L
	standardization codification and variety reduction	1L
	. Material and Capacity Requirements Planning Overview,	1L
	MRP and CRP, MRP Underlying concepts,	1L
	system parameters, MRP Logic, CRP Activities	1L
Unit :4	cheduling and controlling Production Activities:	1L
	Introduction, PAC Objectives and Date Requirements.	1L
	Scheduling Strategy and Guidelines.,	1L
	Scheduling Methodology, Priority Control, Capacity Control	1L

Unit :5	Just in Time (JIT) in manufacturing planning & control.	**1L**
	Major-elements, Characteristics of Just in Time System pre-requisite for JIT manufacturing,	1L
	Elements of Manufacturing, Eliminating Waste, Enforced, Problem Solving and Continuous Improvements,	1L
	Benefits of JIT Purchasing, The Kanban System JIT implementation in Industries..	1L
	Bottleneck scheduling and theory of constraints.	1L
	Issues in choosing manufacturing technologies and strategies:	1L
	product life cycle, standardization,	1L
	simplification, diversification, value analysis	1L
Total Number Of Hours = 35L(35H)		

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Assignment: 1

Define Economic Order Quantity.
2. Discuss the concept of Six Sigma.
3. Define Method Study.
4. Differentiate between quality control and quality assurance.
5. Define value analysis concept.
6. Distinguish between job production and batch production.
7. What do you mean Kanban System of productivity?
8. What are the objectives of Facility layout?
9. Define Control Chart.
10. Differentiate between carrying cost and ordering cost.

Assignment: 2

1. What do you mean by Operation Management? Write a detailed note on its functions.
2. What is meant by Product design? Explain in brief the factors determining the design of a product.
3. Distinguish between production planning and production control. State its objectives and functions.
4. Distinguish between Facility layout and Facility location. Throw some light on basic types of layout.
5. What are the important elements of Total Quality Management (TQM)? Explain how each contributes to products and services of superior quality?

6. What is the meaning and functions of Inventory control? Discuss ABC analysis of inventory control.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Production & Operation Management Subject Code-ME604
Year: 3rd Year Semester: Sixth

Assignment: 3

1. Responsibilities of Operations Manager.
2. Concept of Work Measurement
3. Capacity Planning decisions
4. Types of Production systems
5. Total Quality Management (TQM)
6. Concept of Value Analysis

Assignment: 4

7. What do you mean by operations management? Discuss the contributions of Deming and Taguchi.
8. Discuss the concept of location decision. What are the factors which may affect the location decision?
9. Discuss the procedure of method study. Highlight the process chart to be used in method study also.
10. What do you understand by facility layout? Discuss the different types of layouts along with their suitability to different types of industries.
11. Define quality. Discuss the various quality characteristics of goods and services.
12. What do you understand by statistical quality control? How different control limits can be determined for mean chart and range chart?
13. What is Inventory Management? Discuss the factors affecting inventory control policy of a manufacturing entity.
14. What do you mean by Purchase management? Discuss the different methods of purchase.

Assignment: 5

1. ABC Co. purchases 9000 motor spare parts of its annual requirements. Ordering one month usage at a time. Each part costs Rs. 20. The ordering cost is Rs. 15 per order and carrying cost is 15% of the average inventory per year.

Being a manager you are required to:

a) Suggest a more economical purchasing policy.
b) Find the annual cost if company follows the purchasing policy suggested by you.

c) How much the new purchase policy will save for the company?

2. XYZ Ltd does the ABC classification of the various components and parts it uses for assembling its tractors. As an operation manager, you are required to classify the following parts and components into A, B and C categories according to their usage values. Draw the ABC distribution curve. Item # 8 has a high critically class i.e. a shortage of this item may lead to a complete halt in the production process. What special treatment can be given to this item?

Item ID #	**Unit Price (Rs.)**	**Annual usage(Units)**
1	5	1,00,000
2	35	2,600
3	79	420
4	68	13,600
5	800	210
6	2,300	670
7	450	76
8	6	400
9	92	6,100
10	3	2,50,000

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Mechatronics — Subject Code-ME605V

Year: 3rd Year — Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	Introduction about Mechatronics,	**1L**
	scope of Mechatronics, application,	1L
	process control automation and N/c Machines. . .	1L
	Hydraulic And Pneumatic Actuation Systems:	1L
	Overview: Pressure Control Valves,	1L
	Cylinders, Direction Control Valves,	1L
	Rotary Actuators, Accumulators,	1L
	Amplifiers, and Pneumatic Sequencing Problems	1L
Unit :2	**Electrical Actuation Systems: Switching Devices,**	**1L**
	Mechanical Switches – SPST, SPDT, DPDT,	1L
	Debouncing keypads; Relays,	1L
	Solid State Switches, Diodes,	1L
	Thyristors, Transistors,	1L
	Solenoid, Types Devices: Solenoid Operated Hydraulic and Pneumatic Vlaves,	1L
	Electro-Pneumatic equencing Problems.	1L
	Control of DC Motors, Permanent Magnet DC Motors,	1L
	Control of DCMotors, Bush less Permanent Magnet DC Motors,	1T
	AC Motors, Stepper Motors, Stepper Motor Controls, Servo Motors.,	1L
Unit :3	Sensors and transducers and application:	**1L**
	Performance Terminology,	1L
	Static and Dynamic Characteristics, Displacement,	1L
	Position and Proximity Sensors, Potentiometer Sensors,	1L
	Strain Gauge Element, LVDT,	1L
	Optical Encoders, Pneumatic Sensors,	1L
	Hall Effect Sensors,Tachogenerators,	1L

	Strain Gauge Load Cell,	1L
	Thermostats, Photo Darlington	1L
	. Interfacing Sensors in Mechantronic System as – Temperature Switch Circuit, Float Systems	1L
Unit :3	Flow control valves – fixed and variable, Temperature and pressure compensated	1L
	Electrical control solenoid valves	1L
	Operation and graphical symbols of valves	1L
Unit :4	Interfacing controllers: Interfacing,	**1L**
	Buffers, Darlington Pair, I/O Ports, Interface Requirements,	1L
	Handshaking, Serial and Parallel Port Interfacing,	1L
	Peripheral Interface, Adapters. Data Acquisition and Control System -	1L
	Introduction, Quantitizing theory,	1L
	Analog to Digital Conversion, Digital to Analog (D/A) conversation	1L
	, transfer function, transient response & frequency response	1L
	& frequency response, stability criteria	1L
Unit :5	Design of Mechatronic systems - Introduction,.	**1L**
	Automatic front and book and cutting in steel rolling mill,	1L
	lift control system, CNC lathe	1L
	, temperature control of a heat treatment furnace,	1L
	EOT crane control panel,	1L
	Grey grain separators,	1L
	electrode arm control in electric arc furnace	1L
Total Number Of Hours = 48L(48H)		

Assignments

UNIT I (INTRODUCTION)

PART-A

1. Define mechatronics. (NOV/DEC 2005)
2. Mention the function of a mechatronic system. (APR/MAY 2013)
3. What are the elements of a mechatronic system? (APR/MAY 2010)
4. What are the basic elements of the measurement system? (APR/MAY 2005)
5. Distinguish between measurement system and control system. (NOV/DEC 2010)
6. Draw the basic feedback system. (APR/MAY 2006)
7. Distinguish between open loop and closed loop control system. (NOV/DEC 2007)
8. How do you classify the sensors? (APR/MAY 2005), (APR/MAY 2013)
9. State the difference between primary and secondary transducers. (NOV/DEC 2003)

10. Define Hysteresis. (NOV/DEC 2009)
11. State the dynamic characteristics. (APR/MAY 2004)
12. What is the working principle of an eddy current proximity sensor? (NOV/DEC 2008)
13. List any four applications of proximity sensors. (NOV/DEC 2011)
14. What is the working principle of temperature sensor? (NOV/DEC 2004)
15. What is RTD? State its applications. (NOV/DEC 2015)
16. What is the basic principle of thermocouples? (APR/MAY 2016)
17. List out the key elements of Mechatronics. (NOV/DEC 2015)
18. Name few types of Proximity Sensors. (NOV/DEC 2015)
19. Brief on the working principle of Hall Effect Sensor. (MAY/ JUNE 2016)
20. Differentiate between position and proximity sensor. (MAY/ JUNE 2016)

PART – B

1. With an example explain the various functional units of a measurement system. (NOV/DEC 2012)
2. Explain open loop and closed loop control system with neat sketches. (APR/MAY 2005)
3. Explain the basic elements of a closed loop system. (NOV/DEC 2007) 4. Explain the functioning of a closed loop system with a neat sketch for controlling the speed of a shaft. (NOV/DEC 2010), (APR/MAY 2006)
5. Explain the functioning of a closed loop system with a neat sketch for temperature control system. (NOV/DEC 2011)
6. Explain the functioning of a closed loop system with a neat sketch for automatic water level controller. (NOV/DEC 2007), (NOV/DEC 2009)
7. Explain the static performance characteristics of a sensor. (NOV/DEC 2008), (APR/MAY 2006) (NOV/DEC 2010), (APR/MAY 2010)
8. Explain the dynamic characteristics of a sensor. (NOV/DEC 2010), (APR/MAY 2005), (NOV/DEC 2012), (APR/MAY 2008)
9. Describe neatly potentiometer sensor. (NOV/DEC 2013)
10. Explain the functions of a capacitive sensor with neat sketch. (APR/MAY 2008)
11. Explain the function of a LVDT with neat sketch. (APR/MAY 2013), (APR/MAY 2006)
12. Explain the Hall Effect sensor with neat sketch. (NOV/DEC 2010)
13. Explain the functions of a bimetallic strip with neat sketch. (NOV/DEC 2014), (APR/MAY 2013)
14. Explain the functions of a thermocouple with neat sketch. (NOV/DEC 2013), (APR/MAY 2006)
15. Explain the functions of a RTD with neat sketch. (NOV/DEC 2014), (NOV/DEC 2009)
16. Explain any two types of light sensors with neat sketch. (APR/MAY 2005)
17. Explain the working and construction of Hall Effect Sensor, Thermocouples and RTD. (NOV/DEC 2015)
18. Explain the dynamic characteristics of Sensors. (NOV/DEC 2015)
19. Explain about the model of a measurement system.(10) (MAY/ JUNE 2016)
20. Discuss the control systems with example.(6) (MAY/ JUNE 2016)
21. Discuss on the Static and Dynamic characteristics of Sensors in detail. (MAY/ JUNE 2016)

UNIT-II (8085 MICROPROCESSOR AND 8051 MICROCONTROLLER)

PART – A

1. What is the function of Accumulator?

2. List the advantages of microprocessor.
3. Define machine cycle.
4. What are the flags available in 8085 microprocessor?
5. What is the function of IO/M signal in the 8085?
6. What is meant by wait state?
7. What are the steps involved to fetch a byte in 8085?
8. What is an instruction?
9. What is the use of ALE?
10. What is assembler?
11. What do you meant by opcode and the operand?
12. What are the main features of 8051 microcontroller?
13. What are the addressing modes available in 8051?
14. What is TRAP interrupt and its significance?
15. List the control and status signals of 8085 microprocessor and mention its need.
16. What is a stack in an 8085 microcomputer system?
17. What is indexing?
18. What is the function of program counter in 8085 microprocessor?
19. What is the different control machine instruction used in 8085 microprocessor?

PART – B

1. Explain with a neat block diagram the architecture of 8085 Microprocessor.
2. Explain the addressing modes of 8085 Microprocessor with suitable instructions.
3. Explain the pin diagram of 8085 Microprocessor.
4. Explain about instruction format of Intel 8085.
5. Explain about 8051 architecture with neat diagram.
6. Mention the difference between the Microprocessor and Microcontrollers.

UNIT –III (PROGRAMMABLE PERIPHERAL INTERFACE)

PART – A

1. What is key debouncing?
2. Define PPI.
3. Write down the function of OPF in 8255.
4. Name the modes available in 8255.
5. What are the applications of D/A converter interfacing with 8255?
6. What is keyboard interfacing?
7. State the purpose of NOP instructions.
8. Show the control word format of 8255 in BSR mode.
9. Name any two types of ADCs.
10. What is the bit set Reset mode of 8255 PPI?
11. What is the need for interfacing?
12. Mention some performance parameters of DAC.
13. Define conversion time.
14. Define Resolution.
15. What are the kinds of interface available in stepper motor?

PART – B

1. Explain the operating modes of 8255 PPI.
2. Explain the interface 8085 microprocessor with A/D and D/A converters.
3. Explain the Mode 1 input mode operation of 8255 in detail.
4. Explain the seven segment LED interface with microprocessor.
5. Describe with a neat diagram the stepper motor control using Microprocessor 8085.
6. Describe with a neat diagram the traffic light control using Microprocessor 8085.
7. Describe with a neat diagram the temperature control using Microprocessor 8085.

UNIT –IV (PROGRAMMABLE LOGIC CONTROLLER)

PART-A

1. Define a PLC. (NOV/DEC 2012), (NOV/DEC 2013)
2. What is shift register? (NOV/DEC 2013)

3. Derive a PLC timing circuit that will switch on output on for 10 seconds and then switch off.
(NOV/DEC 2007), (NOV/DEC 2008)
4. What are the logic functions that can be obtained by using switches in series? (NOV/DEC 2007
5. Explain delay on and delay off timer with ladder diagrams. (APR/MAY 2008)
6. Explain latching with ladder diagram. (APR/MAY 2008)
7. Draw the ladder logic diagram to represent two switches that are normally open and both have to be closed for a motor to operate. (NOV/DEC 2008)
8. Draw the general ladder rungs to represent a latch circuit. (NOV/DEC 2009)
9. Obtain a NOR logic function using ladder diagram. (APR/MAY 2010)
10. How does the PLC differ from relay logic? (NOV/DEC 2010)
11. State the use of JUMP control in PLCs. (NOV/DEC 2011)
12. Define Adoptive control. (NOV/DEC 2011)
13. What is an internal relay in a PLC? (NOV/DEC 2012)
14. State the purpose of shift registers.(APR/MAY 2013)
15. How will you the input and output of PLC? (APR/MAY 2014)
16. Draw a Ladder diagram for NAND operation. (NOV/DEC 2015)
17. What are the features of PLC?(NOV/DEC 2015)
18. Brief on Shift Registers. (MAY/ JUNE 2016)
19. What are the advantages of master relay?(MAY/ JUNE 2016)

PART –B

1. Explain the architecture of a PLC. (NOV/DEC 2007)
2. Explain the basics of ladder programming used in PLC. (APR/MAY 2008)
3. Write a short notes on Jump control used in PLC using a ladder diagram. (NOV/DEC 2009),
(NOV/DEC 2014)
4. Explain the factors to be considered while selecting a PLC. (NOV/DEC 2007), (NOV/DEC 2009),
(NOV/DEC 2014), (APR/MAY 2014)
5. Explain the timers, counters, internal relays. (NOV/DEC 2013), (APR/MAY 2014)
6. Using simple programs, explain the data handling operation in a PLC. (NOV/DEC 2012)
7. Explain how the shift register can be used to sequence the event with a neat diagram.
(NOV/DEC 2010)
8. Explain latching with ladder diagram. (NOV/DEC 2014)
9. With a neat sketch, discuss about the internal structure of a PLC.(10) (NOV/DEC 2015)
10. Discuss on selection of PLC.(6) (NOV/DEC 2015) (MAY/ JUNE 2016)
11. Discuss in detail about data handling.(8) (NOV/DEC 2015)
12. Explain about Mnemonics with examples.(8) (NOV/DEC 2015)
13. Explain the architecture of a PLC.(10) (MAY/ JUNE 2016)
14. Discuss on input/output Processing.(6) (MAY/ JUNE 2016)
15. Discuss in detail about cylinder sequencing with PLC and its programming.(10) (MAY/ JUNE
2016)

UNIT-V (ACTUATORS AND MECHATRONIC SYSTEM DESIGN)

PART-A

1. Write down any four primary functions of mechanical systems. (NOV/DEC 2014)
2. List the advantages and disadvantages of hydraulic system.(APR/MAY 2010)
3. Distinguish between AC and DC motors. (APR/MAY 2011)
4. What are the properties of a stepper motor? (APR/MAY 2013), (APR/MAY 2014)
5. Stepper motor is an open loop control-Justify. (APR/MAY 2011)

6. Write down the applications of stepper motors. (NOV/DEC 2010), (APR/MAY 2010)
7. What is a servo motor? (APR/MAY 2012)
8. List down the various stages in mechatronic design system. (NOV/DEC 2009), (APR/MAY 2014)
9. List the drawbacks of traditional design. (APR/MAY 2012)
10. Compare the traditional and mechatronic design. (NOV/DEC 2007), (APR/MAY 2010), (NOV/DEC 2013), (APR/MAY 2014)
11. What is timed switch? (NOV/DEC 2009)
12. Name the sensors used in car Engine management system. (NOV/DEC 2011)
13. Give advantages of PLC system over traditional mechanical system. (APR/MAY 2014)
14. Mention the various applications of servomotor. (APR/MAY 2010)
15. Write the basic steps if the program to run a stepper motor. (NOV/DEC 2013), (NOV/DEC 2014)
16. Write the governing equation for the motion of a DC motor. (NOV/DEC 2015)
17. Why Latching is needed to switch on the DC Motor? (NOV/DEC 2015)
18. What are uses of micro motors? (MAY/ JUNE 2016)

PART-B

1. Explain construction and working principle of AC and DC motor. (NOV/DEC 2012), (APR/MAY 2010), (NOV/DEC 2013), (APR/MAY 2014)
2. Explain the working principle of stepper motor. (NOV/DEC 2010), (APR/MAY 2010)
3. What are the various stages in designing a mechatronics system? Explain. (NOV/DEC 2005), (NOV/DEC 2010)
4. Briefly explain traditional and mechatronics designs. (NOV/DEC 2010)
5. Design a pick and place robot using mechatronics elements and explain about the robot control. (NOV/DEC 2005) (NOV/DEC 2007) (NOV/DEC2009) (APR/MAY 2010) (NOV/DEC 2011)(NOV/DEC 2013)
6. With necessary diagrams, explain the automatic car park system. (APR/MAY 2006)(APR/MAY 2008)(APR/MAY 2014)
7. Explain about the basis of mechatronics system design considering vehicle engine management systemas example. (APR/MAY 2006)(NOV/DEC 2009)(NOV/DEC 2014)(NOV/DEC 2007)(NOV/DEC 2013) (MAY/ JUNE 2016)
8. With neat sketches explain various types of Stepper motors with the control. (NOV/DEC 2015)
9. Explain about construction and working principle of DC and AC motors. (MAY/ JUNE 2016)

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Air Conditioning & refrigeration　　　　Subject Code-ME605A
Year: 3rd Year　　　　Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	Introduction - Refrigeration and second law of Thermodynamics, Refrigeration effect and unit of Refrigeration,	1L
	Heat pump, reversed Carnot cycle. Vapour Compression Refrigeration System -.	1L
	Analysis of simple vapour compression Refrigeration cycle by p-h and T-S diagram.	1L
	Effect of operating conditions, liquid vapour heat exchangers, actual refrigeration cycle.	1L
	Multiple Evaporator and compressor system - Application, air compressor system,	1L
	Individual compressor, compound compression, cascade system.	1L
	Application, air compressor systems, individual compressor,	1L
	compound compression, cascade system.	1L
Unit :2	Gas cycle Refrigeration -	1L
	Limitation of Carnot cycle with gas,	1L
	reversed Brayton cycle,	1L
	Brayton cycle with regenerative heat exchanger	1L
	. Air cycle for air craft -	1L
	Basic cycle, boot strap,	1L
	regenerative type air craft refrigeration cycle..	1L
	Necessity of cooling of air craft,	1L
Unit :3	Vapour Absorption System - Simple Vapour absorption system,	1L
	Electrolux Refrigerator, ,	1L
	Lithium Bromide Absorption Refrigeration System. Refrigerants -	1L
	Classification, Nomenclature, selection of Refrigerants, global warming potential of CFC Refrigerants.	1L
	Refrigeration Equipments -	1L
	evaporator, expansion devices – types & working	1L
	Analysis of Ammonia absorption refrigeration	1L

	system	
	Compressor, condenser,.	1L
Unit :4	Other Refrigeration System: Principle and applications of steam jet refrigeration system,	1L
	Performance; vortex tube refrigeration, thermoelectric refrigeration systems.:	1L
	Psychrometry- Psychrometric properties, psychometric relations,	1L
	pyschrormetric charts, psychrometric processes, cooling coils,	1L
	By-pass factor and air washers. Human Comfort -	
	Mechanism of body heat losses, factors affecting	
	human comfort, effective temperature, comfort chart	
Unit :5	Cooling load calculations - Internal heat gain,.	1L
	system heat gain, RSHF, ERSHF, GSHF	1L
	psychometric calculation for cooling, selection of air conditioning, apparatus for cooling and dehumidification,	1L
	Air conditioning system..	1L
	Distribution and Duct systems:	1L
	Distribution of air in conditioned space et location, return and exhaust grills.	1L
	Duct materials and sizing, design of Supply and return air ducts	1L
	, cooling load estimation, heating load estimation,	1L
Total Number Of Hours = 39L(39H)		

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Assignment: 1

(a) Explain the working of Vapour compression refrigeration system with the help of a neat sketch. Mention the advantages of vapour compression refrigeration system over air refrigeration system.

(b) Explain the following terms briefly :

1) Refrigerating effect 5) Wet bulb temperature

2) Dew point temperature 6) Psychrometry

3) Comfort Air conditioning 7) Relative humidity

4) Cooling and Dehumidification

Q.2 (a) An air refrigerator working on Bell coleman cycle takes in air at 1 bar and at a temperature of 100 C. The air is compressed to 5 bar abs. The same is cooled to 250 C in the cooler before expanding in the expansion cylinder to cold chamber pressure of 1 bar. Th compression and expansion laws followed are pv1.35 = C and pv1.3 = C respectively. Determine C.O.P of the plant and net refrigeration effect per kg of air.

Take Cp = 1.009 kJ/kg K and R = 0.287 kJ/kg K for air.

(b) State the principle of Steam jet refrigeration system. Explain the working of Steam jet refrigeration system.

(C) State main applications of Refrigeration. Explain Ice making plant with a suitable diagram.

Assignment: 2

Q.1 Briefly explain construction and working of Practical vapour absorption refrigeration system. Also mention the advantages of this system.

Q.2 Mention the limitations of Simple vapour compression refrigeration cycle. Briefly explain the working of Two stage compression with water intercooler and liquid sub-cooler employed for vapour compression system.

(Q.3) The atmospheric air at 300 C dry bulb temperature and 75 % relative humidity enters a cooling coil at the rate of 200 m3 /min. The coil dew point temperature is 140 C and the by-pass factor of the coil is 0.1. Determine: 1. The temperature of air leaving the cooling coil; 2. The capacity of the cooling coil in tonnes of refrigeration 3. The sensible heat factor for the process.

Assignment: 3

Q.1 Classify air conditioning systems. Explain Central air conditioning system with a neat sketch.

(Q.2) A small office hall of 25 persons capacity is provided with summer air conditioning system with the following data: Outside conditions = 340

C DBT and 280

C WBT Inside conditions = 240

C DBT and 50 % RH

Volume of air supplied = 0.4 m3 /min/person

Sensible heat load in room = 125600 kJ/h

Latent heat load in the room = 42000 kJ/h

Find the sensible heat factor of the plant.

Q.3 Write note on :

(a) Shell and tube condenser

(b) Screw compressor

Q.4 Describe with neat sketch Li-Br and water system. What are its limitations?

Assignment: 4

Q.1 Write short note on :

(a) Split air conditioner

(b) Sources of Heat load

Q.2 Explain in brief the following :

(1) Filters

(2) Humidifiers used in air conditioning systems

Q.3 Attempt the following:

(1) What is Refrigerant? Name some important refrigerants. State the properties of sound refrigerant.

(2) State various evaporators in use. Compare Flooded and DX (dry expansion) type evaporators.

Q.4 A circular duct of 40 cm is selected to carry air in an air conditioned pace at a velocity of 440 m/min to keep the noise level at desired level. If this duct is replaced by a rectangular duct of aspect ratio of 1.5, find out the size of rectangular duct for equal friction method when (a) the velocity of air in two ducts is same, (b) the discharge rate of air in two ducts is same.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Fluid Power Control — Subject Code-ME605C

Year: 3rd Year — Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	**Introduction:**	**10L**
	Introduction :- Need for fluid power, application fluid power with respect to type of production.	1L
	Advantages of fluid power, applications of fluid power	1L
	Types of fluid power systems, Properties of fluids	1L
	General Types of fluids – relative merits and demerits	1L
	Graphic symbols of fluid power components	1L
	Graphic symbols of fluid power components	1L
	Graphic symbols of fluid power components	1L
	Basics of Hydraulics – Pascals Law, Force Multiplication, Cylinder design based on pascals law	1L
	Definition of Mass, weight, specific weight, specific gravity of hydraulic fluids, continuity equation	1L
	Laminar and turbulent flow, Reynold's number, Darcy's equation for losses in pipes, valves and fittings	1L
Unit :2	**Hydraulic system & components**	**8L**
	Sources of hydraulic power, Pumping theory, Pump classification	1L
	Construction details of gear, Vane pumps	1L
	Construction details of piston pumps	1L
	Pump Performance, selection of pumps, variable displacement pumps	1L
	Fluid power actuators, Types, Linear actuators, Types of linear actuators,	1L
	Single acting, Double acting, Construction of double acting cylinder	1L
	Force, velocity and power from a cylinder	1L
	Fluid motors-gear, vane and piston motors.	1T
Unit :3	**Design of hydraulic circuits**	**7L**
	Direction control valve – construction details-classification of direction control valve	1L
	Various Types of DCV's	1L
	Check valve construction details, types of check valves	1L

	Pressure control Valve – applications, construction details, types of pressure control valves	1L
Unit :3	Flow control valves – fixed and variable, Temperature and pressure compensated	1L
	Electrical control solenoid valves	1L
	Operation and graphical symbols of valves	1L
Unit :4	**Symbols For Hydraulic Components**	**7L**
	Single acting cylinder control,	1L
	Double acting cylinder control,	1L
	Regenerative circuit,	1L
	Pump unloading circuit	1L
	Double pump hydraulic system,	1L
	Cylinder synchronization circuit	1L
	Circuit to lift and hold heavy load.	1L
Unit :5	**Advantages & Disadvantages**	**6L**
	Advantages & disadvantages of pneumatic system compared to hydraulic system;	1L
	constructional details and operation of a reciprocating compressor	1L
	working principle and use of filter, pressure regulator, lubricator and silencer;	1L
	symbols of different pneumatic components;	1L
	compressed air distribution system in a plant	1L
	pneumatic circuits for different operations	1L
Unit :6	**Electrical Devices For Controlling**	**4L**
	function of electrical devices and their symbols	1L
	Control of a solenoid actuated cylinder using one limit switch;	1L
	Reciprocation of a cylinder using pressure or limit switches,	1L
	Two cylinder sequencing circuit using two limit switches.	1L
Total Number Of Hours = 42L(42H)		

Assignment:

UNIT-1 & 2

1. What is deference between hydraulic pump and motor?
2. Write names of different components of double acting hydraulic cylinder control circuit.
3. What is function of pump in Hydraulic System Also Explain Positive displacement and non positive Displacement Pump with Diagram?
4. Explain working principal of Swash plate Pump with neat sketch also explain working of each components.
5. What is Pascal's Law?
6. Explain properties of Hydraulic Fluid also Explain requirements of Hydraulic fluid.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Fluid Power Control Subject Code-ME605C
Year: 3rd Year Semester: Sixth

UNIT-3 & 4:

1. Explain Working of double acting Hydraulic cylinder and double acting regenerative hydraulic cylinder with neat sketch and example, also draw neat sketch of one example.
2. What is function of Direction Valve? Explain its working with diagram.
3. Derive expression for cylinder speed and load carrying capacity for the Extending stroke and retracting stroke for double acting and double acting regenerative cylinder.
4. The flow rate of certain fluid in a pipe is 0.001 m^3/s and an operating pressure is 70 bars. The maximum recommended velocity is 6.1 m/s and the factor of safety of 8 is allowed. Select a metric steel tube when
   (a) Material is SAE 1010 with a tensile strength of 380 MPa.
   (b)Material is AISI 4130 with a tensile strength of 570 MPa.
   For a pipe, From Table 1.4, t = 1 mm, and OD = 15mm.
   Calculate working pressure and justify that pipe is suitable for system or not.

UNIT-5 & 6:

1. What is fluid power system, How to Classify it and Also Write merits and Demerits of Fluid Power system.
2. Define the burst pressure and working pressure of hydraulic pipes also defines difference between hydraulic tubing and hoses?
3. List five advantages and five disadvantages of hydraulic & pneumatic System.
4. What are functions of Dryer, Oiler, Filter and Lead hose in pneumatic system?
5. What do you mean by pneumatic power? Also write two applications of pneumatic System.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Material Handling Subject Code-ME606A
Year: 3rd Year Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	**Introduction:**	**1L**
	Definition, importance and scope of materials handling (MH);	1L
	classification of materials; codification of bulk materials	1L
	utility of following principles of MH – (i) materials flow, (ii) simplification, (iii) gravity, (iv) space utilization, (v) unit size, (vi) safety, (vii) standardization, (viii) dead-weight, (ix) idle time, (x) motion.	1L
	Unit load : Definition; advantages & disadvantages of unitization;	1L
	unitization by use of platform,	1L
	container, rack, sheet,	1L
	bag and self contained unit load;	1L
	descriptive specification and use of pallets,	1L
	skids, containers, boxes,	1L
	crates and cartons; shrink and stretch wrapping	1L
Unit :2	**Classification of MH Equipment :**	**1L**
	Types of equipment – (i) industrial trucks & vehicles, (ii) conveyors,.	1L
	(iii) hoisting equipment, (iv) robotic handling system and	1L
	(v) auxiliary equipment	1L
	; Independent equipment wise sub	1L
	classification of each of above type of equipment	1L
	Industrial trucks & vehicles : Constructional features and use of the following equipment – (i) wheeled hand truck,	1L
	(ii) hand pallet truck, (iii) fork lift truck;	1L
	Major specifications, capacity rating and attachments of fork lift truck	1T
Unit :3	**Conveyors :** Use and characteristics of belt conveyor,	**1L**
	constructional features of flat and troughed belt conveyor; Use and constructional features of Flg. types of chain conveyors – (i) apron, car	1L

	and trolley type;	
	Construction of link-plate chains; Dynamic phenomena in chain drive; Use and constructional features of roller conveyors;	1L
	Gravity and powered roller conveyor; Pneumatic conveyor-use and advantages;	1L
	Positive, negative and combination system of pneumatic conveyors; constructional feature, application and conveying capacity of screw conveyor.	1L
Unit :4	**Hoisting Equipment :** Advantage of using steel wire rope over chain;	1L
	constructional features of wire ropes; Rope drum design; Pulley system-simple vs. multiple pulley;	1L
	Load handling attachments : hooks, grabs, tongs, grab bucket;	1L
	Arrangement of hook suspension with cross piece and pulleys (sheaves);	1L
	Use and constructional features of (i) hand operated trolley hoist , (ii) winch;	1L
	(iii) bucket elevator, (iv) Jib crane	1L
	, (v) overhead travelling crane and (vi) wharf crane;	1L
	Level luffing system of a wharf crane; Utility of truck mounted and crawler crane.	1L
Unit :5	**Robotic handling :** Materials handling at workplace;	**1L**
	Major components of a robot; Applications of robotic handling.	1L
	Auxiliary Equipment : Descriptive specification and use of – (i) Slide and trough gates	1L
	, (ii) belt, screw and vibratory feeders,	1L
	(iii) Chutes,	1L
	(iv) positioners like elevating platform, ramps, universal vise;	1L
	(v) ball table	1L
Total Number Of Hours = 39L(39H)		

Assignment No -1

1. Give the example of each:-

(a) Hand truck (b) powered truck
Describe one truck of each category in brief.

2. A belt conveyor consists of an Endless, Flat and Flexible belt. Explain the three underlined terms. What are the different types of pulleys used in a belt conveyor?

3. The tension in the tight side of the conveyor belt is 150 KN. μ=0.45 and α=150^0 if the belt speed is to be 1.5 m/s, what will be the power required at the driving pulley just for driving. Find the value in Kilowatt.

4. What is the difference between steel wire, strand and steel wire rope? Draw the cross section of steel wire rope of diameter 12 mm with fibre core and it is a 6x7 steel wire rope.

5. What is pneumatic conveying and what are its advantages and disadvantages? What are the different methods of pneumatic conveying?

6. What are the major specifications of bridge crane (overhead travelling crane)? What is its functioning and where is it used?

7. Explain unit load, pallet, and container.

8. Name ten material handling principles and explain in brief, out of which, one principle you discuss in detail.

9. **(a)** With the help of simple sketch explain two different types of belt tensioning device.

(b) Calculate the conveying capacity of a troughed belt conveyor if B= belt width= 1000mm, V= velocity of belt = 1200mm/s, γ= bulk density= 2000kg/m^3, ϕ= static angle of repose=45^0 and inclination of inclined troughing idlers =20^0.

(c) Boxes of size 220mm x 180mm x 120mm have to be conveyed by a suitable belt conveyor at the rate of 2400 boxes per hour. What is the belt width and speed of the conveyor? The boxes have to be placed with a gap of 200mm between boxes.

10. Draw a simple diagram of a fork lift truck and mark the major components.
Generally for a 3 ton FLT what will be the standard voltage?
A battery operated fork lift truck weight 4000 litre includes weight of battery and operator it is carrying a weight of 2000 pounds .The FLT carries the load to a distance of 200ft of which 170ft along level road and balance 30 ft on an upgrade of 6%. After discharge the load it returns over the same route. Calculate total watt-hours of energy spent by the truck. Ignore the energy spent during lifting of load and tilting of most.

Chart on approximate watt hour required by FLT to travel or level road

Weight (truck plus load in pounds)	**Length of run in feet**		
	50 ft	**100 ft**	**200 ft**
2000	3.5 watt hr	6 watt hr	8 watt hr
4000	7	10	16
6000	10.5	15	24

Assignment No -2

11. **(a)** What are the major components of a robot and what are their functions?
(b) How robot manipulation is classified? Explain
(c) What are the major applications of robotic handling?

13. **(a)** Name four principle groups of material handling equipment and discuss the essential characteristics of any two groups in detail.
(b) What are the different types of crane? Briefly describe any two of them.

14. Write short notes on (any three)
(a) Simple and multiple pulley system.
(b) Rope drum and winch drum.
(c) Stacker and reclaimer (explain how stacking and reclaiming is done)
(d) Steel wire rope vs chain
(e) Grab bucket

Assignment No . 3

15. What is deference between unit load and unitization of load? Write at least two points on advantage and two points on disadvantage associated with unitization of load.
16. With a neat sketch show the general arrangement of belt conveyor and label all the components.
17. What are the major advantages of using steel wire rope compared to chains? What is
a) Parallel lay rope and
b) Regular lay ropes.
18. Boxes of size 200mm x 180mm x 100mm have to be conveyed by a belt conveyor of sufficient belt strength at the rate of 2000 boxes per hour. What is the belt width and speed of the conveyor? The boxes will be placed with a gap of 200mm between two consecutive boxes. What will be the side clearance? What will be the time rate at which each box should be loaded?

19. What are the major advantages of over head travelling carne? What is a gantry crane? What is the basic difference between the two?

20. Describe a screw conveyor. For which type of material it is suitable.

21. In a belt Conveyor the driver motor does not directly run the belt then how the belt runs and how slipping of belt over the pulley is avoided? For running and stopping an inclined belt conveyor what extra precaution have to be taken and how?

Assignment No. 4

22. A) What are the principle groups of material handling equipment? Briefly discuss the essential characteristics of any four groups.

B) What are the important technical factors that should be considered in the choice of material handling equipment? Briefly discuss any one factor.

23. A) What are the different types of idler used in belt conveyor and where?

B) The Power required at the driving pulley just for driving the belt is 120KW. The tension in slack side is 50KN. And μ=0.4, $\alpha=165^0$ Calculate the belt speed in meter per second.

C) In a belt conveyor carrying bulk material , static angle of repose is Φ belt width is B meter , V is Velocity in M/s, R is Bulk Density in tons/m^3 and troughing angle is α. It is a three roller troughed belt conveyor. Find the conveying capacity in tons/Hours.

24. **A)** Explain any two of the following material handling principle (if possible with example) 1. Gravity principle 2. Dead weight principle 3. Standardization principle

B) Name the major components of robots with their function.

C) Classify the robot manipulators.

25. **A)** What is the function and what are the different components of a fork lift truck

B) Rated capacity of a fork lift truck is 2000kg and load centre is 450mm the distance between front wheels to heel of the fork is 350mm. what is the true capacity of the FLT? Now if a load is to be carried whose C.G. is at a distance of 550mm from the heel of the fork then what is the maximum safe weight that can be carried?

C) Describe briefly (any two) 1. Batteries for fork lift truck 2. Side shifter of FLT. 3. Rotator of FLT.

26. A) Explain the functioning of 1. Stacker and bucket wheel reclaimer 2. Belt feeder and vibrating feeder

B) Jib crane or Crawler crane

27. Write short notes on any three of the followings

A) Pallet and skid
B) Classification and alpha numeric codification of bulk materials as per IS8730:1997.
C) Pneumatic conveying
D) Deferent types of belt tensioning device in a belt conveyor.
E) Applications of robot handling

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Finite Element Method — Subject Code-ME606B

Year: 3rd Year — Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	Introduction: Historical background,	1L
	Relevance of FEM to design problems, Application to the continuum–	1L
	Discretisation, Matrix approach,	1L
	Matrix algebra– Gaussian elimination,	1L
	Governing equations for continuum,	1L
	Classical Techniques in FEM,	1L
	Weighted residual method,	1L
	Ritz method,	1L
	Galerkin method	1L
Unit :2	One dimensional problems: Finite element modeling–	1L
	Coordinates and shape functions,	1L
	Potential energy approach– Element matrices and vectors,	1L
	Assembly for global equations, Boundary conditions,	1L
	Higher order elements- Shapes functions,	1L
	Applications to axial loadings of rods– Extension to plane trusses,	1L
	Bending of beams– Finite element formulation of stiffness matrix and load vectors,	1L
	Assembly to Global equations	1L
	, boundary conditions, Solutions and Post processing, Example Problems	1T
Unit :3	Two dimensional problems– scalar variable problems:	1L
	Finite element modeling– CST element, Element equations,	1L
	Load vectors and boundary conditions,	1L
	Assembly, Application to heat transfer,	1L
	Examples	1L
Unit :4	Two dimensional problems– vector variable problems:	1L

	Vector Variable problems,	1L
	Plane Strain and Axis	1L
	Elasticity equations– Plane Stress,	1L
Unit :5	Isoparametric elements for two dimensional problems:	1L
	Natural coordinates, Iso parametric elements,	1L
	Four node quadrilateral element,	1L
	Shape functions,	1L
	Element stiffness matrix and force vector,	1L
	Numerical integration, Stiffness integration,.	1L
	Displacement and Stress calculations	1L
	Examples	1L
Unit :6	Computer implementation:	1L
	Pre-processor,	1L
	Processor, Post-processor.	1L
	Discussion about finite element packages	1L
Total Number Of Hours = 41L(41H)		

Assignment No. 1

1. **A SSB is subjected to UDL over entire span. Determine the bending moment and deflection at mid span by using Rayleigh-Ritz method and compare with exact solutions.**
2. **A beam AB of span 'l' simply supported at ends and carrying a point load W at the centre 'C' as shown in fig. Determine the deflection at midspan by using Rayleigh-Ritz method and compare with exact result.**
3. **A SSB subjected to UDL over entire span and it is subjected to a point load at centre of the span. Calculate the bending moment and deflection at midspan by using Rayleigh- Ritz method and compare with exact solution. .**
4. **A bar of uniform cross section is clamped at left end at other end free and it is subjected to a uniform axial load P as shown in figure. Calculate the displacement and stress in a bar by using two terms polynomial and three terms polynomial. Compare with exact solutions.**

Assignment No. 2

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Finite Element Method Subject Code-ME606B
Year: 3rd Year Semester: Sixth

1. **A spring assemblage with arbitrarily numbered nodes are shown in fig. The nodes 1 and 2 are fixed and a force of 500kN is applied at node 4 in the x-direction. Calculate the following:**

(i) Global stiffness matrix. (ii) Nodal displacements. (iii) Reactions at each nodal points. Take Spring constant, k1=100kN/m; k2=200kN/m; k3=300kN/m.

2. **Derive stiffness matrix for one dimensional truss element.**
3. **For the two bar truss shown in fig. Determine the displacements of nod 1 and the stress in element 1-3.**
4. **Consider a four bar truss as shown in figure. It is given that E = 200000 N/mm² and Ae= 625 mm² for all elements. Determine element stiffness matrix for each element, assemble the structural stiffness matrix K for the entire truss and displacements at all nodes**

Assignment No. 3

1. **Derive the shape function for constant strain triangular element.**
2. **Derive the strain-displacement matrix for constant strain triangular element**
3. **Derive stress-strain relationship matrix or constitutive matrix for two dimensional elements.**
4. **Determine the stiffness matrix for the CST element shown in figure. The co-rdinates are given in units of millimeters. Assume plane stress conditions. Take E = 210 GPa, v = 0.25 and t = 10mm.**

Assignment No. 4

1. **Find the natural frequency of longitudinal vibration of the unconstrained stepped bar.**
2. **For the bar as shown in fig. with length 2L, modulus of elasticity E, mass density ρ, and cross sectional area A, determine the first two natural frequencies.**
3. **Consider a uniform cross-section bar an shown in fig. of length "L" made up of a material whose young's modulus and density are given by E and ρ. Estimate the natural frequencies of axial vibration of the bar using both lumped and consistent mass matrix.**
4. **Determine the natural frequency of vibration for a beam fixed at both ends as shown in fig. The beam has mass density ρ, modulus of elasticity E, cross-sectional area A, moment of inertia I, and length 2L. For simplicity of the long hand calculations, the beam is discretized into two elements of length L**

Assignment No. 5

1. **A wall of 0.6m thickness having thermal conductivity of 1.2 W/mK. The wall is to be insulated with a material of thickness 0.06m having an average thermal conductivity f 0.3 W/mK. The inner surface temperature is 1000°C and outside of the insulation is exposed to atmospheric air at 30°C with heat transfer coefficient of 35 W/m^2 K. Calculate the nodal temperature.**
2. **A furnace wall is made up of three layers, inside layer with thermal conductivity 8.5 W/mK, the middle layer with conductivity 0.25 W/mK, the outer layer with conductivity 0.08 W/mK. The respective thickness of the inner, middle and outer layer are 25cm, 5cm and 3cm respectively. The inside temperature of the wall is 600°C and outside of the wall is exposed to atmospheric air at 30°C with heat transfer coefficient of 45 W/m2 K. Determine the nodal temperatures.**
3. **An aluminium alloy fin of 7mm thick and 50mm long protrudes from a wall, which is maintained at 120°C. The ambient air temperature is 22°C. The heat transfer coefficient and thermal conductivity of the fin material are 140 W/m2 K and 55 W/mK respectively.Determine the temperature distribution of fin.**
4. **A Steel rod of diameter d = 2cm, length L = 5 cm and thermal conductivity k = 50 W/m°C is exposed at one end to a constant temperature of 320°C. The other end is in ambient air of temperature 20°C with a convection coefficient of h = 100 W/m2 C. Determine the temperature at the midpoint of the rod.**

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lession- Plan

Subject Name: Turbo Machinery — Subject Code-ME606C

Year: 3rd Year — Semester: Sixth

Module/Unit Number	Topics	Number of Lectures
Unit :1	Introduction:	1L
	Classification: Incompressible and compressible flow machines;	2L
	Radial, axial and mixed flow machines;	1L
	Turbines vs pumps,.	1L
	Applications: Water supply,	1L
	fans and compressors	1L
	ventilation,	1L
	power generation, propulsion	1L
Unit :2	Incompressible- Flow Machines:	1L
	Hydraulic Turbines:	1L
	Headrace, penstock, nozzle,	1L
	runner, draft tube and tail race;	1L
	Gross head and net head;	1L
	Velocity diagrams for impulse and reaction turbines;	1L
	Discharge, head, power and efficiencies.	1L
	Pumps: Reservoir, foot valve, suction line,	1L
	pump, delivery line and overhead tank;	1L
	Static head and losses; Velocity diagrams;	1L
	Discharge, head, power and efficiencies	1L
Unit :3	Compressible-Flow Machines:	1L
	Static and stagnation states;	1L
	Isentropic and adiabatic expansion and compression processes;	1L
	Nozzle, diffuser and rows of stationary	1L

	and moving blades; Efficiencies	1L
Unit :4	Dimensional Analysis: Similarity laws,	1L
	Volume-flow, mass-flow head and power coefficients, pressure ratio, enthalpy ratio,	1L
	Reynolds number, Mach number; Specific speed and machine selection	1L
Unit :5	Testing and Performance Analysis:	1L
	Measurement devices;	1L
	affinity laws and unit quantities.	1L
	Set up and operating characteristics of pumps,	1L
	turbines;	1L
	fans and turbo-compressors.	1L
	Cavitation– cause of cavitation and definition of Thoma's cavitation parameter,	1L
	surge and choking.	1L
Total Number Of Hours = 36L(36H)		

Assignments

MODULE I

1. a) Explain briefly with the help of neat sketch different types of impellers.
b) With the help of an h-s diagram discuss specific work.
2. a) Define and classify turbo machine.
b) Explain the different variables involved in determine the performance of an axial turbo machines.

MODULE II

3. Draw the following for axial flow compressor and turbine cascades:
i) typical static pressure and velocity distribution curves around the blades, and
ii) velocity and direction profiles at the cascade exit
4. a) Illustrate nomenclature of an axial compressor cascade.
b) Derive the optimum space chord ratio of turbine blades.

MODULE III

5. a) A centrifugal compressor runs at a speed of 15000 rpm and delivers 30 kg of air per second. Exit radius is 0.35m, relative velocity at exit is 100 m/s at an exit angle of 750 Assume axial inlet and T01=300 K and p01= 1 bar. Calculate (a) the torque (b) the power required to drive the compressor (c) the ideal head developed (d) the work done and (e) the exit total pressure
b) Derive an expression for Degree of Reaction for an axial flow compressor.

16. A centrifugal air compressor stage has the following data:

Type of impeller	radial-tipped
Speed	17000 rpm
Impeller tip diameter	48cm
Eye tip diameter	24cm
Eye hub diameter	12cm
Mass flow rate	8kg/s
Slip factor	0.92
Stage efficiency	0.77
Entry conditions	p_{01} =1.05bar, T_{01} = 306k

Determine:

Determine:

a) The air angles at the hub, mean and tip sections of the inducer, maximum Mach number at the inducer entry, total pressure ratio developed and power required to drive the compressor without IGVs.

b) The air angles at the hub, mean and tip sections of the IGVs at exit for axial entry to the inducer, total pressure ratio developed and the power required.

MODULE IV

17. a) How are the loss coefficients for stationary and moving rows of blades in a turbine stage defined?

b) How would you predict the cascade losses in a stage from its velocity triangles?

18. A ninety degree IFR stage has the following data:

Total-to-static pressure ratio	P_{01}/P_3=3.5
Exit pressure	1 bar
Stagnation temperature at entry	650 ^{0}c
Blade-to-isentropic speed ratio	σ =0.66
Rotor diameter ratio	d_3/d_2 =0.45
Rotor speed	N=16000rpm
Nozzle exit air angle	α_2=20 ^{0}
Nozzle efficiency	η_N =0.95
Rotor width at entry	b_2=5cm

Determine a) the rotor diameter, b) the rotor blade exit air angle, c) the mass-flow rate, d) hub and tip diameters at the rotor exit, e) the power developed and f) the total-to-static efficiency of the stage.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lab Manual

Title of Course: IC Engine Lab
Course Code: ME691
L-T –P Scheme: 3P **Course Credits: 2**

Course Description & Objectives:

The main objective of this lab is to develop an idea of fuel properties and their variation with temperature, determination of kinematic viscosity and calorific value of fuels, understanding of basic internal combustion engine performance, determination of friction power and volumetric efficiency of I.C. engines and the use of multi-stage compression.

Course Outcomes:

After the completion of this course, the student should be able to:

1. Understand the complete operation of 2 stroke and 4 stroke I.C engines which can be further confirmed through V.T.D and P.T.D
2. Find the performance of 2-S and 4-S engines and the variation of various performance parameters with load and speed.
3. Know how to balance the heat energy available in engine cylinder after the combustion process.
4. Understand the working and performance evaluation of mechanical power consuming devices like compressors.
5. Analyze the performance of the variable compression ratio engine with computerized set up which enables the understanding of pressure variation with crank angle during a cycle of operation.
6. Find the kinematic viscosity of fuels and its variation with temperature.

Course Contents:

Any 6 (six) of the following experiments to be conducted.

1) Determination of calorific value of a fuel by Bomb calorimeter.
2) Flue gas analysis by ORSAT apparatus.
3) Study of valve timing diagram of Diesel Engine.
4) Performance Test of a muticylinder Petrol Engine by Morse method.
5) Performance Text of an I.C. Engine using electric (eddy current) dynamometer.
6) Use of catalylitic converters and its effect on flue gas of an I.C. Engine.
7) Study of MPFI (multipoint fuel injection system).

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lab Manual

Text Books:

1. Mathur. R.B. and R.P. Sharma, “Internal Combustion Engines”., Dhanpat Rai & Sons 2007. 2. Duffy Smith, “Auto Fuel Systems”, The Good Heart Willcox Company, Inc., 1987. 3. Eric Chowenitz, “Automobile Electronics”, SAE Publications, 1995.

Manual

ME691_IC ENGINE_LM.pdf

LABORATORY MANUAL

I. C. ENGINES

LIST OF EXPERIMENTS

<u>Note</u>:-

1) **At least ten experiments are to be performed in the semester**.

2) **At least seven experiments should be performed from the above list**. **Remaining three experiments may either be performed from the above list or designed & set by the concerned institution as per the scope of the syllabus.**

EXPERIMENT NO.1

Aim: **-To Study the construction details & working principal of 2-Stroke / 4-Stroke Petrol Engine.**

Apparatus: **- Models of 2-Stroke / 4-Stroke Engines.**

Theory: - The working Principle of Engines.

- **Four Stroke (S.I) Engine.**

In a four stroke engine, the cycles of operations is completed in 4 strokes of piston or 2 revolution of crank shaft. Each stroke consists of 180° & hence the fuel cycle consists of 720° of crank rotation. The 4-Strokes are: -

- **Suction or Intake Stroke**: - In starts at, when the piston is at top dead centre & about to move downwards. The inlet valve is open at that time and exhaust valve is closed due to suction created by the motion of the piston towards the bottom dead centre, the charge containing air fuel mixture is drawn into the cylinder. When the piston reaches BDC the suction stroke ends and inlet valve is closed.
- **Compression Stroke**: - The charge taken into the cylinder during suction stroke is compressed by return stroke of piston. During this stroke both the valves are closed. The mixture which fills the entire cylinder volume is now compressed into the clearance volume. At the end, the mixture is ignited with the help of electrode of spark plug. During the burning process the chemical energy of fuel is converted to heat energy. The pressure is increased in the end due to heat release.
- **Expansion Stroke**: - The burnt gases escape out and the exhaust valve opens but inlet valve remaining closed the piston moves from BDC to TDC and sweeps the burnt gases out at almost atmospheric pressure. The exhaust valve gets closed at the end of this stroke. Thus, for one complete cycle of engine, there is only one power stroke while crank shaft makes 2 revolutions.
- **Exhaust Stroke**: - During the upward motion of the piston, the exhaust valve is open and inlet valve is closed. The piston moves up in cylinder pushing out the burnt gases through the exhaust valve. As the piston reaches the TDC, again the inlet valve opens and fresh charge is taken in during next downward movement of the piston and the cycle is repeated.

2-Stroke (S.I) Engines.

In a 2-Stroke engine, the filling process is accompanied by the change compressed in a crank case or by a blower. The induction of compressed charge moves out the product of combustion through exhaust ports. Therefore, no piston stroke is required. For these 2-strokes one for compression of fresh charge and second for power stroke.

The charge conducted into the crank case through the spring loaded valve when the pressure in the crank case is reduced due to upward motion of piston during the compression stroke. After the compression & ignition expansion takes place in usual way.

During the expansion stroke the charge in crankcase is compressed. Near the end of the expansion stroke, the piston uncovers the exhaust ports and the cylinder pressure drops to atmosphere pressure as combustion produced leave the cylinder.

Construction Details

- **Cylinder**: - It is a cylindrical vessel or space in which the piston makes a reciprocating produces.
- **Piston**: - It is a cylindrical component fitted into the cylinder forming the moving boundary of combustion system. It fits in cylinder perfectly.
- **Combustion Chamber**: - It is the space enclosed in the upper part of cylinder, by the cylinder head & the piston top during combustion process.
- **Inlet Manifold**: - The pipe which connects the intake system to the inlet valve of engine.
- **Exhaust Manifold**: - The pipe which connects the exhaust system to the exhaust valve of engine.
- **Inlet / Exhaust Valves**: - They are provided on the cylinder head to head to regulate the charge coming into or going out of the chamber.
- **Spark Plug**: - It is used to initiate the combustion process in S.I engines.
- **Connected Rod**: - It connects piston & the crank shaft.
- **Crank shaft**: - It converts the reciprocating motion of the piston into useful rotary motion of output shaft.
- **Gudgeon pins**: - It forms a link between connection rod and the piston.
- **Cam shaft**: - It controls the opening & closing of the valves.
- **Cam**: - They open the valves at the correct tunes.
- **Carburetor**: - Used in S.I engine for atomizing & vaporizing and mixture it with air in varying proportion.

Viva Questions

1. Describe the working principle of 2-Stroke petrol Engine?
2. Describe the working principle of 4-Stroke petrol Engine?
3. What is Suction Stroke?
4. What is compression Stroke?

EXPERIMENT NO.2

Aim: - **To study the constructional details & working principles involved in a 2-Stroke & 4-Stroke Diesel Engines.**

Apparatus: - **Model of 2-Stroke / 4-Stroke Diesel Engine.**

Theory: -

- **Four Stroke (C.I.) Engine.**

  In four strokes C.I. Engine compression ratio is from 16 to 20. During suction stroke air is inducted. In C.I. engines high pressure. Fuel pump and injectors are provided to inject the fuel into combustion chamber and ignition chamber system is not necessary.

Construction Details

1. **Suction**: - During suction stroke, air is inducted through inlet valve.
2. **Compression**: - The air inducted is compressed into the clearance volume.
3. **Expansion**: - Fuel injection starts nearly at the end of the compression stroke. The rate of injection is such that the combustion maintains the pressure constant inspired of piston movement on its expansion stroke increasing the volume. After injection of fuel, the products of combustion chamber expand.
4. **Exhaust**: - The piston traveling from BQC to TDC pushes out the products of combustion out of cylinder.

- **Two Stroke (C.I.) Engine.**

In two stroke engines, the cycle is completed in one revolution of the crankshaft. In 2-stroke engine, the filling process is accomplished by the charge compressed in crankcase or by a blower. The induction of compressed charge moves out of the exhaust ports. Therefore, no piston strokes are required for these 2 operations. Two strokes are sufficient to complete the cycle one for compressing the fresh charge and other for expansion or power stroke.

1. **Compression:** - The air or charge is inducted into the crankcase through the spring loaded inlet valve when the pressure in crankcase is reduced due to upward motion of piston.

2. **Expansion**: - During this, the charge in the crankcase is compressed. At the end the piston uncovers the exhaust ports and cylinder pressure drops to the atmospheric pressure. Further movement of piston opens the transfer ports, permitting the slightest compressed charge in the crankcase to enter the engine cylinder.

Construction Details

1. **Cylinder**: - In it the piston makes a reciprocating process motion.
2. **Piston:** - It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system. It fits into cylinder.
3. **Combustion Chamber**: - The space enclosed in the upper part of the cylinder, by the head and the piston top during the combustion process.
4. **Inlet/ Outlet ports**: - They are provided on the side of cylinder to regulate the charge coming in and out of cylinder.
5. **Fuel Injector**: - It injects the fuel in combustion chamber to initiate combustion process for power stroke.
6. **Connecting Rod**: - It interconnects crank shaft and the piston.
7. **Fly Wheel**: - The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates cow sing change in angular velocity of shaft. In order to achiever uniform torque an internal mass is attached to the output shaft & this is called as fly wheel.

Viva Questions

1. Describe the working principle of 2-Stroke Diesel Engine?
2. Describe the working principle of 4-Stroke Diesel Engine?
3. What is compression Stroke?
4. Describe Expansion / Power Stroke?
5. What are the construction details of a four stroke Diesel Engine?
6. What is the main deference in 2-Stroke Diesel Engine and 4-Stroke Diesel Engine?
7. Describe the deference in 2-stroke Diesel Engine & 2-Stroke Petrol Engine?

EXPERIMENT No. 3

AIM:- Analysis of exhaust gases from Two-Stroke single-cylinder petrol engine by Orsat Apparatus.

APPARATUS USED:- Orsat apparatus, caustic potash solution, alkaline solution of pyrogallic acid, cuprous chloride solution, brine and dry flue gas sample.

THEORY:-

To check the combustion efficiency of I. C. engines, it is essential to know the constituents of the flue gases being exhausted. The various constituents the flue gases are CO_2, excess O_2, CO, SO_2, and N_2.The volumetric analysis of mainly CO_2, O_2, and CO is required, because the heat released is sufficiently large when carbon of the fuel burns to rather than when it burns to CO, secondly to determine the requisite amount of oxygen for proper burning of fuel. Such an analysis can be carried out conveniently with the help of Orsat apparatus.

An Orsat apparatus is shown in figure. It consists of three flasks to absorb different gases. Flask no. 1 contains caustic potash solution and this absorbs CO_2 present in the flue gas. Similarly flask no. 2 and 3 contains alkaline solution of pyrogallic acid, and cuprous chloride solution to absorb O_2, and CO respectively.

100 ml of a dry flue gas sample is sucked in the eudiometer tube of the apparatus and is allowed to react with the three solutions turn by turn. The amount of CO_2, O_2, and CO absorbed in the respective solution is estimated from the eudiometer scale.

PROCEDURE:-

1. Fill 2/3 of the aspirator bottle with the brine solution.
2. Fill three flasks i.e. flask no. 1, 2,and 3 with the required quantity of the caustic potash solution, alkaline solution of pyrogallic acid, and cuprous chloride solution respectively and close their valves.
3. Open the valve of flask no. 1, now by operating the rubber bladder and opening the three way cock to the atmosphere, bring the level of caustic potash solution to the mark A. close the valve of flask no. 1.
4. Repeat as step 3, to bring the level of alkaline solution of pyrogallic acid, and cuprous chloride solution to their respective marks B and C. Close the valves of flask no. 2 and 3.
5. Open the three-way cock to the atmosphere and raise the aspirator bottle so that air present in the Eudiometer is expelled to atmosphere. Close the three way cock and lower the aspirator bottle to read zero on eudiometer scale. The eudiometer is ready to receive 100 ml of gas sample.
6. Open the three-way cock and allow the flue gas sample to enter the eudiometer. Close the three-way cock, now 100 ml of gas has entered the apparatus. Open the three-way cock to the atmosphere and raise the aspirator bottle so that whole gas present in the eudiometer is expelled to atmosphere. Repeat this step twice or thrice so that 100 ml of representative flue gas sample remain in the apparatus. Close the three way cock finally.
7. Now open the valve of flask no. 1. Raise and lower the aspirator bottle few times so that gas is passed-in and out of flask several times. Lower the aspirator bottle and bring the level of caustic potash solution again to mark A. Close the valve of flask. Bring the aspirator bottle near the eudiometer and position it so that, the liquid level in the both is same. Note the liquid level on the scale. This gives the %age of CO_2 present in the flue gas sample.
8. Repeat the procedure as step 7 to determine the %age of O_2, and CO respectively by passing the remaining sample through the two flasks.

OBSERVATIONS:-

Amount of flue gas after absorption by caustic potash solution = X ml

Amount of flue gas after absorption by alkaline solution of pyrogallic acid = Y ml

Amount of flue gas after absorption by cuprous chloride solution = Z ml

CALCULATIONS:-

(i) Amount of flue gas sample = 100 ml

(ii) Amount of CO_2 = (100 - X) ml

(iii) Amount of O_2 = (X –Y) ml

(iv) Amount of CO = (Y + Z) ml

(v) Amount of N_2 = (100 – Z) ml

PRECAUTIONS:-

1. The apparatus should be air tight.
2. The eudiometer tube of the apparatus should be well flushed with the flue gas sample before performing the experiment.
3. The brine solution in the aspirator bottle should be saturated, as it may absorb some constituents of the gas sample and thereby cause errors.

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Question

1. What is the working of orsat apparatus ?
2. What is the purpose of orsat apparatus ?
3. Which solution is mainly used in orsat Appratus?
4. Define the brine and dry flue gas?

EXPERIMENT No. 4

AIM:- To prepare heat balance sheet on Single-Cylinder Diesel Engine.

APPARATUS USED :- Single-Cylinder Diesel Engine (Constant Speed) Test Rig, Stop Watch and Digital Tachometer.

THEORY:-

The thermal energy produced by the combustion of fuel in an engine is not completely utilized for the production of the mechanical power. The thermal efficiency of I. C. Engines is about 33 %. Of the available heat energy in the fuel, about 1/3 is lost through the exhaust system, and 1/3 is absorbed and dissipated by the cooling system.

It is the purpose of heat balance sheet to know the heat energy distribution, that is, how and where the input energy from the fuel is is distributed.

The heat balance sheet of an I. C. Engine includes the following heat distributions:

a. Heat energy available from the fuel brunt.
b. Heat energy equivalent to output brake power.
c. Heat energy lost to engine cooling water.
d. Heat energy carried away by the exhaust gases.
e. Unaccounted heat energy loss.

FORMULE USED :-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and*

$W\ (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{B\,P = (2\pi N\,T) / 60,000}$ KW

; Where $N = rpm,$ $T = Torque$ *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So 1 ml = 10^{-6} m^3

(iv) Heat energy available from the fuel brunt, $\mathbf{Q_s = m_f \times C. V. \times 3600}$ KJ/hr

(v) Heat energy equivalent to output brake power, $\mathbf{Q_{BP} = BP \times 3600}$ KJ/hr

(vi) Heat energy lost to engine cooling water, $\mathbf{Q_{CW} = m_w \times C_w (t_{wo} - t_{wi}) \times 3600}$ KJ/hr

(vii) Heat energy carried away by the exhaust gases, $\mathbf{Q_{EG} = m_{fg} \times C_{fg} (t_{fg} - t_{air}) \times 3600}$ KJ/hr

; *Where* $m_{fg} = (m_f + m_{Air})$ *Kg/Sec, and* $m_{Air} = C_d A_o \sqrt{2 g h}\, \rho_{Air}\, \rho_{Water}$ Kg/ Sec

; *Where* C_d *(Co-efficient of Discharge) = 0.6,* $\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ *Kg/* m^3*,*

A_o *(Area of Orifice) =* $(\pi d_o^{\,2})/4$ m^2*,* $P_1 = 1.01325$ *Bar,* $R = 0.287$ *KJ/Kg . K,*

$T_a = (t_a + 273)$ *K,* t_a *= Ambient Temperature* ^oC

(viii) Unaccounted heat energy loss, $\mathbf{Q_{Unaccounted} = Q_s - \{ Q_{BP} + Q_{CW} + Q_{EG} \}}$ KJ/hr

<u>PROCEDURE</u> :-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load and run the engine till it attain the working temperature and steady state condition.

3. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
4. Set the dynamometer to 20 % of the full load, till it attains the steady state condition. Note down the fuel consumption rate, Engine cooling water flow rate, inlet and outlet temperature of the engine cooling water, Exhaust gases cooling water flow rate, Air flow rate, and Air inlet temperature.
5. Repeat the experiment at 40 %, 60 %, and 80 % of the full load at constant speed.
6. Disengage the dynamometer and stop the engine.
7. Do the necessary calculation and prepare the heat balance sheet.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg
Specific Heat of Water, C_w	= 4.187	KJ/Kg . K
Specific Heat of Exhaust Flue Gases, C_{fg}	= 2.1	KJ/Kg . K
Gas Constant, R	= 0.287	KJ/Kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	Bar
Orifice Diameter, d_o	= 25 x 10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Density of fuel (Diesel), ρ_{Fuel}	= 810 to 910	Kg/m^3

Density of Water, ρ_{water} = 1,000 Kg/m^3

Brake Drum Diameter, D = 181.5×10^{-3} m

Rope Diameter, d = m

Or Belt thickness, t_{Belt} = 5.5×10^{-3} m

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Engine Cooling Water Flow Rate, m_w (Kg/hr)	Engine Cooling Water Temperatures, (^{o} C)		Exhaust Gas Temperature, t_{fg} (^{o} C)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)			t_{wi} (^{o} C)	t_{wo} (^{o} C)		
1.	1500								
2.	1500								
3.	1500								
4.	1500								

CALCULATIONS:-

RESULT TABLE :-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/hr)	Air Flow Rate, m_{air} (Kg/hr)	Exhaust Gas Flow Rate, m_{fg} (Kg/hr)
1.	1500				
2.	1500				
3.	1500				
4.	1500				

HEAT BALANCE SHEET :-

Heat Energy Supplied	KJ/hr	% age	Heat Energy Consumed (Distribution)	KJ/hr	% age
Heat energy available from the fuel brunt			(a) Heat energy equivalent to output brake power.		
			(b) Heat energy lost to engine cooling water.		
			(c) Heat energy carried away by the exhaust gases.		
			(d) Unaccounted heat Energy Loss.		
Total	____	100 %	Total	__________	100 %

RESULT:-

Viva Questions

1. Explain the air-fuel ratio?
2. What is Injection Timing?
3. What are the methods of available for improving the performance of an engine?
4. Distinguish between power and specific output?
5. What is the importance of specific fuel consumption?
6. What is the torque of an engine?

EXPERIMENT No. 5

AIM:-To find the indicated power (IP) on Multi-Cylinder Petrol Engine by Morse test.

APPARATUS USED: - Multi- Cylinder Petrol Engine Test Rig, Stop Watch, Hand Gloves, and Digital Tachometer.

THEORY :-

The purpose of Morse Test is to obtain the approximate Indicated Power of a Multi-cylinder Engine.It consists of running the engine against a dynamometer at a particular speed, cutting out the firing of each cylinder in turn and noting the fall in BP each time while **maintaining the speed constant**. When one cylinder is cut off, power developed is reduced and speed of engine falls.

Accordingly the load on the dynamometer is adjusted so as to restore the engine speed. This is done to maintain FP constant, which is considered to be independent of the load and proportional to the engine speed. The observed difference in BP between all cylinders firing and with one cylinder cut off is the IP of the cut off cylinder. Summation of IP of all the cylinders would then give the total IP of the engine under test.

FORMULE USED :-

(i) Brake Power**, BP = WN/ C** KW

; Where W = Load on the Dynamometer Kg, N = rpm of the Engine,

and C = Dynamometer Constant.

(ii) Indicated Power **(IP)** of each Cylinders:

$$IP_1 = (BP_T - BP_{2,3,4}) \quad KW$$

$$IP_2 = (BP_T - BP_{1,3,4}) \quad KW$$

$$IP_3 = (BP_T - BP_{1,2,4}) \quad KW$$

$$IP_4 = (BP_T - BP_{1,2,3}) \quad KW$$

(iii) Total IP of the Engine, $IP_T = (IP_1 + IP_2 + IP_3 + IP_4)$ KW

(iv) Mechanical Efficiency, $\eta_{mechanical} = BP_T / IP_T$

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition. Adjust the dynamometer load to obtain the desired engine speed. Record this engine speed and dynamometer reading for the BP calculation.
4. Now cut off one cylinder. Short-circuiting its spark plug can do this.
5. Reduce the dynamometer load so as to restore the engine speed as at step 3 . Record the dynamometer reading for BP calculation.
6. Connect the cut off cylinder and run the engine on all cylinders for a short time. This is necessary for the steady state conditions.
7. Repeat steps 4, 5, and 6 for other remaining cylinders turn by turn and record the dynamometer readings for each cylinder.
8. Bring the dynamometer load to zero, disengage the dynamometer and stop the engine.
9. Do the necessary calculations.

OBSERVATIONS:-

Engine Speed, N = rpm

No. of Cylinders, n = Four

Calorific Value of Fuel, C.V. = 42,000 KJ/Kg

OBSERVATIONS TABLE :-

Sl. No.	Cylinders Working	Dynamometer Reading, (KW)	Brake Power, BP (KW)	IP of the cut off cylinder, (KW)
1.	1-2-3-4	-------------------	BP_T	
2.	2-3-4		$BP_{2,3,4}$ =	IP_1 =
3.	1-3-4		$BP_{1,3,4}$ =	IP_2 =
4.	1-2-4		$BP_{1,2,4}$ =	IP_3 =
5.	1-2-3		$BP_{1,2,3}$ =	IP_4 =

CALCULATIONS:-

RESULT:- Total IP of the Multi-Cylinder Petrol Engine by Morse Test, IP_T =
KW

Viva Questions

1. Define the morse test?
2. What is transmission dynamometer?
3. What is need of measurement of speed of an I.C. Engine?
4. What is a smoke and classify the measurement of a smoke?
5. What is the break power of I.C. Engines?

EXPERIMENT No. 6

AIM:- To prepare variable speed performances test on a Two -Stroke, Single-Cylinder Petrol Engine and prepare the curves: (i) BP, BSFC, BMEP, Torque Vs Speed and (ii) Volumetric Efficiency & A/F Ratio Vs Speed.

APPARATUS USED :- Two-Stroke, Single-Cylinder Petrol Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY :-

S.I. Engines are often used for automotive purposes. It is important to know the torque, brake mean effective pressure, and specific fuel consumption over the engine working speed range. For this purpose variable speed test at full load and part load is conducted.To test the park ignition engine at full load the throttle valve is kept wide open and the brake load is adjusted to obtain the lowest desired speed. The ignition timing may be set to obtain maximum output at this speed. Rate of fuel consumption, dynamometer load reading and speed are recorded.

FORMULE USED:-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; Where $R_{Effective} = (D + d)/2$ *m, and* $W\ (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; Where $N = rpm$, $T = Torque$ *N-m,*

(iii) Indicated Power, $\mathbf{IP = n\,(P_m \times L_{Stroke} \times A \times N') / 60{,}000}$ KW

; Where $P_m = Mean\ Effective\ Pressure$ N/m^2,

L_{Stroke} = Stroke m, A (Cross Section of the Cylinder) = $(\pi D^2_{Bore})/4$ m^2,

N' (Number of Power Strokes/ min.) = N/ 2 per min. ; For Four-Stroke Engine.

= N per min ; For Two-Stroke Engine.,

N = rpm, and n = Number of Cylinders.

(iv) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So 1 ml = 10^{-6} m^3

(v) Brake Mean Effective Pressure, $\mathbf{BMEP = (BP \times 60,000)/ (L_{Stroke} \times A \times N')}$ N/ m^2

; Where L_{Stroke} = Stroke m, A (Cross Section of the Cylinder) = $(\pi D^2_{Bore})/4$ m^2,

N' (Number of Power Strokes/ min.) = N/ 2 per min.;

For Four-Stroke Engine. = N per min;

For Two-Stroke Engine., and N = rpm.

(vi) Brake Specific Fuel Consumption, $\mathbf{BSFC = (m_f \times 3600) / BP}$ Kg/ KW . hr

(vii) Indicated Specific Fuel Consumption, $\mathbf{ISFC = (m_f \times 3600) / IP}$ Kg/ KW .hr

(viii) Indicated Thermal Efficiency, $\mathbf{\eta_{Indicated\ Thermal} = (IP \times 100) / (m_f \times C.V.)}$%

(ix) Brake Thermal Efficiency, $\mathbf{\eta_{Brake\ Thermal} = (BP \times 100) / (m_f \times C.V.)}$ %

(x) Mass of the Air, $\mathbf{m_{Air} = C_d A_o \sqrt{2 g h} \rho_{Air} \rho_{Water}}$ Kg/ Sec ;

Where C_d (Co-efficient of Discharge) = 0.6, $\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ Kg/ m^3

A_o (Area of Orifice) = $(\pi d_o^2)/4$ m^2, P_a = 1.01325 Bar, R = 0.287 KJ/ Kg . K, $T_a = (t_a + 273)$ K, t_a = Ambient Temperature ^oC

(xi) Air Fuel Ratio, $\mathbf{A/F = (m_{Air} / m_f)}$ Kg/ Kg of Fuel

(xii) Volumetric Efficiency, $\eta_{Volumetric} = (V_{Air} \times 100) / V_s$ %

; Where V_{Air} (Volume of air inhaled/ Sec.) = $(m_{Air} / \rho_{Air})\ m^3/Sec.$

V_s (Swept Volume/ Sec.) = $n \cdot (L_{Stroke} \cdot A.. N')/ 60\ m^3/Sec.$,

*And Volume of fuel is Neglected **(Based on free air conditions)**,*

L_{Stroke} = Stroke m, A (Cross Section of the Cylinder) = $(\pi D^2_{Bore})/ 4\ m^2$,

N' (Number of Power Strokes/ min.) = N/ 2 per min. ;

For Four-Stroke Engine.

= N per min ;

For Two-Stroke Engine.,

N = rpm., and n = Number of Cylinders.

(xiii) Mechanical Efficiency, $\eta_{mechanical} = BP / IP$

<u>PROCEDURE</u>:-

1. Before starting the engine check the fuel supply, lubrication oil.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed. Note down the fuel consumption rate.
5. Adjust the dynamometer to the new value of the desired speed. Note and record the data as in step 4.
6. Repeat the experiment for various speeds upto the rated speed of the engine.
7. Do the necessary calculations.

OBSERVATIONS:-

No. of Cylinders, n	= Single	
Brake Drum Diameter, D	$= 156 \times 10^{-3}$	m
Rope Diameter, d	$= 18 \times 10^{-3}$	m
Bore, D_{Bore}	$= 56.5 \text{ X } 10^{-3}$	m
Stroke, L_{Stroke}	$= 58.04 \times 10^{-3}$	m
Engine Displacement, V_{Swept}	$= 145.45 \times 10^{-6}$	m^3
Engine Horse Power, BHP	= 7.48	BHP at 5500 rpm.
Density of fuel (Petrol), ρ_{Fuel}	= 720 to 790	Kg/m^3
Density of Manometer fluid, ρ_{Water}	= 1,000	Kg/m^3
Calorific value of fuel (Petrol), C.V.	= 42000	KJ/ Kg
Orifice Diameter, d_o	$= 25 \times 10^{-3}$	m
Co-efficient of Discharge, C_d	= 0.6	
Ambient Temperature, t_a	=	K
Atmospheric Pressure, P_a	= 1.01325	Bar

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)		

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Torque (N-m)	Brake Power, BP (KW)	Air Consumption Rate, m_{air} (Kg/hr)	Fuel Consumption Rate, m_f (Kg/hr)	BSFC (Kg/ KW . hr)	BMEP (N/m^2)	A/F Ratio	η_{mech} % age
1.									
2.									
3.									
4.									

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Questions

1. What is volumetric efficiency?
2. What is air fuel ratio in two stroke single cylinder petrol engine?
3. What is air delivery ratio in two stroke single cylinder petrol engine?
4. What is tapping efficiency?
5. Define pressure lose co-efficient?
6. Define excess Air factor?

EXPERIMENT No. 7

AIM:- To determine Frictional Power of Four-Stroke , Single Cylinder Diesel (Constant Speed) Engine by Willian's Line Method.

APPARATUS USED :- Four-Stroke , Single Cylinder Diesel (Constant Speed) Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY:-

A curve between the fuel consumption rate and the Brake Power is called the Willain's Line. This method is used for determining the FP of the Diesel Engine, which is assumed to be independent of the load at constant speed. In this method, fuel consumption rate is measured for various loads at constant speed. The load on the engine is varies with the help of dynamometer and corresponding to each setting BP is calculated. Then a graph is drawn of fuel consumption rate against the BP, and is extended back to cut the BP axis. The negative BP then corresponds to the FP at a particular speed. This method is also enables to determine IP without the use of an indicator.

FORMULE USED :-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and* $W\,(Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; Where $N = rpm$, $T = Torque$ *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So, 1 ml = 10^{-6} m^3

(iv) Brake Specific Fuel Consumption, **BSFC = (m_f x 3600) / B P** Kg/ KW . hr

(v) Friction Power, **F P = From BSFC vs BP Curve.** KW

(vi) Indicated Power, **IP = BP + FP** KW

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed. Note down the fuel consumption rate.
5. Change the dynamometer load so that the engine speed Change, to maintain the engine speed constant fuel consumption increases.
6. Note down the fuel consumption rate at this load setting.
7. Repeat steps 5 and 6 for various loads.
8. Disengage the dynamometer and stop the engine.
9. Do the necessary calculation.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg
Density of fuel (Diesel), ρ_{fuel}	= 810 to 910	Kg/m^3
Brake Drum Diameter, D	= 181.5×10^{-3}	m
Rope Diameter, d	=	m
or		
Belt thickness, t_{Belt}	= 5.5×10^{-3}	m

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)
		S_1 (Kg)	S_2 (Kg)	
1.	1500			
2.	1500			
3.	1500			
4.	1500			

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/Sec)	Brake Specific Fuel Consumption, BSFC (Kg/ KW . hr)
1.	1500			
2.	1500			
3.	1500			
4.	1500			

RESULT:- Performance curves are plotted and they are similar to the standard performance Curves and FP is calculated By **Willian's line Method**.

Viva Questions

1. What is fan dynamometer?
2. Explain an automatic fuel flow meter?
3. Explain the method of measurement of smoke by comparison method?
4. Define the friction power?
5. Define Willian's lines methods?

EXPERIMENT No. 8

AIM:- To perform constant speed performance test on a Four-Stroke Single-Cylinder Diesel Engine & Draw curves of (i) BP vs Fuel Rate, Air Rate and A/F ratio and (ii) BP vs BMEP, Mechanical Efficiency & BSFC.

APPARATUS USED: - Four-Stroke , Single-Cylinder (Constant Speed) Diesel Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY:-

Under some circumstances (i.e Electric Generator) C. I. Engines are required to run at constant speed. For this purpose the test is to be performed at constant speed and the load is varied from zero to maximum. When load on the engine increases its speed decreases. Accordingly the fuel supply is adjusted to keep the engine speed constant. Corresponding to each load setting, dynamometer readings and fuel consumption rate are measured. The BP, BSFC, BMEP, A/F, and Mechanical Efficiency are calculated from measured data and plotted against the load.

FORMULE USED:-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

Where $R_{Effective} = (D + d)/2$ *or* $(D + t_{Belt})/2$ *m, and* $W\,(Load) = (S_1 - S_2)\,Kg$,

(ii) Brake Power, $\mathbf{BP = (2\pi N T) / 60,000}$ KW

; Where $N = rpm$, $T = Torque$ *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So, 1 ml = 10^{-6} m^3

(iv) Brake Mean Effective Pressure, **BMEP = (BP x 60,000)/ (L_{Stroke} x A x N') N/ m^2**

; Where L_{Stroke} = Stroke m, A (Cross Section of the Cylinder) = $(\pi D^2_{Bore})/4$ m^2,

N' (Number of Power Strokes/ min.) = N/ 2 per min. ; For Four-Stroke Engine.= N per min; For Two-Stroke Engine., and N = rpm.

(v) Brake Specific Fuel Consumption, **BSFC = (m_f x 3600) / B P** Kg/ KW . hr

(vi) Mass of the Air, **$m_{Air} = C_d A_o \sqrt{2 g h \rho_{Air} \rho_{Water}}$** Kg/ Sec

; Where C_d (Co-efficient of Discharge) = 0.6, $\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ Kg/ m^3 A_o (Area of Orifice) = $(\pi d_o^2)/4$ m^2, P_a = 1.01325 Bar, R = 0.287 KJ/Kg . K, $T_a = (t_a + 273)$ K, t_a = Ambient Temperature ^oC

(vii) Air Fuel Ratio, **A/F = (m_{Air} / m_f)** Kg/ Kg of Fuel

(viii) Mechanical Efficiency, **$\eta_{mechanical}$ = BP / IP**

PROCEDURE:-

1. Before starting the engine check the fuel supply, lubrication oil, and availability of cooling water.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed. Note down the fuel consumption rate.
5. Change the dynamometer load so that the engine speed Change, to maintain the engine speed constant fuel consumption increases.
6. Note down the fuel consumption rate, speed, air inlet temperature, at this load setting.
7. Repeat steps 5 and 6 for various loads.
8. Disengage the dynamometer and stop the engine.
9. Do the necessary calculation.

OBSERVATIONS:-

Engine Speed, N	= 1500	rpm
No. of Cylinders, n	= Single	
Bore Diameter, D_{bore}	=	m
Stroke Length, L_{stroke}	=	m
Calorific Value of Fuel, C.V.	= 38,000	KJ/Kg
Gas Constant, R	= 0.287	KJ/Kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	Bar
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Specific Gravity of fuel, ρ_{fuel}	= 810 to 910	Kg/m^3
Density of Water, ρ_{water}	= 1,000	Kg/m^3
Brake Drum Diameter, D	= 181.5×10^{-3}	m
Rope Diameter, d	=	m
or		
Belt thickness, t_{Belt}	= 5.5×10^{-3}	m

OBSERVATIONS TABLE :-

S. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)		
1.	1500				
2.	1500				
3.	1500				
4.	1500				

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Brake Power, BP (KW)	Fuel Consumption, m_f (Kg/hr)	BSFC (Kg/ KW . hr)	BMEP (N/ m²)	A/F Ratio	Air Consumption Rate (Kg/ hr)	η_{mech} % age
1.	1500							
2.	1500							
3.	1500							
4.	1500							

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Questions

1. What is break power ?
2. Define speed performance test on a four-stroke single – Cylinder diesel engine?
3. What is Air rate and A/F ratio in a four-stroke single – Cylinder diesel engine?
4. What is combustion phenomenon?
5. What is indicated power ?

EXPERIMENT No. 9

AIM:- To Study and Determine the effect of A/F Ratio on the performance of the Two-Stroke, Single-Cylinder Petrol Engine.

APPARATUS USED :- Two-Stroke, Single-Cylinder Petrol Engine Test Rig, Stop Watch, and Digital Tachometer.

THEORY:-

Air fuel ratio has a major effect on the performance of the I. C. Engine. The Air fuel ratio of a S. I. Engine lies in the range of 10: 1, to 22: 1 depends upon the power requirements and the economic running of the engine. Richer mixtures are required for idle and full throttle running of the engine. Whereas for the mid-range , weaker mixtures are required. The mixture corresponding to the minimum fuel consumption is known as the Best Economy Mixture. It is nearly 15:1.Accurate measurement of air flow into the engine is difficult to achieve in practice, due not only to the nature of the air itself, but also the conditions under which the measurement has to be made.The common method of measuring the air flow rate is the tank and orifice method. During suction stroke the pressure inside the tank is less than the atmospheric pressure. The air enters the tank through the orifice plate , and by applying the Bernaulli's equation the air flow rate can be measured. The fuel consumption can be measured by noting down the fuel consumed during specified time. Thus the air fuel ratio can be set to desired value. The accuracy of the air flow measurement depends on the steady state conditions of air flow through the orifice and the damping of the pulsating effect.

FORMULE USED:-

(i) Torque, $\mathbf{T = 9.81 \times W \times R_{Effective}}$ N-m.

; *Where* $R_{Effective} = (D + d)/ 2$ *m, and* $W (Load) = (S_1 - S_2)$ *Kg,*

(ii) Brake Power, $\mathbf{B\,P = (2\pi N\,T) / 60,000}$ KW

; *Where* $N = rpm,$ $T = Torque$ *N-m,*

(iii) Fuel Consumption, $\mathbf{m_f = (50\ ml \times 10^{-6} \times \rho_{Fuel}) / (t)}$ Kg/Sec.

⇨ Here; 1 ml = 10^{-3} liters, and 1000 liters = 1 m^3

⇨ So, 1 ml = 10^{-6} m^3

(iv) Brake Specific Fuel Consumption, $\mathbf{BSFC = (m_f \times 3600) / B\,P}$ Kg/ KW . hr

(v) Mass of the Air, $\mathbf{m_{Air} = C_d A_o \sqrt{2 g\ h \rho_{Air} \rho_{Water}}}$ Kg/ Sec

; *Where* C_d *(Co-efficient of Discharge) = 0.6,*

$\rho_{Air} = (P_a \times 10^2) / (R \times T_a)$ Kg/ m^3

A_o *(Area of Orifice)* $= (\pi d_o^2)/ 4$ m^2,

$P_a = 1.01325$ *Bar,* $R = 0.287$ *KJ/Kg . K,*

$T_a = (t_a + 273)$ *K,* t_a *= Ambient Temperature* ^oC

(vi) Air Fuel Ratio, $\mathbf{A/F = (m_{Air} / m_f)}$ Kg/ Kg of Fuel

PROCEDURE:-

1. Before starting the engine check the fuel supply, and lubrication oil.
2. Set the dynamometer to zero load.
3. Run the engine till it attains the working temperature and steady state condition.
4. Adjust the dynamometer load to obtain the desired engine speed.
5. Note down the dynamometer load reading and fuel consumption rate.
6. Repeat the experiments for various air fuel ratios and different loads, and same speed.
7. Disengage the dynamometer, and stop the engine.
8. Do the necessary calculation, and plot the graphs.

OBSERVATIONS:-

No. of Cylinders, n	= Single	
Calorific Value of Fuel, C.V.	= 42,000	KJ/Kg
Gas Constant, R	= 0.287	KJ/Kg . K
Ambient Temperature, t_a	=	^oC
Atmospheric Pressure, P_a	= 1.01325	Bar
Orifice Diameter, d_o	= 25×10^{-3}	m
Co-efficient of Discharge, C_d	= 0.6	
Density of fuel (Petrol), ρ_{fuel}	= 720 to 790	Kg/m^3
Density of Water, ρ_{water}	= 1,000	Kg/m^3
Brake Drum Diameter, D	= 156×10^{-3}	m
Rope Diameter, d	= 18×10^{-3}	m
Bore, D_{Bore}	= $56.5 X 10^{-3}$	m
Stroke, L_{Stroke}	= 58.04×10^{-3}	m
Engine Displacement, V_{Swept}	= 145.45×10^{-6}	m^3
Engine Horse Power, BHP	= 7.48	BHP at 5500 rpm.

OBSERVATIONS TABLE :-

Sl. No.	Engine Speed, N (rpm)	Dynamometer Spring Balance Readings, (Kg)		Time taken for 50 ml fuel, t (Sec.)	Manometer Reading, Δh (m)
		S_1 (Kg)	S_2 (Kg)		
1.					
2.					
3.					
4.					

CALCULATIONS:-

RESULT TABLE:-

Sl. No.	Engine Speed, N (rpm)	Torque (N-m)	Brake Power, BP (KW)	Air Consumption Rate m_{air} (Kg/hr)	Fuel Consumption, m_f (Kg/hr)	BSFC (Kg/ KW . hr)	A/F Ratio, (Kg/ Kg of Fuel)
1.							
2.							
3.							
4.							

RESULTS:- Performance curves are plotted and they are similar to the standard performance Curves.

Viva Questions

1. Mention the simplified various assumptions used in fuel Air-cycle Analysis
2. Explain the significance of the fuel-Air cycle ?
3. What is the difference between Air – Standard cycle & Fuel – Air cycle analysis?
4. Define carburetion?
5. What are the different Air – Fuel Mixture on which an Engine can be operated?
6. Explain the rich mixture, Lean Mixture & Stoichionetric Mixture ?

EXPERIMENT No. 10

AIM:- To study and draw the valve timings diagram Four-Stroke, Single-Cylinder Diesel Engine.

APPARATUS USED :- Four-Stroke, Single-Cylinder Diesel Engine Test Rig, Sprit Level,Marking Pencil, and Device for measuring crank angle.

THEORY :-

In four- stroke S. I. Engine the opening and closing of the valves, and the ignition of the air fuel mixture do not take place exactly at the dead centre positions. The valve open slightly earlier and close after their respective dead centre positions. The ignition also occurs prior, to the mixture is fully compressed, and the piston reaches the top dead centre position.Similarly in a C. I. Engine both the valves do not open and close exactly at dead centre positions, rather operate at some degree on either side in terms of the crank angles from the dead centre positions. The injection of the fuel is also timed to occur earlier.

PROCEDURE:-

1) Fix a plate on the body of the Engine touching the flywheel.
2) Mark the positions of the both the dead centers on the flywheel with the reference to the fixed plate. TDC and BDC in case of vertical Engines, IDC and ODC in case of horizontal Engines.
3) Mark on the flywheel when the inlet and exhaust valves open and close as the flywheel is rotated slowly.
4) Measure the valves (Tappet) Clearance.
5) Mark the spark ignition timing in case of petrol Engine and fuel injection timing in case of Diesel Engine.
6) Measure the angles of the various events and plot the valve timing diagram.

<u>OBSERVATIONS TABLE</u> :-

Sl. No.	Engine Types	Tappet Clearance		Valve Timings				
		Inlet Valve (mm)	Exhaust Valve (mm)	Inlet Valve		Exhaust Valve		Injection Timing (^{O})
				Open (^{O})	Close (^{O})	Open (^{O})	Close (^{O})	
1.	Four-Stroke, Single-Cylinder (Vertical) Diesel Engine.							

<u>CALCULATIONS</u>:-

<u>RESULT</u>:-Based on final calculation valve timing diagram is drawn and compare with the standard valve timing diagram.

Viva Questions

1. Define valve timing in four stroke petrol engine?
2. What is overlapping?
3. What is inlet valve?
4. What is exhaust valve?
5. What do you mean by ignition?
6. What are the various types of ignition systems that are commonly used?

UNIVERSITY OF ENGINEERING AND MANAGEMENT, JAIPUR

Machining & Machine Tools Lab Manual

Subject code - ME-692

LIST OF EXPERIMENTS

1. Study of Measurement of cutting forces (Pz and Px or Py) in straight turning at different feeds and velocities with dynamometer.

2. Study of Measurement of average cutting temperature in turning under different speed – feed combinations

3. Measurement of surface roughness in turning under different conditions

4. Study of chip formation (type, color & thickness) in turning mild steel and evaluation of role of variation of cutting velocity and feed on chip reduction coefficient /cutting ratio and shear angle

5. Measurement of tool – wear and evaluation of tool life in turning mild steel by HSS or carbide tool

6. Geometrical and kinematic test of a centre lathe or a drilling machine

7. Producing a cast iron vee – block by machining

8. Production of a straight toothed spur gear from a cast or forged disc.

9. Study of Single Point and Multi Point Cutting Tool.

10. Study of Capstan & Turret Lathe.

NOTE - At least 6 (six) of the following experiments/ assignments to be conducted.

Exp no- 01.Study of Measurement of cutting forces (Pz and Px or Py) in straight turning at different feeds and velocities with dynamometer.

INTRODUCTION/ THEORY:

NEED/ PURPOSE OF ESTIMATION OF CUTTING FORCES:

- Estimation of cutting power consumption, which also enables
- selection of the power source(s) during design of the machine tools
- Evaluation of role of the various machining parameters on
- cutting
  forces.
- Study of behaviour and machinability characterisation of the
- work
  materials
- Condition monitoring of the cutting tools and machine tools.

CUTTING FORCE MEASUREMENT DYNAMOMETER:-
To estimate power required for machining operations, the force has to be measured by a suitable measuring instruments. Generally, cutting forces in cutting tool are measured in different ways such as: Dynamometer, Ammeter, Wattmeter, Calorimeter, Thermocouple, etc. Among these, dynamometers are generally used for measuring cutting forces. Especially, strain gauge dynamometers are used. In this case, spring deflection is measured which is proportional to the cutting forces.

Design requirements for Tool force Dynamometers:

For consistently accurate and reliable measurement, the following requirements are consideredduring design and construction of any tool force dynamometers:

Sensitivity: The dynamometer should be reasonably sensitive for precision measurement.

Rigidity: The dynamometer need to be quite rigid to withstand the forces without causing much deflection which may affect the machining condition.

Cross Sensitivity: The dynamometer should be free from cross sensitivity such that one force(say P_Z) does not affect measurement of the other forces (say P_X and P_Y).

Stability against humidity and temperature.

Quick time response.

High frequency response such that the readings are not affected by vibration within a reasonably high range of frequency.

Consistency: The dynamometer should work desirably over a long period.

Construction and working principle of turning dynamometers:

The dynamometers being commonly used nowadays for measuring machining forces accurately and precisely (both static and dynamic characteristics) are either strain gauge type or piezoelectric type. Strain gauge type dynamometers are inexpensive but less accurate and consistent, whereas, the piezoelectric type are highly accurate, reliable and consistent but very expensive for high material cost and rigid construction. Turning dynamometers may be strain gauge or piezoelectric type and may be of one, two or three dimensions capable to monitor all of (Pz ,Px and Py). For ease of manufacture and low cost, strain gauge type turning dynamometers are widely used and preferably of 2D for simpler construction, lower cost and ability to provide almost all the desired force values. Design and construction of a strain gauge type 2D turning dynamometer is shown schematically in Fig. 2.59 (a and b) and Fig. 2.59 (c) shows the photographic view. Two full bridges comprising fourlive strain gauges are provided for (Pz and Px or Py). channels which are connected with the strain measuring bridge for detection and measurement of strain in terms of voltage which provides(Pz and Px or Py) the magnitude of the cutting forces through calibration. Fig. 2.59 (d) shows the photographic view of a piezoelectric type 3D turning dynamometer.

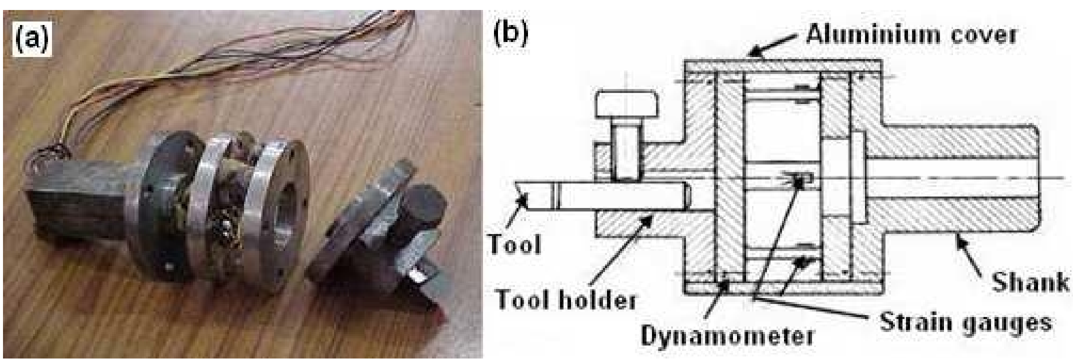


Fig. 2.59 (c) Photographic view of a strain gauge type 2D turning dynamometer
Fig. 2.59 (d) Photographic view of a piezoelectric type 3D turning dynamometer

General methods of measurement of cutting forces :

(a) Indirectly

From Cutting Power Consumption

By Calorimetric Method

By merchant theory

Characteristics

1. Inaccurate
2. Average Only
3. Limited Application Possibility

(B) Directly

Using Tool Force Dynamometer(S)

Characteristics

1. Accurate
2. Precise / Detail
3. Versatile
4. More Reliable

Significance of Pz, Pyand Px

- *Pz: called the main or major component as it is the largest in magnitude. It is also called power component as it being acting along and being multiplied by Vc decides cutting power (Pz.Vc) consumption.*

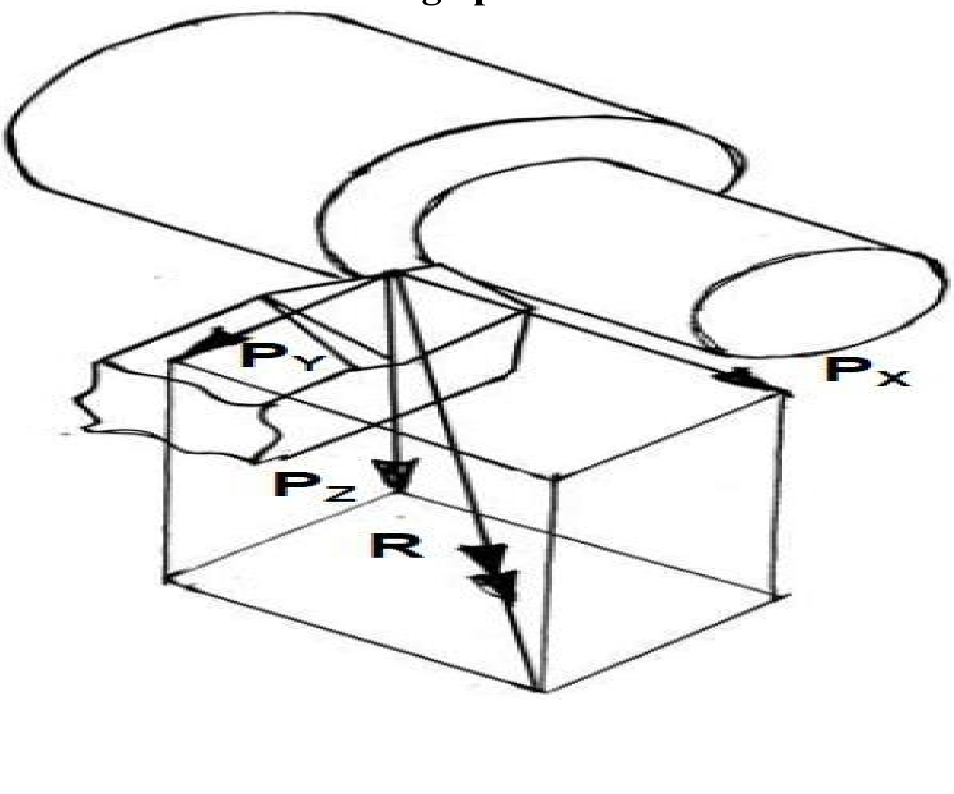
- *Py : may not be that large in magnitude but is responsible for causing dimensional inaccuracy and vibration.*
- *Px: It, even if larger than Py, is least harmful and hence least significant.*

MEASUREMENT OF CUTTING FORCES IN TURNING ON LATHE MACHINE:

Let,

Pz = tangential component taken in the direction of Z axis
Px = axial component taken in the direction of longitudinal feed or X axis
Py = radial or transverse component taken along Y axis as shown in fig

Turning operation on lathe machine



Procedure for finding cutting forces by dynamometer:

Tool dynamometer senses cutting forces in different directions. Generally cutting force sensing devises which can be mounted directly on the particular machines. In lathe tool, dynamometer measure the cutting forces coming on the tool tip on the lathe machine. The sensor is designed in such a way that it can be rigidly mounted on the tool post and the cutting tool can be fixed to the sensor directly. This feature will help to measure the forces accurately without loss of the force.

Conclusion:-

Exp no- 02 Study of Measurement of average cutting temperature in turning under different speed – feed combinations.

INTRODUCTION/ THEORY :

PURPOSE OF ESTIMATION OF CUTTING TEMPERATURE:

Of the total energy consumed in machining, nearly all of it (~98%) is converted into heat. This heat can cause temperatures to be very high at the tool–chip interface—over 600 ºC (1100 ºF) is not unusual. The remaining energy (_2%) is retained as elastic energy in the chip.

Cutting temperatures are important because high temperatures

(1) reduce tool life,

(2) produce hot chips that pose safety hazards to the machine operator, and

(3) can cause inaccuracies in workpart dimensions due to thermal expansion of the work material. In this experiment, you will learn about the methods of calculating and measuring temperatures in machining operations.

There are two methods that are generally used:

ANALYTICAL METHODS TO COMPUTE CUTTING TEMPERATURES:-

There are several analytical methods to calculate estimates of cutting temperature. We describe the method by **Cook** ,which was derived using experimental data for a variety of work materials to establish parameter values for the resulting equation. The equation can be used to predict the increase in temperature at the tool–chip interface during machining is

$$\Delta T = \frac{0.4U}{\rho C}\left(\frac{vt_o}{K}\right)^{0.333}$$

where ΔT = mean temperature rise at the tool–chip interface, C° (F°); U = specific energy in the operation, N-m/mm^3 or J/mm^3 (in-lb/in^3); v = cutting speed, m/s (in/sec); t_o = chip thickness before the cut, m (in); ρC = volumetric specific heat of the work material, J/mm^3-C (in-lb/in^3-F); K = thermal diffusivity of the work material, m^2/s (in^2/sec).

For the specific energy obtained in Example 21.4, calculate the increase in temperature above ambient temperature of 20°C. Use the given data from the previous examples in this chapter: $v = 100$ m/min, $t_o = 0.50$ mm. In addition, the volumetric specific heat for the work material = 3.0 (10^{-3}) J/mm^3-C, and thermal diffusivity = 50 (10^{-6}) m^2/s (or 50 mm^2/s).

Solution: Cutting speed must be converted to mm/s: $v = (100\ \text{m/min})(10^3\ \text{mm/m})/(60\ \text{s/min}) = 1667$ mm/s. Eq. (21.22) can now be used to compute the mean temperature rise:

$$\Delta T = \frac{0.4(1.038)}{3.0(10^3)} \,^\circ\text{C} \left(\frac{1667(0.5)}{50}\right)^{0.333} = (138.4)(2.552) = 353^\circ\text{C}$$

MEASUREMENT OF CUTTING TEMPERATURE BY EXPERIMETAL METHOD:

Experimental methods have been developed to measure temperatures in machining. The most frequently used measuring technique is the tool–chip thermocouple. This thermocouple consists of the tool and the chip as the two dissimilar metals forming thermocouple junction. By properly connecting electrical leads to the tool and workpart (which is connected to the chip), the voltage generated at the tool– chip interface during cutting can be monitored using a recording potentiometer or other appropriate data-collection device. The voltage output of the tool–chip thermocouple (measured in mV) can be converted into the corresponding temperature value by means of calibration equations for the particular tool–work combination.

The tool–chip thermocouple has been utilized by researchers to investigate the relationship between temperature and cutting conditions such as speed and feed.

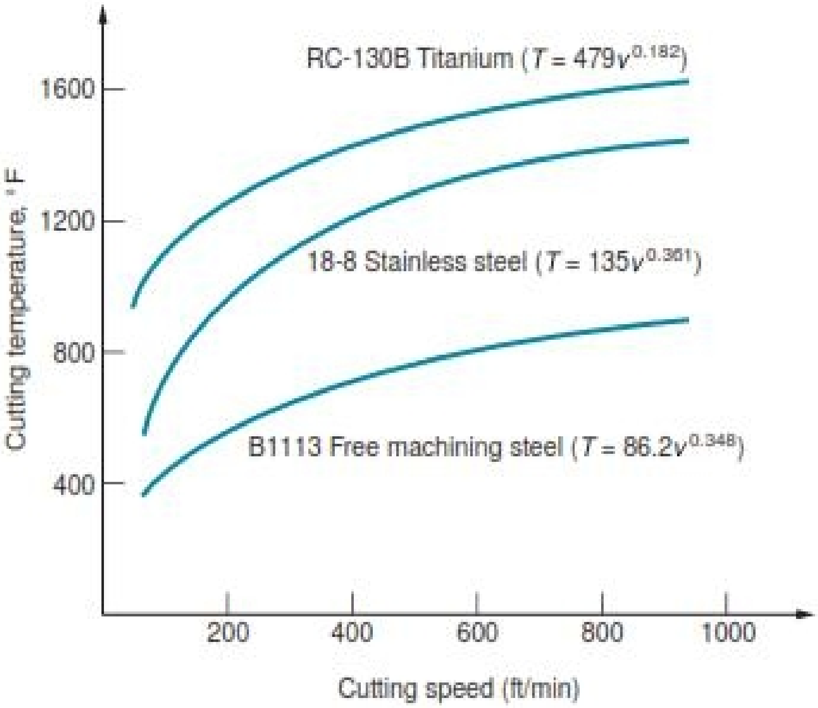


FIGURE 21.15
Experimentally measured cutting temperatures plotted against speed for three work materials, indicating general agreement with Eq. (21.23). (Based on data in [9].)[3]

Conclusion:-

Exp no- 03 Measurement of tool – wear and evaluation of tool life in turning mild steel by HSS or carbide tool

INTRODUCTION/ THEORY :

Purpose measurement of tool – wear and evaluation of tool life:

23.1.2 TOOL LIFE AND THE TAYLOR TOOL LIFE EQUATION

As cutting proceeds, the various wear mechanisms result in increasing levels of wear on the cutting tool. The general relationship of tool wear versus cutting time is shown in Figure 23.3. Although the relationship shown is for flank wear, a similar relationship occurs for crater wear. Three regions can usually be identified in the typical wear growth curve. The first is the ***break-in period,*** in which the sharp cutting edge wears rapidly at the beginning of its use. This first region occurs within the first few minutes of cutting. The break-in period is followed by wear that occurs at a fairly uniform rate. This is called the ***steady-state wear*** region. In our figure, this region is pictured as a linear function of time, although there are deviations from the straight line in actual machining. Finally, wear reaches a level at which the wear rate begins to accelerate. This marks the beginning of the ***failure region,*** in which cutting temperatures are higher, and the general efficiency of the machining process is reduced. If allowed to continue, the tool finally fails by temperature failure.

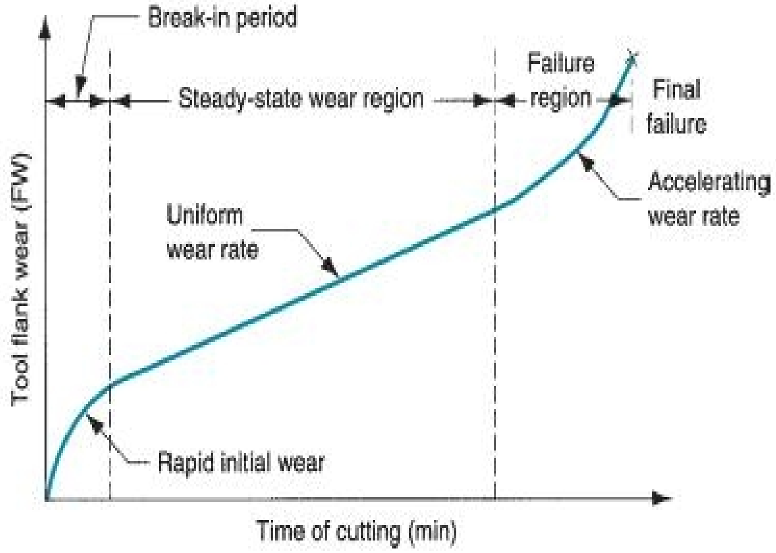


FIGURE 23.3 Tool wear as a function of cutting time. Flank wear (FW) is used here as the measure of tool wear. Crater wear follows a similar growth curve.

Tool Life Criteria in Production Although flank wear is the tool life criterion in our previous discussion of the Taylor equation, this criterion is not very practical in a factory environment because of the difficulties and time required to measure flank wear. Following are nine alternative tool life criteria that are more convenient to use in a production machining operation, some of which are admittedly subjective:

1. Complete failure of the cutting edge (fracture failure, temperature failure, or wearing until complete breakdown of the tool has occurred). This criterion has disadvantages, as discussed earlier.
2. Visual inspection of flank wear (or crater wear) by the machine operator (without a toolmaker's microscope). This criterion is limited by the operator's judgment and ability to observe tool wear with the naked eye.
3. Fingernail test across the cutting edge by the operator to test for irregularities.
4. Changes in the sound emitting from the operation, as judged by the operator.
5. Chips become ribbony, stringy, and difficult to dispose of.
6. Degradation of the surface finish on the work.
7. Increased power consumption in the operation, as measured by a wattmeter connected to the machine tool.
8. Workpiece count. The operator is instructed to change the tool after a certain specified number of parts have been machined.
9. Cumulative cutting time. This is similar to the previous workpiece count, except that the length of time the tool has been cutting is monitored. This is possible on machine tools controlled by computer; the computer is programmed to keep data on the total cutting time for each tool.

Conclusion:-

Exp no-04 Study of chip formation (type, color & thickness) in turning mild steel and evaluation of role of variation of cutting velocity and feed on chip reduction coefficient /cutting ratio and shear angle

INTRODUCTION/ THEORY :

In Fig.4.1 the tool is considered stationary, and the work piece moves to the right. The metal is severely compressed in the area in front of the cutting tool. This causes high temperature shear and plastic flow if the metal is ductile.

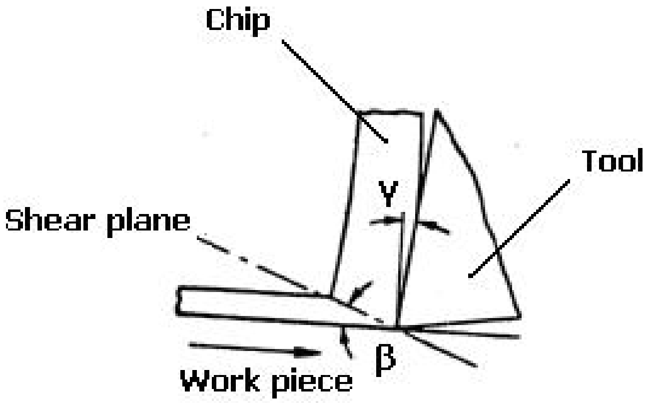


Fig 4.1 Shear plane in metal cutting

When the stress in the work piece just ahead of the cutting tool reaches a value exceeding the ultimate strength of the metal, particles will shear to form a chip element which moves up along the face of the work. The outward or shearing movement of each successive element is arrested by work hardening and the movement transferred to the next element. The process is repetitive and a metal cutting continuous chip is formed having a highly compressed and burnished underside, and a minutely serrated top side caused by the shearing action. The place along which the element shears is called the shear plane.

Actually, the deformation does not occur sharply across the shear plane, but rather it occurs along a narrow band. The structure begins elongating along the line AB below the shear plane and continues to do so until it is completely deformed along the line CD above the shear plane in Fig.4.2. The region between the lower surface AB, where elongation of the grain structure begins, and the upper surface CD, where it is completed and the chip is born, is called the shear zone or primary deformation zone. In Fig.4.2 the shear zone is included between two parallel lines AB and CD. Actually, however, these two lines may not be parallel but may produce a wedge-shaped zone which is thicker near the tool face at the right than at the left. This is one of the causes of curling of chips in metal cutting.

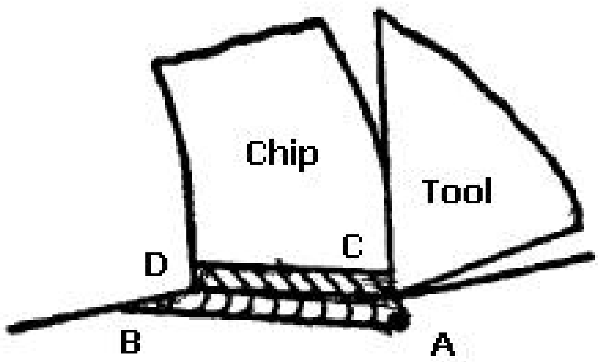


Fig 4.2 Shear zone during metal cutting

In addition, owing to the non-uniform distribution of forces at the chip-tool interface and on the shear plane the shear plane must be slightly curved concave downward. This also causes the chip to curl away from the cutting face of the tool.

Q. List the types of chips. Explain any one of them.

1. The discontinuous or segmental form.
2. The continuous or ribbon type.
3. The continuous with built-up edge.

Discontinuous or segmental chips

- Machining of brittle materials produce these types of chips.
- Small fragments are produced because of lack in ductility of material.
- Friction between tool and chip reduces, resulting in better surface finish.

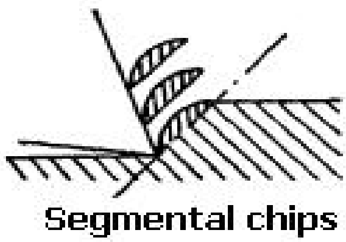


Fig 4.3 Segmental chips

Continuous chips

- Machining of ductile materials produce these types of chips.
- Continuous fragments are produced because of high ductility of material.
- Chips are difficult to handle.

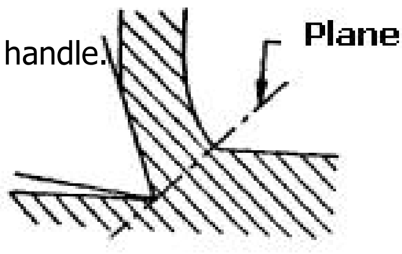


Fig 4.4 Continuous chips

Continuous chips with built-up edge (BUE)

- When machining ductile material, conditions of high local temperature and extreme pressure in the cutting zone and also high friction in the tool-chip interface, may cause the work material to adhere or weld to the cutting edge of the tool forming BUE
- BUE changes its size during cutting operation.
- It protects the cutting edge but it changes the geometry of the tool.

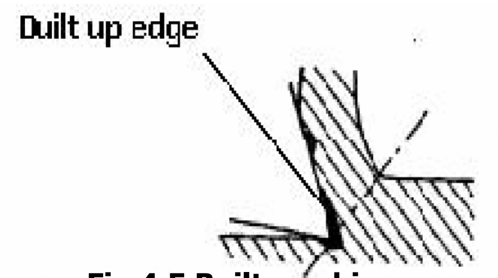


Fig 4.5 Built up chips

Conditions tending to promote the formation of built-up edges include: low cutting speed, low rake angle, high feed, and lack of cutting fluid and large depth of cut.

Conclusion:-

Exp no- 05 Study of Single Point and Multi Point Cutting Tool.

OBJECTIVES:

After the completion of this experiment you will be able to

know: Desirable Properties of good cutting tools

Types of cutting tools

Basic geometry of single point cutting tool

Different angles associated with single point cutting tool

Importance of different angles of single point cutting tool in cutting process

INTRODUCTION/ THEORY:

PROPERTIES OF GOOD CUTTING TOOL MATERIAL:

Ideally, the cutting tool material should have the following properties:

1. High Hardness at elevated temperature to resist the abrasive wear
2. High deformation resistance to prevent the edge from deforming or collapsing under the stresses produced by chip formation.
3. High thermal conductivity to reduce cutting temperatures near the tool edge.
4. High fracture toughness to resist edge chipping and breakage, especially in interrupted cutting.
5. Chemical inertness with respect to the work material to resist diffusion, chemical and oxidation wear.
6. High fatigue resistance, especially for tools used in interrupted cutting.
7. High thermal shock resistance to prevent tool breakage in interrupted cutting
8. High stiffness to maintain accuracy, and
9. Adequate lubricity with respect to the work material to prevent built-up edge, especially for cutting soft, ductile materials.

Types of cutting tools:

🗁✍ **Single Point Cutting Tool:**

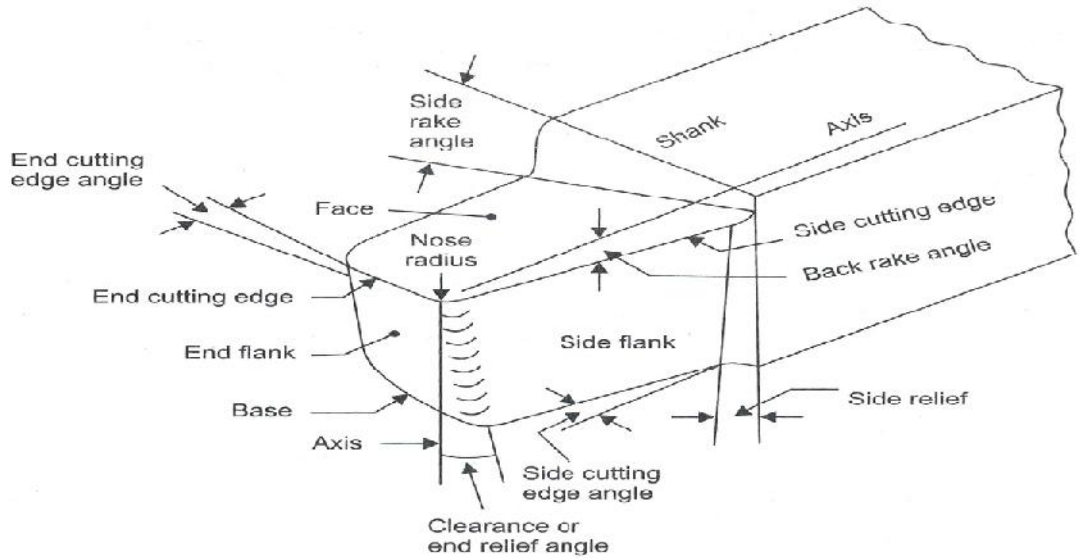
They are having wedge-like action. They find wide applications on lathes and slotting machines.

🗎✍ **Multi Point Cutting Tool:**

They are made by arranging two or more single point cutting tools together as a unit. The milling cutter and broaching tool are good examples of this type.

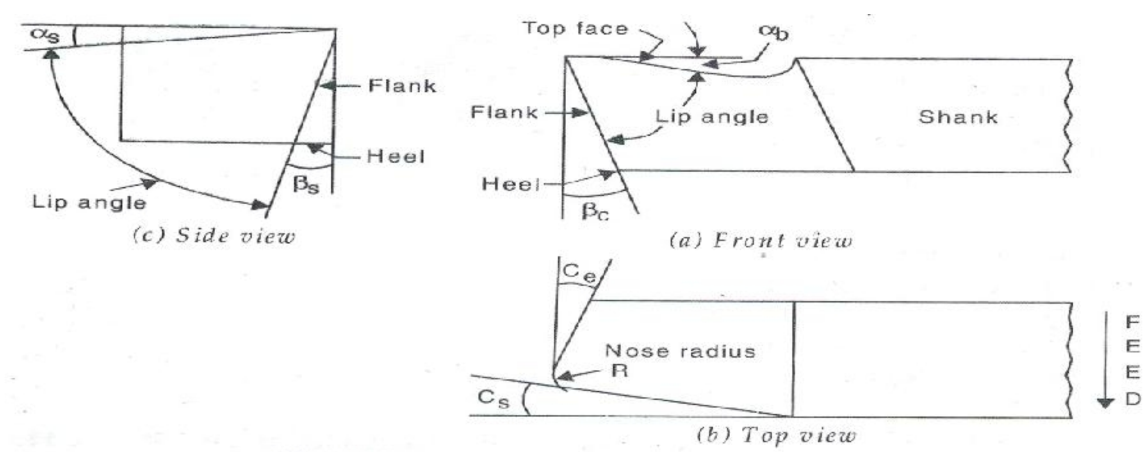
Nomenclature of the single point cutting tool

1. **Shank:** It is the main body of the tool.
2. **Face:** The surface along which the chip moves is called the face of tool.
3. **Cutting Edge:** The edge on the face of the tool which removes the material from the work-piece.
4. **Flank:** The surface below or adjacent to cutting edge is known as flank.
5. The **heel** of a single point tool is the lowest portion of the side-cutting edges.

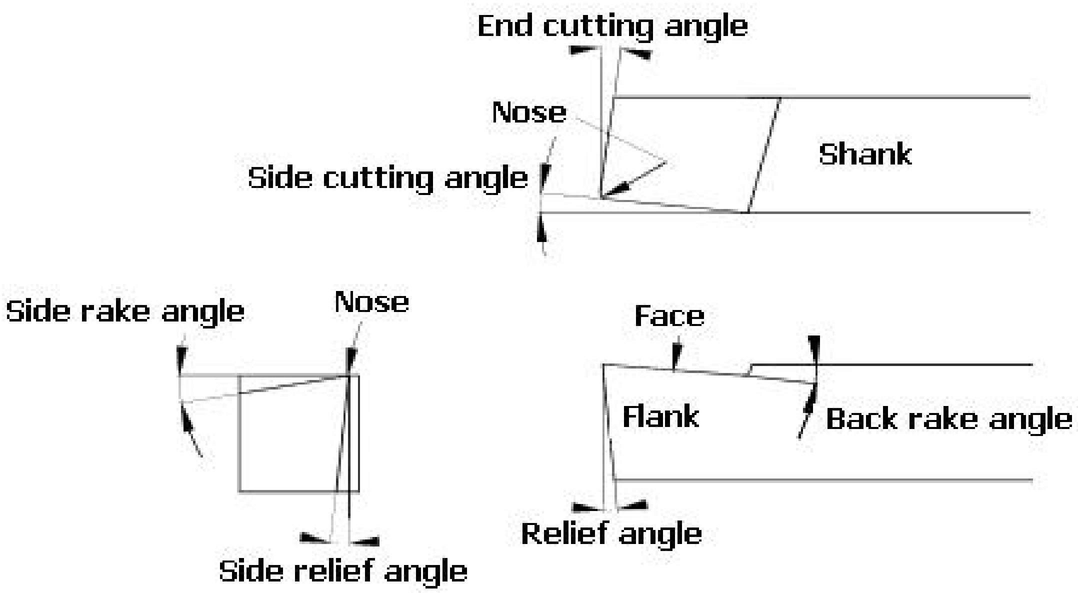


Single point cutting tool geometry

VARIOUS TOOL ANGLES:



Single point cutting tool geometry (various tool angle)



Single point cutting tool geometry (various tool angle in ASA System)

Significance / importance of various tool geometry:

The **nose** of a tool is the conjunction of the side- and end-cutting edges. A nose radius increases the tool life and improves surface finish.

The **base** of a tool is the under-side of the shank.

The **rake** is the slope of the top away from the cutting edge. The larger the rake angle, the larger the shear angle and subsequently the cutting force and power reduce. A large rake angle is conducive to good surface finish. Each tool has a side and back rake. Back rake indicates that the plane which forms the face or top of a tool has been ground back at an angle sloping from the nose. Side rake indicates that the plane that forms the face or top of a tool has been ground back at an angle sloping from the side cutting edge. Side rake is more important than back rake for turning operations.

The **side clearance or side relief** indicates that the plane that forms the flank or side of a tool has been ground back at an angle sloping down form the side cutting edge. Likewise, the end clearance or end relief indicates that the nose or end of a tool has been ground back at an angle sloping down from the end cutting edge.

The **end cutting edge angle** indicates that the plane which forms the end of a tool has been ground back at an angle sloping form the nose to the side of the shank, whereas the side cutting edge angle indicates that the plane which forms the flank or side for a tool has been ground back at an angle to the side of the shank. In the main, chips are removed by this cutting edge. The **lip or cutting angle** is the included angle when the tool has been ground wedged-shaped.

Tool signature / designation in ASA System:

Tool signature (designation) under ASA (American Standards Association) System is given in the order

$$\alpha_b\text{-}\alpha_s\text{-}\gamma_e\text{-}\gamma_s\text{-}C_e\text{-}C_s\text{-}R(\text{inch})$$

α_b = Back rake angle; α_s = Side rake angle; γ_e = End relief angle;

γ_s **=** Side relief angle; C_e = End cutting edge angle;

C_s **=** Side cutting edge angle;

R = Nose radius in inch

Conclusion:

SPECIAL PURPOSE LATHES

The centre lathe is a general purpose machine tool; it has a number of limitations that preclude it to become a production machine tool.

The main limitations of centre lathes are:
The setting time for the job in terms of holding the job islarge. Only one tool can be used in the normal course. Sometimes the conventional tool post can be replaced by a square tool post with four tools.

The idle times involved in the setting and movement of tools between the cuts is large.

Precise movement of the tools to destined places is difficult to achieve if proper care is not taken by the operator.

All these difficulties mean that the centre lathe cannot be used for production work in view of the low production rate. The centre lathe is thus modified to improve the production rate. The various modified lathes are capstan and turret lathes, semi automatics and automatics. Improvements are achieved basically in the following areas:

(i) Work holding methods (ii) Multiple tool availability. (ii) Automatic

feeding of the tools.

(ii) Automatic stopping of tools at precise locations.

(iv) Automatic control of the proper sequence of operations.

Exp no- 06 Study Of Capstan And Turret Lathes

Capstan and turret lathes are production lathes used to manufacture any number of identical pieces in the minimum time. These lathes are development of centre lathes. The capstan lathe was first developed in the year 1860 by Pratt and Whitney of USA.

In contrast to centre lathes, capstan and turret lathes:

(i) Are relatively costlier.

(ii) Are requires less skilled operator.

(iii) Possess an axially movable indexable turret (mostly hexagonal type) in place of tailstock.

(iv) Holds large number of cutting tools; up to four in indexable tool post on the front slide, one in the rear slide and up to six in the turret (if hexagonal) as indicated in the schematic diagrams.

(v) Are more productive for quick engagement and overlapped functioning of the tools in addition to faster mounting and feeding of the job and rapid speed change.

(vi) Enable repetitive production of same job requiring less involvement, effort and attention of the operator for pre- setting of work-speed and feed rate and length of travel of the cutting tools.

(vii) Are suitable and economically viable for batch production or small lot production.

(viii) Capable of taking multiple cuts and combined cuts at the same time.

Major parts of capstan and turret lathes:

Capstan and turret lathes are very similar in construction, working, application and specification. Fig.1 schematically shows the basic configuration of a capstan lathe and Fig. 2 shows that of a turret lathe. The major parts are:

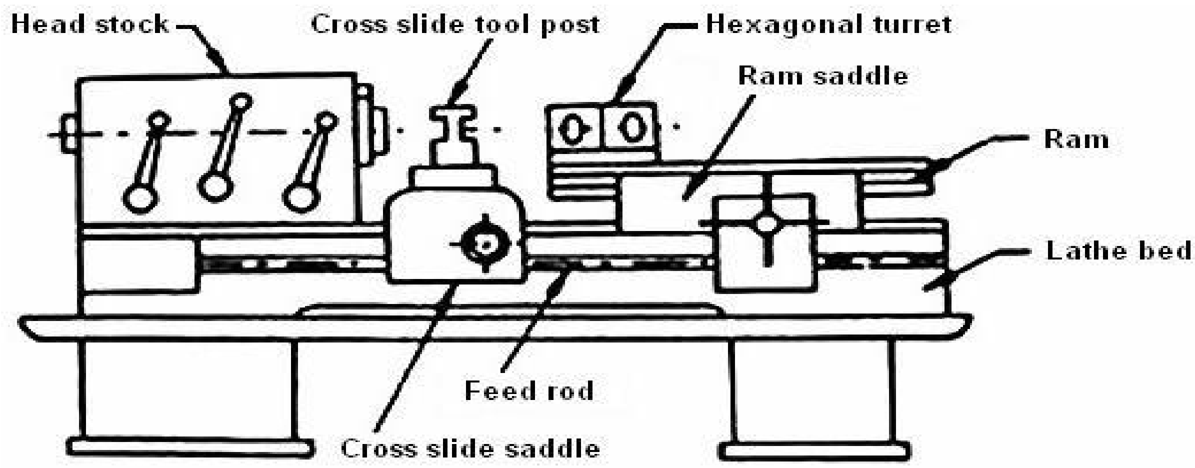


Fig. 1 Basic configuration of a Capstan lathe

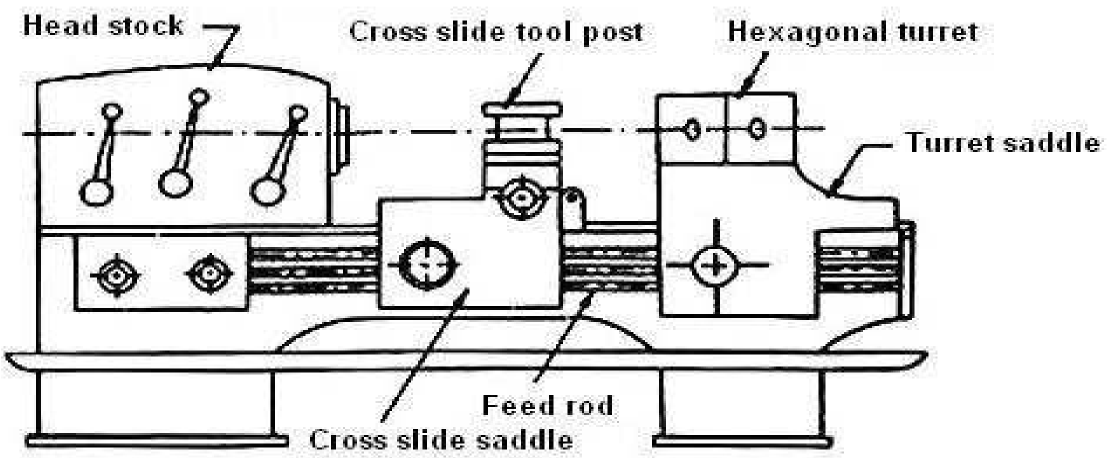
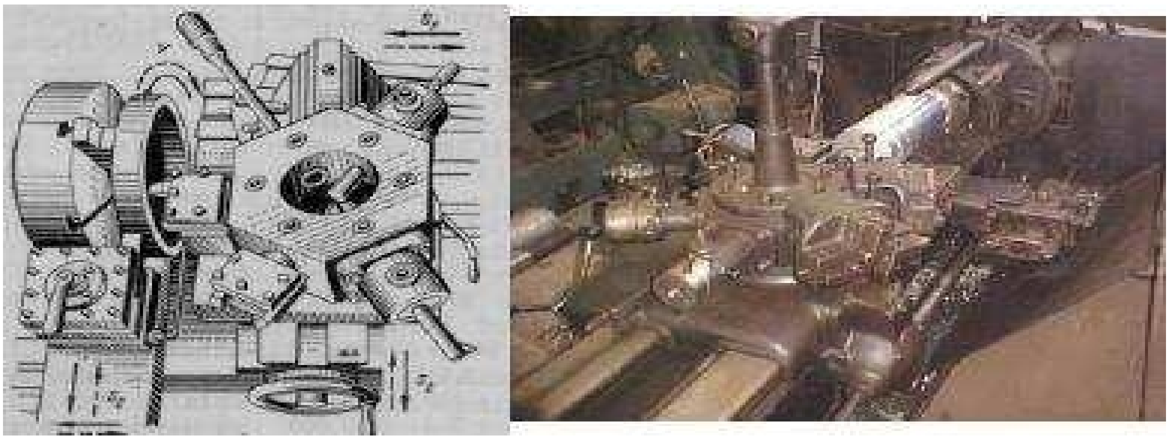


Fig. 2 Basic configuration of a Turret lathe

Turret: *The turret is a hexagonal-shaped tool holder intended for holding six or more tools. Each face of the turret is accurately machined. Through the centre of each face accurately bored holes are provided for accommodating shanks of different tool holders.*

The centre line of each hole coincides with the axis of the lathe when aligned with the headstock spindle. In addition to these holes, there are four tapped holes on each face of the turret for securing different tool holding attachments.



Photographic view of a hexagonal turret

Working principle of capstan and turret lathes:

The work pieces are held in collets or chucks. In turret lathes, large work pieces are held by means of jaw chucks. These chucks may be hydraulically or pneumatically operated. In a capstan lathe,bar stock is held in collet chucks. A bar feeding mechanism is used for automatic feeding of bar stock. At least eleven tools can be set at a time in turret and capstan lathes. Six tools are held on the turret faces, four tools in front square tool post and one parting off tool at the rear tool post. While machining,the turret head moves forward towards the job. After each operation, the turret head goes back. The turret head is indexed automatically and the next tool comes into machining position. The indexing is done by an indexing mechanism.

The longitudinal movement of the turret corresponding to each of the turret position can be controlled independently.

By holding different tools in the turret faces, the operations like drilling, boring, reaming, counter boring, turning and threading can be done on the component. Four tools held on the front tool post are used for different operations like necking, chamfering, form turning and knurling. The parting off tool in the rear tool post is used for cutting off the workpiece. The cross wise movements of the rear and front tool posts are controlled by pre-stops.

Conclusion:

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Subject Name: Design Practice - II Subject Code-ME693

L-T –P Scheme: 3P **Course Credits: 2**

OBJECTIVES:

a) An ability to apply knowledge of mathematics, science, and engineering:

This course builds upon the foundations in mechanics of materials with application to mechanical design activities.

Knowledge in basic engineering science is applied to analysis and design of machine elements.

b) An ability to design and conduct experiments, as well as analyze and interpret data.

c) An ability to design a system, component, or process to meet desired needs:

Design projects and homework sets provide the students with experience in the design of systems and components.

d) An ability to function on multi-disciplinary teams.

e) An ability to identify, formulates, and solve engineering problems:

Through projects and homework, students identify engineering problems and formulate methods for their solution.

f) An understanding of professional and ethical responsibility:

This course includes a review of the canon of ethics for engineers, and a project involving safety and risk analysis.

g) An ability to communicate effectively:

This course requires students to make oral presentations as well as write reports for their projects.The oral and written performance accounts for approximately 10% of their final grade.

h) The broad education necessary to understand the impact of engineering solutions in a global and societal context.

i) A recognition of the need for, and an ability to engage in life-long learning.

j) A knowledge of contemporary issues.

k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice:

Students complete their projects using computational tools, such as spreadsheets and other appropriate software.

LEARING OUTCOMES:

1) Students will be able to identify the elements of the design process.

2) Students will be able to define strict liability, negligence and express and implied warrantee.

3) Students will be able to list the fundamental canons of engineering ethics.

4) Students will be able to identify or define the yield stress and the ultimate stress of a material.

5) Students will be able to calculate the endurance limit of a material with appropriate corrections.

6) Students will be able to identify the stresses acting on a surface and find principal stresses.

7) Students will be able to evaluate loading and stress results using principal shear stress criterion.

8) Students will be able to evaluate loading and stress results using maximum distortion energy criterion.

9) Students will be able to create a Soderberg endurance failure line.

10) Students will be able to calculate stresses and loads involved with fatigue effect.

11) Students will be able to devise a list of concepts for a design application using idea-generation techniques.

12) Students will be able to determine the speeds of gears in spur gear systems including planetary systems.

13) Students will be able to determine stresses in a gear using the Lewis equation or the AGMA equation.

14) Students will be able to calculate the life of ball or roller bearings.

15) Students will be able to determine shaft parameters so that design conditions for performance are met.

16) Students will be able to calculate bounds on parameters in design.

Course Contents:

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

- 2-D and 3-D modeling of mechanical components and systems using software packages like AUTOCAD, CATIA, PRO E or similar software.
- Design analysis of mechanical components using software packages like CATIA, PRO E or similar software.
- Design Practice using codes, e.g., Pressure vessel codes, Gear design codes etc.
- Selection of mechanical components from manufacturers' catalogue, e.g., chain drive, rolling element bearings etc.

Text Book:

1. Shigley and Mischke, Mechanical Engineering Design, TMH.
2. V.B. Bhandari, Machine Design Data Book TMH

Recommended Systems/Software Requirements:

1. Windows XP or Linux Operating System.

2. Auto-CAD, D2S SOLIDWORKS, CATIA, ANSYS, CREO Design Sofwares.

3. Intel based desktop PC or LAPTOP with minimum of 1.4 GHZ or faster processor with at least 2 GB RAM and 40 GB free disk space and AMD READON or NIVIDIA powered at least 1 GB GRAPHICS.

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Design Project 1 - Design of Clutch and Brake Assembly

Project consists of different types of clutch and brake.

Types of clutch:

1. Single plate clutch
2. Multiplate clutch
3. Cone clutch
4. Centrifugal clutch

SCOPE OF THE PROJECT:

The design project consists of one imperial size sheets drawn with 3D/2D CAD software- involving assembly drawing with a part list and overall dimensions and individual components, manufacturing tolerances, surface finish symbols and geometric tolerances should be specified so as to make it working drawing. A design report giving all necessary calculations of the design of components and assembly should be submitted.

Students are required to be submitted a design report giving all necessary calculations of the design of components and assembly.

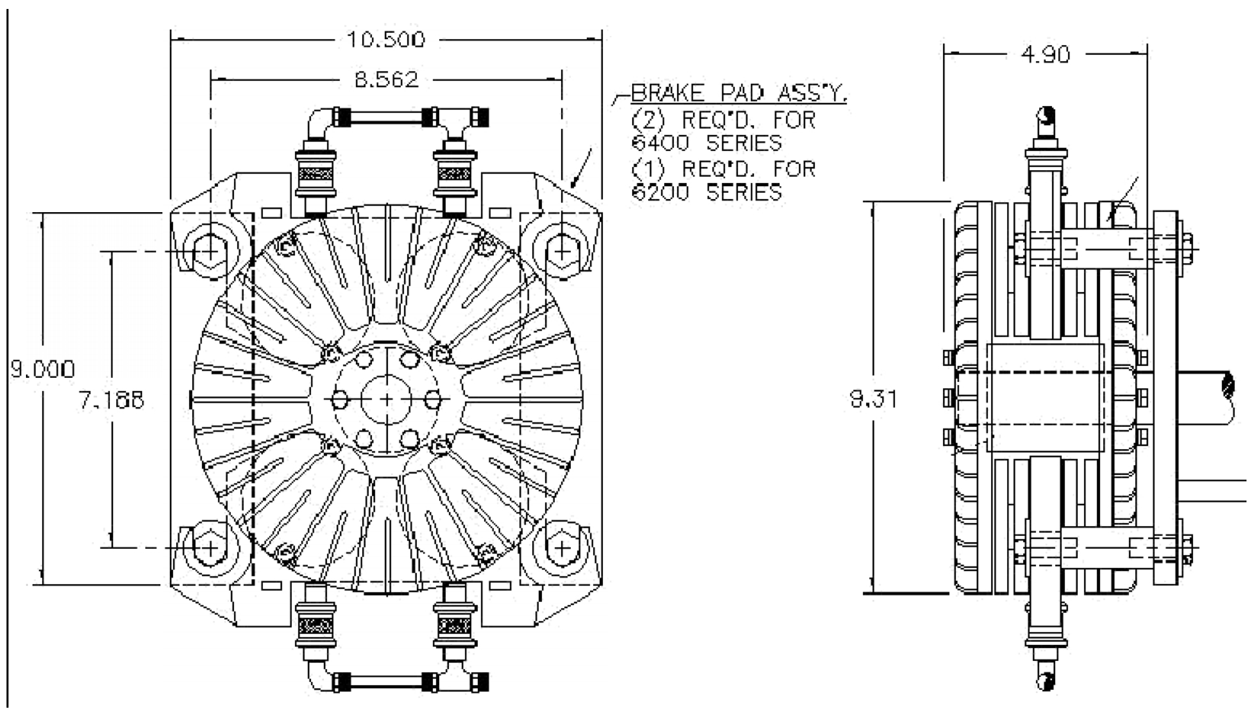
PRE-REQUSITES:

Basics of Strength of Materials, Metallurgy, 2D/3D modelling, etc.

CLUTCH AND BRAKE CALCULATIONS:

Students are supposed to take reference of any standard reference book from the list provided in the Reference Books. ##Each batch having different project.

SAMPLE DRAWINGS:



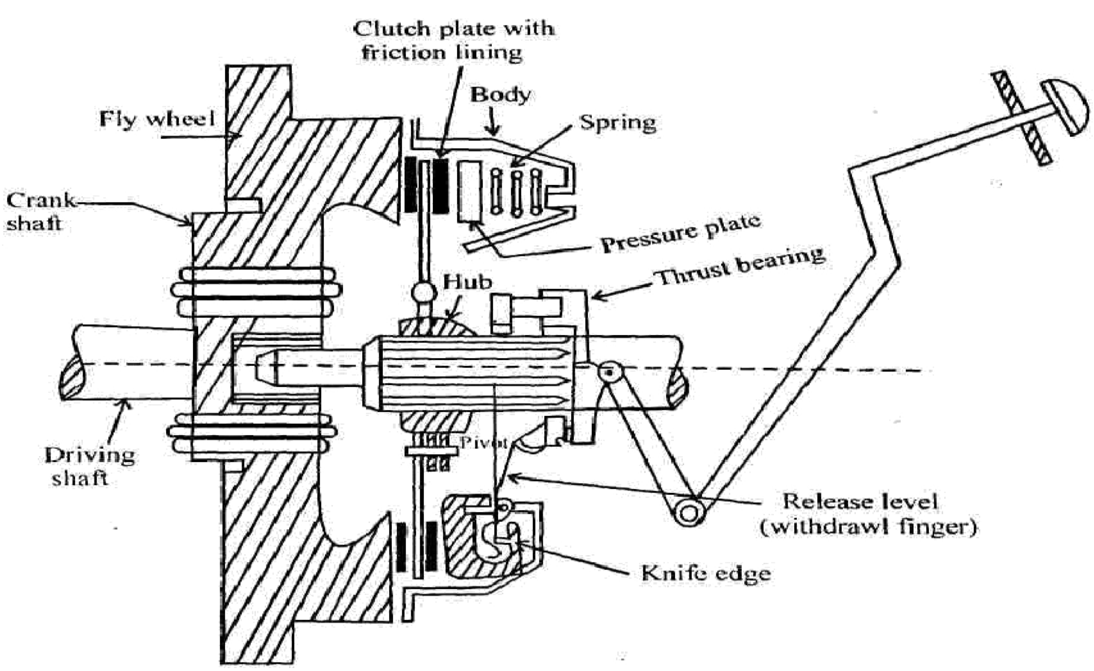
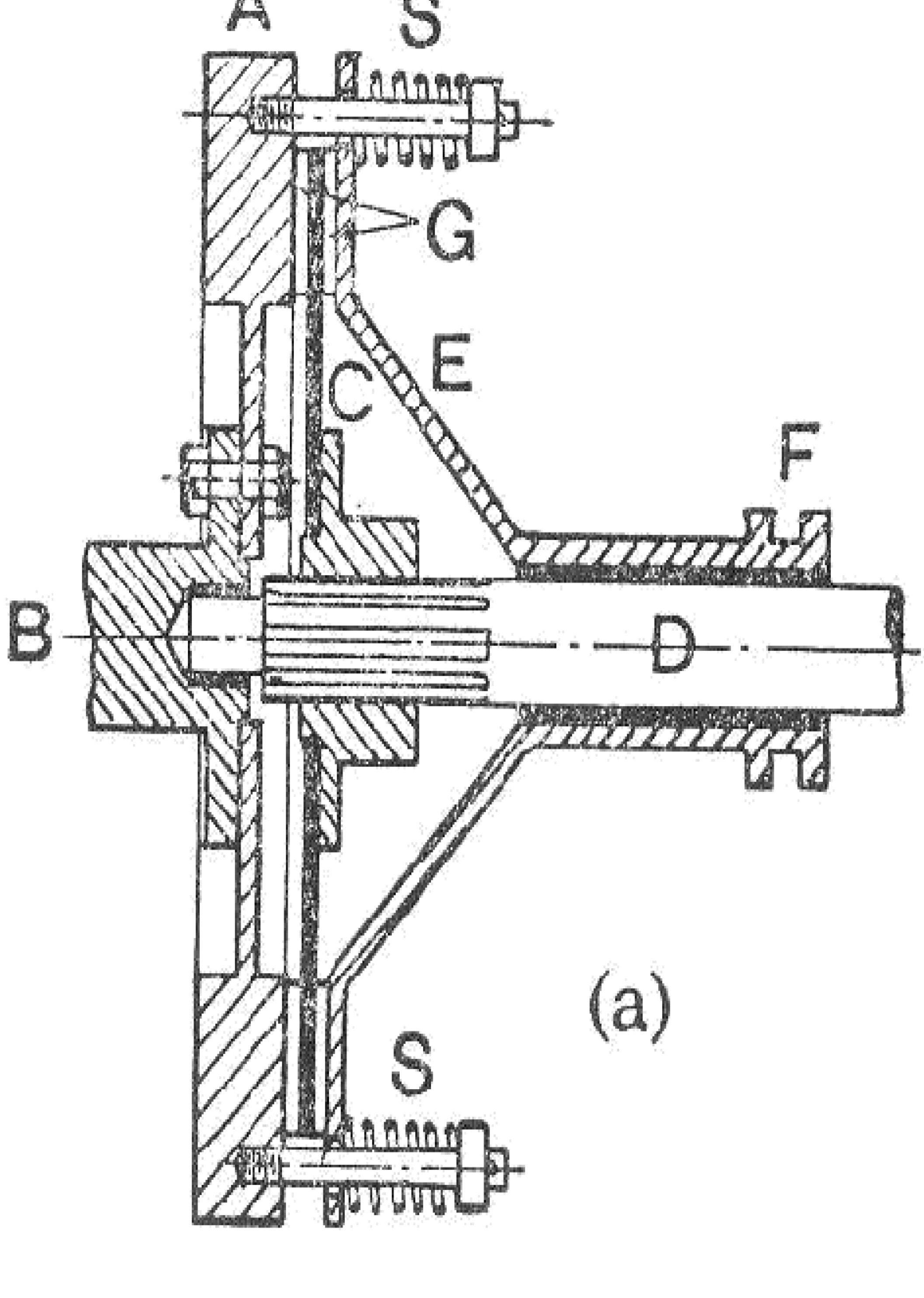


Fig. Single Plate Clutch



(a)

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Design Project 2 - Design of gear assembly

Project report consists of different types of gears:

1. Spur gear
2. Helical gear
3. Bevel gear
4. Worm and worm gear

SCOPE OF THE PROJECT:

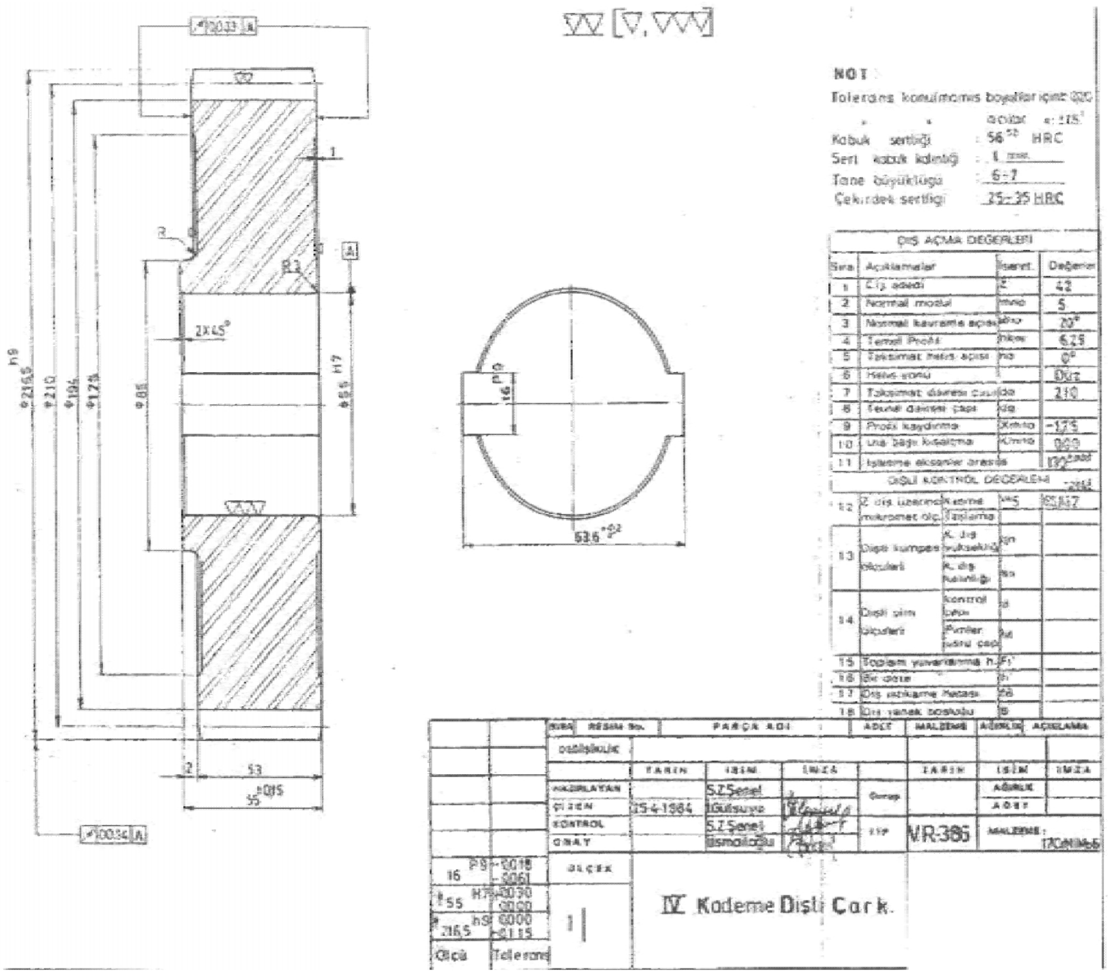
The design project consists of two imperial size sheets drawn with 3D/2D CAD software- one involving assembly drawing with a part list and overall dimensions and the other sheet involving drawings of individual components, manufacturing tolerances, surface finish symbols and geometric tolerances should be specified so as to make it working drawing. A design report giving all necessary calculations of the design of components and assembly should be submitted.

Students are required to be submitted a design report giving all necessary calculations of the design of components and assembly.

PRE-REQUSITES:

Basics of Strength of Materials, Metallurgy, 2D/3D modelling, etc.

SAMPLE DRAWINGS:



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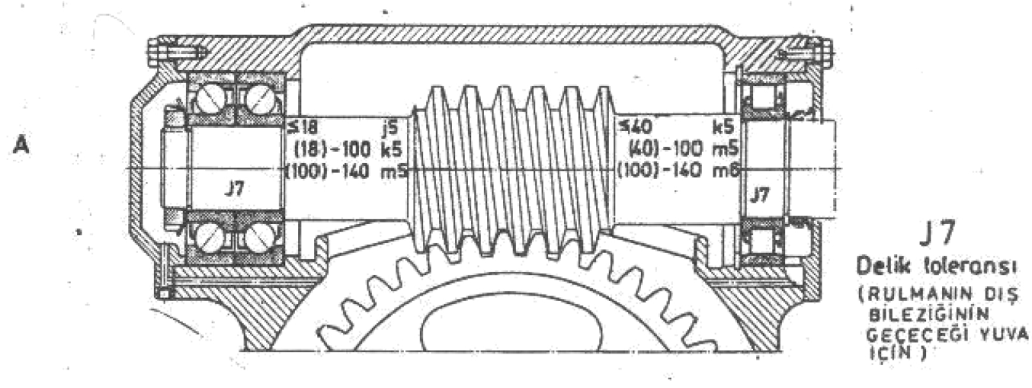
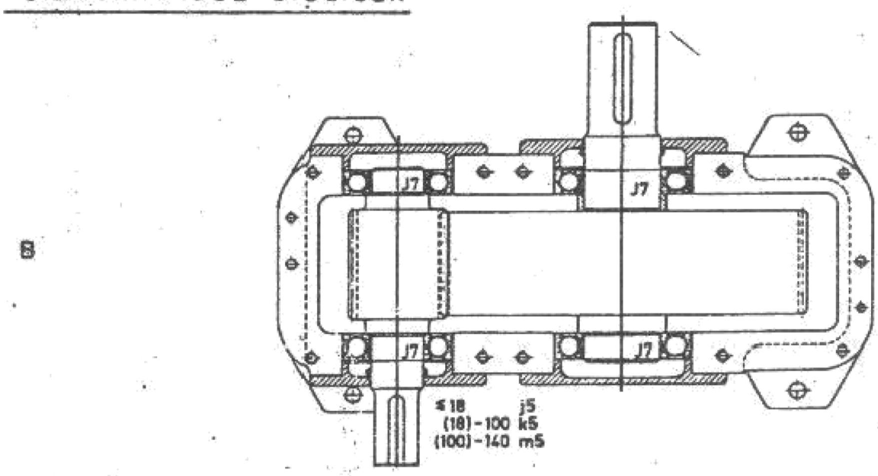
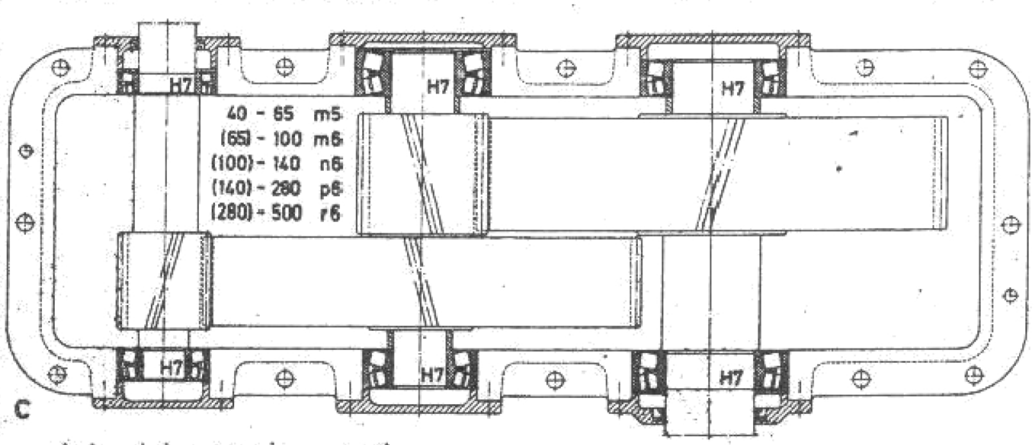


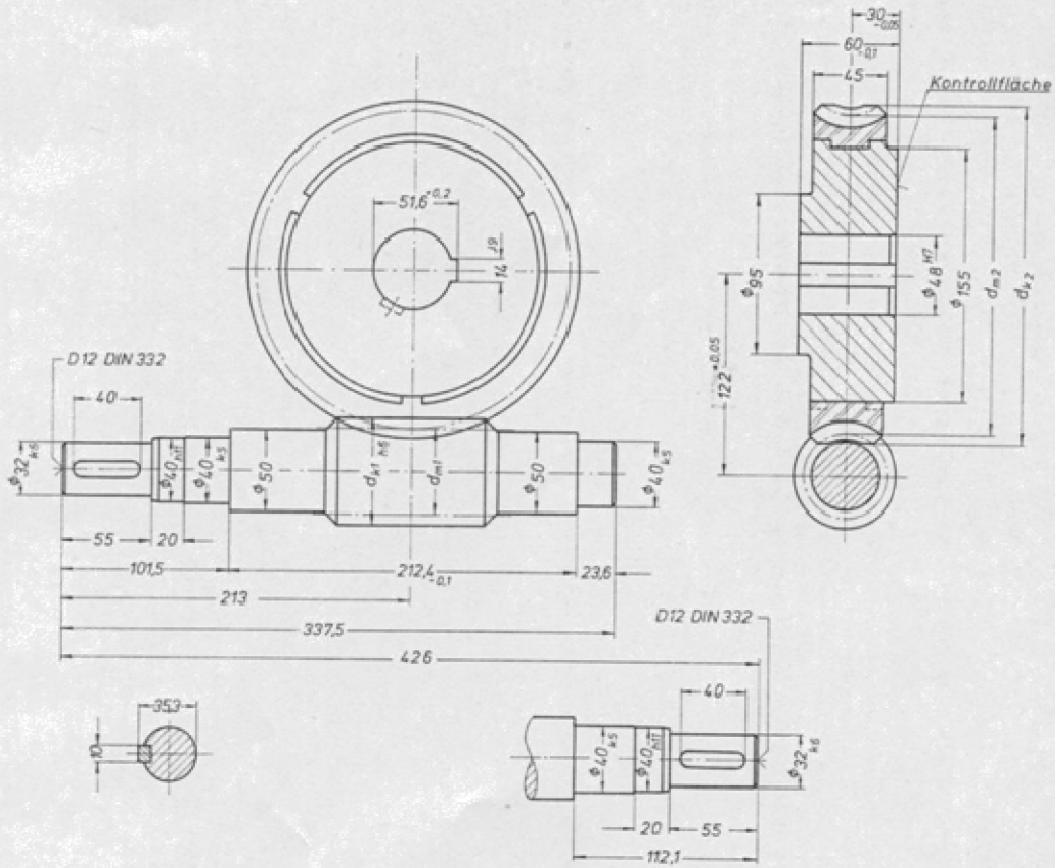
SİLİNDİRİK DÜZ DİŞLİLER





SİLİNDİRİK HELİS DİSLİLER

S4



i_{ist}	dm_1 (mm)	dk_1 (mm)	dm_2 (mm)	dk_2 (mm)	Gewicht Sch. (kg)	Rad (kg)
6,75	54	68	190	210	3,9	10,2
8	52	64	192	210	3,8	10,2
10,66	52	64	192	210	3,8	10,2
12,25	48	56	196	210	3,6	11,0
13,5	54	68	190	210	3,9	10,2
16	52	64	192	210	3,8	10,2
21,5	49	58	195	210	3,6	10,5
24,5	48	56	196	210	3,6	10,8
27	54	68	190	210	3,9	10,2
32	52	64	192	210	3,8	10,2
39	50	60	194	210	3,6	10,8
43	49	58	195	210	3,6	10,5
49 ×	48	56	196	210	3,5	10,8
56 ×	47	54	197	210	3,5	11,0
66 ×	46	52	198	210	3,5	11,2
80 ×	45	50	199	210	3,4	11,2

+ Selbsthemmung aus der Bewegung
× Selbsthemmung aus dem Stillstand

RECOMMENDATIONS FOR REFERENCE BOOK:

1. Bhandari V.B, “ Design Of Machine Element”, Tata Mc-graw Hill Public Co. Ltd

2. Shigley J.E And Mischke C.R “Mechanical Engineering Design”, Tata Mc-grow Hill

3. “Design Data”, P.S.G College Of Technology, Coimbatore.

4. Spott’s M.F, “ Design of Machine Element ” Prentice Hall International.

Title of Course: Dynamics of Machines Lab
Course Code: ME694
L-T-P scheme: 0-0-3 **Course Credit: 2**

Course Objectives

- To impart students with the knowledge about motion, masses and forces in machines.
- To enable students to apply fundamental of mechanics to machines which include engines, linkages etc.,
- To give basic knowledge on kinematic and dynamic design of machinery.
- To facilitate students to understand the function of flywheels, the concept of balancing of rotating and reciprocating masses
- To give awareness to students on the phenomenon of vibration and its effects.
- To Introduce the approaches and mathematical models used in kinematic and dynamic analysis of machinery.

Course Outcomes

- The students will be able to determine velocities & accelerations of various planar mechanisms.
- Students will have an understanding of static force relationships and inertia forces and their effect that exist in machines
- Students will demonstrate the CAM profile and their motion
- Students will be able to perform balancing, vibration and critical speeds with respect to machine dynamics

Course Contents:

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

1. Watt Governor
2. Porter governor
3. Hartnell Governor
4. Cam Analysis – Cam Profile and Jump-speed Characteristics.
5. Whirling of Shaft – Determination of Critical Speed
6. Balancing of Rotating Masses
7. Determination of Gyroscopic Couple

Text Books:

1. S.S. Rattan, Theory of Machines, Tata McGraw Hill.
2. R. S. Kurmi, Theory of Machines, S. Chand Pub.

References:

1. W.T. Thomson, Theory of vibration with Applications, McGraw Hill.

EXPERIMENT NO: 1: Working of Watt Governor

Aim: Study of Watt Governor
(a) Determination of characteristic curve of governor (spindle) speed against sleeve displacement.
(b) Plotting of Governor characteristic curves of radius of rotation of the ball centre against controlling force.

Apparatus required: Displacement measuring system (strain gauge) and Weights

Description:
The apparatus is designed to exhibit the characteristics of the spring-loaded governor and dead weight governor. The apparatus consists of a main spindle driven by a variable speed D.C. Motor with variable speed control unit. The motor is connected through 'V' belt to drive shaft. Motor and main shaft are mounted on a rigid M.S. Base plate in vertical fashion. The spindle is supported in ball bearings. The optional governor mechanism can be mounted on spindle. Speed control unit can control the spindle speed. And counter hole over the spindle shaft allows the use of a hand tachometer to determine the speed. A graduated scale is fixed to the sleeve and guided in vertical direction, which measures the sleeve displacement. The centre sleeve of the porter and proell governors incorporates a weight sleeve to which weights may be added. The Hartnell Governor provides means of varying spring rate, initial compression level and mass of rotating weight. This enables the Hartnell Governor, to be operated as a stable or unstable governor.

EXPERIMENTAL PROCEDURE:
The governor mechanism under test is fitted with the chosen rotating weights and spring, where applicable and inserted into the drive unit. The following simple procedure may then be follows:

• Connect the motor to speed control unit using four ways cable provided.

• The control unit is switched ON and the speed control slowly rotated, increasing the governor speed unit the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale.

• The sleeve position and speed are then recorded. Speed may be determined using a hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve movements, and readings repeated at each stage throughout the range of sleeve movement possible

RESULTS & DISCUSSIONS:
(a) Graph to be plot:
1. Fill up the data sheet.
2. Note down sleeve displacement 'X' at various speeds 'N'.
3. Find the radius of rotation 'r' at any position.
4. The result may be plotted as curves of speed (on y axis) against sleeve displacement (on x axis).
5. Plot the graph of force (on y axis) v/s radius of rotation (on x axis).
6. Further tests are carried out changing the value of variable at a time to draw curves.

(b) Calculations:

For Watt Governor

Radius of rotation 'r' can be calculated as follows:

a) Find height h = (ho – x/2)

b) Find 'α' by using cos α = h/L

c) Then, r = 50 + L Sin α

Force can be calculated as follows:

a) Find the angular velocity 'ω' of the arm and ball about the spindle axis.

$$\omega = \frac{2\pi N}{60} \text{ rad/sec}$$

Where N is the speed of the spindle.

b) Find the centrifugal force acting on the ball

$$\text{Force, } F = \frac{W}{g} \omega^2 r_0 \quad \text{in kg}$$

Where g is the acceleration due to gravity. g = 9.81 m/sec^2

SAMPLE DATA SHEET:

WATT GOVERNOR

Arrangement is shown in Fig.

Length of each link, L, mm =

Initial height of governor, ho, in mm =

Initial radius of rotation, Ro, in mm =

Weight of each ball, W, kg =

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	cos α = h/L	Radius of rotation, r r = 50 + L Sin α cm	Force F(kg)

PERFORMANCE OF WATT GOVERNOR

Following steps are incurred for the performance of Watt governor:

EXPERIMENTAL PROCEDURE:

Step1: Note down the length of each link ‘L’ in mm in data sheet.
Step2: Note down the initial height of governor ‘h_0’ in mm in data sheet.
Step3: Note down the weight of each ball ‘W’ in kg in data sheet.
Step4: The governor mechanism is fitted and inserted into the drive unit. Step5: Connect the motor to speed control unit using four-way cable provided.
Step6: The control unit is switched ON and the speed control is slowly rotated, increasing the governor speed until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale.
Step7: The sleeve position ‘X’ in mm and speed ‘N’ in rpm are then recorded in the data sheet. Speed may be determined using a hand tachometer on the spindle.
Step8: The governor speed is then increased in steps to give suitable sleeve movements. Step7 is repeated for every reading throughout the range of sleeve movement possible.

CALCULATION:

Step9: Find out the actual height ‘h’ in mm of the governor and note down in the data sheet. $h = (h_0 - X/2)$

Step10: Find the angle ‘α’ subtended by the arm with the spindle axis using $\cos\alpha = h/L$ and note down in the data sheet.
Step11: Find the radius of the path of rotation of the ball ‘r’ in mm i.e. horizontal distance from the center of the ball to the spindle axis.
$r = 50 + L \sin\alpha$
Step12: Find the angular velocity ‘ω’ in rad/sec of the arm and ball about the spindle axis and note down in the data sheet.

$$\omega = \frac{2\pi N}{60}$$

Step13: Find the centrifugal force ‘F’ in kg acting on the ball

$$\text{Force, } F = \frac{W}{g}\,\omega^2.r$$

Where, g is the acceleration due to gravity. $g = 9.81\ m/sec^2$

SAMPLE DATA SHEET:

Arrangement is shown in Fig.

a. Length of each link, L, mm = 125
b. Initial height of governor, h_o, mm = 94
c. Weight of each ball, W, kg = 0.6

S. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	α (deg)	Radius of rotation, $r = 50 + L \sin \alpha$ (cm)	Angular speed ω rad/sec	Force F (kg)

GRAPH TO PLOT:
Step14: Plot the graph of speed 'N' (on y axis) against sleeve displacement 'X' (on x axis).
Step15: Plot the graph of force 'F' (on y axis) v/s radius of rotation 'r' (on x axis).
Step16: Further tests are carried out changing the value of variable at a time to draw curves.

SENSITIVENESS:
For maintaining constant sped of rotation, the movement of sleeve should be as large as possible and the corresponding change of equilibrium speed as small as possible. The bigger the displacement of the sleeve for a given fractional change of speed, the more sensitive is the governor. Sensitiveness is more correctly defined as the ratio of the difference between the maximum and minimum equilibrium speeds to the mean equilibrium speed.
If N_{max} = maximum equilibrium speed
N_{min} = minimum equilibrium speed

N_{mean} = mean equilibrium speed

$$= \frac{N_{max} + N_{min}}{2}$$

Then sensitiveness $= \frac{N_{max} - N_{min}}{N_{mean}}$

A too sensitive governor changes the fuel supply by a large amount when a small change in the speed of rotation takes place. This causes wide fluctuations in the engine speed, resulting in hunting of the governor.

STABILITY:

A governor is said to be stable, when for each speed within the working range, there is only one radius of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of the governor balls must also increase.

PRECAUTIONS:

01. Do not keep the mains "ON' when trial is complete.
02. Increase the speed gradually.
03. Take the sleeve displacement reading when the pointer remains steady.
04. See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
05. While closing the test bring the dimmer to zero position and then switch "OFF" the motor.

EXPERIMENT NO: 2 WORKING OF PROELL GOVERNOR

Aim: STUDY of Proell Governor
(a) Determination of characteristic curve of governor (spindle) speed against sleeve displacement.
(b) Plotting of Governor characteristic curves of radius of rotation of the ball centre against controlling force.

Apparatus required: Displacement measuring system (strain gauge) and Weights

Description:

The apparatus is designed to exhibit the characteristics of the spring-loaded governor and dead weight governor. The apparatus consists of a main spindle driven by a variable speed D.C. Motor with variable speed control unit. The motor is connected through 'V' belt to drive shaft. Motor and main shaft are mounted on a rigid M.S. Base plate in vertical fashion. The spindle is supported in ball bearings. The optional governor mechanism can be mounted on spindle. Speed control unit can control the spindle speed. And counter hole over the spindle shaft allows the use of a hand tachometer to determine the speed. A graduated scale is fixed to the sleeve and guided in vertical direction, which measures the sleeve displacement. The centre sleeve of the porter and proell governors incorporates a weight sleeve to which weights may be added. The Hartnell Governor provides means of varying spring rate, initial compression level and mass of rotating weight. This enables the Hartnell Governor, to be operated as a stable or unstable governor.

EXPERIMENTAL PROCEDURE:

The governor mechanism under test is fitted with the chosen rotating weights and spring, where applicable and inserted into the drive unit. The following simple procedure may then be follows:

- Connect the motor to speed control unit using four ways cable provided.
- The control unit is switched ON and the speed control slowly rotated, increasing the governor speed unit the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale.
- The sleeve position and speed are then recorded. Speed may be determined using a hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve movements, and readings repeated at each stage throughout the range of sleeve movement possible

RESULTS & DISCUSSIONS:

(a) Graph to be plot:

1. Fill up the data sheet.

2. Note down sleeve displacement ‘X’ at various speeds ‘N’.

3. Find the radius of rotation ‘r’ at any position.

4. The result may be plotted as curves of speed (on y axis) against sleeve displacement (on x axis).

5. Plot the graph of force (on y axis) v/s radius of rotation (on x axis).

6. Further tests are carried out changing the value of variable at a time to draw curves.

(b) Calculations:

For Proell Governor

Radius of rotation ‘r’ can be calculated as follows:

a) Find height h = (ho – x/2)

b) Find ‘α’ by using cos α = h/L

c) Then, r = 50 + L Sin α

Force can be calculated as follows:

a) Find the angular velocity ‘ω’ of the arm and ball about the spindle axis.

$$\omega = \frac{2\pi N}{60} \text{ rad/sec}$$

Where N is the speed of the spindle.

b) Find the centrifugal force acting on the ball

$$\text{Force, } F = \frac{W}{g} \omega^2 r_0 \quad \text{in kg}$$

Where g is the acceleration due to gravity. $g = 9.81\ m/sec^2$

SAMPLE DATA SHEET:

In the Proell Governor, with the use of flyweight (Forming full ball) the governor becomes highly sensitive. Under this conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

a. Length of each link, L, mm =

b. Initial height of governor, ho, mm =

c. Initial radius of rotation, r_o, mm =

d. Weight of each ball, W, kg =

e. Weight of sleeve, kg =

f. Extension of Length BG, mm =

Sr. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	Radius of rotation, r $r = 50 + L \sin \alpha$ cm	Force F(kg)

PERFORMANCE OF PROELL GOVERNOR

Arrangement is shown in fig.

In the Proell Governor, with the use of flyweight (Forming full ball) the governor becomes highly sensitive. Under this conditions large sleeve displacement is observed for very small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side. In the Proell governor the extension arms are attached to the links and the balls are attached to the extension links. Again a central mass is attached to the sleeve. Working is same as of the Watt governor/Porter governor.

a. Length of each link, L, mm =

b. Initial height of governor, ho, mm =

c. Weight of each ball, W, kg =

d. Weight of sleeve, kg =

e. Weight on sleeve, kg =

f. Extension of length BG, mm =

S. No.	Sleeve displacement, X (mm)	Speed, N (rpm)	Height $h = h_o - X/2$ (mm)	$\cos \alpha = h/L$	α (deg)	Radius of rotation, $r = 50 + L \sin \alpha$ (cm)	Angular speed ω rad/sec	Force F (kg)

PRECAUTIONS:

01. Do not keep the mains "ON' when trial is complete.
02. Increase the speed gradually.
03. Take the sleeve displacement reading when the pointer remains steady.
04. See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
05. While closing the test bring the dimmer to zero position and then switch "OFF" the motor.

EXPERIMENT NO: 3: WORKING OF HARTNELL GOVERNOR

Aim: Study of Hartnell Governor

(a) Determination of characteristic curve of governor (spindle) speed against sleeve displacement.

(b) Plotting of Governor characteristic curves of radius of rotation of the ball centre against controlling force.

Apparatus required: Displacement measuring system (strain gauge) and Weights

Description:

The apparatus is designed to exhibit the characteristics of the spring-loaded governor and dead weight governor. The apparatus consists of a main spindle driven by a variable speed D.C. Motor with variable speed control unit. The motor is connected through 'V' belt to drive shaft. Motor and main shaft are mounted on a rigid M.S. Base plate in vertical fashion. The spindle is supported in ball bearings. The optional governor mechanism can be mounted on spindle. Speed control unit can control the spindle speed. And counter hole over the spindle shaft allows the use of a hand tachometer to determine the speed. A graduated scale is fixed to the sleeve and guided in vertical direction, which measures the sleeve displacement. The centre sleeve of the porter and proell governors incorporates a weight sleeve to which weights may be added. The Hartnell Governor provides means of varying spring rate, initial compression level and mass of rotating weight. This enables the Hartnell Governor, to be operated as a stable or unstable governor.

EXPERIMENTAL PROCEDURE:

The governor mechanism under test is fitted with the chosen rotating weights and spring, where applicable and inserted into the drive unit. The following simple procedure may then be follows:

• Connect the motor to speed control unit using four ways cable provided.

• The control unit is switched ON and the speed control slowly rotated, increasing the governor speed unit the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale.

• The sleeve position and speed are then recorded. Speed may be determined using a hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve movements, and readings repeated at each stage throughout the range of sleeve movement possible

RESULTS & DISCUSSIONS:

(a) Graph to be plot:

1. Fill up the data sheet.
2. Note down sleeve displacement 'X' at various speeds 'N'.
3. Find the radius of rotation 'r' at any position.
4. The result may be plotted as curves of speed (on y axis) against sleeve displacement (on x axis).
5. Plot the graph of force (on y axis) v/s radius of rotation (on x axis).
6. Further tests are carried out changing the value of variable at a time to draw curves.

(b) Calculations:

For Hartnell Governor

Radius of rotation 'r' can be calculated as follows:

$$r = r_o + \frac{X(a)}{(b)}$$

Where a & b are the length and X is the sleeve displacement

SAMPLE DATA SHEET:

HARTNELL GOVERNOR

Arrangement is shown in Fig.

a. Length, a, mm =
b. Length, b, mm =
c. Initial radius of rotation, r_o, mm =
d. Weight of each ball, W, kg =
e. Weight of sleeve, kg =
f. Free height of spring, mm =
g. Spring stiffness (P) = …. kg/cm.
h. Initial compression of the spring. =

Sr. No.	Sleeve displacement X (mm)	Speed, N (rpm)	Radius of rotation, r = r_0 + X a/b (cm)	Force, F (kg)

PERFORMANCE OF HARTNELL GOVERNOR

The Hartnell governor is of the spring-loaded type. It consists of two bell crank levers pivoted at points to the frame. The frame is attached to the governor spindle and rotates with it. Each lever carries a ball at the end of the vertical arm and a roller at the other end of the horizontal arm. A helical compression spring provides equal downward forces on the two rollers through the sleeve. The spring force may be adjusted by the nut.

Following steps are incurred for the performance of Watt governor:

EXPERIMENTAL PROCEDURE:

Step1: Note down the length 'a' and 'b' in mm in data sheet.

Step2: Note down the initial radius of rotation 'r0' in mm in data sheet.

Step3: Note down the weight of each ball 'W' in kg in data sheet.

Step4: Note down the weight of the sleeve.

Step5: Note down the free height of spring in mm in data sheet.

Step6: Note down the spring stiffness of the spring in kg/cm in data sheet.

Step7: The governor mechanism is fitted and inserted into the drive unit.

Step8: Note down the initial compression of the spring in mm in data sheet.

Step9: Connect the motor to speed control unit using four-way cable provided.

Step10: The control unit is switched ON and the speed control is slowly rotated, increasing the governor speed until the centre sleeve rises off the lower stop and aligns with the first division on the graduated scale.

Step11: The sleeve position 'X' in mm and speed 'N' in rpm is then recorded in the data sheet. Speed may be determined using a hand tachometer on the spindle.

Step8: The governor speed is then increased in steps to give suitable sleeve movements.

Step7 is repeated for every reading throughout the range of sleeve movement possible.

CALCULATION:

Step9: Find the radius of the path of rotation of the ball 'r' in mm i.e. horizontal distance from the centre of the ball to the spindle axis.

$$r = r_o + \frac{X(a)}{(b)}$$

Step10: Find the angular velocity 'ω' in rad/sec of the arm and ball about the spindle axis and note down in the data sheet.

$$\omega = \frac{2\pi N}{60}$$

Step11: Find the centrifugal force 'F' in kg acting on the ball

$$\text{Force,} \quad F = \frac{W}{G} \omega^2.r$$

where, g is the acceleration due to gravity. g = 9.81 m/sec^2

SAMPLE DATA SHEET:

a. Length, a, mm =
b. Length, b, mm =
c. Initial radius of rotation, r_o, mm =
d. Weight of each ball, W, kg =
e. Weight of sleeve, kg =
f. Free height of spring, mm =
g. Spring stiffness (P) = kg/cm.
h. Initial compression of the spring. =

Sr. No.	Sleeve displacement X (mm)	Speed, N (rpm)	Radius of rotation, r = r_0 + X a/b (cm)	Angular speed ω rad/sec	Force, F (kg)

GRAPH TO PLOT:

Step12: Plot the graph of speed 'N' (on y axis) against sleeve displacement 'X' (on x axis).
Step13: Plot the graph of force 'F' (on y axis) v/s radius of rotation 'r' (on x axis).
Step14: Further tests are carried out changing the value of variable at a time to draw curves.

PRECAUTIONS:

01. Do not keep the mains "ON' when trial is complete.
02. Increase the speed gradually.
03. Take the sleeve displacement reading when the pointer remains steady.
04. See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
05. While closing the test bring the dimmer to zero position and then switch "OFF" the motor.

EXPERIMENT NO: 4 CAM ANALYSIS

Aim: To study the profile of given cam using cam analysis system and to draw the displacement diagram for the follower and the cam profile. Also to study the jump-speed characteristics of the cam & follower mechanism.

Apparatus required: Cam analysis system and Dial gauge

1) Cams - Eccentric, tangent & circular arc cam one each.
2) Followers -Flat faced Mushroom, and Roller follower's one each.
3) Push rod assembly with spring and dead weights.
4) Variable speed motor to drive the cams.
5) Angular scale and dial gauge - 1 each.

DESCRIPTION:

A cam is a machine element such as a cylinder or any other solid with a surface of contact so designed as to give a predetermined motion to another element called the follower. A cam is a rotating body importing oscillating motor to the follower. All cam mechanisms are composed of at least there links viz: 1.Cam, 2. Follower and 3. Frame which guides follower and cam.

SPECIFICATION:

Diameter of base circle = ……mm
Lift = …….mm
Diameter of cam shaft =…………mm
Diameter of follower shaft =……... mm
Diameter of roller = ………..mm,
Dwell period = ……..
Type of follower motion = SHM (during ascent & descent)

EXPERINMENTAL PROCEDURE : -

1) Fit the required cam over the cam shaft and required follower to the push rod.
2) Set angular scale at required position.
3) Adjust the weight seat and dial gauge.
4) Rotate the cam by hand and note down the dial - gauge reading at every 30^0 intervals.
5) Remove the dial gauge. Switch 'ON' the power supply. Slowly increase the motor speed.

6) At particular speed a peculiar striking sound is heard. This speed is called 'Jump Speed'. At this speed, follower does not follow the exact path guided by cam contour. Note down this speed. Use of this cam-follower system beyond this speed is useless, because desired follower motion is not obtained.

7) Repeat the procedure for different dead weight and spring tension configurations at different cam - follower configurations.

Graph:

Displacement diagram and also the cam profile is drawn using a polar graph chart.
The Force Vs Jump-speed curve is drawn configurations at different cam - follower configurations.

OBSERVATIONS : -

Cam ---------   Follower----------

Sr No.	Cam Angle	Follower displacement mm
1.	0	
2.	30	
3.	60	
4.	90	
⇓	⇓	
⇓	⇓	
12.	360	

Result.
Tabulation:
1. Cam profile

Sl. No.	Angle of rotation (degrees)	Lift in mm	Lift + base circle radius (mm)

2. Jump-speed.

Sl. No.	Load on the Follower, F (N)	Jump-speed N (RPM)

PRECAUTIONS : -

1) Fix the key and bolt, for cam tightening properly.
2) While starting the motor, ensure that the dial gauge has been removed.
3) Tighten the loaded weights by the check nut.

EXPERIMENT NO. 5 WHIRLING OF SHAFTS DEMONSTRATOR

Aim: Demonstration of whirling of shafts

Apparatus required: 1) Shaft - ∅ 3 mm, 5 mm, and 7 mm - 2 No. each

2) Bearing blocks -

i) Driving End - Fixed end shaft support with two SRDG bearings - 1No.

ii) Tail End - a) fixed end shaft support with two SRDG bearings - 1No.

b) Free end shaft support with self aligning ball bearing -1No.

3) Motor - 1/ 2 H.P., 1500 rpm, D.C. Motor

4) Eccentric rotating discs - One for each shaft

DESCRIPTION:

If a body or disc mounted upon shafts rotates about it, then C. G. of disc must be at shaft axis, if perfect running balance is to be obtained. But practically, because of difficulty of perfect machining, disc C. G. does not coincide with shaft axis. Hence, when such shaft rotates, it deflects towards heavier side of disc due to unbalanced centrifugal force. As we go on increasing the speed of shaft, the amplitude of vibrations goes on increasing; this speed is the critical speed. After passing this speed, the shaft again runs inline.

Critical speeds depend upon the magnitude and location of the load carried by the shaft, length and diameter of shaft and support conditions. The shaft may be operated below or above critical speed safely, i.e. in general practice the shaft is to operate at a speed far away from the critical speed. Higher speeds are rarely used. Some steam turbines exceed critical speed, but they do not run long enough at critical speed for vibrations to build up to excessive amplitude.

The apparatus is designed to demonstrate this phenomenon. It consists of a base frame, over which two bearing supports are mounted. The driving end carries a bearing block with two ball bearings giving fixed end condition for shaft. At tail end, two types of bearing blocks are provided, one for fixed tail end and one for free tail end. A variable speed motor drives the shaft.

Each shaft is provided with eccentric revolving disc. Thus, the students can visualize the effect of whirling of the shaft.

EXPERIMENTAL PROCEDURE: -

1) Fix the required shaft at the driving end.
2) Fix the bearing block at tail end (either for fixed end condition or free end condition) and tighten the shaft.
3) Start the motor and slowly increase the speed. At a certain speed, disc will vibrate violently. Hold the shaft by hand to avoid shaft bending and note down the speed.
4) Increase the speed. Now shaft will operate above critical speed without vibrations.
5) Repeat the procedure by changing the end conditions.
6) Repeat the procedure by changing the shaft.

OBSERVATIONS: -

Sr. No.	Shaft size (mm)	End Conditions	Whirling Speed (Rpm)

DATA:

1) m_1 = Uniformly distributed load (own weight of shaft)

= ………..Kg/m for Dia. 3 mm. shaft.

= …………Kg/m for Dia. 4 mm. shaft.

= ………. Kg/m for Dia. 7 mm. shaft.

2) m_2 = Mass of disc.

= ……….Kg disc for Dia 3 mm shaft.

= ………..Kg disc for Dia 4 mm shaft.

= ……….Kg disc for Dia 7 mm shaft.

3) ℓ = Length of shafts = 0.9 m

4) E = Modulus of Elasticity

= 2.7×10^{11} N/m^2

5) I = Moment of inertia of shaft = $(\pi/64) . D^4$ m^4

= 3.97×10^{-12} m^4 for Dia. 3 mm shaft

= 1.256×10^{-11} m^4 for Dia. 4 mm shaft

= 1.17×10^{-10} m^4 for Dia. 7 mm shaft.

CALCULATIONS: -

1) Considering own weight of shaft.

Deflection of shaft under own weight,

$$\delta_{S1} = \frac{5. m_1 . g . (l)^4}{384.E.I}$$ .... Ends fixed.

OR

$$\delta_{S2} = \frac{m_1 . g . (\ell)^4}{185 E.I}$$ .... One end fixed and One end free

2) Considering mass of disc only (Located centrally)

$$\delta_{d1} = \frac{m_2 . g (\ell)^3}{192 E.I}$$ ------------------------ both ends fixed

OR

$$\delta_{d2} = \frac{7 . m_2 . g . (\ell)^3}{768 E.I}$$ ------------------------ one end fixed and one end free

3) Frequency for own weight of shaft -

$$f_{ns} = \frac{0.5623}{\sqrt{\delta_S}}$$

4) Frequency for disc weight only

$$f_{nd} = \frac{0.4987}{\sqrt{\delta d}}$$

5) Resultant Frequency of shaft be f_n -

then,

$$\frac{1}{f_n^2} = \frac{1}{f_{ns}^2} + \frac{1}{f_{nd}^2}$$

NOTE : -

The calculated values of frequencies may vary greatly from theory because practically it is not possible to have perfectly straight shaft and whirling of shafts is actually a destructive test.

PRECAUTIONS: -

1) Operate all the controls gently.

2) Check all nut bolts for tightening before starting the experiment.

3) Do not allow to strike the disc to the frame at critical speeds.

SAMPLE DATA:

1) m_1 = Uniformly distributed load (own weight of shaft)

= 0.052 Kg/m for Dia. 3 mm. shaft.

= 0.155 Kg/m for Dia. 5 mm. shaft.

= 0.295 Kg/m for Dia 7 mm. shaft.

2) m_2 = Mass of disc.

= 0.295 Kg disc for Dia 3 mm shaft.

= 0.400 Kg disc for Dia 5 mm shaft.

= 0.435 Kg disc for Dia 7 mm shaft.

3) ℓ = Length of shafts = 0.9 m

4) E = Modulus of Elasticity

= 2.7×10^{11} N/m^2

5) I = Moment of inertia of shaft = $(\pi/64). D^4$ m^4

= 3.97×10^{-12} m^4 for dia 3 mm shaft

= 3.06×10^{-11} m^4 for dia 5 mm shaft

= 1.17×10^{-10} m^4 for Dia. 7 mm shaft.

SAMPLE DATA: -

1) m_1 = Uniformly distributed load (own weight of shaft)

= 0.15 Kg/m for Dia. 5 mm. shaft.

= 0.220 Kg/m for Dia. 6 mm. shaft.

= 0.392 Kg/m for Dia 8 mm. shaft.

2) m_2 = Mass of disc.

= 0.320 Kg disc for Dia 5 mm shaft.

= 0.400 Kg disc for Dia 6 mm shaft.

= 0.450 Kg disc for Dia 8 mm shaft.

3) ℓ = Length of shafts = 0.950 m

4) E = Modulus of Elasticity

= 2.7×10^{11} N/m^2

5) I = Moment of inertia of shaft = $(\pi/64) . D^4$ m^4

= 3.067×10^{-11} m^4 for dia 5 mm shaft

= 6.36×10^{-11} m^4 for dia 6 mm shaft

= 2.01×10^{-10} m^4 for Dia. 8 mm shaft

DATA: -

1) m_1 = Uniformly distributed load (own weight of shaft)

= 0.15 Kg/m for Dia. 5.1 mm. shaft.

= 0.26 Kg/m for Dia. 6.50 mm. shaft.

= 0.392 Kg/m for Dia 8.1 mm. shaft.

2) m_2 = Mass of disc.

= 0.312 Kg disc for Dia 5.1 mm shaft.

= 0.4342 Kg disc for Dia 6.50 mm shaft.

= 0.48 Kg disc for Dia 8.1 mm shaft.

3) ℓ = Length of shafts = 0.824 m

4) E = Modulus of Elasticity

= 2.7×10^{11} N/m^2

5) I = Moment of inertia of shaft

= 3.32×10^{-11} m^4 for dia 5.1 shaft

= 8.76×10^{-11} m^4 for dia 6.50 shaft

= 2.11×10^{-10} m^4 for Dia. 8.1 shaft

DATA:

1) m_1 = Uniformly distributed load (own weight of shaft)

= 0.052 Kg/m for Dia. 3 mm. shaft.

= 0.155 Kg/m for Dia. 5 mm. shaft.

= 0.295 Kg/m for Dia 7 mm. shaft.

2) m_2 = Mass of disc.

= 0.295 Kg disc for Dia 3 mm shaft.

= 0.400 Kg disc for Dia 5 mm shaft.

= 0.435 Kg disc for Dia 7 mm shaft.

3) ℓ = Length of shafts = 0.9 m

4) E = Modulus of Elasticity

= 2.7×10^{11} N/m^2

5) I = Moment of inertia of shaft = $(\pi/64) \cdot D^4 \quad m^4$

= 3.97×10^{-12} m^4 for dia 3 mm shaft

= 3.06×10^{-11} m^4 for dia 5 mm shaft

= 1.17×10^{-10} m^4 for Dia. 7 mm shaft.

WHIRLING OF SHAFT DEMONSTRATOR

- : SAMPLE CALCULATIONS : -

1) Considering own weight of shaft.

Deflection of shaft under own weight,

$$\delta_{S1} = \frac{5 \cdot m_1 \cdot g \cdot (\ell)^4}{384\, E.I} \text{ --------------------------------- ends fixed.}$$

$$\text{a) } \delta_{S1} = \frac{5\,(0.15) \cdot 9.81 \cdot (0.824)^4}{384\,(2.7 \times 10^{11} \times 3.32 \times 10^{-11})} \text{ ------------- ends fixed.}$$

$$= 1.05 \times 10^{-3} \text{ m}$$

$$\text{b) } \delta_{S1} = \frac{5\,(0.26) \cdot 9.81 \cdot (0.824)^4}{} \text{ ------------- ends fixed.}$$

$384 (2.7 \times 10^{11} \times 8.76 \times 10^{-11})$

$= 6.72 \times 10^{-4}$ m

c) $\delta_{S1} = \dfrac{5 \ (0.392) \ . \ 9.81.. \ (0.824)^4}{384 (2.7 \times 10^{11} \times 2.11 \times 10^{-10})}$ ------------ ends fixed.

$= 4.196 \times 10^{-4}$ m

OR

$\delta_{S2} = \dfrac{m_1 \ . \ g \ . \ (\ell)^4}{185 \ E.I}$ ------------------------------- one end fixed and one end free

$\delta_{S2} = \dfrac{0.15 \times 9.81 \ (0.824 \ )^4}{185 \times (2.7 \times 10^{11} \times 3.32 \times 10^{-11})}$ ----------- one end fixed and one end free

$= 4.36 \times 10^{-4}$ m

$\delta_{S2} = \dfrac{0.26 \times 9.81 \ (0.824 \ )^4}{185 \times (2.7 \times 10^{11} \times 8.76 \times 10^{-11})}$ -------------- one end fixed and one end free

$= 2.79 \times 10^{-4}$ m

$\delta_{S2} = \dfrac{0.392 \times 9.81 \ (0.824 \ )^4}{185 \times (2.7 \times 10^{11} \times 2.11 \times 10^{-10})}$ -------------- one end fixed and one end free

$= 1.74 \times 10^{-4}$ m

2) Considering mass of disc only (Located centrally)

$\delta_{d1} = \dfrac{m_2 \ . \ g \ \ (\ell)^3}{192 \ EI}$ ------------------------------- both ends fixed

$\delta_{d1} = \dfrac{0.312 \times 9.81 \times \ (0.824 \ )^3}{192 \ \times 2.7 \times \ 10^{11} \times 3.32 \times 10^{-11}}$ ------------ both ends fixed

$= 0.8198 \times 10^{-3}$ m

$$\delta_{d1} = \frac{0.4342 \times 9.81 \times (0.824)^3}{192 \times 2.7 \times 10^{11} \times 8.76 \times 10^{-11}}$$ ------------- both ends fixed

$= 5.25 \times 10^{-4}$ m

$$\delta_{d1} = \frac{0.48 \times 9.81 \times (0.824)^3}{192 \times 2.7 \times 10^{11} \times 2.11 \times 10^{-10}}$$ -------------- both ends fixed

$= 2.41 \times 10^{-4}$ m

OR

$$\delta_{d2} = \frac{7 \,.\, m_2 \,.\, g \,.\, (\ell)^3}{768\, EI}$$ ----------------------- one end fixed and one end free

$$\delta_{d2} = \frac{7 \times 0.312 \times 9.81 \,.\, (0.824)^3}{768 \times 2.7 \times 10^{11} \times 3.32 \times 10^{-11}}$$ ------ one end fixed and one end free

$= 1.74 \times 10^{-3}$ m

$$\delta_{d2} = \frac{7 \times 0.4342 \times 9.81 \,.\, (0.824)^3}{768 \times 2.7 \times 10^{11} \times 8.76 \times 10^{-11}}$$ ------- one end fixed and one end free

$= 0.918 \times 10^{-3}$ m

$$\delta_{d2} = \frac{7 \times 0.48 \times 9.81 \,.\, (0.824)^3}{768 \times 2.7 \times 10^{11} \times 2.11 \times 10^{-10}}$$ ---------- one end fixed and one end free

$= 4.21 \times 10^{-4}$ m

3) Frequency for own weight of shaft -

$$f_{ns} = \frac{0.5623}{\sqrt{\delta_S}}$$

(For both ends fixed)

a) $$f_{ns} = \frac{0.5623}{\sqrt{1.05 \times 10^{-3}}} = 17.35$$

b) $$f_{ns} = \frac{0.5623}{\sqrt{6.72 \times 10^{-4}}} = 21.69$$

c) $$f_{ns} = \frac{0.5623}{\sqrt{4.196 \times 10^{-4}}} = 27.45 \text{ Hz}$$

(For one end free and one end fixed)

$$f_{ns} = \frac{0.5623}{\sqrt{4.36 \times 10^{-4}}} = 26.93 \text{ Hz}$$

$$f_{ns} = \frac{0.5623}{\sqrt{2.79 \times 10^{-4}}} = 33.66 \text{ Hz}$$

$$f_{ns} = \frac{0.5623}{\sqrt{1.74 \times 10^{-4}}} = 42.63 \text{ Hz}$$

4) Frequency for disc weight only

$$f_{nd} = \frac{0.4987}{\sqrt{\delta d}}$$

(For both ends fixed)

$$f_{nd} = \frac{0.4987}{\sqrt{0.8198 \times 10^{-3}}} = 17.396 \text{ Hz}$$

$$f_{nd} = \frac{0.4987}{\sqrt{5.25 \times 10^{-4}}} = 21.77 \text{ Hz}$$

$$f_{nd} = \frac{0.4987}{\sqrt{2.41 \times 10^{-4}}} = 32.12 \text{ Hz}$$

(For one end free and one end fixed.)

$$f_{nd} = \frac{0.4987}{\sqrt{1.74 \times 10^{-3}}} = 11.96 \text{ Hz}$$

$$f_{nd} = \frac{0.4987}{\sqrt{0.918 \times 10^{-3}}} = 16.46 \text{ Hz}$$

$$f_{nd} = \frac{0.4987}{\sqrt{4.21 \times 10^{-4}}} = 24.31 \text{ Hz}$$

5) Resultant Frequency of shaft be f_n -

then,

$$\frac{1}{f_n^{\,2}} = \frac{1}{f_{ns}^{\,2}} + \frac{1}{f_{nd}^{\,2}}$$

$$\frac{1}{f_n^{\,2}} = \frac{1}{(17.35)^2} + \frac{1}{(17.396)^2}$$

(For both ends fixed)

a) $\therefore f_n$ = 12.28 Hz. 12.28 x 60 = 737 R.P.M

b) $\therefore f_n$ =15.365Hz. 15.365 x 60 = 921.92 R.P.M

c) $\therefore f_n$ = 20.87 Hz. 20.87 x 60 = 1252 R.P.M

1 Hz = 60 R.P.M.

(For one end free and one end fixed.)

a) 10.93 x 60 = 655.83 R.P.M.

b) 14.79 x 60 = 887.2 R.P.M.

c) 21.12 x 60 = 1267 R.P.M.

EXPERIMENT NO: 6 STATIC & DYNAMIC BALANCING APPARATUS

Aim: Study of static or dynamic balancing of rotating masses.

APPRATUS: static & dynamic balancing apparatus

DESCRIPTION:

Balancing of masses plays an important role in machine design and manufacture. When a mass is stationary, it can be balanced easily by putting suitable counter weight acting in the opposite direction of unbalanced mass. When an unbalanced mass is rotating and it is left unbalanced, then a centrifugal force is developed, which changes its direction during the rotation. This causes vibrations of the machine & premature failure of bearings and shaft. Hence, balancing is essential for satisfactory operation of the machine.

The apparatus consists of a frame which is hung by chains from the main frame. A shaft rotates within bearings in the frame. Four slotted discs are mounted over the shafts. The weights can be attached in the slots of discs at different radial distances. An angular scale provided enables the disc (and consequently the weights) to be fitted at required angular position. Also the discs can slide over the shaft so that linear distances can be adjusted.

SPECIFICATIONS: -

1) slotted disc - 4 nos.
2) Revolving shaft with frame & f. h. p. motor. - 1 no.
3) Scales for angular & longitudinal mounting of weights over the shaft.

EXPERIMENTAL PROCEDURE: -

For experiment of balancing, it is necessary to have an unbalanced system of known unbalance. For this, with one or two discs provided, attach the weights in the slots, at known radial distance and known angle between them. Now, this becomes a known unbalanced system. For solving the problems, let us assume that the system is to be balanced with two weights whose radial distances are known.

1) Static balancing : -

Let unknown system be $m_1 r_1$ & $m_2 r_2$ at an angle θ_1.

This is to be balanced by $m_3 r_3$ & $m_4 r_4$.

Draw the position diagram as shown. Draw vector ab parallel to $m_1 r_1$, to some scale. Draw bc parallel to $m_2 r_2$. from point c, draw an arc with radius of scaled $m_3 r_3$. from point a, draw an arc with radius of scaled $m_4 r_4$. point of intersection of arcs is d. join cd & ad, from scale, unknown values of m_3 and m_4 can be determined as r_3 and r_4 are known (assumed) values.

Now draw parallel line to cd from origin in position diagram. this gives direction of $m_3 r_3$. Also draw parallel line to ad from origin in position diagram. This will give the direction of $m_4 r_4$.

Set the weights over the shaft at required radius and angle. Rotate the shaft by hand, & see that system is balanced i.e. static balancing.

2) DYNAMIC BALANCING -

Consider the above balanced system to be dynamically balanced. let distance between $m_1 r_1$ & $m_2 r_2$ be a_1, distance a_2 between $m_1 r_1$ & $m_3 r_3$ and a_3 between $m_1 r_1$ & $m_4 r_4$ is to be determined.

Select the reference plane suitably, let the reference plane be at $m_1 r_1$.

Taking the moments about references plane,

MASS	DISTANCES FROM REF. PLANE	MOMENT
$M_1 R_1$	0	0
$M_2 R_2$	A_1	$M_2 R_2 A_1$
$M_3 R_3$	A_2	$M_3 R_3 A_2$
$M_4 R_4$	A_3	$M_4 R_4 A_3$

Now, draw couple polygon. Draw 'ef'' parallel to $m_2 r_2$ to some suitable scale, Proportional to $m_2 r_2 a_1$ from point e, draw parallel to $m_3 r_3$. From point 'f", draw parallel to $m_4 r_4$ from e to intersect the previous line at g, eg is couple vector $m_3 r_3 a_2$. From the scale & known value of $m_3 r_3$ determine a_2 .fg is couple vector parallel to $m_4 r_4 a_3$. From scale and from known value of $m_4 r_4$ determine a_3. (Note - while drawing the couple polygon, see that couple polygon closes in one direction only, i.e. all the vectors should be either in clockwise or anticlockwise direction). Set the weights over the shaft as calculated by locking the shaft with the locking screw. After setting all the weights in their proper positions, remove the locking screw, rotate the shaft with the help of motor and see that system is balanced i.e. Dynamic Balancing

The maximum and minimum limits are -

1) Minimum radial distance - 25 mm.

2) Maximum radial distance - 65 mm.

3) Length of shaft - 300 mm.

4) Minimum linear distance between weights - 30mm

i) Minimum weight on disc (with nut-bolt) - 45 gm.

ii) Maximum weights on disc (with nut-bolt) - 65 gm.

5) Minimum mr Value - 1125 gm mm.

6) Maximum mr value - 3900 gm mm.

PRECAUTIONS: -

1) While fixing the discs and weights, see that they are properly tightened. Under tightened bolts may loosen during rotation & over tightened bolts may get damaged or break.

2) Depending upon the initial assumed unbalance, the radial & linear distances will vary. Initially, it is necessary to understand the limiting sizes of the frame disc. If distances determined from diagrams are out of the limit of equipment, then it is necessary to modify or change the problem.

SAMPLE CALCULATION:

FOR STATIC BALANCING: -

1) Select the known mass, radius and angle

$m_1 = 45$ gm, $r_1 = 30$ mm & $\theta = 0^0$

$m_2 = 45$ gm, $r_1 = 35$ mm & $\theta_1 = 20^0$

2) Select the known mass and radius for balancing the above masses.

$m_3 = 65$ gm , $r_3 = 31.3$ mm.

$m_4 = 45$ gm , $r_4 = 33.95$ mm.

3) Draw the position of m_1 r_1 & m_2 r_2.

4) Draw the force polygon with some scale say, (1mm = 40 units).

Draw 'ab' parallel to 'm1r1' (33.75 mm) & 'bc' parallel to 'm2r2 '

(39.37 cm). Draw arc from 'c' and ' a' points. Point of intersection of arcs is d. draw lines 'cd' & 'da' .

a] measure length m_3 r_3 (cd) = 50.87 mm find out m_3 r_3 values 2034.5 gm-mm { 2034.5 / 40 = 50.87 mm }.
b] Measure length m_4 r_4 (da) =38.2 mm. Find out m_4 r_4 values 1527.75 gm-mm { 1527.75 / 40 = 38.2 mm }.
According to product find out m_3 r_3 ,m_4 r_4 values.

6) Draw the parallel lines 'cd' & 'ad' on the position diagram.

& find out the angles. [θ_3 160 ^{0} & θ_4 233 ^{0}] .

7) Set the weight over the shaft at the radius and angle.

Rotate the shaft by hand & see that system is balanced statically.

FOR DYNAMIC BALANCING : -

8) Now, for couple polygon select scale of 1mm = 8800 units.

Draw the 'ef ' parallel to m2 r2 , 'fg' parallel m3 r3 and complete the polygon by ' ge ' parallel to m4 r4 .

m2r2a1 = 37.74

$$a1 = \frac{37.74}{45 \times 35} \times 8800 \quad \text{(select scale of 1mm = 8800 units.)}$$

a1 = 211 mm.

Same, finding out the lengths of a2= 93.63 mm. & a3 = 145.22 mm

10) According to above values fix the weights on the disc.

For 1st plate , m1 = 45 gm, r1 = 30 mm, θ1 = 00 .

2nd plate ,m3 = 65 gm, r3 =31.3 mm , θ3 = 160 0

& a2 = 93.63 mm

3rd plate ,m4 = 45 gm, r4 =33.95 mm, θ2 = 233 0

& a3 =145.22mm

4thplate,m2 = 45gm,r2 =35 mm,θ4=20 0 & a1 =211mm.

Rotate the shaft with the help of motor and see that system is balanced dynamically.

M_1 - 45 GM	M_2 - 45 GM	M_3 - 65 GM	M_4 -45 GM

R_1 - 30 MM	R_2- 35 MM	R_3- 31.3 MM	R_4 - 33.95 MM
θ_1 - 0^0	θ_2 - 20^0	θ_3------ 160^0	θ_4 --- 233^0
A - 0 MM	A_1 - 211 MM	A2 ----- 93.63 MM	A_3----145.22MM

PRECAUTIONS:

1. Do not run the motor at low voltage i.e. less than 180 volts.

2. Increase the motor speed gradually.

3. Experimental set up is proper tightly before starting experiment.

4. Always keep apparatus free from dust.

5. Before starting the rotary switch, check the needle of dimmer stat at zero position.

EXPERIMENT NO. 7 MOTORISED GYROSCOPE APPARATUS

AIM: To determine the gyroscopic couple on motorized gyroscope

THE APPARATUS

The apparatus consists of a rotor disc, mounted in bearings. The disc is driven by a variable speed FHP motor, so that disc can be rotated at a required speed. The disc bracket rests over knife-edges. The knife-edge base blocks are clamped to a yoke. The yoke can rotate about vertical axis in the bearings fitted in the round base. Thus, the motions about all the three axis are possible.

On the opposite side of the motor, a balance weight is provided to balance the motor. A stud is provided over the balance weight, onto which the required weights can be placed to apply the required torque. An angular scale with pointer is provided which enables us to measure the angular motion about the vertical axis.

THEORY: -

Gyroscope is an interesting instrument, used for control of airplanes, guided missiles etc. It basically consists of a spinning rotor, rotating about a horizontal axis called the 'axis of spin'. The rotor is mounted in such a way that the axis of spin of the rotor can rotate in a horizontal plane about a vertical axis called the 'axis of precession' and another horizontal axis called the 'axis of gyroscopic couple.' When torque is applied to spinning rotor, the rotor turns about the 'axis of precession' as well as, it also bends about the axis of gyroscopic couple. This is caused by a couple generated due to spinning of the rotor, called Gyroscopic couple.

1) **Velocity of Spin** - The angular velocity of rotor is called velocity of spin. It is denoted by 'ω'. It is measured in rad/sec.
2) **Velocity of precession** - Angular velocity of rotation of the rotor axis is called velocity of precession. This rotation is about the vertical axis. It is denoted by ω_P. It is also measured in rad/sec.
3) **Gyroscopic couple** - The couple generated due to change of direction of angular velocity of rotor, is called Gyroscopic couple.
4) **Applied Torque** - The torque applied to change the direction of angular velocity of rotor is applied torque.

Numerically, it is the product of weight placed in the weight stud and its distance from center of the disc.

5) **Moment of Inertia of rotor** -

$$I = m \cdot k^2$$

where,

I = Moment of inertia, kg. m^2

m = Mass of disc = 4.230 kg.

k = Radius of gyration = $\frac{r}{\sqrt{2}}$

r = Radius of rotor = 0.125 m

$\therefore$ K = 0.09

6) **Angular Momentum** :- The product of angular velocity of rotor and moment of inertia of the disc is called angular momentum.

Angular momentum.= $I \cdot \omega$

As the torque is applied, direction of angular velocity is changed and hence angular momentum is also changed. Thus,

Couple applied = Rate of change of momentum.

If , (I. ω.) is change of momentum in the time interval ,

Then,

$$T = \frac{d(I.\omega)}{dt}$$

If do is angle of precession turned during the time at, then.

$$T = (I.\omega) . \frac{do}{dt}$$

but do/dt is velocity of precession,

$$\therefore T = I.\omega.\omega p$$

EXPERIMENTAL PROCEDURE : -

1) Check the rotor for vertical position. Adjust the balance weight slightly, if required.
2) Keep the dimmer at zero position & put 'ON' the supply.

3) Start the motor by applying the voltage of around 170 volts & then reduce.
4) Adjust the rotor speed as required.
5) Note down the rotor speed with the help of tachometer.
(Not supplied with the unit) Speed is to be noted when it becomes steady, it takes around 5 minutes to stabilise.
6) Put the required weight in the weight stud & at the same instant, start the stop clock. Note down the time required for 45^0 precession.
7) Repeat the procedure for different weights and rotor speeds.

OBSERVATION : -

Sr. No.	Rotor Speed 'N' rpm	Weight 'W' N	Time for 45^0 Precession 't' sec

CALCULATIONS: -

1) **Velocity of Spin** -

$$\therefore \quad \omega = \frac{2 \pi N}{60} \text{ rad / sec.}$$

Where, N = Rotor speed (rpm)

2) **Velocity of precession** -

Let time for 45^0 Precession be **t ,** sec.

$$45^0 = \frac{\pi}{4} \text{ rad.}$$

$$\therefore \quad \omega_p = \frac{\pi}{4} \times \frac{1}{\mathbf{t}} \text{ rad / sec.}$$

3) **Moment of inertia** -

Mass of the disc is 4.230 Kg.

∴ Moment of inertia, $I = m.k^2$

$$I = 4.230 \times (0.09)^2$$

$$I = 0.03426 \ Kg - m^2$$

4) **Applied Torque** -

Let distance of weight stud from centre of disc be 'L' mtrs.

i) Applied torque,

T_{act} = weight (in N) . (L) --------------- (where, L = 0.305 m)

ii) Now, as derived earlier theoretical torque,

$T_{th} = I . \omega . \omega p$

CONCLUSION : -

1) When torque is applied to spinning rotor, rotating about horizontal axis, precession takes place about vertical axis.
2) The applied torque equals to rate of change of angular momentum of rotor.

PRECAUTIONS : -

1) Check all the fastenings to be tight before start.
2) Check balance of the rotor before start.
3) Lubricate the bearings periodically.
4) Keep the base over a leveled platform.

- : SAMPLE CALCULATIONS : -

OBSERVATIONS :-

Sr. No.	Rotor Speed N,rpm	Weight w,N	Time for 45^0 Precession t, Sec
1	2900	9.81	3.20
2	2900	4.905	6.44

For Sr. No. 1

1) **Velocity of Spin** -

$$\therefore \quad \omega = \frac{2\pi \times 2900}{60} = 303.69 \text{ rad / sec.}$$

2) **Velocity of precession** -

$$\therefore \quad \omega p = \frac{\pi}{4} \times \frac{1}{3.20} = 0.245 \text{ rad / sec.}$$

4) **Applied torque** -

Let distance of weight stud from centre of disc be ‘x’ mtrs.

i) Applied torque,

T_{act} = (weight) . (x) --------------- (where, x = 0.278 m)

= 9.81 x 0.278

= 2.73

ii) Theoratical torque ,

$T_{th} = I . \omega . \omega p$ --------------------- (I = 0.036 Kg - m^2)

= 0.036 x 303.69 x 0.245

= 2.68

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Lab Manual

Title of Course: Mechatronics Lab
Course Code: M695B
L-T –P Scheme: 3P **Course Credits: 2**

Objectives:
1. To present architecture of the mechatronics system
2. Method of experimental identification of the control system
3. To study interfacing of the electromechanical devices.

Outcome: Learner will be able to…
1. Identify the suitable sensor and actuator for a control system
2. Indigenously design and develop a mechatronic system

Course Contents:

At least 6 (six) experiments of the following list of topics to be conducted.
Experiments on:
1. Open loop position control;
2. Closed loop position control using positional and velocity feedback;
3. Use of analog and digital servosystems,
4. Use of PID control;
5. Experiments on pneumatic drives and actuators;
6. Experiments on hydraulic drives and actuators;
7. Use of logic gates;
8. Programming on a 8085 Microprocessor training kit;
9. Programming on a PLC for simple control operations..

Pre-requisites:
1. MTC503: Sensors and Actuators
2. MTC504: Control Systems
3. MTC502: Machine Design
4. MTC505: Embedded Systems

LAB # 1: Component Information Gathering

Objective:
The objective of this lab is to practice gathering technical information about different types of components used in

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Lab Manual

Mechatronic Systems.

Introduction:
An important step in the design of mechatronic systems is to gather technical information about components that can be used in design of a system. In this lab session you will practice collecting information and selecting components to satisfy some constraints. This involves reading data sheets and extracting information from them.

Part 1:

Using Internet search, obtain the data sheets for the following components. Use the data sheet to provide the required data.

1. Provide the following information about TTL 7400 (or 74ACT00)

- The purpose of this IC
- Sketch the IC pin-out (DIP if available)
- Temperature operating range
- Supply voltage (min –max)
- Input Voltage level for OFF (low)
- Input Voltage Level for ON (high)
- Output Voltage level for OFF (low)
- Output Voltage Level for ON (high)
- High level input current
- Low level input current
- Typical propagation delay
- A company that produce such IC.(Name-address)

2. Provide a CMOS IC to do the function similar to the TTL 7400 and provide the same information asked for in (1).

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Part 2

In the following, you need to search for and provide information about several components. In some cases a specific name (component number) is provided. In other cases a general name indicating the function of the component is provided. You are asked to do a search on the internet to get more details about those components.
There could be many components to do the required job. Provide information about one such component.

Required information include the company providing the component, URL location for specification sheet if available , Pin-out diagram, component number
How does it work? How much does it cost?

1. 4-digit LED display unit that can be used to display 0,1,2,..9.
2. SN7490 Decay Counter
3. LM7414 Schmitt Trigger **(How does it work?)**
4. NE555 timer. **(How does it work?)**
5. Optical Isolator TTL, DIP format
6. 0.25 W resistors DIP resistor (8 resistors, 10 M ohm if available)
7. Potentiometer (rotary type , power rating <5 W, Rotation Angle>200 degrees)
8. 12-bit DAC
9. Toggle Switches (lower power, voltage < 20V, small size, ON-OFF)
10. Keypads (4X4 , small size)
11. Speed and position transducer (Shaft Encoder) (<100 pulse/rev)

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Groups of 2 can work on this lab project
Soft copy of the report can be submitted through webCT.
Due date for submission is the beginning of the next lab.

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Lab Manual
CISE 412: MECHATRONICS

(Term 092)

Lab # 2: Modeling and Controller Design of Magnetic Levitation System

Equipment Needed

- **PC with MATLAB and SIMULINK**

Introduction:

Magnetic levitation system finds applications in engineering including aerospace, high speed transportation system, levitated micro-robotics, magnetic levitated automotive engine valves, magnetic bearings. Control and identification of magnetic levitation system physical system is challenging research problem as the system is nonlinear and unstable [1-4]. From educational point of view the magnetic levitation provides a test bed for learning controller design as it is unstable and nonlinear and must be operated in a closed loop [1]. There are a number of other physical systems which are unstable and must be operated in closed loop such as an aircraft, helicopter, inverted pendulum (e.g. Segway), position control system, liquid level process control. However the maglev system has poles strictly in the right half plane system whereas the above stated systems have poles at the origin (each behaves as an integrator) and hence poses difficulties in the design of a robust controller and its implementation.

Objective:

The objective of this lab is as follows:

- Model the maglev system using the physical laws governing the electro-magnetic circuits, and Newton law's laws of motion.
- Design an analog/ digital controller.
- Evaluate the performance of the closed loop control system in time domain (settling time, overshoot and control input magnitude, and in frequency domain including the bandwidth, resonance frequency and resonance peak.
- Iterate the design till the controller performance is acceptable for implementation

Modeling of a Magnetic Levitation System

We will use physical laws governing the attractive force generated by the interaction of the electromagnetic field and an iron ball, and the resulting motion by the Newton's Law. Consider a magnetic levitation shown in Fig. 1. It consists of an electromagnet which produces a magnetic field that attracts an iron ball. The vertical motion of the ball is measured by an optical system.

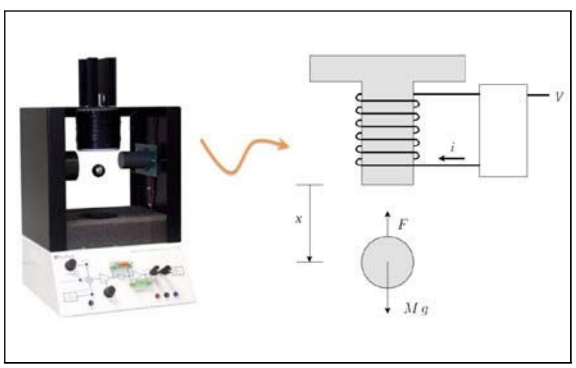

Fig. 1. MAGLEV system

Electromagnetic force

A magnetic material such as an iron ball placed in the magnetic field will experience a force, f, due to attraction between the magnetic poles, one in the electromagnetic and the other induced in the magnetic material as shown in the Fig. 2.

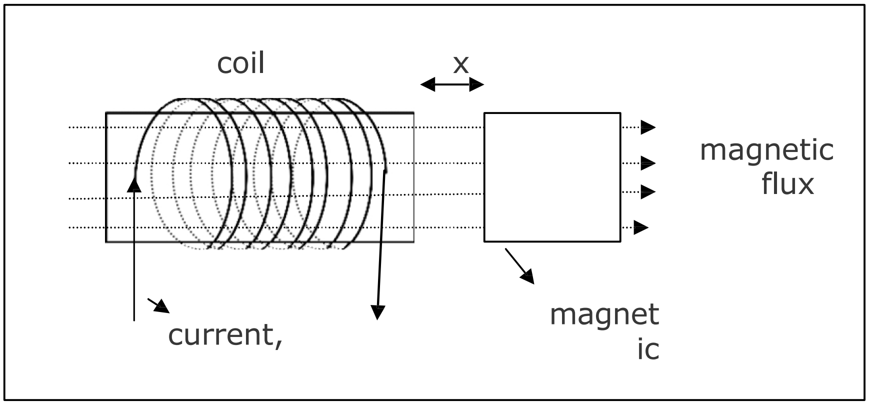

Fig. 2. Force in the magnetic material placed in a magnetic field

The attractive force on the iron ball, F, is

$$F = \frac{N^2 \mu A i^2}{2\left(\ell_0 + X\right)^2}$$

where N is the number of turn of the coil, A is the area of the electromagnetic, *i* is current in the coil which creates the magnetic field, $\ell = \ell_0 + X$ is the length of the magnetic path, *X* is the distance between the iron ball and the electromagnet and ℓ_0 is the length of the magnetic path in the magnetic materials of the electro-magnetic and the iron ball.

The direction of this force is vertically upwards.

Comments: Applications of the force between the flux and a magnetic material include the following:

- Magnetic levitation train (the train levitates thanks to the force experience by the electromagnet attached to the train and the ferrous rail).
- magnetic bearing (rotating shaft is suspended in a circular magnetic field so that the rotating shaft does not touch any component thereby eliminating friction)
- Electromagnetic switches, e.g. solenoids , relays. Solenoids are inexpensive and are used in latching, locking. Examples include automobile door latches and starter solenoids, opening and closing of valves in washing machines, relays in power systems. It has advantage over semiconductor switches as it can handle very large currents, and the circuit controlling the electromagnetic switches is isolated
- Stepper motor and reluctance motors

Model of the coil: current I and the voltage V
=

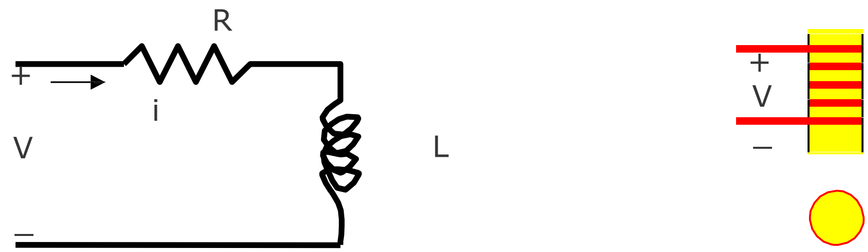

Fig. 3 RL circuit

Consider the coil of the electromagnet shown in Fig. 3. Let *R* be the resistance and *L* be the inductance.

Verify that the differential equation governing applied voltage to the coil and the current through the coil is

$$L\frac{di}{dt} + Ri = V$$

Verify that the transfer function relating *V* and *i* is given by

$$\frac{i(s)}{V(s)} = \frac{1}{Ls + R} = \frac{1/R}{s\tau + 1} \quad where \quad \tau = \frac{L}{R}$$

The electromagnetic coil is generally designed to have very low resistance to reduce the power loss i^2R and thereby reduce the heat generated. In practical systems such as magnetron particle accelerators and magnetic levitation systems very low temperature (cryogenic) is created to reduce the resistance and hence the heat loss.

As L/R is negligible the inductance may be neglected, and thus the relation between the voltage and the resistance, R is a simple static equation

$$i = \frac{V}{R}$$

Comment: The model of a *RL* circuit of an electromagnet is a first order system with a time constant $\tau = \frac{L}{R}$, since the time constant τ is very small, it is neglected. In modeling of systems and in controller design, neglecting very low time constant systems is termed as *unmodelled dynamics* or *model reduction*. In other words the transfer function of the coil is approximated:

$$\frac{i(s)}{V(s)} = \frac{1/R}{s\tau + 1} \approx \frac{1}{R}$$

In practice it is common to neglect fast dynamics and an approximate reduced order model so as to simplify the design of controller without affecting the performance.

With this approximation, the vertical force on the iron ball becomes

$$F = \frac{N^2 \mu A}{2R^2} \frac{V^2}{\left(\ell_0 + X\right)^2}$$

Model of the maglev system using Newton's law of motion

Consider the iron ball. Let m be the mass of the ball. Using Newton's law of motion (mass times the acceleration equals the net force), the force and the distance are related by the following differential equation

$$m\ddot{X} = F - mg$$

Substituting for the force F and simplifying we get

$$\ddot{X} = k \frac{V^2}{\left(X + \ell_0\right)^2} - g$$

where $k = \frac{N^2 \mu A}{2mR^2}$

Equilibrium point

There is a upward force, F, on the iron ball and there is a downward force due to gravity, mg. The question arises as to where will the iron ball go. Will it fall down, will it be attracted upwards and crash on the electromagnet or it will remain at some location where the upward force will balance the downward force. The answer to this question will depend upon the **equilibrium point** also termed the **singular point** of the differential equation. The equilibrium point is obtained by setting all the derivatives, first order, second and higher order derivatives to zero. In this case we only have second order derivative. Setting it to zero yields the equilibrium point, X_0, is obtained from

$$0 = k\frac{V_0^2}{\left(X_0 + \ell_0\right)^2} - g$$

where V_0 is the voltage applied.

$$0 = k\frac{V_0^2}{\left(X_0 + \ell\right)^2} - g$$

The equilibrium point, X_0, is given by

$$X_0 + L = V_0\sqrt{\frac{k}{g}}$$

Substituting for *k* we get

$$X_0 + L = \frac{VR}{N}\sqrt{\frac{\mu A}{2mg}}$$

Linearization of the Differential Equation

Consider the differential equation model

$$\ddot{X} = f(X,V) - g$$

where $f(X,V) = k\frac{V^2}{X^2}$

It is second order nonlinear system. For designing a controller, a linear approximate model is employed as it is very difficult to design a controller for a nonlinear system. A linear approximation is obtained by linearizing the nonlinear function, $f(X,V)$ about the equilibrium point, x_0 and the nominal voltage input, V_0, using Taylor's series

$$f(X,V) \approx f(X_0,V_0) + \left(X - X_0\right) \left.\frac{df}{dX}\right|_{X=X_0,V=V_o} + \left(V - V_0\right) \left.\frac{df}{dV}\right|_{X=X_0,V=V_0}$$

This approximation is valid for small variations of X about X_0, $\left|X - X_0\right| \leq \in$, and $\left|V - V\right| \leq \in$.

Verify that the expression for linear approximation of $f(X,V)$ becomes

$$f(X,V) = \frac{kV_0^2}{\left(X_0 + L\right)^2} - 2k\frac{V_0^2}{\left(X_0 + L\right)^3}\left(X - X_0\right) + \frac{2kV_0}{\left(X_0 + L\right)^2}\left(V - V_0\right)$$

Let us define $x = X - X_0$ and $u = V - V_0$,. Using this definition we get

$$f(X,V) = \frac{kV_0^2}{\left(X_0 + L\right)^2} - 2k\frac{V_0^2}{\left(X_0 + L\right)^3}x + \frac{2kV_0}{\left(X_0 + L\right)^2}u$$

Since $g = k\dfrac{V_0^2}{\left(X_0 + L\right)^2}$ we get

$$f(X,V) = g - \alpha x + \beta u$$

where $\alpha = 2k\dfrac{V_0^2}{\left(X_0 + L\right)^2}$, $\beta = \dfrac{2kV_0}{\left(X_0 + L\right)^2}$

Substituting the nonlinear function by its linear approximation in $\ddot{X} = g - f(X,V)$

we get

$$\ddot{x} = \alpha x - \beta u$$

The above is a linear approximation model of the nonlinear maglev system. This approximation is valid for excursion in the neighborhood of X_0 and V_0,

$|x| \le \in$ and $|u| \le \in$

Taking the Laplace transform, the transfer function relating *x* and *u* becomes

$$\frac{x(s)}{u(s)} = G(s) = -\frac{\beta}{s^2 - \alpha}$$

The system is unstable as there is pole in the right half of the s-plane. The poles, p, of the plant are real and are symmetrically located about the imaginary axis

$$p = \pm\sqrt{\alpha}$$

Analysis of the open loop system

Stability analysis

The system is unstable as there is pole in the right half of the s-plane. The poles, p, of the plant are real and are symmetrically located about the imaginary axis

$$p = \pm\sqrt{\alpha}$$

The poles are symmetrically located about the imaginary axis in the s-plane.

Step response

Verify that the step response will be unbounded and is given by

$$x(t) = \frac{1}{\alpha}\left[1 - \frac{1}{2}\left(e^{-\sqrt{\alpha}t} + e^{\sqrt{\alpha}t}\right)\right]$$

The step response is unbounded.

$$\lim_{t\to\infty} x(t) = \infty$$

Frequency response

Consider the transfer function, $G(s)$. Setting $s = j\omega$ the frequency response becomes

$$\frac{x(j\omega)}{u(j\omega)} = G(j\omega) = \frac{1}{\omega^2 + \alpha}$$

The frequency response is real and positive for all frequencies thanks to the symmetric location of the poles.

This shows that one can analyze the maglev system using frequency response and not step response.

Design of controller

Controller structure and controller design approach

There are a number of choices of controller structures including, proportional integral derivative (PID) controller, lead-lag compensator, and state feedback controller and number of approaches for designing a controller.

The maglev system in the laboratory has lead-lag compensator. Hence we will choose a lead-lag compensator. As for the design approach we will choose a simple approach based on pole-placement.

The lead-lag compensator, $C(s)$, takes the general form

$$C(s) = k\left(\frac{s+b}{s+a}\right)$$

Closed loop system

Since the plant, G(s) is unstable it must be operated in a closed loop configuration formed of the plant G(s) and the controller, C(s) as shown in Fig. 4 below.

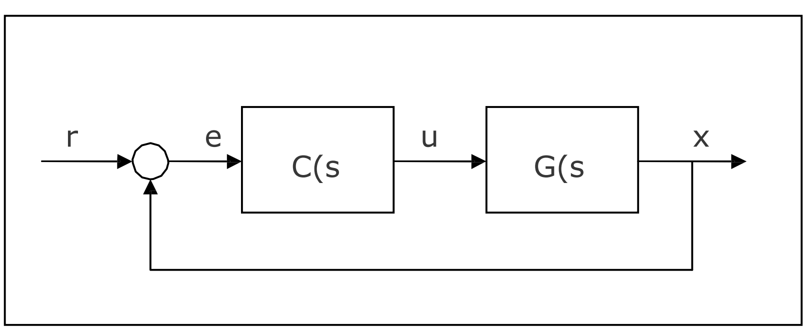

Fig. 4. Closed loop system formed of the plant G(s) and the controller, C(s)

The close loop transfer function relating the reference input, r and the plant output, x is given by

$$\frac{x(s)}{r(s)} = \frac{G(s)C(s)}{1+G(s)C(s)}$$

Substituting for G(s) and C(s) the closed loop numerator polynomial, N(s) and denominator polynomial (also termed characteristic polynomial), D(s) become

$$N(s) = -k\beta(s+b)$$

$$D(s) = (s+a)\left(s^2-\alpha\right) - k\beta\left(s+b\right)$$

Consider the characteristic polynomial, D(s). Simplifying yields

$$D(s) = s^3 + as^2 - s(\alpha + k\beta) - \alpha a - k\beta b$$

Design using pole-placement approach

We will use pole-placement approach to design the controller, C(s), that is obtain the controller parameters, k, a and b.

- Choice of desired pole location

  The closed loop system is of third order. Let us choose for convenience all poles to be equal to p.

  Verify that the desired characteristic polynomial, $\varphi(s)$ becomes

  $$\varphi(s) = \left(s+p\right)^3 = s^3 + 3s^2p + 3sp^2 + p^3$$

- Equate the actual characteristic polynomial and the desired characteristic polynomial

  $D(s) = \varphi(s)$

  Substituting for D(s) and $\varphi(s)$ yields

  $s^3 + as^2 - s(\alpha + k\beta) - \alpha a - k\beta b = s^3 + 3s^2p + 3sp^2 + p^3$

- Solve for the unknown controller parameters, k, a, and b by equating the coefficients of the equal powers of *s*.

Verify that the solution of the equations yields

$$a = 3p$$

$$b = -\frac{p^3 + \alpha p}{3p^2 + \alpha}$$

$$k = -\frac{3p^2 + \alpha}{\beta}$$

Deliverables

Each student should submit a word file containing the following**:**

- Verification of marked expressions.
- The mathematical model of maglev system
- Analysis of the linear approximation model of the Maglev system in time and frequency domain using SIMULINK.
- Evaluation of the performance

REFERENCES

[1] Galvão, R. K. H., Yoneyama, T., Araújo, F. M. U., Machado, R. G. "A Simple Technique for Identifying a Linearized Model for a Didactic Magnetic Levitation System". IEEE Transactions on Education, v. 46, n. 1, p. 22-25, 2003.

[2] K.Peterson, J.W.Grizzle, and A.G.Stefanpolou, Nonlinear magnetic levitation of automotive engine valves

[3] David Craig and Mir Behrad Khamesee, " Black box model identification of a magnetically levitated microrobotic system" Smart Materials and Structures, 16, 2007, pp.739-747

University of Engineering & Management
Lab Manual
CISE 412: MECHATRONICS (Term 082)

Lab # 3: Modeling and Controller Design of Magnetic Levitation System

Introduction:

Magnetic levitation system finds applications in engineering including aerospace, high speed transportation system, levitated micro-robotics, magnetic levitated automotive engine valves, magnetic bearings. Control and identification of magnetic levitation system physical system is challenging research problem as the system is nonlinear and unstable [1-4]. From educational point of view the magnetic levitation provides a test bed for learning controller design as it is unstable and nonlinear and must be operated in a closed loop [1]. There are a number of other physical systems which are unstable and must be operated in closed loop such as an aircraft, helicopter, inverted pendulum (e.g. Segway), position control system, liquid level process control. However the maglev system has poles strictly in the right half plane system whereas the above stated systems have poles at the origin (each behaves as an integrator) and hence poses difficulties in the design of a robust controller and its implementation.

Objective:

The objective of this lab is as follows:

- Model the maglev system using the physical laws governing the electro-magnetic circuits, and Newton law's laws of motion.
- Design an analog/ digital controller.

- Evaluate the performance of the closed loop control system in time domain (settling time and overshoot, control input magnitude, and in frequency domain including the bandwidth, resonance frequency and resonance peak.
- Iterate the design till the controller performance is acceptable for implementation

Modeling of a Magnetic Levitation System

We will use physical laws governing the attractive force generated by the interaction of the electromagnetic field and an iron ball, and the resulting motion by the Newton's Law. Consider a magnetic levitation shown in Fig. 1. It consists of an electromagnet which produces a magnetic field that attracts an iron ball. The vertical motion of the ball is measured by an optical system.

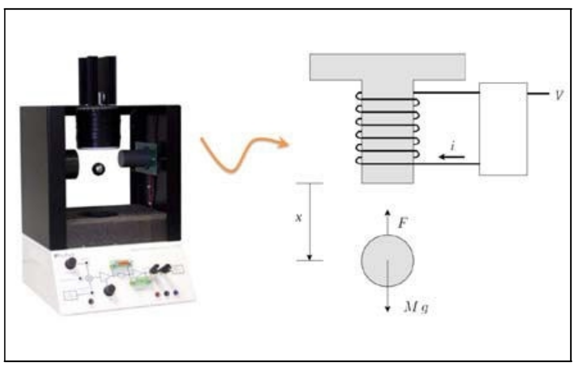

Fig. 1. MAGLEV system

Electromagnetic force

A magnetic material such as an iron ball placed in the magnetic field will experience a force, f, due to attraction between the magnetic poles, one in the electromagnetic and the other induced in the magnetic material as shown in the Fig. 2.

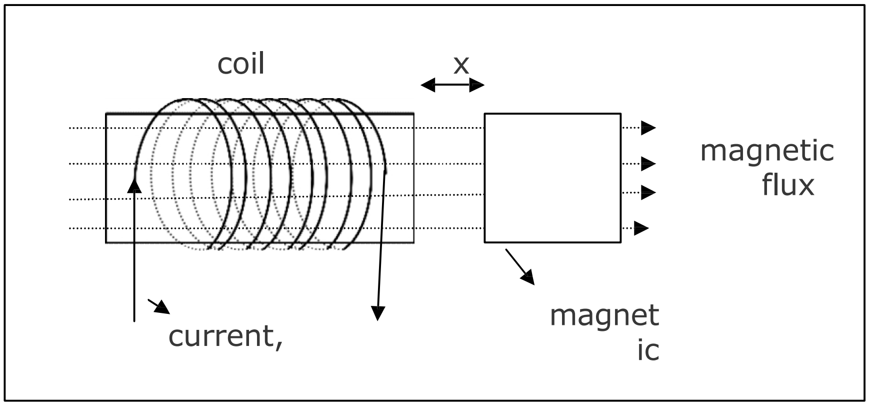

Fig. 2. Force in the magnetic material placed in a magnetic field

The attractive force on the iron ball, F, is

$$F = \frac{N^2 \mu A i^2}{2\left(\ell_0 + X\right)^2}$$

where N is the number of turn of the coil, A is the area of the electromagnetic, *i* is current in the coil which creates the magnetic field, $\ell = \ell_0 + X$ is the length of the magnetic path, *X* is the distance between the iron ball and the electromagnet and ℓ_0 is the length of the magnetic path in the magnetic materials of the electro-magnetic and the iron ball.

The direction of this force is vertically upwards.

Comments: Applications of the force between the flux and a magnetic material include the following:

- Magnetic levitation train (the train levitates thanks to the force experience by the electromagnet attached to the train and the ferrous rail).
- magnetic bearing (rotating shaft is suspended in a circular magnetic field so that the rotating shaft does not touch any component thereby eliminating friction)
- Electromagnetic switches, e.g. solenoids , relays. Solenoids are inexpensive and are used in latching, locking. Examples include automobile door latches and starter solenoids, opening and closing of valves in washing machines, relays in power systems. It has advantage over semiconductor switches as it can handle very large currents, and the circuit controlling the electromagnetic switches is isolated
- Stepper motor and reluctance motors

Model of the coil: current I and the voltage V

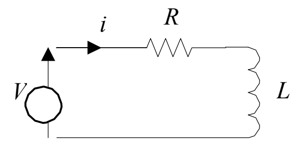

Fig. 3 RL circuit

Consider the coil of the electromagnet shown in Fig. 3. Let *R* be the resistance and *L* be the inductance. The differential equation governing applied voltage to the coil and the current through the coil is

$$L\frac{di}{dt} + Ri = V$$

The transfer function relating *V* and *i* is given by

$$\frac{i(s)}{V(s)} = \frac{1}{Ls + R} = \frac{1/R}{s\tau + 1} \quad where \quad \tau = \frac{L}{R}$$

The electromagnetic coil is generally designed to have very low resistance to reduce the power loss i^2R and thereby reduce the heat generated. In practical systems such as magnetron particle accelerators and magnetic levitation systems very low temperature (cryogenic) is created to reduce the resistance and hence the heat loss.

As L/R is negligible the inductance may be neglected, and thus the relation between the voltage and the resistance, R is a simple static equation

$$i = \frac{V}{R}$$

Comment: The model of a *RL* circuit of an electromagnet is a first order system with a time constant $\tau = \frac{L}{R}$, since the time constant τ is very small is very small, it is neglected. In modeling of systems and in controller design, neglecting very low time constant systems is termed as *unmodelled dynamics* or *model reduction*. In other words the transfer function of the coil is approximated:

$$\frac{i(s)}{V(s)} = \frac{1/R}{s\tau+1} \approx \frac{1}{R}$$

In practice it is common to neglect fast dynamics and an approximate reduced order model so as to simplify the design of controller without affecting the performance.

With this approximation, the vertical force on the iron ball becomes

$$F = \frac{N^2 \mu A}{2R^2} \frac{V^2}{\left(\ell_0 + X\right)^2}$$

Model of the maglev system using Newton's law of motion

Consider the iron ball. Let m be the mass of the ball. Using Newton's law of motion (mass times the acceleration equals the net force), the force and the distance are related by the following differential equation

$$m\ddot{X} = F - mg$$

Substituting for the force F and simplifying we get

$$\ddot{X} = k \frac{V^2}{\left(X + \ell_0\right)^2} - g$$

where $k = \frac{N^2 \mu A}{2mR^2}$

Equilibrium point

There is a upward force, F, on the iron ball and there is a downward force due to gravity, mg. The question arises as to where will the iron ball go. Will it fall down, will it be attracted upwards and crash on the electromagnet or it will remain at some location where the upward force will balance the downward force. The answer to this question will depend upon the equilibrium point also termed the singular point of the differential equation. The equilibrium point is obtained by setting all the derivatives, first order, and second and higher order derivatives to zero. In this case we only have second order derivative. Setting it to zero yields the equilibrium point, X_0, is obtained from

$$0 = k\frac{V_0^2}{(X_0 + \ell_0)^2} - g$$

where V_0 is the voltage applied.

$$0 = k\frac{V_0^2}{(X_0 + \ell)^2} - g$$

The equilibrium point, X_0, is given by

$$X_0 + L = V_0\sqrt{\frac{k}{g}}$$

Substituting for *k* we get

$$X_0 + L = \frac{VR}{N}\sqrt{\frac{\mu A}{2mg}}$$

Linearization of the Differential Equation

Consider the differential equation model

$$\ddot{X} = f(X,V) - g$$

where $f(X,V) = k\frac{V^2}{X^2}$

It is second order nonlinear system. For designing a controller, a linear approximate model is employed as it is very difficult to design a controller for a nonlinear system. A linear approximation is obtained by linearizing the nonlinear function, $f(X,V)$ about the equilibrium point, x_0 and the nominal voltage input, V_0, using Taylor's series

$$f(X,V) \approx f(X_0,V_0) + (X - X_0)\left.\frac{df}{dX}\right|_{X=X_0,V=V_o} + (V - V_0)\left.\frac{df}{dV}\right|_{X=X_0,V=V_0}$$

This approximation is valid for small variations of X about X_0, $|X - X_0| \le \in$, and $|V - V| \le \in$. Using the expression for linear approximation of $f(X,V)$ becomes

$$f(X,V) = \frac{kV_0^2}{(X_0+L)^2} - 2k\frac{V_0^2}{(X_0+L)^3}(X - X_0) + \frac{2kV_0}{(X_0+L)^2}(V - V_0)$$

Let us define $x = X - X_0$ and $u = V - V_0$,. Using this definition we get

$$f(X,V) = \frac{kV_0^2}{(X_0+L)^2} - 2k\frac{V_0^2}{(X_0+L)^3}x + \frac{2kV_0}{(X_0+L)^2}u$$

Since $g = k\frac{V_0^2}{(X_0+L)^2}$ we get

$$f(X,V) = g - \alpha x + \beta u$$

where $\alpha = 2k\frac{V_0^2}{(X_0+L)^2}$, $\beta = \frac{2kV_0}{(X_0+L)^2}$

Substituting the nonlinear function by its linear approximation in $\ddot{X} = g - f(X,V)$

we get

$$\ddot{x} = \alpha x - \beta u$$

The above is a linear approximation model of the nonlinear maglev system. This approximation is valid for excursion in the neighborhood of X_0 and V_0,

$|x| \le \in$ and $|u| \le \in$

Taking the Laplace transform, the transfer function relating *x* and *u* becomes

$$\frac{x(s)}{u(s)} = G(s) = -$$

$\frac{\beta}{s}$

2

–

α

The system is unstable as there is pole in the right half of the s-plane. The poles, p, of the plant are real and are symmetrically located about the imaginary axis

$p = \pm\sqrt{\alpha}$

Analysis of the open loop system

Stability analysis

The system is unstable as there is pole in the right half of the s-plane. The poles, p, of the plant are real and are symmetrically located about the imaginary axis

$p = \pm\sqrt{\alpha}$

The poles are symmetrically located about the imaginary axis in the s-plane.

Step response

The step response will be unbounded and is given by

$$x(t) = \frac{1}{\alpha}\left[1-\frac{1}{2}\left(e^{-\sqrt{\alpha}t}+e^{\sqrt{\alpha}t}\right)\right]$$

The step response is unbounded.

$$\lim_{t\to\infty} x(t) = \infty$$

Frequency response

Consider the transfer function, $G(s)$. Setting $s = j\omega$ the frequency response becomes

$$\frac{x(j\omega)}{u(j\omega)} = G(j\omega) = \frac{1}{\omega^2 + \alpha}$$

The frequency response is real and positive for all frequencies thanks to the symmetric location of the poles.

This shows that one can analyze the maglev system using frequency response and not step response.

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Design of controller

Controller structure and controller design approach

There are a number of choices of controller structures including, proportional integral derivative (PID) controller, lead-lag compensator, and state feedback controller and number of approaches for designing a controller.

The maglev system in the laboratory has lead-lag compensator. Hence we will choose a lead-lag compensator. As for the design approach we will choose a simple approach based on pole-placement.

The lead-lag compensator, $C(s)$, takes the general form

$$C(s) = k\left(\frac{s+b}{s+a}\right)$$

Closed loop system

Since the plant, G(s) is unstable it must be operated in a closed loop configuration formed of the plant G(s) and the controller, C(s) as shown in Fig. 4 below.

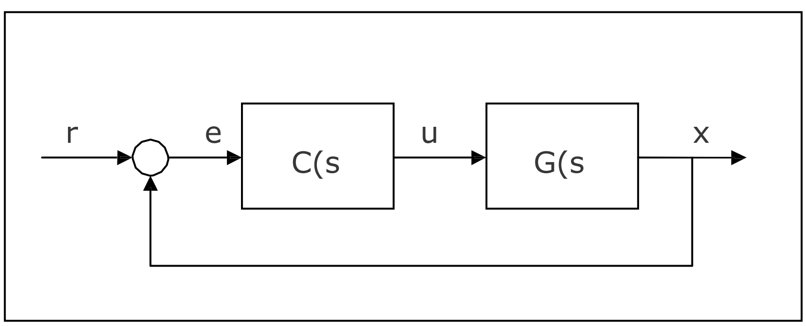


Fig. 4. Closed loop system formed of the plant G(s) and the controller, C(s)

The close loop transfer function relating the reference input, r and the plant output, x is given by

$$\frac{x(s)}{r(s)} = \frac{G(s)C(s)}{1+G(s)C(s)}$$

Substituting for G(s) and C(s) the closed loop numerator polynomial, N(s) and denominator polynomial (also termed characteristic polynomial), D(s) become

$$N(s) = -k\beta(s+b)$$

$$D(s) = (s+a)\left(s^2-\alpha\right) - k\beta(s+b)$$

Consider the characteristic polynomial, D(s). Simplifying yields

$$D(s) = s^3 + as^2 - s(\alpha + k\beta) - \alpha a - k\beta b$$

Design using pole-placement approach

We will use pole-placement approach to design the controller, C(s), that is obtain the controller parameters, k, a and b.

- Choice of desired pole location

  The closed loop system is of third order. Let us choose for convenience all poles to be equal to p. The desired characteristic polynomial, $\varphi(s)$ becomes

  $$\varphi(s) = (s+p)^3 = s^3 + 3s^2p + 3sp^2 + p^3$$

- Equate the actual characteristic polynomial and the desired characteristic polynomial

  $$D(s) = \varphi(s)$$

  Substituting for D(s) and $\varphi(s)$ yields

  $$s^3 + as^2 - s(\alpha + k\beta) - \alpha a - k\beta b = s^3 + 3s^2p + 3sp^2 + p^3$$

- Solve for the unknown controller parameters, k, a, and b by equating the coefficients of the equal powers of *s*

  $$a = 3p$$
  $$\alpha + k\beta = -3p^2$$
  $$-\alpha a - k\beta b = p^3$$

  Solving the above equations yields

$$a = 3p$$
$$b = \frac{p^3 + \alpha p}{3p^2 + \alpha}$$
$$k = -\frac{3p^2 + \alpha}{\beta}$$

Deliverables

Each student should submit a word file containing the following**:**

- The mathematical model of maglev system
- Analysis of the linear approximation model of the Maglev system in time and frequency domain using SIMULINK.
- Design of a lead-lag compensator
- Evaluation of the performance

University of Engineering & Management
Lab Manual
CISE 412: MECHATRONICS

(Term 092)

Lab # 5:

Design and Implementation of Operational Amplifier Circuits

Equipment Needed

- **Operational Amplifiers (LM 741, LM 311, or equivalent)**
- **Resistors (500 Ω, 1k Ω,1M Ω,)**
- **Variable Resistor**
- **Capacitors (22 pF, 33 pF,...)**
- **Multi-meter**
- **Oscilloscope**
- **Signal Generator**
- **Power Supply**

Introduction:

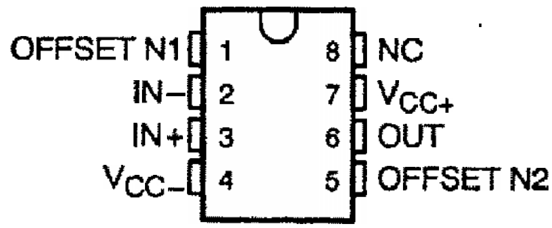
Operational Amplifiers are important devices that can be used for signal conditioning and interfacing sensors and actuators. In this lab, you will practice using the op- amp in different ways. LM 741 in a classical operational amplifier that is widely used. It comes in DIP or metallic package. The one used in this lab is an 8-Pin DIP package.

Prelab Activity 0:

Down load the Op-Amp data sheets from the manufacture's web site.

Identify the main characteristics of the LM 741.

(TOP VIEW)



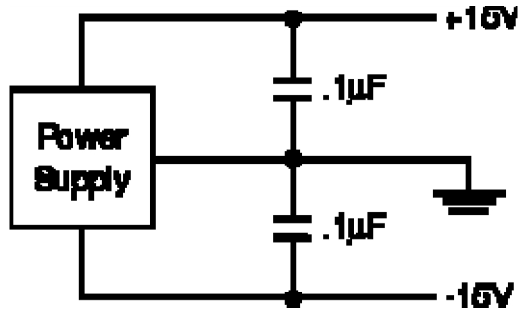
Part 1: How to connect the LM 741

Step 1:

If you have not already done so, wire the bus strips on your breadboard to provide positive power, negative power and ground buses. Whatever color scheme you have chosen for your wires, you should use the green binding post for ground, the black for -15 V, and the red for +15 V.

Step 2:

Connect a 0.1μF capacitor between the +15 V power bus and ground. Connect another 0.1μF capacitor between the -15 V power bus and ground. The power buses for your board should look like this:



These capacitors are the first of several bits of "magic" we will employ to try to avoid amomolous behavior. As we will see when we study control systems, feedback also has a dark side. In particular, feedback which becomes positive at some frequency can cause instabilities. Although we have not deliberately introduced any positive feedback, feedback can occur where we don't intend it. The purpose of these capacitors is to prevent it from occurring via the power supply, which at high frequencies is not a very ideal voltage source.

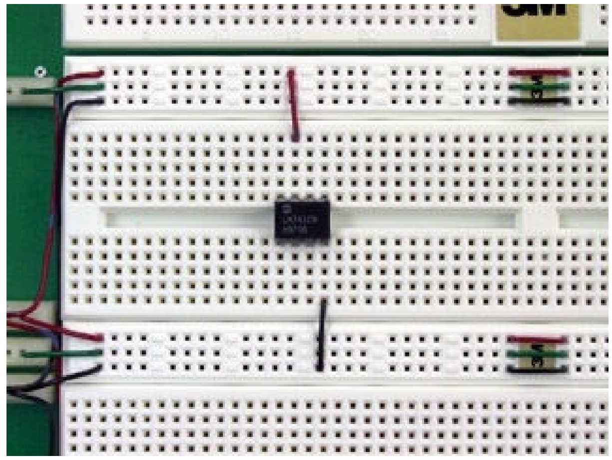
Step 3:

Plug an op-amp into the breadboard so that it straddles the gap between the top and bottom sections of the socket strip. If you have wired the power buses as suggested above, Pin 1 should be to the left.

Warning
Do not try to unplug the op-amp with your thumb and forefinger. Use IC puller.

Step 4:

Connect Pin 4 (Vcc-) to the negative power supply bus (-15 V). Connect Pin 7 (Vcc+) to the positive power supply bus (+15 V).



Step 5: Set the METER SELECTOR on the power supply to +20V. With the power supply disconnected from the breadboard, turn on the supply and adjust the left-hand voltage control until the meter reads 15 volts.

Step 6: Turn off the supply and connect the supply to the breadboard with banana plug patch cables. Connect the 0 to -20V terminal (black) to the black binding post on your breadboard, the 0 to +20V terminal (red) to the red breadboard binding post, and the COMMON terminal (light blue) to the green breadboard binding post. Note that none of the power supply output terminals are connected to ground. If we want the power supply zero volt reference connected to ground, we must make the connection ourselves.

Part 2: Non-inverting Amplifier

Pre-lab Activity 2 :

Design a non-inverting Amplifier circuit. The closed loop gain of the amplifier is required to be 2.

Lab Activity 2:

1. Select the resistors needed to implement the designed non-inverting amplifier.
2. Connect the circuit
3. Use the signal generator to provide the input to the amplifier. Use sine wave with Peak to peak value of 2Volts. Use Frequencies of 1 Hz, 100 Hz and 1000Hz.
4. Use the oscillator to display the output of the amplifier

Observations and Comments:

Part 3: Inverting Amplifier

Pre-lab Activity 3 :

Design an Inverting Amplifier circuit. The closed loop gain of the amplifier is required to be 2.

Lab Activity 3:

5. Select the resistors needed to implement the designed inverting amplifier.
6. Connect the circuit
7. Use the signal generator to provide the input to the amplifier. Use sine wave with Peak to peak value of 2Volts. Use Frequencies of 1 Hz, 100 Hz and 1000Hz
8. Use the oscillator to display the output of the amplifier

Observations and Comments:

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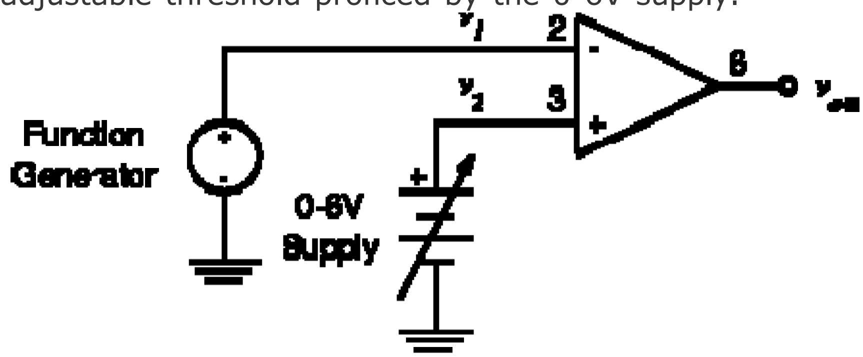
Part 3: The Op Amp as a Comparator

Step 1: With the power turned off, wire the following circuit. This will compare the function generator output with an adjustable threshold proficed by the 0-6V supply.



Step 2: Set the function generator to produce a 4 V p-p, 100 Hz triangle wave.

Step 3: Pull out the DC OFFSET control and adjust it so that the waveform has an average value of 2.5 V (i.e. the negative peaks have a value of +0.5 V).

Step 4: Connect the function generator output to **Vin** of the circuit above. Connect CH1 of the scope to **Vin** and CH2 to **Vout**. Set the CH2 VOLTS/DIV to 5. Make sure both channels of the scope are on DC.

Step 5: Turn on the power supply and set the 0-6V output to zero.

Step 6: Slowly increase the 0-6V control until **Vout** begins to change. Sketch the waveform.

Step 7: Increase $\mathbf{V_2}$ in steps of 0.4 V until **Vout** stops changing. At each step sketch **Vout**, noting the positive and negative peak values and the duration of the high and low states.

Step 8: Set $\mathbf{V_2}$ to zero and push the DC OFFSET control back in. **Vout** should be approximately a square wave. Is this what you expect?

Question: Explain the waveforms observed in this Part. Develop an expression for the *duty cycle* (the percentage of the time that the waveform is in the "high" state) as a function of

1: v_2.

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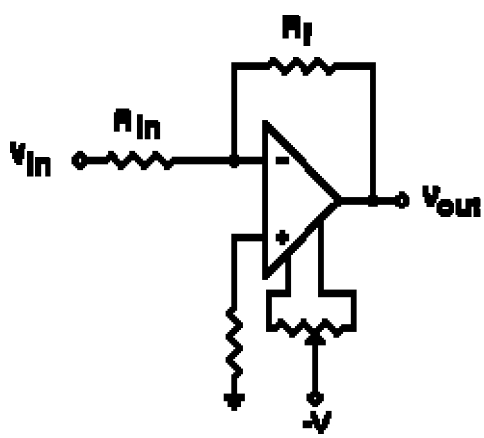
Balancing the Input Offset

Introduction

In the previous experiment (The Basic Op Amp Inverter), we learned that there are at least three basic limitations on the accuracy of an op amp circuit: the tolerance of the resistors, input offset voltage and current, and output saturation. We can't do anything about output saturation, and we can only deal with resistor tolerances by selecting resistors of the degree of precision required for a specific application. However, in those cases where it is necessary, we can make use of a feature of the basic 741 op amp to balance out the input offsets and thus remove their influence on the output voltage.

Fortunately, in most applications this is not necessary. This permits the construction of dual- and quad-op amp packages, where the offset adjustment connections are not available outside the package. However, there are some cases where the input offset must be balanced as closely as possible. Therefore, we will examine the required method in this experiment.

Schematic Diagram



The recommended circuit for balancing out the input offset is quite simple, as shown here. The offset null pins (1 and 5) give direct access to the 1K emitter resistors in the input stage, and the offset null circuit is simply a 10K potentiometer connected between them, with its slider connected to the negative power supply. This is equivalent to putting a 5K resistance in parallel with each of the 1K resistors inside the IC. The difference is that we can vary the external resistances by adjusting the potentiometer, until the voltage offset becomes zero.

Since we're dealing with the input stage of a high-gain amplifier, the output voltage will be very sensitive to potentiometer changes. Therefore, we'll use a 15-turn trimpot here.

So how do we tell when we have exactly balanced out the offset? After all, the input offset is internal to the IC, and is rated to be no more than 6.0 millivolts (0.006 V) and 1.2 milliamps (0.0002 A). These require very accurate and sensitive measuring equipment, and are inaccessible in any case.

What we can do is select R_{in} and R_f to amplify an input voltage of zero. We'll make R_{in} = 1K and R_f = 100K, and connect the input end of R_{in} to ground. This will give the overall circuit a gain of 100, and assure us that the correct output voltage should nevertheless be 0.000 volt. Any output voltage will be due to offsets in the op amp itself, and we will use the 10K trimpot to balance them out as closely as possible.

Parts List

To construct and test the offset balancing circuit on your breadboard, you will need the following experimental parts:

- (2) 1K, 1% resistors (brown-black-black-brown).
- (1) 100K, 1% resistor (brown-black-black-orange).
- (1) 10K trimmer potentiometer.

Performing the Experiment

Turn on your voltmeter and set it to measure voltages in the range of ±20 volts, and connect it to monitor the output voltage of the 741 op amp at pin 6 (the top end of the 100K resistor). Turn on power to your experimental circuit, and note the output voltage of this circuit. If the trimpot is still at one end of its range from the last experiment, the output voltage may well be quite high. This is not a problem; simply note it for now.

Adjust the trimpot over its range and note the effect on the output voltage. Then, readjust the trimpot to reduce the output voltage to below ±1.00 volt.

Reduce the range on your voltmeter to measure voltages up to ±2 volts, and then continue to adjust the trimpot to reduce the output voltage to zero.

If your voltmeter has a 200 mV range, switch down to that and use the trimpot to adjust the output voltage to as close to zero as you can. By now the adjustment will be very sensitive to slight changes, so you may have difficulty balancing out the last millivolt. If so, don't worry about it; just do the best you can.

When you have reduced the output voltage as closely as possible to zero, leave the trimpot alone and simply observe the output voltage for a few minutes. What does this observation show you?

Finally, remove the trimpot from the breadboard socket and set it aside. What is the output voltage now? Keeping in mind the op amp gain of 100, what was the effective initial input offset voltage?

When you have made your determinations, turn off the power to your experimental circuit and voltmeter and compare your results with the discussion below.

Discussion

1. Why balancing is needed?
2. How can we balance the LM 741 op-amp?

Part 5: Design and implement a summing amplifier.

The required equation is

$$Vout = -(V_1 + 2V_2)$$

The inputs are two constant voltages

- Draw the circuit diagram
- Connect the circuit
- Turn on the power supply
- Check the result and comment on it.

Part 6: Design and implement a low pass first order active filter. The required equation is

The input is a sign wave with frequencies 10Hz, 100Hz and 10000Hz.

- Draw the circuit diagram
- Connect the circuit
- Turn on the power supply
- Check the result and comment on it.
-

When you have completed this experiment, make sure power to your experimental circuit and voltmeter is turned off. Remove all of your experimental components from the breadboard socket and put them aside for use in later experiments.

Turn the power supply off during the connection of the circuit

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Lab # 6: Introduction to Boe-Bot

Objectives:

- ❖ Getting and installing the BASIC STAMP Editor
- ❖ Setting up hardware and testing the system
- ❖ Writing the first program for the Boe-Bot

Lab activities:

In this lab session, students are expected to do the following six activities. Details of the activities are available in Chapter 1 of the Boe-Bot manual

1. **Getting the software**: The instructor will provide the CD to be used in installing the BASIC STAMP Editor. You can follow the steps in pages 4-8 to download most recent version of the software.
2. **Software Installation:** to install the BASIC STAMP Editor, you need to follow the procedure in pages 10-12.
3. **Setting up Hardware and Testing the System:** Follow the details given in page 13-20.
4. **Writing the First Program:** Follow the details given in page 22-36.
5. **Projects:** Each student group must do Projects 1 and 2.

The instructor need to check that all activities are done correctly.

Deliverables:

- ❖ Lab report summarizing what was done in the lab.
- ❖ Short description and program listings for Projects 1 and 2.

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Lab # 7: Servomotors for the Boe-Bot

Objectives:
- ❖ Connect, adjust and testing the servomotors

Lab activities:
In this lab session, students are expected to do the following six activities. Details of the activities are available in Chapter 2 of the Boe-Bot manual

1. **Time Tracking and Repeat Actions**: To practice software instructions for time tracking and timed loops.
2. **Testing LEDs:** Practice instructions of the microcontroller to send outputs. Do the steps in page 48 to connect the LEDs and write a program to turn the LEDs ON and OFF.
3. **Using Pulseout and Pause** Follow the details given in page 52-58 to generate specific timing diagrams.
4. **Connecting Servomotors:** Follow the details given in page 58-66.
5. **Centering the Servos:** Follow the details given in page 66-70.
6. **Testing the Servos:**
7. **Projects:** Each student group must do Projects 1 and 2 given in page 87

The instructor need to check that all activities are done correctly.

Deliverables:
- ❖ Lab report summarizing what was done in the lab.
- ❖ Short description and program listings for Projects 1 and 2.

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Lab # 8: Assembling and Testing the Boe-Bot

Objectives:

- ❖ Build the Boe-Bot
- ❖ Test the servomotors
- ❖ Connect the speaker and test it
- ❖ Use Debug to control and test the servo speed

Lab activities:

In this lab session, students are expected to do the following six activities. Details of the activities are available in Chapter 2 of the Boe-Bot manual

1. **Assembling the Boe-Bot**: Follow the steps in 91-100 to assemble the Boe-Bot .
2. **Re-Testing the Servos:** to test the servos, Follow the steps in 101-105.
3. **Start/Rest Indicator and program**
4. **Testing Speed Control**
5. **Projects:** Each student group must do Projects 1 and 2 given in page 119.

The instructor need to check that all activities are done correctly.

Deliverables:

- ❖ Lab report summarizing what was done in the lab.
- ❖ Short description and program listings for Projects 1 and 2.

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Lab # 9: Basic Boe-Bot Navigation

Objectives:

- ❖ Program the Boe-Bot to do the basic maneuvers: Move forward, backward, rotate left, rotate right, pivot turn
- ❖ Calculate required time to move Boe-bot precise distances.
- ❖ Program Boe-Bot to accelerate and decelerate
- ❖

<u>Lab activities:</u>

In this lab session, students are expected to do the following seven activities. Details of the activities are available in Chapter 4 of the Boe-Bot manual

1. **<u>Basic Boe-Bot Maneuvers</u>**
2. **<u>Tuning the basic maneuvers</u>**
3. **<u>Calculating distances</u>**
4. **<u>Ramping maneuvers</u>**
5. **<u>Subroutines for maneuvers</u>**
6. **<u>Building complex maneuvers in the EEPROMS</u>**
7. **<u>Projects:</u>** Each student group must do Projects 1 and 2 given in page 159.

The instructor need to check that all activities are done correctly.

<u>Deliverables:</u>

- ❖ Lab report summarizing what was done in the lab.
- ❖ Short description and program listings for Projects 1 and 2.

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Lab # 10: Boe-Bot Navigation with Whiskers

Objectives:

- Build Tactile switches using whiskers
- Program Boe-Bot to use the tactile switches in navigation
-

Lab activities:

In this lab session, students are expected to do the following seven activities. Details of the activities are available in Chapter 5 of the Boe-Bot manual

1. **Building and Testing the Whiskers**
2. **Testing the Whiskers**
3. **Navigation with Whiskers**
4. **Projects:** Each student group must do Projects 1 and 2 given in page 189.

The instructor need to check that all activities are done correctly.

Deliverables:

- Lab report summarizing what was done in the lab.
- Short description and program listings for Projects 1 and 2.

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Lab # 11: Boe-Bot Navigation with Photoresistors

Objectives:

- ❖ Build and test photoresistor circuit
- ❖ Program Boe-Bot to use the photoresistor in navigation
- ❖

Lab activities:

In this lab session, students are expected to do the following seven activities. Details of the activities are available in Chapter 6 of the Boe-Bot manual

5. **Building and Testing photoresistor circuit**
6. **Avoiding Shadows**
7. **Navigation with photoresistor**
8. **Roaming toward the light**
9. **Projects:** Each student group must do Project 1 given in page 228.

The instructor need to check that all activities are done correctly.

Deliverables:

- ❖ Lab report summarizing what was done in the lab.
- ❖ Short description and program listings for Project 1.

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Lab Manual

Title of Course: Air Conditioning & Refrigeration Lab
Course Code: ME695 A
L-T –P Scheme: 3P **Course Credits: 2**

Objectives:
This course deals with the design and implementation of refrigeration and air conditioning systems and building services. The objectives of the course is to enable the student;

- To understand the principles of refrigeration and air conditioning.
- To calculate the cooling load for different applications.
- To select the right equipment for a particular application.
- To design and implement refrigeration and air conditioning systems using standards.
- Energy Conservation and Management.

Learning Outcomes:

At the end of the course, the student will be able to
1. Introduce students to HVAC technology, engineering, research, systems, system designs, energy impacts, and overall goals.
2. Develop understanding of the principles and practice of thermal comfort
3. Develop understanding of the principles and practice and requirements of ventilation
4. Develop generalized psychrometrics of moist air and apply to HVAC processes.
S Review heat transfer and solar energy engineering and develop techniques for the analysis of building envelope loads
6. Review thermodynamics and thermal systems engineering and develop understanding of vapor compression and possibly heat-driven refrigeration systems and evaporative cooling systems.
7. Review fluid mechanics and engineering and develop techniques for the analysis of duct and piping systems and room air distribution systems and review associated turbomachines and control systems.
8. Present overview of methods to predict seasonal and annual energy consumption and overview design guidelines and standards for energy efficient buildings and building energy systems

Course Contents:
At least 4 (four experiments) to be conducted of which No. 4 is compulsory.
1. Study of a Domestic Refrigerator.
2. To determine the COP and tonnage capacity of the chilling plant.
3. To determine COP and tonnage capacity of a Air conditioning system.

4. To determine the COP and tonnage capacity of a Mechanical Heat Pump.
5. To determine the COP and tonnage capacity of an Ice plant.
6. To study the cut sectional model of reciprocating, rotary and centrifugal compressor.
7. To study various controls used in Refrigeration and Air-conditioning system.
8. To study different psychometric process & chart.

Text Books:

i. Refrigeration and Air Conditioning by Jordan and Priester, TH 7687. J6 1985
ii. Heating, Ventilating and Air Conditioning – Analysis and Design by McQuister & Parker, TH 7222.M38 1994
iii. Faber and Kell’s Heating and Air Conditioning of Buildings by Martin and Oughton, TH 7222.M35 1995

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lab Manual

UNIVERSITY OF ENGINEERING & MANAGEMENT, JAIPUR

Lab Manual

REFRIGERATION & AIR CONDITIONING

LIST OF EXPERIMENTS

S.No.	NAME OF EXPERIMENTS
1.	Study of a Domestic Refrigerator.
2.	To determine the COP and tonnage capacity of the chilling plant.
3.	To determine COP and tonnage capacity of a Air conditioning system.
4.	To determine the COP and tonnage capacity of a Mechanical Heat Pump.
5.	To determine the COP and tonnage capacity of an Ice plant.
6.	To study the cut sectional model of reciprocating, rotary and centrifugal compressor.
7.	To study various controls used in Refrigeration and Air-conditioning system.
8.	To study different psychometric process & chart.

Note : 1. At least ten experiments are to be performed in the semester.

2. At least seven experiments should be performed form the above list. Remaining three experiments may either be performed from the above list or as designed & set by the concerned institute as per the scope of the syllabus.

EXPERIMENT NO.1

Aim: - Study of a Domestic Refrigerator.

Apparatus used: -

Refrigeration test Rig consists of (Compressor (rotary), Air cooler condenser, Capillary tube, Evaporator coil, voltmeter, current meter, voltmeter, energy meter, Thermocouple pressure gauge, vacuum gauge, and freezer

Description of the Test Rig:-

The experimental refrigeration cycle test rig consist of a compressor unit, condenser, evaporator, cooling chamber, controlling devices and measuring instruments those are fitted on a stand and a control panel. The apparatus is fabricated in such a way; to refrigeration system hermetically sealed compressor is fitted on stand with the help of flexible foundation bolts to minimize vibrations. Electric power input to the compressor is given through thermostatic switch.

Temperature sensor details: -

1. T_1 = Temperature Sensor : Fixed at Compressor Discharge Line
2. T_2 = Temperature Sensor : Fixed after Condenser
3. T_3 = Temperature Sensor : Fixed after Capillary Tube
4. T_4 = Temperature Sensor : Inside freezer
5. T_5 = Temperature Sensor: Fixed at Compressor Suction Line.

Theory: -

The coefficient of performance of refrigeration plant is given by the ratio of heat absorbed, by the refrigerant when passing through the evaporator or the system, to the working input to the compressor to compress the refrigeration.

Co-efficient of Performance = Heat removed by refrigerant / Power input

Cop $_{plant}$ = m Cp ΔT / K. Wh

Where

m = mass of water kept in cooling chamber Cp = specific heat of water = 4.18 Kj /Kg K ΔT = temperature of cooling water K

Kwh = 1000 x V.I x 60 x 60 KJ = V.I x KJ = V.I x 3600 KJ

KWH = reading of energy meter.

Co-efficient of refrigeration cycle is given by the ratio of net refrigeration effect to the power required to run the compressor.

COP (cycle) Net refrigerant effect in unit time / Power input in unit time

= m CpΔT / KwH

Where (Q), = mass flow rate of the refrigerant m^3 / sec Cp

= Specific heat of refrigerant

ΔT= Temperature difference (T_1-T_3)

KWH = Kilowatt hours energy meter reading.

The co-efficient of performance of a refrigeration system is given by the ratio of heat absorb, to the work input.

COP = Heat removed by refrigerant / Power input

= m x CpΔT / K.Wh

Where,

m = mass of water kept in cooling chamber Cp = specific heat of water = 4.18 Kj /Kg K ΔT = temperature of cooling water K

Kwh = power consumed by the compressor in unit time.

Tonnage capacity:

The capacity of a refrigeration machine is the refrigeration effect in a given time from a body. This capacity of machine is given by standard commercial ton of refrigeration. This is called as refrigerating effect i.e. melting of 1 ton of ice at 0 C in 24 hours.

TR = 336 x 1000 / 24 x 60 x 60 = 3.88 Kj / sec.

Tonnage capacity of the machine = Net refrigerating effect of machine / 3.88

$= m \times Cp\Delta T / 3.88$

Procedure:

Switch on the compressor and let it run for considerable time. Say for automatic cut off by thermostatic switch at normal position. Fill a measured quantity of water in ice cane (100 gm) and put it into cooling chamber. Measure initial temperature of water before putting into cooling chamber by noting the value of $T4$ as $T4i$ note down the energy meter reading. Wait till compressor starts. Compressor shall be started automatically as and when temperature of cooling chamber falls up to adjusted temperature.

After starting the compressor note down the temperature $T4$ at the interval of every 15 minutes and note it down as $T4C$.

Note down the power consumed by compressor till ice forms i.e. temperature T4 should reach O C. At 0 C of ice cane note down all the temperature i.e. T1, T2, T3, T4and T5. Also note down the suction and discharge pressure by the respective gauges. Note down the flow rate of refrigerant by rotometer.

Hence Refrigeration effect TR= 336 x 1000 / 24 x 14000 KJ / hour Where

latent heat of fusion of ice = 336 KJ / kg.

Tonnage capacity of the plant

= Net refrigerant effect of plant / 14000 KJ / hour

= m x $Cp\Delta T$ / 14000

Where, m = mass of water kept in cooling chamber Cp
= initial and final heat of water = 4.18

ΔT = initial temp. T_c = final temperature water T_1- T_2

T_1 = initial temperature of water.

T_c = final temperature of water

Tonnage capacity of cycle

= Net refrigerating effect produced by refrigerant / 14000 Kj /h

= m x $Cp\Delta T$ / 14000 tones

Where, m = mass flow rate of refrigerant

Cp = Specific heat of refrigerant

ΔT = Temperature of refrigerant at discharge and suction = T_1, T_5

Observation Table

Sr no.	Energy meter reading			Mass of water	Temperature of chilling water initial	T1	T2	T3	T5
	Initia l	Fina l	C = (a-						

Calculation:

1- COP (plant) = m x CpΔT / KWH

Where m = Mass of water kept in ice cane (kg)

Cp = Specific heat of water = 4.18
$\Delta T = T_{4i} - T_{4C}$
KWH = Total energy meter reading
(Final value – initial value of energy meter.)

Sample Calculation

COP= m. CpΔT / KWh = (20 x 4.187 x 12) / (245 x 3.9)

Tonnage capacity = COP / 3.88 TR

Result: -

Viva Question: -

1. Mention the advantages of vapour compression refrigeration system?
2. Describe the mechanism of a simple vapour compression refrigeration system?
3. What is sub cooling?
4. What is superheating?
5. Why is superheating considered to be good in certain cases?

EXPERIMENT NO.2

Aim: - To determine the COP and Tonnage capacity of the chilling plant.
Apparatus: - Compressor, Condenser, Evaporator, Capillary Tube, Ammeter, Voltmeter.

Theory: -

The apparatus consist of a hermitically sealed compressor which is fitted on the base of a M.S stand on a wooden stand. The compressed refrigerant from the compressor flows towards the air cooled finned condenser. After the condenser condensed refrigerant is collected in the receiver tank and from receive it passing through a filter drier and capillary tube and enter into evaporator (cooling coil) unit. Evaporator unit is a shell and tube type heat exchanger, which consist of stainless steel vassal and evaporator coil is wounded in this vassal (tank) an arrangement is provided to flow water to be chilled in this tank. Flow rate of the chilled water is measured by using a Rota meter. Refrigerant after the evaporator unit is sucked back in compressor. Power input to the compressor is measured by using the energy meter which giving power consumed by compressor directly. A pressure and vacuum range is fitted on the control panel to measure pressure at the discharge and suction respectively. Digital temperature indicator is also fitted on control panel to measure temperature at different positions. A selector switch is provided over these by turning its position respective temperature may be noted.

Coefficient of Performance

The Co-efficient of performance of a chilling plant is given by the ratio of heat absorb to the work input.

COP = Heat removed by refrigerant / Power input

$= m \times Cp\Delta T / K.Wh$

Where,

m = mass of water kept in the evaporator unit / mass flow rate of the water. Cp = specific heat of water = 4.18 Kj /Kg K

ΔT = temperature difference of chilling water

Kwh = power consumed by the compressor in unit time.

Tonnage capacity:-

The capacity of a refrigeration machine is the refrigeration effect in a given time from a body. This capacity of machine is given by standard commercial tone of refrigeration. This is called as refrigerating effect i.e. melting of 1 ton of ice at 0 C in 24 hours.

TR= 336 x 1000 / 24 x 60 x 60 = 3.88 KJ / sec.

Tonnage capacity of the machine = Net refrigerating effect of machine / 3.88

= m x CpΔT / 3.88

Temperature sensor details: -

1. T_1 = Temperature Sensor : Fixed at Compressor Discharge Line
1. T_2 = Temperature Sensor : Fixed after Condenser
2. T_3 = Temperature Sensor : Fixed after Capillary Tube
3. T_4 = Temperature Sensor : Inside Water Cooling Tank
4. T_5 = Temperature Sensor : Fixed at Compressor Suction Line.

Procedure:

Switch on the compressor and let it to run for considerable time, until thermostatic switch starts functioning. Now fill the measured quantity of the water in evaporator or allow water to flow through the tank. Note down the reading of energy meter and initial temperature of chilling water and start stop watch and take the readings required for calculations in the table for certain interval.

Observation Table

Sr no.	Energy meter reading			Mass of water	Temperature of chilling water initial	T1	T2	T3	T5
	Initial	Final	C = (a-b)						

Sample Calculation

COP

$= m.\ Cp\Delta T\ /\ KWh = 20 \times 4.187 \times (12)\ /\ 245 \times\ 3.9$

Tonnage capacity

$= COP\ /\ 3.88$ TR

Precautions: -

1. Keep all the hand shut off valves tight closed until not required.
2. Keep small flow rate of the chilling water.
3. Compressor should not continuously for long time that should be hermetically cut down by the by the thermostat switch.
4. Do not disturb the copper piping, because it may cause leakage of the refrigerant from the system.

Result: -

Viva Questions: -

- What is the purpose of chilling plant?
- What is the use of thermostat control in ice plant?
- What are the applications of ice plant?
- What is freezing Drying?
- What is defrosting?

EXPERIMENT NO: 3

Aim: - To Determine COP and Tonnage capacity of a Air Conditioning system.

Apparatus: - Compressor, Condenser, Evaporator, Capillary Tube, Ammeter, Voltmeter.

Theory: -

Air conditioning equipment is used to maintain controlled atmospheric conditions as per required. The controlled atmospheric conditions may be required for human comfort or manufacturing processes of engineering goods. Air conditioning systems are classified in two groups.

1. Packed Units
2. Central Unit

A packed unit is self-contained unit, because complete unit including compressor, evaporator, condenser, fan motor etc. are kept in a common enclosure. Capacity of packed or window AC is 1 to 1.5 T.R. This AC is mounted with the room which is required for controlled atmosphere.

A window AC mainly consists of following sub-assemblies:

1. System assembly includes compressor, condenser, evaporator, expansion device, and filter.
2. Motor with blower & fan assembly includes, a double ended shaft motor, a fan and a motor and suitable bracket for it.
3. Cabinet and air distributing assembly – it includes a cabinet as enclosure for whole system, an air distributing system.
4. Control panel assembly – it includes the switched those required to control the entire AC system as per the requirement, IC temperature, humidity etc.

The AC Test Rig is designed and fabricated, to determine the performance and to study its working principle. The AC test Rig consist a 1.5 T sealed compressor unit, a finned condenser (heating coil) and evaporator (cooling coil), a double ended (shaft) motor to run fan and blower simultaneously and fitted on a wooden stand and properly covered by grill. A duct is assembled along with blower unit as a carrier of comfort air, the velocity of the air passing through the coil is measured by using a pilot tube fitted in duct itself and connected to V-tube manometer which is fitted on control panel. The control panel is fitted over compressor and fan- blower assembly. Control panel consist of 1 phase energy meter to measure power consumed by compressor, a Rota meter to measure flow rate of refrigerant pressure gauge to measure pressure of discharge side compound vacuum gauge to measure suction side pressure, a digital temperature indicator to measure temperature at various places. The desired temperature find out by changing position of selector switch with it. A voltmeter and ammeter is also fitted on control panel.

Specifications of AC Test Rig:

Compressor	:	Hermetically sealed compressor 1.5 T.R. with starting and running capacitor.
Refrigerant	:	R – 22
Pressure gauge	:	0.300 PSI
Suction gauge	:	- 30-0-150 PSI
Rota meter	:	0-5 L L PM
Fan blower motor	:	1 / 30 HP 1- 0
Condenser & evaporator	:	Double row finned.

Window type air conditioner

The performance of an air-conditioning system is expressed in terms of co-efficient of performance. And COP is the ratio of net refrigerating effect and power supplied to do the work i.e.

$$COP = R_n / W$$

Where

R_n = heat removed by system

$= m.\ Cp\Delta T$

Where

m= mass of air supplied / minute.

Cp = Specific heat of air

ΔT = Difference in temperatures.

$T_1 - T_2$

T_1 = Surrounding temperature

T_2 = Air duct temperature

Mass of circulated air can be calculated by m

$= V_a / V_{sa}$

Where

V_a = Quantity of air supplied m3 / min.

V_{sa} = Area of duct x velocity of the air.

P (stag) = Stagnation or total pressure. P (stat) = Static pressure

W = Power input time and measured by energy meter reading.

Procedure: -

Switch on the power supply to system i.e. start the compressor simultaneously start fan blower motor also. Now compressed refrigerant passing through the condenser and after condensing. It goes to evaporator, where due to cooling effect air, which is sucked by blower cools. After few minute the air at the outlet of air duct will become cool at that time. And also measure the static and total pressure by using V-tube manometer and pilot tube.

Temperature sensor details: -

1. T_1 = Temperature Sensor : Fixed at Compressor Discharge Line
2. T_2 = Temperature Sensor : Fixed after Condenser
3. T_3 = Temperature Sensor : Fixed after Capillary Tube
4. T_4 = Temperature Sensor : Inside Cooling Tank
5. T_5 = Temperature Sensor : Fixed at Compressor Suction Line.

Observation Table

S. No.	T1	T2	P stag	P stat	P Total	No. of revolution	W = Total power consumed

Sample Calculation

COP = m. CpΔT / KWh = 20 x 4.187 x (12) / 245 x 3.9

And C O P = m. CpΔT / W

Precautions: -

1. Run the system for quite some time before taking readings.
2. Note down number of revolutions of energy meter carefully with the help of stop watch.
3. Insure considerable cooled air output from air duct.
4. The system should not switch OFF immediately after once switched ON.
5. The control valve of pressure and compound gauge should open partly; when it is required to measure pressure otherwise valves must be closed.
6. Do not twist any pipe line and handle all switches valves very carefully only as and when required.

Result: -

Viva Questions: -

1. What do you mean by conditioning of air?
2. Explain the working principle of air conditioning system?
3. What are the different types of air conditioning system?
4. What are the various controls system used in air conditioning system?

EXPERIMENT NO. 4

Aim: -To determine the COP and Tonnage capacity of a Mechanical Heat pump.

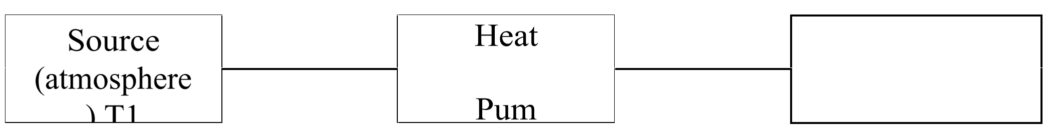
Apparatus Used: - Compressor, Condenser, Evaporator, Capillary Tube, Ammeter, and Voltmeter.

Theory: -

A mechanical heat pump is mechanical equipment which is used to supply the heat to the system, where it is installed, and maintain its temperature more than that of surrounding. Mechanical heat pump absorbs heat from surrounding (atmosphere). Work input to a heat pump is supplied by compressor. With reference to the fig. Heat Q_2 is supplied to the room and temperature T_2 is maintained above the T_1 whereas heat Q_1 is absorbed by the surrounding. Hence performance of heat pump is given by

$$C\,O\,P = Q / W$$

Where Q = heat removed from the system.
W = work supplied in compressor.



Theory: -

Coefficient of performance of mechanical heat pump is the ratio of heat removed by it and work supplied i.e.

$$C\,O\,P = Q / W$$

Where,

Q = heat removed W
= m. CpΔT watts.

m = mass of water in heating (condensation) or cooling (evaporator) tank.

Cp = Specific heat of water kJ / kg. K

ΔT = Initial and final temperature of water for unit time K.
W = Power consumer by compressor of unit time W.

= energy meter reading.

Technical Specification: -

Compressor = hermetically sealed of 1/3 T
Discharge pressure gauge = 0-3 - PSI Suction
pressure gauge = - 30-0-150 PSI

T_1 & T_2 are temperature of discharge suction side 0 C
T_3 and T_7 are temperature of water 0 C

T_2, T_3, T_5 and T_6 are temperature of inlet and outlet of heating and cooling coil.

Procedure: -

Fill measured quantity of water in condenser and evaporator banks and note down the initial temperature of tanks by means of selector switch as T_{4i}. Now note down the energy meter and switch on the power supply to compressor. Run the compressor for unit time (say 30 minute) and note down the change in temperature of T_{4f} and energy meter reading. Above procedure may be repeated for cooling coil also.

Temperature sensor details: -

1. T_1 = Temperature Sensor: Fixed at Compressor Discharge Line
2. T_2 = Temperature Sensor: Fixed after Condenser
3. T_3 = Temperature Sensor: Inside hot water tank
4. T_4 = Temperature Sensor: fixed after capillary tube
5. T_5 = Temperature Sensor : Inside cold water tank
6. T_6 = Temperature Sensor : Fixed at Compressor Suction Line

Observation Table

S. no.	Time	T_{3I}	T_{4f}	Mass of water in condensation	Mass of water in evaporator	Energy meter reading

Calculation:

Q = m.Cp T = ……….Watts W=………Watts

COP = Q/W ………%.

Precautions: -

1. Use stabilized power supply.
2. Drain the water from tanks after performing experiment.
3. When apparatus is no longer in use condense the refrigerant.
4. Use stop watch for time measurement.

Result: -

Viva Questions: -

1. Explain the working principle of mechanical heat pump?
2. What is the COP of mechanical heat pump?
3. What is the difference between air conditioning and mechanical heat pump?
4. How the cooling and heating is done in mechanical heat pump?

Experiment No.5

Aim: - To determine the COP and Tonnage capacity of an Ice Plant.

Apparatus: - Compressor, Condenser, Evaporator, Capillary Tube, Ammeter, and Voltmeter.

Introduction: -

Ice plant machine is used to manufacture ice. Solid state of water is called the ice. Working principle of ice plant is based on compression system. An ice plant consists of following components.

1. Compressor:-Compressor increases the pressure and temperature of refrigerant and pumps it out towards condenser in vapour form. After condensation that refrigerant goes to evaporator and again converted into vapour form. From the evaporator refrigerant is sucked by the compressor during the suction stroke and again being pump to condenser.
2. Condenser: - This is a heat exchanger and made of copper tubes of U-shape refrigerant flows through these tubes & getting condensed by the surrounding air to forced or natural air according to the capacity of the plant. In condenser vapour refrigerant is converted into liquid form.
3. Receiver Tank:- This is one sort of storage tank, which is filled by the liquid refrigerant. This tank is made of steel to withstand the high pressure and get stored. The main advantage of receiver in only during the shut off period of plant, at which time refrigerant can keep safe after condensation.
4. Filter driver: - To absorb moisture from the refrigerant filter drier is used. This is made of brass and filled by silica jell or activated alumina.
5. Expansion service: - For expansion of refrigerant in evaporated expansion device are used. There are two types of expansion devices commonly in use, (I) expansion valve, (II) capillary tube. Capillary tube is a copper tube of very small size. Due to its small size gas is form in is end portion which causing low temperature in evaporator.
6. Evaporator: - This is made of U-shaped tubes. In these tubes refrigerant circulated. Evaporator is an ice plant is fitted next to expansion device. The refrigerant in evaporator converted into vapour form and in result low temperature creating in surrounding, due to heat transfer. Evaporator also called as cooling coil or freezing unit.

Theory: -

The ratio of useful heat to work input is called the co-efficient of performance of a refrigerating machine i.e.

COP = Heat output / Power input

= m. $Cp\Delta T$ / Kwh

Where

m = Mass of water is ice cane in kg.

Cp =Specific heat of water = 4.18

ΔT = Temperature drop of ice cane water in unit time, k

kwh = Power consumed by the compressor in unit time.

Procedure: -

Fill the water in ice box and add the solid salt in it, which that the gravity of brine becomes 1.2. Fill the water in ice canes. The measured quantity of water should be filled. And keep the ice canes in brine tank and close the door. Switch on the power supply to compressor, at the time of starting note down the initial temperature of ice cane water and energy meter reading. Also switch on the stop on the stop watch take the readings of ice cane temperature and energy meter at the interval of 5 minutes. Take enough set of readings for considerable difference in temperature.

Switch off the compressor and drain the ice can water.

Observation Table: -

Sr. No.	Mass of water (kg)	Temperature			Energy meter		Time (sec)
		Initial	Final (b)	ΔT (b-a)	Initial	Final	

Applications: -

Experimental ice plant unit consist of a hermetically sealed compressor which is fitted on a press wood foundation and M.S stand. Discharge pipe of compressor goes to condenser. From here refrigerant flows towards evaporator or ice tank, through the receiver tank, drier filter and capillary tube. Condenser is of fin type and made of U-shaped copper tubes in rows. A fan motor is fitted at stand to supply forced air to condenser to increase heat transfer rate. Ice tank consist is a brine tank and ice cans, those are packed in an insulation box. Refrigerant flow towards compressor from the evaporator coil. Thermocouples are embedded on different positions. Thermocouple number T1 at selector switch indicated the temperature of discharge side, T2 after condensation, T3 ice can water temperature, T4 at the end of evaporator coil and T5 at control panel is also provided which consist, energy meter, digital temperature indicator, ammeter, voltmeter, pressure gauge and suction gauge. Hand shut off valves are connected with pressure and suction gauge. By opening these valves pressure of discharge or suction side can be checked as and when required. Density of brine is measured with the help of hydrometer.

Calculations: -

q = Heat removed by refrigerant in unit time = m. Cp. ΔT = ………………….

W = Power consumed by compressor in unit time = …………..…………...

COP = q / w

Precautions: - Insure correct gravity of the brine solution

- Measure time precisely
- Store the refrigerant in receiver tank
- Drain water from ice canes
- Do not open the door of ice box
- Keep thermocouple well in deep in ice cane

Results:--

Viva Question:

1. What is the working principle of ice plant?
2. What is the role of brine in ice plant?
3. Why ammonia is used as a refrigerant in ice plant?
4. Which refrigerant is mostly used in ice plant & why?
5. What is TR of ice plant?

EXPERIMENT NO-06

Aim: - To study the cut sectional model of reciprocating, rotary and centrifugal compressor.

Apparatus used: - Cut sectional Model of Reciprocating, Centrifugal and Rotary compressor

1. Reciprocating compressor:

Theory: -

The compressors in which the vapour refrigerant is compressed by reciprocating motion of the piston are called reciprocating compressors. These compressors are used for refrigerant which have comparatively low volume per Kg and a large differential press. Such as NH_3 (R-717), R-12, R-22 and CH_3Cl (R-40). The reciprocating compressors are available in sizes as small as ½ KW which are used in small domestic refrigeration and up to about 150 KW for large capacity.

The two types of reciprocating compressor in general are: -

1.1 Single acting vertical compressor.
1.2 Double acting horizontal compressor.

The single acting compressors usually have their cylinder arranged vertically radially or in 'V' or 'W' form. The double acting compressors usually have their cylinder arranged horizontal.

Working: -

When the piston moves downwards, the refrigerant left in the clearance space expands. Thus, the volume of the cylinder increase and the pressure inside the cylinder decreases. When the pressure become slightly less than the valve gets opened and the vapour refrigerant flows into the cylinder. This flow continuous until the piston reaches the bottom of the stroke. At bottom of the stroke, the suction valve closes because of spring action. Now, when the piston moves upwards, the volume of the piston moves upwards, the volume of the cylinder decreases and the pressure inside the cylinder increases. When the pressure inside the cylinder becomes greater than that on the top of the discharge valve, the discharge valve gets opened & the vapour refrigerant is discharged into the condenser and the cycle is repeated.

1. ***Work done during isothermal compression*: -**

Work done during suction stroke: - W_1 = Area A B B' A' = p_1v_1

Work done during Compression: - W_2 = Area B C_1 C_1' B' = p_1v_1 loge (v_1 / v_2)

Work done during Discharge: - = 2.3 m RT_1 log $_r$

2. ***Work done during polytropic compression*: - (p v^n = Constant)**

Work done during suction stroke: - W_1 = Area A B B' A' = p_1v_1
Work done during Compression: - W_2 = Area BCC' B' = p_2v_2-p_1v_1/n - 1
Work done during Discharge: - W_2 = Area CDA'C = p_2v_2

3. *Work done during Isentropic Compression: -*

W = y / y-1 x m cp (y-1 / y) (T_2-T_1) = m cp (T_1-T_2)

2. Rotary compressor

Theory: - In rotary compressor, the vapour refrigerant from the evaporator is compressed due to movement of blades. The rotary compressors are positive displacement type compressor. Since, the clearance in rotary compressors is negligible; therefore, they have high vol. These may be used for refrigerants like R- 12, R-22, and R-144 & NH_3.

The two types of rotary compressors are: -

2.1 Single stationary blade type
2.2 Rotating blade type

Working: -

Single stationary blade type

It consists of a stationary cylinder, a roller and a shaft. The shaft has an eccentric on which the roller is mounted. A blade is set into the slot of a cylinder in such a manner that it always maintains contacts with a sloter by means of a spring. The blade moves in and out of the slot to follow the rotor when it rotates. Since the blade separates the suction and discharge parts, therefore it is often called a sealing blade. When the shaft rotates, the roller also rotates the roller rotates so that it always touches the cylinder wall.

Rotating Blade type

It consists of a cylinder and a slotted rotor containing a number of blades. The centre of the rotor is eccentric with the centre of the cylinder. The blades are forced against the cylinder wall by the centrifugal action during the rotation of the motor.

The low pressure and temperature vapour refrigerant from the evaporator is drawn through the suction port. As the rotor turns, the suction vapour refrigerant entrapped between the two adjacent blades is compressed. The compressed refrigerant at high pressure and temp is discharged through the discharge port to the condenser.

Centrifugal Compressor

The centrifugal compressor increases the pressure of low pressure vapour refrigerant to a high pressure by centrifugal force. The centrifugal compressor is generally used for refrigerants that require large displacement and low condensing pressure, such as R-12 is and R-113. However, the refrigerant R-12 is also employed for large capacity applications and low-temperature applications.

Theory:-

A single stage centrifugal compressor, in its simplest form, consists of an impeller to which a number of curved vanes are fitted symmetrically. The impeller rotates in an air volute casing with inlet and outlet points.

The impeller draws in low pressure vapour refrigerant from the evaporator. When the impeller rotates, it pushes the vapour refrigerant from the centre of the impeller to its periphery by centrifugal force. The high speed of the impeller leaves the vapour refrigerant at a high velocity at the vane tips of the impeller. The kinetic energy thus attained at the impeller outlet is converted into pressure energy when the high velocity vapour refrigerant passes over the diffuser. The diffuser is normally a vane less type as it permits more efficient part load operation which is quite and it further converts the kinetic energy into pressure energy before it leves the refrigerant to the evaporator.

Viva Questions

1. What is the effect of clearance volume in reciprocating compressor?
2. Draw ideal and actual P-V diagrams for a reciprocating compressor?
3. On what factors does the volumetric efficiency of a compressor depend?
4. What is the effect of compression index and the discharge pressure on volumetric efficiency?
5. What is a multi-stage compressor? Give its advantages.
6. What do you understand by hermetic sealed compressor? Give its advantages.

EXPERIMENT NO.07

Aim: - To study the various controls used in Refrigeration and Air conditioning system.

Apparatus used: - Schematic diagrams of Refrigeration and Air Conditioning controls.

Theory: -

The controls are very essential for satisfactory and economical working of a refrigerant. The electrical connection diagram of a domestic refrigerator is shown in fig. The refrigerant is fitted with following controls.

1. **Starting Relay: -**

The starting relay is used to provide the necessary starting torque required to start the motor. It also disconnects the starting winding of the motor when the motor speed increases. When the compressor motor is to be started, the thermostat is in closed position. When the electric supply is given, an electric current passes through the running winding of the motor and the starting relay. Due to the flow of electric current through relay coil & due to electromagnetism, its armature is pulled thereby closing the starting winding contacts. The current through starting winding provides the starting torque and the motor starts. As, the motor speed increase, the running winding current decrease. The current in the starting relay is no longer able to hold the relay and it gets released thereby opening the starting winding contacts. Thus, the starting winding gets disconnected.

2. **Overload protector : -**

The basic function is to protect the compressor motor winding from damage due to excessive current, in the event of overloading or due to some fault in the electric circuit. It consists of a bimetallic strip. During the normal working of the compressor, the contacts are closed. Whenever there is any abnormal behavior, the bimetallic strip gets heated and bands, thereby opening the motor contacts, and de- energizing it. The overload protector is fitted on the body of the compressor and operates due to the combined action of heat produced when current passes through the bimetallic strip and a heater element, and heat transferred from the compressor body. It may be noted that the abnormal behavior of compressor may be due to low voltage, high voltage, high load, low suction pressure, high suction & discharge pressure.

3. Thermostat: -

A thermostat is used to control the temperature in the refrigeration. The bulb of the thermostat is clamped to the evaporator or Freezer. The thermostat bulb is charged with few drops of refrigerant. The thermostat can be set to maintain different temperature at a time. When the desired temperature is obtained, the bulb of the thermostat senses it; the liquid in it compresses and operates the bellows of the thermostat and open compressor motor contacts. The temperature at which motor stops is called cut-out temperature. When the temperature increases, the liquid in the bulb expands thereby closing the bellow contact of the compressor motor. The temperature, at which compressor motor starts, is called cut-in temperature. A thermostat is very crucial in operation of refrigerator as the running time of compressor is reduced considerably thereby cutting the operation cost as well as enhancing the compressor life due to non-continuous working.

Viva Questions: -

1. Describe the functioning of various controls in a refrigerator?
2. What is Thermostat?
3. What is over load protector?
4. What is starting relay?
5. What is the Function of over load protector?

EXPERIMENT NO. 08

Aim: - To study different psychometric process & chart.

Apparatus Used: - Psychometric Process chart.

Theory: - The psychometric is a branch of Engineering Sciences which, deals with the study of moister mixed with water vapour or humidity.

The various psychometric processes involved in air conditioning to vary the psychometric properties of air according to the requirement are as follows:

(i) Sensible Heating –

The heating of air, without any change is its specific humidity is known as sensible heating. Let air at temperature t_{d1} passes over a heating coil of temperature t_{d3}. It may be noted that the temperature of air leaving the heating coil (t_{d2}) will be less that t_{d3}. The process of sensible heating on psychometric chart is shown by horizontal line 1-2, extending left to right. The point 3 represents the surface temperature of the heating coil.

The heat absorbed by the air during sensible heating may be obtained from the psychometric chart by the enthalpy difference (h_2 - h_1). It may be noted that the specific humidity during the sensible heating remains constant (W_1-W_2). The dry bulb temperature increases from t_{d1} to t_{d2} and relative humidity reduces from $\varphi 1$ to $\varphi 2$ and relative humidity reduces from $\varphi 1$ to $\varphi 2$. The amount of heat added during sensible heating may also be obtained from the relation.

Heat added: $q = h_2 - h_1$

$= C_{pa} (t_{d2} - t_{d1}) + W C_{ps} (t_{d2} - t_{d1})$

$= (C_{pa} + W C_{ps} (t_{d2} - t_{d1}) = (t_{d2}-$

$t_{d1})$ $q = 1.022 (t_{d2} - t_{d1})$ kJ/kg

(ii) Sensible cooling –

The cooling of air without any change in its specific humidity is known sensible cooling. Let air at temperature t_{d1} passes over a cooling coil of temperature t_{d3} as shown.

1. It may be noted that the temperature of air leaving the cooling coil (t_{d2}) will be more than t_{d3}. The process of sensible cooling is shown by horizontal line 1- 2 extending from right to left. The point 3 represents the surface temperature of the cooling coil. The heat rejected by air during sensible cooling may be obtained from the psychometric chart by the enthalpy difference (h_1- h_2). It may be noted that the specific humidity during the sensible cooling remains constant. The dry bulb temperature reduces from t_{d1} to t_{d2} and relative humidity increases from φ1 to φ2. The amount of heat rejected during sensible cooling may also be obtained from the relation.

Heat rejected $q = h_1 - h_2$

$$= C_{pa} (t_{d1}-t_{d2}) = W\ C_{ps} (t_{d1} - t_{d2})$$

$$= (C_{pa}+ W\ C_{ps}) (t_{d1}-t_{d2}) = C_{pm} (t_{d1} - t_{d2})$$

The term (C_{pa}+ W C_{ps}) is called humid specific heat C_{pm} and its value is taken as 1.022 kJ / kg K.

Heat rejection, $q = 1.022 (t_{d2}-t_{d1})$ kJ / kg.

(iii) By pass factor of heating and cooling coil:

Let one kg of air at temperature t_{d1} is passed over the coil having its temperature (i. e. coil surface temperature) t_{d3}. A little consideration will show that when air passes over a coil, some of it (say x kg) just by-passes unaffected while the remaining (1-x) kg comes in direct contact with the coil. This by-pass process of air is measured in terms of a by-pass factor. The amount of air that by-passes or the by-pass factor depends upon the following factors:

- The no. of fins provided is a unit length i.e., pitch of cooling coil fins.
- The no. of row in a coil in the direction of flow; and
- Velocity of flow of air.

It may be noted that the by-pass factor of a cooling coil decreases with decrease in fin spacing and increase in number of rows.

Balancing the enthalpies; we get: x

$C_{pm}\ t_{d1} + (1-x)\ C_{pm}\ t_{d3}$

$= 1 \times C_{pm} t_{d2}$

$x (t_{d3} - t_{d1}) = t_{d3} - t_{d2}$

$x = (t_{d3} - t_{d2}) / (t_{d3}-t_{d1})$

Where x is called the by-pass factor of the coil and is generally written as BPF. Therefore, by-pass factor for heating coil,

$BPF = (t_{d3} - t_{d2}) / (t_{d3}-t_{d1})$

Similarly, by-pass factor for cooling coil,

$BPF = (t_{d2} - t_{d3}) / (t_{d1}-t_{d3})$

(iv) Humidification and Dehumidification

The addition of moisture to the air, without any change in its dry bulb temperature is known as humidification. Similarly, removal of moisture from the air, without change in its dry bulb temperature is known as dehumidification. The heat added during humidification process and heat removed during dehumidification process is shown on the psychometric chart.

It may be noted that in humidification, the relative humidity increase from $\varphi 1$ to $\varphi 2$ and specific humidity also increases from w_1 to w_2. Similarly, in dehumidification, the relative humidity decreases $\varphi 1$ to $\varphi 2$ and specific humidity also decreases from w_1 to w_2. It may be noted that in humidification, change in enthalpy is shown by intercept (h_2-h_1) on the psychometric chart. Since the dry bulb temperature of air during the humidification remains constant, therefore its sensible heat also remains constant. It is thus obvious, that the change in enthalpy per kg of dry air due to the increased moisture content equal to (w_2-w_1) kg per kg of dry air is considered to cause a latent heat transfer (LH).

Mathematically,

$LH = (h_2-h_1) h_{fg} (w_2-w_1)$

Where h_{fg} is the latent heat of vaporization at dry bulb temperature (t_{d1})

(v|) Cooling with adiabatic humidification

When the air is passed through an insulated chamber having sprays of water (known as air washer) maintained at a temperature (t_1) higher than the dew point temperature of entering air (t_{dp1}), but lower than its dry bulb temperature (t_{d1}) of entering air (or equal the wet bulb temperature of the entering air (t_{w1}) then air is said to be cooled and humidified. Since no heat is supplied or rejected from the spray water as the same water is re-circulated again and again, therefore, in this case, a condition of adiabatic saturation will be reached.

The temperature of spray water will reach the thermodynamic wet bulb temperature of the air entering the spray water. This process is shown by line 1-3 on the psychometric chart and follows the path along the constant wet bulb temperature line or constant enthalpy line. In an ideal case when the humidification is perfect (or the humidifying efficiency of the spray chamber is 100%). In actual practice, perfect humidification is never achieved. Therefore, the final condition of air at outlet in represented by point 2 on the line 1-3.

The effectiveness or the humidifying efficiency of the spray chamber is given by

$$H = \frac{\text{Actual drop in DBT}}{\text{Ideal drop in DBT}} = \frac{\text{Actual drop sp. humidity}}{\text{Ideal drop sp. humidity}}$$

$$= \frac{td_1 - td_2}{td_1 - td_3} = \frac{W_2 - W_1}{W_3 - W_1}$$

(vi) Cooling and humidification by water injection (Evaporative cooling)

Let water at a temperature t_1 is injected into the flowing steam of dry air (a). The final condition of air depends upon the amount of water evaporation. When the water is injected at a temperature equal to the wet bulb temperature of the entering air (t_{w1}), then the process follows the path of constant wet bulb temperature line.

Let,

M_w = Mass of water supplied,
m_a = Mass of dry air,
W_1 = Specific humidity of entering air, W_2
= Specific humidity of leaving air, and
H_w = Enthalpy of water injected into the air.

Now for the mass balance, $W_2 = W_1 + m_w / m_a$

And by heat balance,

$$h_2 = h_1 + m_w / m_a \times h_{fw}$$

$$= h_1 + (W_2 - W_1) h_{fw}.$$

Since $(W2-W1) h_{fw}$ is very small as compared to h1 and h2, therefore it may be neglected. Thus the water injection process is a constant enthalpy process, irrespective of the temperature of water injected (i.e. whether the temperature $t_1 < t_w$ or $t_1 > t_w$).

(vii) Heating and humidification

This process is generally used in winter air conditioning to warm and humidify the air. It is the reverse process of cooling & humidity. When air is passed through a humidifier having spray water temperature higher than the dry bulb temperature of the entering air, the unsaturated air will reach the condition of saturation and thus the air becomes hot. The heat of vaporization of water is absorbed from the spray water itself and hence it gets cooled. In this way, the air becomes heated and humidified. The process of heating and humidification is shown by line 1-2 on the psychometric chart. The air enters at condition 1 and leaves at condition 2. In this process, the dry bulb temperature as well as specific humidity of air increases. The final relative humidity of the air can be lower or higher than that of the entering air.

Let,

m_{w1} and m_{w2} = Mass of spray water entering and leaving the humidifier in kg, h_{fw1}

and h_{fw2}= Enthalpy of spray water entering and leaving the humidifier in kJ / kg.

W_1 and W_2 = Specific humidity of the entering and leaving air in kg / kg of dry air,

h_1 and h_2 = Enthalpy of entering and leaving air in kJ / kg of dry air, and m_a = Mass of dry air entering in kg.

For mass balance of spray water, $(m_{w1} - m_{w2}) = m_a (W_2 - W_1)$

$$m_{w2} = m_{w1} - m_a (W_2 - W_1)$$

For Enthalpy balance,

$$m_{w1} h_{fw1} - m_{w2} h_{fw2} = m_a (h_2 - h_1)$$

Substituting the value of mw2 from equation (i), we have m_{w1}

$$h_{fw1} - \{m_{w1} - m_a (W_2 - W_1)\} h_{fw2} = m_a (h_2 - h_1)$$

$$h_2 - h_1 = m_{w1} / m_a (h_{fw1} - h_{fw2}) + (W_2 - W_1) h_{fw2}$$

The temperatures t_{s1} and t_{s2} denote the temperatures of entering and leaving spray water respectively. The temperature t_3 is the mean temperature of the spray water which the entering air may be assumed to approach.

Actually, the heating and humidification process follows the path as shown by dotted curve, but for the calculation of psychometric properties, only the end points are important. Thus, the heating and humidification process shown by a line 1-2 on the psychometric chart may be assumed to have followed the path 1- A and A – 2. We see that the total heat added to the air during heating and humidification is,

Total heat added to the air during heating humidification: q=

$$h_2 - h_1 = (h_2 - h_a) + (h_a - h_1) = q_i + q_s$$

(viii) Heating and humidification by steam injection

The stream is normally injected into the air in order to increase its specific humidity. This process is used for the air conditioning of textile industries where high humidity is maintained. The dry bulb temperature of air changes very little during the process.

Let

m_s = Mass of steam supplied, m_a = Mass of dry air entering,

W_1 = Specific humidity of air entering,
W_2 = Specific humidity of air leaving, h_1 = Enthalpy of air entering,

h_2 = Enthalpy of air leaving, and

h_s = Enthalpy of steam injected into the air.

Now for mass balance;

$$W_2 = W_1 + m_s / m_a$$

For heat balance;

$$h_2 = h_1 + m_s / m_a \times h_s = h_1 + (W_2 - W_1) h_s$$

(ix) Adiabatic Mixing of Two Air Streams

When two quantities of air having different enthalpies and different specific humidity are mixed, the final condition of the air mixture depends upon the masses involved, and on the enthalpy and specific humidity of each of the constituent masses which enter the mixture.

Let

m_1 = Mass of air entering at 1,

h_1 = Enthalpy of air entering at 1,

W_1 = Specific humidity of air entering at 1,

m_2, h_2, W_2 = Corresponding values of air entering at 2 and m_3, h_3, W_3 = Corresponding values of mixture leaving at 3.

Assuming no loss of enthalpy and specific humidity during the air mixing process, we have for the mass balance,

$$m_1 + m_2 = m_3$$

For the energy balance,

$$m_1 h_1 + m_2 h_2 = m_3 h_3$$

and for the mass balance of water vapour,

$m_1 W_1 + m_2 W_2 = m_3 W_3$

Substituting the value of m_3 from equation (i) in equation (ii), $m_1 h_1$

$+ m_2 h_2 = (m_1 + m_2) h_3 = m_1 h_3 + m_2 h_3$

or $m_1 h_1 - m_1 h_3 = m_2 h_3 - m_2$

h_2 $m_1 (h_1 - h_3) = m_2 (h_3 -$

$h_2)$

$m_1 / m_2 = h_3 - h_2 / h_1 - h_3$

Similarly, substituting the value of m3 from equation (i) in equation (iii), we have m_1 /

$m_2 = W_3 - W_2 / W_1 - W_3$

Now from equation (iv) and (v),

$m_1 / m_2 = h_3 - h_2 / h_1 - h_3 = W_3 - W_2 / W_1 - W_3$

The adiabatic mixing process is represented on the psychometric chart as shown in fig. The final condition of the mixture (point 3) lies on the straight line 1-2. The point 3 divides the line1-2 in the inverse ratio of the mixing masses. By calculating the value of W_3 from equation (vi), the point 3 is plotted on the line 1-2.

It may be noted that when warm high humidity air is mixed with cold air, the resulting mixture will be a fog and the final condition (point 3) on the psychometric chart will lie to the left or above the saturation curve which represents the fog region. The temperature of the fog is that of the extended wet bulb line passing through point 3.

The fog may also result when steam or a very fine water spray is in injected into air in a greater quantity that required saturate the air. Even lesser quantity of steam, if not mixed properly, may result fog.

The fog can be cleared by heating the fog, mixing the fog with warmer unsaturated air or mechanically separating the water droplets from the air.

Viva Questions

1. What do you understand by the term ‘psychometric’?
2. Define Specific humidity?
3. Define Absolute humidity?
4. What is Relative humidity?
5. What is Dew point temperature?
6. What is a sling psycho- meter?
7. What is by-pass factor for cooling coils?
8. Define sensible heat factor?
9. What is fog?