LABORATORY MANUAL

MACHINE DESIGN LAB

SUBJECT CODE: KME-652

B.TECH. (ME) SEMESTER -VI

Academic Session: 2022-23, Even Semester

Student Name:	
Roll. No.:	
Branch/Section:	

Dronacharya Group of Institutions
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Vision and Mission of the Institute

Vision:

"Dronacharya Group of Institutions, Greater Noida aims to become an Institution of excellence in imparting quality Outcome Based Education that empowers the young generation with Knowledge, Skills, Research, Aptitude and Ethical values to solve Contemporary Challenging Problems"

Mission:

We, at Dronacharya Group of Institutions, are absolutely committed to serve the society and improve the mode of life by imparting high quality education in the field of Engineering and Management catering to the explicit needs of the students, society, humanity, and industry. 'Shiksha evam Sahayata' i.e. Education and help are the two words etched on our banner soaring higher year after year.

Vision and Mission of the Department

Vision:

"To become a Centre of Excellence in teaching and research in Mechanical Engineering for producing skilled professionals having a zeal to serve society"

Mission:

M1: To create an environment where students can be equipped with strong fundamental concepts.

M2: To provide an exposure to emerging technologies by providing hands on experience for generating competent professionals.

M3: To promote Research and Development in the frontier areas of Mechanical Engineering and encourage students for pursuing higher education.

M4: To inculcate in students ethics, professional values, team work and leadership skills**.**

Program Educational Objectives (PEOs)

PEO 1. Engineers will practice the profession of engineering using a systems perspective and analyze, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO 2. Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO 3. Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO 4. Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO 5. Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Program Outcomes (POs)

PO1: Engineering knowledge: Apply knowledge of mathematics, science, and engineering in Mechanical Engineering.

PO2: Problem analysis: Design and conduct experiments, as well as to analyze and interpret data.

PO3: Design/development of solutions: To design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Apply principles of engineering, basic science, and mathematics to design and realize physical systems, components, or processes.

Use the techniques, skills, and modern engineering tools necessary for engineering practice like AUTOCAD.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO 1: Graduates of the program will achieve excellence in product design, thermal engineering and manufacturing system by acquiring knowledge in mathematics, science and designing principles.

PSO 2: Graduate will be able to analyze, interpret and provide solutions to the real life mechanical engineering problems.

PSO 3: Graduate will develop an approach to solve multidisciplinary problems of manufacturing and allied industries.

University Syllabus

A. Design of Machine Elements

1. Design a knuckle joint subjected to given tensile load.

2. Design a riveted joint subjected to given eccentric load.

3. Design of shaft subjected to combined constant twisting and bending loads

4. Design a transverse fillet welded joint subjected to given tensile load.

5. Design & select suitable Rolling Contact Bearing for a shaft with given specifications

6. Design a cylinder head of an IC Engine with prescribed parameters.

7. Design of Piston & its parts of an IC Engine

B. Computer Programs for conventional design
Computer and Language

Students are required to learn the basics of computer language such as C/C++/MATLAB so that they should be able to write the computer program.

1. Design a pair of Spur Gear with given specifications to determine its various dimensions using Computer Program in C/C++.

2. Design a pair of Helical Gear with given specifications to determine its various dimensions using Computer Program in C/C++.

3. Design of Sliding Contact Bearing with given specifications & determine its various parameters using Computer Program in C/C++.

Course Outcomes

CO 1	Apply the principles of solid mechanics to design various machine elements subjected to static and fluctuating loads.
CO 2	Write computer programs and validate it for the design of different machine elements
CO 3	Evaluate designed machine elements to check their safety.

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO 1	1		1		3			2	3	1	3	1
CO 2	1		3		3			2	3	1	3	1
CO 3	1		3		3			2	3	1	3	1

CO-PSO Mapping

	PSO1	PSO2	PSO3
CO 1	2		2
CO 2	2		2
CO 3	2		2

Course Overview

1. Basics of Engineering Design
2. Selection of Engineering Materials for Mechanical Design
3. Analysis of Machine Elements

List of Experiments mapped with COs

S. No	Aim of the Experiment	COs
1.	Design of shaft subjected to combined constant twisting and bending loads	**CO1**
2.	Design a riveted joint subjected to given eccentric load.	**CO1**
3.	Design a cylinder head of an IC Engine with prescribed parameters.	**CO1**
4.	Design of Piston & its parts of an IC Engine	**CO1**
5.	Design & select suitable Rolling Contact Bearing for a shaft with given specifications	**CO1**
6.	Design a knuckle joint subjected to given tensile load.	**CO1**

DOs and DON'Ts

DOs

1. Revise and be prepared with all the basics of machine design theories taught in theory class by instructor. Students are advised to bring class notes of Machine Design.
2. Read the procedure as set forth in the lab manual before you begin any design.
3. Student must carry record and observation.
4. Take signature of lab in charge after completion of observation and record.
5. If any equipment fails in the experiment report it to the supervisor immediately.
6. It is compulsory to bring machine design data book in laboratory.
7. For numerical calculations students have to bring scientific calculator without fail.

DON'Ts

1. Don't touch the equipment without instructions from lab supervisor.
2. Don't crowd around the experiment and behave in-disciplinary.
3. Using the mobile phone in the laboratory is strictly prohibited.

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as firewood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If the main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.

Precautions (In case of Fire)

1. Turn the equipment off. If the power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire if possible, by using the fire extinguisher or by covering it with a heavy cloth if possible isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.

Guidelines to Students for Report Preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows:-

1) All files must contain a title page followed by an index page. ***The files will not be signed by the faculty without an entry in the index page.***

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

3) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Pre-experiment work (as given by the faculty)

(iii) Lab assignment questions and their solutions

(iv) Test Cases (if applicable to the course)

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Lab Assessment Criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes are assessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

Grading Criteria	Exemplary (4)	Competent (3)	Needs Improvement (2)	Poor (1)
AC1: Pre-Lab written work (this may be assessed through viva)	Complete procedure with underlined concept is properly written	Underlined concept is written but procedure is incomplete	Not able to write concept and procedure	Underlined concept is not clearly understood
AC2: Program Writing/ Modeling	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied, Program/solution written is readable	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed & correct solution designed	Assigned problem is properly analyzed
AC3: Identification & Removal of errors/ bugs	Able to identify errors/ bugs and remove them	Able to identify errors/ bugs and remove them with little bit of guidance	Is dependent totally on someone for identification of errors/ bugs and their removal	Unable to understand the reason for errors/ bugs even after they are explicitly pointed out
AC4:Execution & Demonstration	All variants of input /output are tested, Solution is well demonstrated and implemented concept is clearly explained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearly explained	Only few variants of input /output are tested, Solution is well demonstrated but implemented concept is not clearly explained	Solution is not well demonstrated and implemented concept is not clearly explained
AC5:Lab Record Assessment	All assigned problems are well recorded with objective, design constructs and solution along with Performance analysis using all variants of input and output	More than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 40 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output

LAB EXPERIMENTS

EXPERIMENT 1: DESIGN A SHAFT SUBJECTED TO COMBINED CONSTANT TWISTING AND BENDING LOADS.

Objective:-Design of shaft subjected to combined bending and twisting load.

Design of Shafts

The shafts may be designed on the basis of

1. Strength, and

2. Rigidity and stiffness

In designing shafts on the basis of strength, the following cases may be considered:

(a) Shafts subjected to twisting moment or torque only,

(b) Shafts subjected to bending moment only,

(c) Shafts subjected to combined twisting and bending moments, and

(d) Shafts subjected to axial loads in addition to combined torsional and bending loads.

Shafts Subjected to Combined Twisting Moment and Bending Moment:-

When the shaft is subjected to combined twisting moment and bending moment, then the shaft must be designed on the basis of the two moments simultaneously.

The following two theories are important from the subject point of view:

1. Maximum shear stress theory or Guest's theory. It is used for ductile materials such as mild steel.

2. Maximum normal stress theory or Rankine's theory. It is used for brittle materials such as cast iron.

Let τ = Shear stress induced due to twisting moment, and

σ_b= Bending stress (tensile or compressive) induced due to bending moment.

According to maximum shear stress theory, the maximum shear stress in the shaft,

$$\tau_{max}=\frac{1}{2}\sqrt{{\sigma_b}^2+4\tau^2}$$

Substituting the values of τ and σ_b

$$\tau_{max}=\frac{1}{2}\sqrt{(\frac{32M}{\pi d^3})^2+4(\frac{16T}{\pi d^3})^2}$$

$$\frac{\pi d^3}{16}\tau_{max}=\sqrt{M^2+T^2}$$

The expression $\sqrt{M^2+T^2}$ is known as ***equivalent twisting moment*** and is denoted by

$$T_e=\frac{\pi d^3}{16}\tau_{max}=\sqrt{M^2+T^2}$$

—

From this expression, diameter of the shaft (d) may be evaluated.

Now according to maximum normal stress theory, the maximum normal stress in the shaft,

$$\sigma_{b(max)} = \frac{1}{2}\sigma_b + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2}$$

$$= \frac{1}{2} \times \frac{32M}{\pi d^3} + \frac{1}{2}\sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2}$$

$$= \frac{32}{\pi d^3}\left[\frac{1}{2}(M + \sqrt{M^2 + T^2})\right]$$

The expression $\frac{1}{2}\left[(M + \sqrt{M^2 + T^2})\right]$ is known as ***equivalent bending moment*** and is

denoted by *Me*.

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] = \frac{\pi}{32} \times \sigma_b \times d^3$$

From this expression, diameter of the shaft (d) may be evaluated.

2. It is suggested that diameter of the shaft may be obtained by using both the theories and the larger of the two values is adopted.

EXPERIMENT 2: DESIGN A RIVETED JOINT SUBJECTED TO GIVEN ECCENTRIC LOAD.

Objective:- Design of eccentrically loaded riveted joint

Eccentrically loaded riveted joint:

When the line of action of external force does not pass through the centre of gravity of the group of the rivets employed, the joint is called an eccentrically loaded joint.

Procedure for designing eccentrically loaded riveted joint is as follows:

Step-1:- Find out the value of primary shear force.

$$\text{Primary shear force} = \frac{Eccentrical\ load}{Number\ of\ rivets}$$

Consider there are four rivets in the system, the value of primary shear force will be same on each rivet.

$$F_1' = F_2' = F_3' = F_4' = \frac{F}{4}$$

Step-2:- Find out the value of secondary shear force as:

$F_1'' = Cr_1$

$F_2'' = Cr_2$

$F_2'' = Cr_3$

$F_2'' = Cr_4$

Where C is constant of proportionality, it is given by:

$$C = \frac{Fe}{r_1^2 + r_2^2 + r_3^2 + r_4^2}$$

Where, e= eccentricity of load.

r_1=distance first rivet from the C.G. of group of rivet.

r_2=distance second rivet from the C.G. of group of rivet.

r_3=distance third rivet from the C.G. of group of rivet.

r_4=distance fourth rivet from the C.G. of group of rivet.

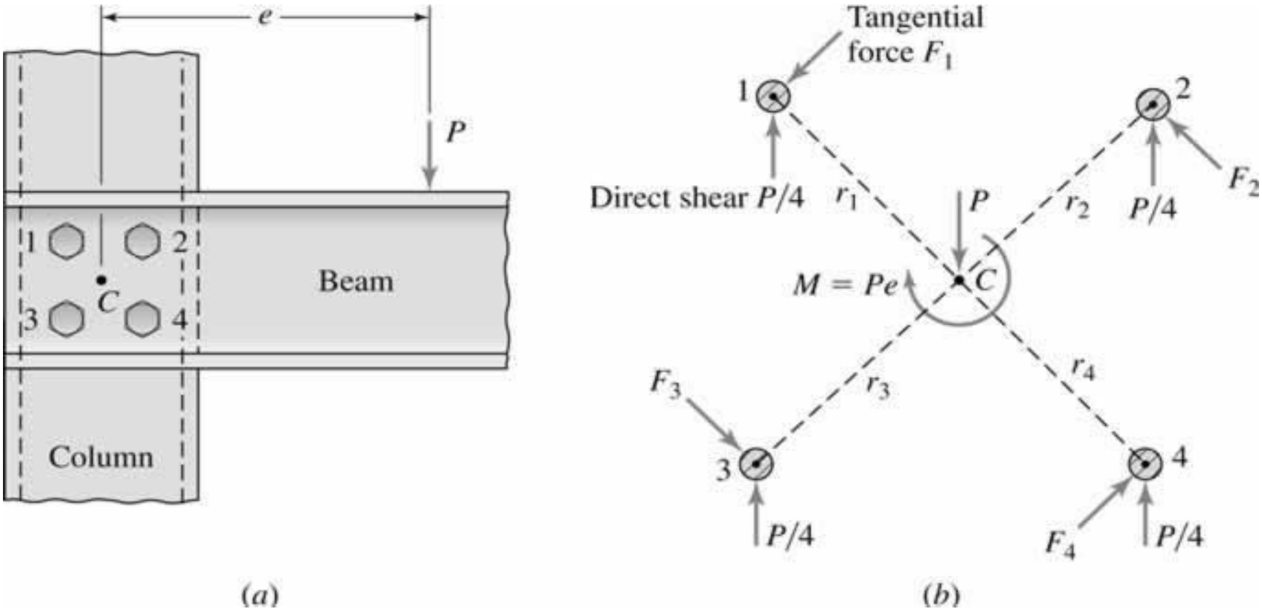
Step-3:- Add algebraically primary and secondary shear force and find out resultant shear force on eachrivet**.**

Step-4:- Select the maximum loaded rivet for criterion of design.

Step-5:- Find out the value of maximum induced shear stress in the critical rivet by the help of:-

$$r_{max} = \frac{F_{max}}{\frac{\pi}{4}d^2}$$

Step-6:- For safe design this induced stress should be equal to permissible shear stress of therivet material and find out the diameter of the rivet.



EXPERIMENT 3: DESIGN CYLINDER HEAD OF AN IC ENGINE WITH PRESCRIBED PARAMETER

Objective: To design cylinder head of an IC Engine with prescribed parameter.

Theory:

Functions of cylinder

- Primary function is to retain the working fluid such as mixture of air and petrol or air and diesel.
- Secondary function is to guide the piston

Cylinder Material

a. Grey cast iron (usually)
b. Nickel cast iron or Nickel Chromium cast iron for heavy duty applications
c. Cast steels and Aluminium alloys may also be used.

Design of Cylinder

Involves assessment of following dimensions:

1. Bore of cylinder
2. Length of cylinder
3. Thickness of cylinder wall
4. Thickness of cylinder head
5. No. and diameter of cylinder head studs
6. Pitch circle diameter of studs

Bore and Length of cylinder

- BP = $\frac{P_{mb}LAN}{60}$
- IP = $\frac{P_{mi}LAN}{60}$
- Mechanical Efficiency, $\eta = \frac{BP}{IP}$
- Length of stroke is usually 1.5 times bore diameter.
- Length of cylinder is more than length of stroke (usually 15%).

Thickness of Cylinder Wall

$$\boldsymbol{t = \frac{P_{max}D}{2\sigma_c} + C}$$

t = thickness of cylinder wall (mm)

P_{max} = maximum gas pressure inside cylinder (10 times indicated mep)

σ_c = permissible circumferential stress for cylinder material (35 to 100 MPa)

D = Bore diameter (mm)

C = re-boring allowance (according to bore diameter from data book)

Thickness of Cylinder Head

$$t_h = D\sqrt{\frac{KP_{max}}{2\sigma_c}}$$

t_h = thickness of cylinder head (mm)

D = Bore diameter (mm) K = a constant (= 0.162)

P_{max} = maximum gas pressure inside cylinder (10 times indicated mep)

σ_c = permissible circumferential stress for cylinder head material (30 to 50 MPa)

Studs for Cylinder Head

Minimum no. of studs = 0.01 D + 4

Maximum no. of studs = 0.02 D + 4

Diameter of studs

$$(\frac{\pi}{4}D^2)\ P_{max} = z\ (\frac{\pi}{4}{d_c}^2)\ \sigma_t$$

z = no. of studs

d_c = core diameter of studs (= 0.8 times nominal diameter d)

σ_t = allowable tensile stress for stud material (35 to 70 MPa)

Pitch circle diameter of studs D_p = D + 3d

EXPERIMENT 4: DESIGN OF PISTON & ITS PARTS OF AN IC ENGINE

Objective: To design piston and its parts of an IC Engine

Theory:

Functions of Piston

- Transmits force inside the gas cylinder to the crank shaft.
- Compresses gas during compression stroke.
- Seals the inside portion of the cylinder from the crankcase by means of piston rings.
- Takes side thrust resulting from obliquity of connecting rod.
- Dissipates large amount of heat from combustion chamber to the cylinder walls.

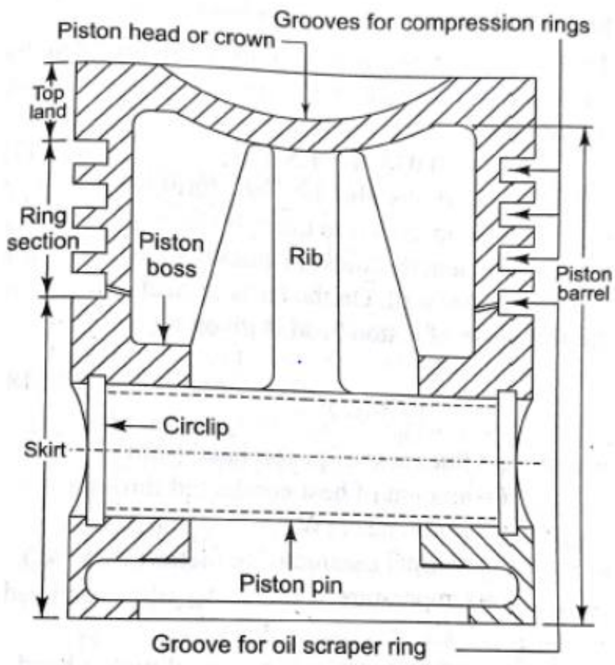
Piston Material

a. Aluminium

- thermal conductivity thrice as that of cast iron
- density one third that of cast iron (reduced weight)

b. Cast Iron

- higher strength as compared to Aluminium
- relatively more wear strength (than Aluminium)
- approx. half coefficient of thermal expansion



Design of Piston

Involves assessment of following dimensions:

1. Thickness of piston head (t_h)
2. Thickness of Rib (t_r)
3. Radial thickness of piston rings (a_1)
4. Axial thickness of piston rings (h_1)
5. Width of top land
6. Thickness of piston barrel at the top end (t_3)
7. Thickness of piston barrel at open end (t_4)
8. Length of piston skirt
9. Total length of piston

Thickness of piston head

- **Strength Consideration**

$$t_h = D\sqrt{\frac{3P_{max}}{16\sigma_b}}$$

D = cylinder bore (mm)

P_{max} = maximum gas pressure (4 to 5 MPa)

σ_b = permissible bending stress (35 to 40 MPa for C.I. and 50 to 90 MPa for Al)

- **Heat Dissipation Consideration**

$$t_h = [\frac{H}{12.56k(T_C - T_e)}] \times 10^3$$

H = amount of heat conducted through piston head (W)

k = thermal conductivity factor (46.6 W/m°C for C.I. and 175 W/m°C for Al)

T_c = Temperature at the centre of Piston head

T_e = Temperature at the edge of piston head

$T_c - T_e$ = 220°C for C.I. and 75°C for Al

$$H = [C \times HCV \times m \times BP] \times 10^3$$

C = ratio of heat absorbed by piston to total heat developed by cylinder (5%)

HCV = higher calorific value (44000 kJ/kg for diesel and 47000 kJ/kg for Petrol)

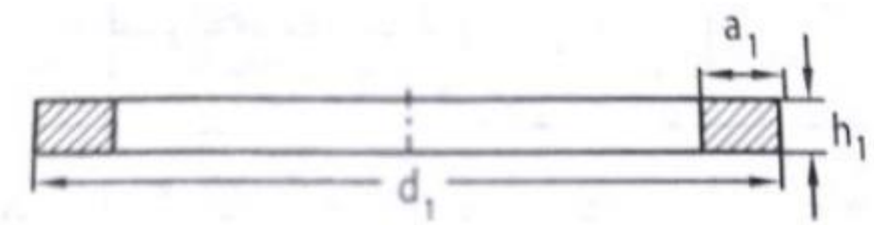
m = average fuel consumption (0.24 to 0.3 kg/kW/hr)

B.P. = Brake power

$$\textbf{BP} = \frac{P_{mb}LAN}{60} \textbf{ (in kW)}$$

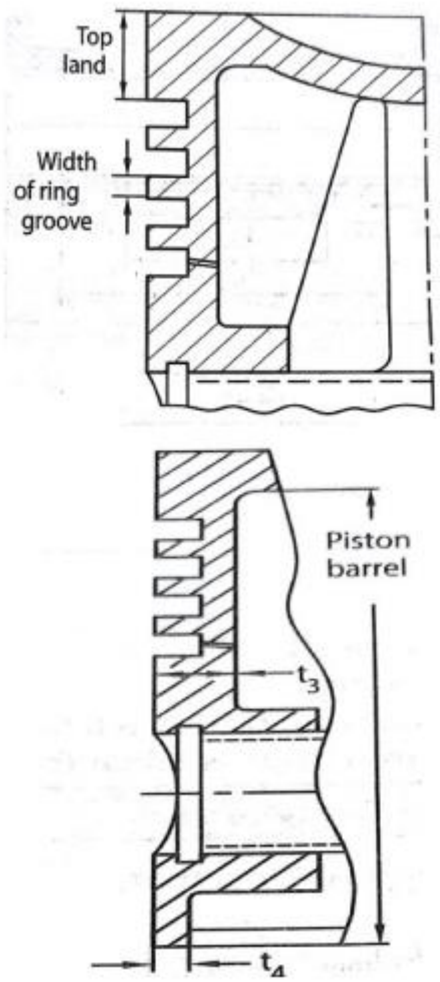
Thickness of rib = 1/3 to 1/2 (thickness of piston head)

Radial thickness of piston rings



$$a_1 = d_1\sqrt{\frac{3P_w}{\sigma_t}}$$

d_1 = diameter of cylinder bore (mm)
P_w = allowable pressure (0.025 to 0.042 MPa)
σ_t = permissible tensile stress (85 to 110 MPa)



Axial width of piston ring, h_1 = 0.7 to 1.0 a_1
Width of top land = 1.0 to 1.2 t_h
Width of ring groove = 0.75 to 1.0 h_1
Thickness of piston barrel at the top end t_3 = 0.03 d + a_1 + 4.9

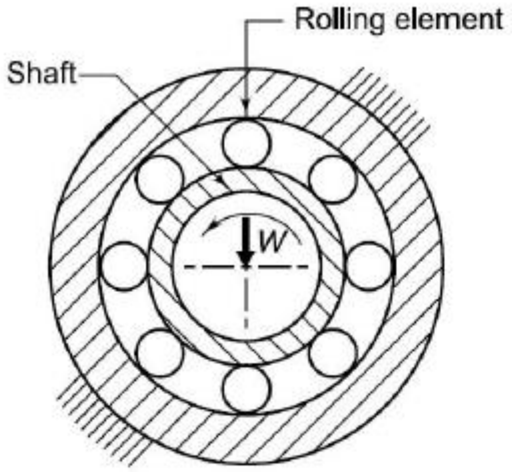
Thickness of piston barrel at open end t_4 = 0.25 to 0.35 t_3
Length of piston skirt 0.65 to 0.8 D
Total length of piston 1.0 to 1.5 D

EXPERIMENT 5: DESIGN & SELECT SUITABLE ROLLING CONTACT BEARING FOR A SHAFT WITH GIVEN SPECIFICATIONS.

Objective: Selection of Rolling Element Bearing from Manufacturer's Catalogue

Theory: Bearing is mechanical device that permits relative motion between two parts, such as the shaft and the housing, with minimum friction. Bearings are classified in different ways the most important criterion to classify the bearings is the type of friction between the shaft and the bearing surface. Depending on type of friction, bearings are classified into two main group Sliding contact bearing and Rolling contact bearing.

Rolling Contact Bearing: Rolling contact bearing are also called antifriction bearings or simply ball bearing. Rolling element such as balls or rollers, are introduced between the surfaces that are in in relative motion. Figure 1 shows rolling contact bearing. Rolling contact bearing are used in following applications: Machine tool spindle, Automobile front and rear axle, Gear boxes, Small size electric motors and Rope etc.



(b) Rolling contact bearing

Figure 1. Rolling Contact Bearing

The types of rolling contact bearing, which are frequently used are: (i) Deep Groove Ball bearing (ii) Cylindrical roller bearing (iii) Angular contact bearing (iv) Self aligning bearing (v) Taper roller bearing (vi) Thrust ball bearing. Different types of rolling contact bearing are shown in Figure 2.

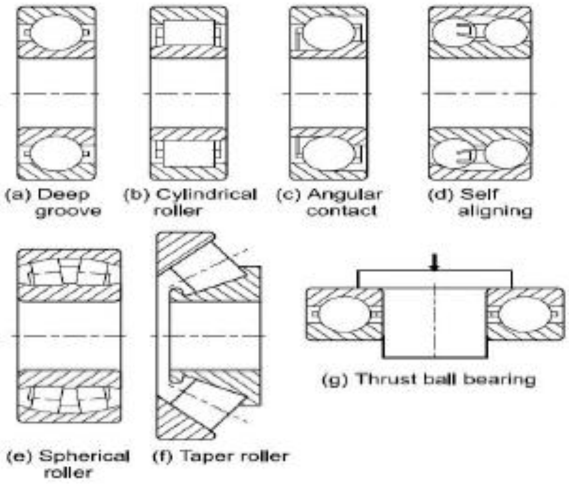


Figure 2. Types of Rolling Contact Bearing

Materials: Chrome Steel - SAE 52100, Stainless Steels, Stainless Steel Bearings– ACD34 /KS440 / X65Cr13 etc.

Selection of Rolling Element Bearing: The information given here should serve to indicate which are the most important of the following points to be considered when selecting bearing type and thus facilitate an appropriate choice.

• Cylindrical & Needle roller – pure radial load.

• Thrust (cylindrical roller, ball), four point angular contact ball bearings – pure axial load.

• Taper roller, spherical roller, angular contact ball bearings – combined Load.

• Cylindrical roller, angular contact ball bearing– high speed.

• Deep groove, angular contact, and cylindrical roller bearing – high running accuracy.

Design equations/data:

• Equivalent dynamic load:

$P = XVF_r + YF_a$	P = equivalent dynamic load (N) F_r = radial load acting on bearing (N), F_a = axial or thrust load acting on bearing V = race- rotation factor X = radial factor, Y= thrust factor

- **Load life equation:**

$L_{10} = \left(\frac{C}{P}\right)^p$	where, L_{10} = rating bearing life (in million revolutions) C = dynamic load capacity (N) p = 3 (for ball bearings) p = 10/3 (for roller bearing)

- **Life in hours:**

$L_{10} = \frac{60nL_{10h}}{10^6}$	where, L_{10h} = rated bearing life (hours) n = speed of rotation (rpm)

- **Cyclic loads and speed:**

$P_e = \sqrt[3]{[\frac{N_1P_1^3+N_2P_2^3+\cdots}{N_1+N_2+\cdots}]}$ $P_e = \sqrt[3]{[\frac{\sum NP^3}{\sum N}]}$	where N = $N_1 + N_2 + \cdots N_n$ P_e = equivalent dynamic load for complete work cycle (N) $P_1, P_2 \ldots P_n$ = dynamic load during first, second, ... nth element of work cycle $N_1, N_2 \ldots N_n$= number of revolutions completed by first, second.... nth element of work cycle N = life of complete work cycle (rev)

- **Cyclic loads and speeds (continuous variation of load):**

  $P_e = [\frac{1}{N}\int P^3\, dN]^{1/3}$

- **Bearing with probability of survival other than 90%:**

  $R = e^{-(L/a)^b}$, where R = reliability (in fraction), L = corresponding life (in million of revolution), a and b = constants (a = 6.84 and b = 1.17)

  $\left(\frac{L}{L_{10}}\right) = [\frac{\log_e\left(\frac{1}{R}\right)}{\log_e\left(\frac{1}{R_{90}}\right)}]^{1/b}$, where L_{10} = life corresponding to a reliability of 90% or R_{90}, R_{90} = 0.9

- **System reliability:** $R_S = (R)^N$, where N = number of bearings in the system (each having the same Reliability R), R_S = reliability of the complete system

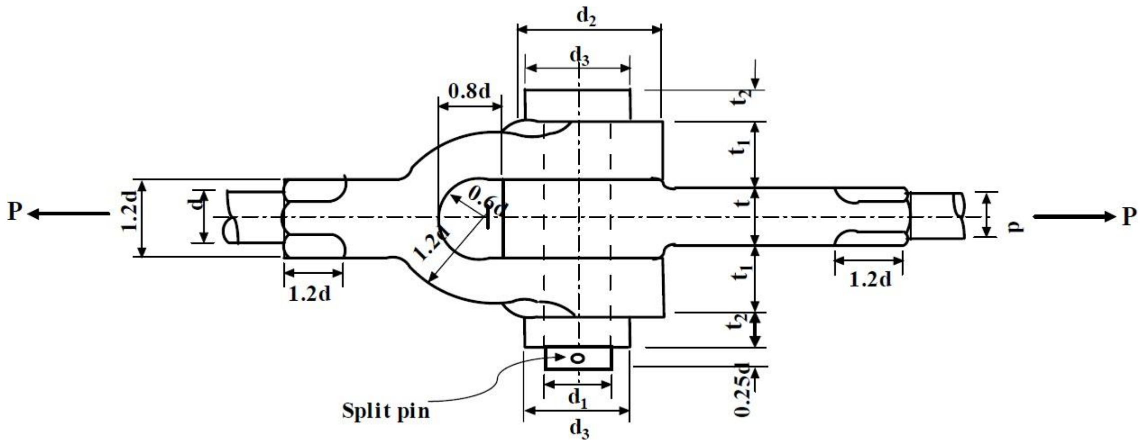
  Refer machine design data book for required data if needed.

EXPERIMENT 6: DESIGN A KNUCKLE JOINT SUBJECTED TO GIVEN TENSILE LOAD

Objective: Design a knuckle joint subjected to given tensile load

Knuckle Joint:

These joints are used for different types of connections e.g. tie rods, tension links in bridge structure. In this, one of the rods has an eye at the rod end and the other one is forked with eyes at both the legs. A pin (knuckle pin) is inserted through the rod-end eye and fork-end



eyes and is secured by a collar and a split pin.

d = diameter of rod

$d_1 = d$ $\quad$ $t = 1.25d$

$d_2 = 2d$ $\quad$ $t_1 = 0.75d$

$d_3 = 1.5.d$ $\quad$ $t_2 = 0.5d$

Mean diameter of the split pin = 0.25 d

However, failures analysis may be carried out for checking. The analyses are shown below assuming the same materials for the rods and pins and the yield stresses in tension, compression and shear are given by σ_t, σ_c and τ.

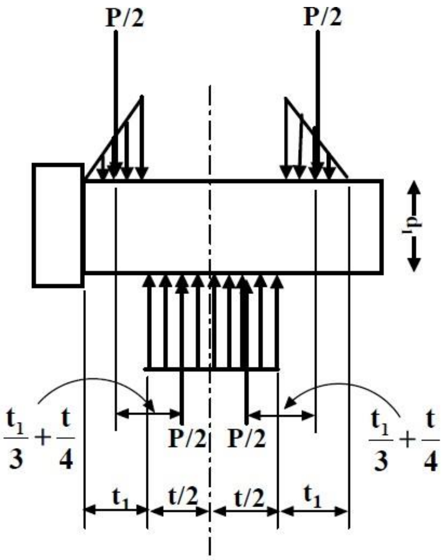
1. Failure of rod in tension:

$$\frac{\pi}{4}d^2\sigma_t = P$$

2. Failure of knuckle pin in double shear:

$$2\frac{\pi}{4}d_1{}^2\tau = P$$

3. Failure of knuckle pin in bending (if the pin is loose in the fork)



4. Failure of rod eye in shear:

$$(d_2 - d_1)t\tau = P$$

5. Failure of rod eye in crushing:

$$d_1 t\sigma_c = P$$

6. Failure of rod eye in tension:

$$(d_2 - d_1)t\sigma_t = P$$

7. Failure of forked end in shear:

$$2(d_2 - d_1)t_1\tau = P$$

8. Failure of forked end in tension:

$$2(d_2 - d_1)t_1\sigma_t = P$$

9. Failure of forked end in crushing:

$$2d_1 t_1 \sigma_c = P$$

The design may be carried out using the empirical proportions and then the analytical relations may be used as checks.

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