GATE 2019

MACHINE DESIGN

MECHANICAL ENGINEERING

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CONTENTS

CHAPTER - 1
STATIC AND DYNAMIC LOADING

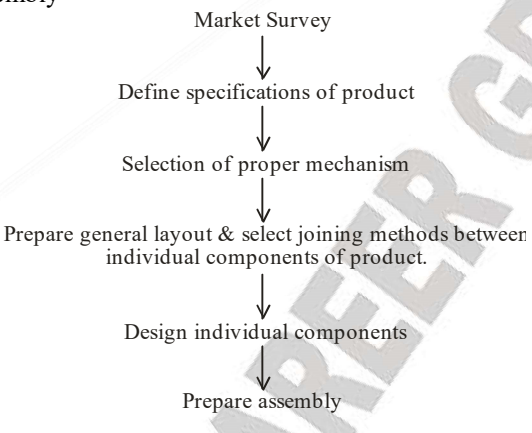
1.1 INTRODUCTION

Machine design is defined as the use of scientific principles, technical information and imagination in the dissipation of a machine

Or a mechanical system to perform specific functions with maximum economy and efficiency.

1.2 BASIC PROCEDURE OF MACHINE DESIGN

Example. Gear box assembly



1.3 BASIC REQUIREMENTS OF MACHINE ELEMENTS

1. Strength

2. Rigidity: A machine component should be rigid and it should not deflect or bend too much due to forces or moments that acts on it. For example, a transmission shaft is many times designed on the basis of lateral and torsional rigidities. Therefore, maximum permissible deflection and maximum permissible angle of twist are the criterion of Design.

3. Wear Resistance: Wear is the main reason for putting the machine part out of order. It reduces useful life of the component. Wear also leads to loss accuracy of machine tools. Surface hardening is generally applied to increase wear resistance.

4. Minimum Dimensions & Weight: Material should be strong, hard and rigid with minimum possible dimensions and weight. This will result in minimum material cost.

5. Manufacturability: It is the ease of fabrication and assembly so that labour cost may be minimized.

6. Safety: The shape and dimensions of the machine parts should ensure safety to the operator of the machine.

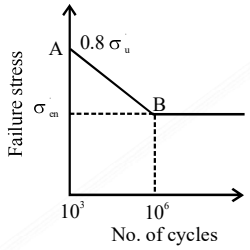
7. Conformance to Standards: It should confirm to national and international standards covering its possible dimensions, grade and material.

8. Reliability: It is the probability that machine part will perform its intended functions under desired operating conditions over specified period of time.

9. Maintainability: It is case by which a machine part can be serviced or repaired.

GATE QUESTIONS

1. A machine element has an ultimate strength (σ_u) of 600N/mm^2, and endurance limit (σ_{en}) of 250 N/mm^2. The fatigue curve for the element on a log – log plot is shown below. If the element is to be designed for a finite life of 10000 cycles, the maximum amplitude of a completely reversed operating stress is _____ N/mm^2



[GATE - 2017]

2. The principal stresses at a point in a critical section of machine component are σ_1 = 60 MPa, σ_2 = 5 MPa and σ_3 = –40 MPa. For the material of the component, the tensile yield strength is σ_y = 200 MPa. According to the maximum shear theory, the factory of safety is

[GATE - 2017]

(a) 1.67 (b) 2.00
(c) 3.60 (d) 4.00

3. A machine component made of a ductile material is subjected to a variable loading with σ_{min} = –50 MPa and σ_{max} = 50MPa. If the corrected endurance limit and the yield strength for the material are σ'_e = 100MP and σ_y = 300 MPa, respectively, the factor of safety is _____

[GATE - 2017]

4. In a structural member under fatigue loading, the minimum and maximum stresses developed at the critical point are 50 Mpa and 150 MPa, respectively. The endurance, yield, and the ultimate strengths of the material are 200 MPa, 300 MPa, and 400 MPA, respectively. The factor of safety using modified Goodman criterion is

[GATE - 2016]

(a) $\frac{3}{2}$ (b) $\frac{8}{5}$
(c) $\frac{12}{7}$ (d) 2

5. In a linear arc welding process, the heat input per unit length is inversely proportional to

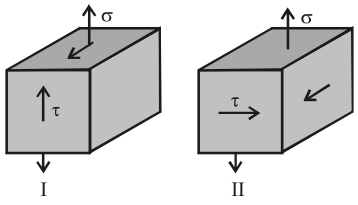
[GATE - 2016]

(a) Welding current
(b) Welding voltage
(c) Welding speed
(d) Duty cycle of the power source

6. A shaft is subjected to pure torsional moment. The maximum shear stress developed in the shaft is 100 MPa. The yield and ultimate strength of the shaft material in tension are 300 MPa and 450 MPa, respectively. The factor of safety using maximum distortion energy (von–Mises) theory is _____.

[GATE - 2014]

7. Consider the following of stress as shown in configurations I and II in the figure below. From the standpoint of distortion energy (von - Mises) criterion, which one of the following statements is true?



[GATE - 2014]

(a) I yields after II
(b) II yields after I
(c) Both Yield simultaneously
(d) Nothing can be said about their relative yielding

8. Which one of the following is not correct?

[GATE - 2014]

ESE OBJ QUESTIONS

1. A machine component is subjected to a flexural stress, which fluctuates between 300 MN/m^2 and –150 MN/m^2. Taking the yield strength = 0.55 of the ultimate strength, endurance strength = 0.50 of the ultimate strength and factor of safety to be 2, the value of the minimum ultimate strength according to modified Goodman relation will be

[ESE - 2017]

(a) 1100 MN/m^2 (b) 1075 MN/m^2
(c) 1050 MN/m^2 (d) 1025 MN/m^2

2. Consider the following statements:
For a component made of ductile material, the failure criterion will be
1. Endurance limit, if the external force is fluctuating
2. Fatigue, if the external force is fluctuating
3. Yield stress, if the external force is static
Which of the above statements are correct

[ESE - 2017]

(a) 1and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

3. Consider the following statements:
On heating an elastomer under tensile load, its shrinkage
1. maximizes the enthalpy
2. maximizes the entropy
3. minimizes the free energy
4. avoids breaking
Which of the above statements are correct?

[ESE - 2017]

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

4. Statement(I) : Directionally solidified materials have good creep resistance.
Statement (II): Directionally solidified materials may be so loaded that there is no shearing stress along, or tensile stress across, the grain boundaries.

[ESE - 2017]

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (i)
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true.

5. A solid shaft is designed to transmit 100 kW while rotating at N r.p.m. If the diameter of the shaft is doubled and is allowed to operate at 2 N r.p.m., the power that can be transmitted by the latter shaft is

[ESE - 2016]

(a) 200 kW (b) 400 kW
(c) 800 kW (d) 1600 kW

6. The diameter of a shaft to transmit 25 kW at 1500 r.p.m.. given that the ultimate strength is 150 MPa and the factor of safety is 3, will nearly be

[ESE - 2016]

(a) 12 mm (b) 16 mm
(c) 20 mm (d) 26 mm

7. A shaft of 50 mm diameter transmits a torque of 800 N-m. The width of the rectangular key used is 10 mm. the allowable shear stress of the material of the key being 40 MPa, the required length of the key would be

[ESE - 2016]

(a) 60 mm (b) 70 mm
(c) 80 mm (d) 90 mm

8. The diameter of the pin in a bushed pin type flexible coupling is to be increased for the purposed of

[ESE - 2016]

(a) Higher stress due to shear

CHAPTER - 2
POWER SCREWS

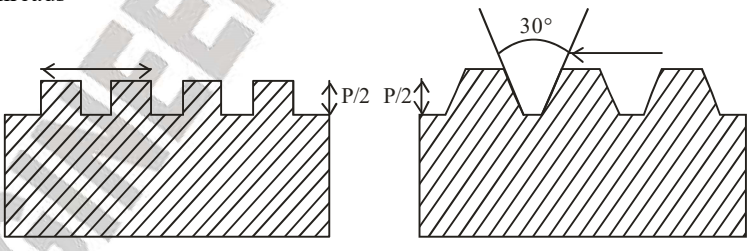
2.1 INTRODUCTION
A power screw is a mechanical device used for converting rotary motion into linear motion and transmitting power. Example; screw jack, lead screw of lathe, vice etc.

2.1.1 Advantages
1. Large head capacity for very smaller dimensions of the power screw resulting in compact design.
2. Simple manufacturing and design.
3. Large mechanical advantage for example, load of 15kN can be raised by applying only 400N.
4. Controlled and accurate linear motion.
5. Smooth and noiseless service.
6. A power screw can be designed with self locking property. In screw jack applications, self locking characteristic is required to prevent the load from falling on its own.

2.1.2 Disadvantages
1. Lower efficiency of 40%
2. High friction in threads causes rapid wear of the screw.

2.1.3 Forms of Threads
1. The threads are used for fastening purpose such as V threads are not suitable for power success. The purpose of fastening threads is to provide high fractional force, which lessons the possibility of loosening the parts assembled by preceded joint.
2. On the other hand, the purpose of power transmission threads is to reduce friction between the screw and nut therefore V threads are not suitable.
3. Screw with smaller angle of thread such as trapezoidal threads are preferred for power transmission.

2.2 TYPES OF POWER SCREW THREADS
There are two mostly used power screw threads are:
1. Square threads
2. Trapezoid threads



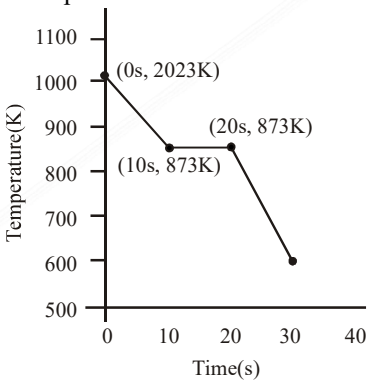
2.2.1 Square Threads
2.2.1.1 Advantages
1. Its efficiency is more than trapezoidal threads.
2. There is no radial pressure or side thrust on the nut.

GATE QUESTIONS

1. Metric thread of 0.8 mm pitch is to be cut on a lathe. Pitch of the lead screw is 1.5mm. If the spindle rotates at 1500 rpm, the speed of rotation of the lead screw (rpm) will be

[GATE - 2017]

2. A hypothetical engineering stress – strain curve shown in the figure has three straight lines PQ, QR, RS with coordinates P(0, 0), Q (0.2, 100), R (0.6, 140) and S (0.8, 130). 'Q' is the yield point, 'r' is the UTS point and s' the fracture point.



The toughness of the material (in MJ/m^3) is __

[GATE - 2016]

3. A bolt of major diameter 12 mm is required to clamp two steel plates. Cross sectional area of the threaded portion of the bolt is 84.3 mm^2. The length of the threaded portion in grip is 30 mm, while the length of the unthreaded portion in grip is 8 mm. Young's modulus of material is 200 GPa. The effective stiffness (in MN/m) of the bolt in the clamped zone is _____.

[GATE - 2014]

4. For the three bolt system shown in the figure, the bolt material has shear yield strength of 200 MPa. For a factor of safety of 2, the minimum metric specification required for the bolt is

[GATE - 2014]

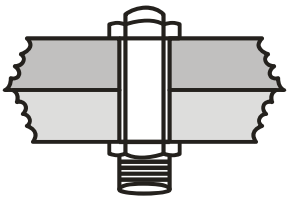
(a) M 8 (b) M 10
(c) M 12 (d) M 16

5. Two threaded bolts A and B of same material and length are subjected to identical tensile load. If the elastic energy stored in bolt A is 4 times that of the bolt B and the mean diameter of bolt A is 12 mm, the mean diameter of bolt B in mm is

[GATE - 2013]

(a) 16 (b) 24
(c) 36 (d) 48

6. In a bolted joint two members are connected with an axial tightening force of 2200 N. If the bolt used has metric threads of 4 mm pitch, the torque required for achieving the tightening force is.



[GATE - 2004]

(a) 0.7 Nm (b) 1.0 Nm
(c) 1.4 Nm (d) 2.8 Nm

7. Bolts in the flanged end of pressure vessel are usually pre-tensioned. Indicate which of the following statements is true.

[GATE - 1998]

(a) Pre-tensioning helps to seal the pressure vessel.
(b) Pre-tensioning increase the fatigue life of the bolts.
(c)Pre-tensioning reduces the maximum tensile stress in the bolts.

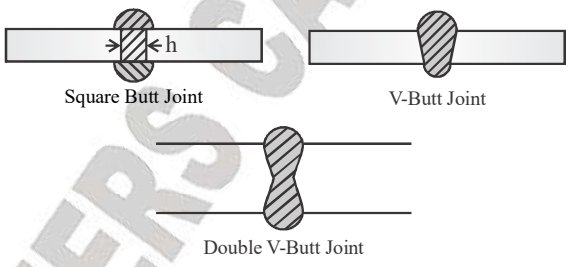
CHAPTER - 3
WELDED JOINTS

3.1 INTRODUCTION
Welding is permanent jointing but un-separable. Riveting is also permanent jointing but separable

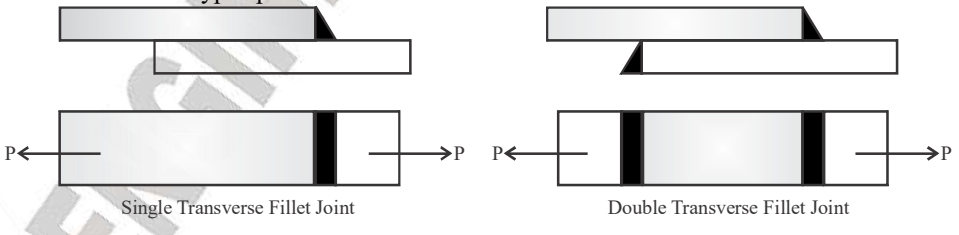
3.1.1 Advantages of Welded Joints
1. Lighter assemblies as compared to riveting where additional cover plates, gussets plates are required
2. Lower cost
3. Changes can be easily made
4. Leak-proof joints
5. Lesser production time
6. Drilling holes in reverted points reduces strength of material.
7. Bad appearance of riveted joints
8. Strength of welded joint is high

3.1.2 Disadvantages
1. Poor vibration damping ability.
2. Thermal distortion due to thermal residual stress therefore stress reliving is a necessity.
3. Quality of weld has to be maintained.

3.2 BUTT JOINTS
A butt joint can be defined as a joint between two components lying approximately in the same plane.



3.3 FILLET JOINTS
It is also called a lap joint, is a joint between two overlapping plates or components. A fillet weld consists of an approximately triangular cross-section joining two surfaces at right angles to each other. It is of two types parallel and transverse.



GATE QUESTIONS

1. A butt weld joint is developed on steel plates having and ultimate tensile strength of 500 MPa and 700 MPa, respectively. The thickness of the plates is 8 mm and width is 20 mm. Improper selection of welding parameters caused an undercut of 3 mm depth along the weld. The maximum transverse tensile load (in kN) carrying capacity of the developed weld joint is _____.

[GATE - 2014]

2. A fillet welded joint is subjected to transverse loading F as shown in figure. Both legs of the fillet are of 10 mm size and the weld length is 30 mm. If the allowable shear stress of the weld is 94 MPa, considering the minimum throat of the weld, the maximum allowable transverse load in kN is

[GATE - 2012]

(a) 14.44 (b) 17.92
(c) 19.93 (d) 22.16

3. A 60 mm long and 6 mm thick fillet weld carries a steady load of 15 kN along the weld. The shear strength of the weld material is equal to 200 MPa. The factor of safety is

[GATE - 2006]

(a) 2.4 (b) 3.4
(c) 4.8 (d) 6.8

4. Weldments in fabricated steel beams are designated for

[GATE - 1987]

(a) Bending stresses at the flange
(b) Shear stresses in transverse plane
(c) Combination of bending and shear
(d) None of these because in fabricated beams welds not to get stressed.

SOLUTIONS

Sol 1. (70kN)

$P_t = \sigma_t (t_{under\ cut}) L$
$= 700 \times 20 \times (8 - 3)$
$= 700 \times 100\ N = 70\ kN$

Sol 2. (*)

Sol 3. (b)

$P_{PPW} = 0.707\ t \times L_e \times \tau_s$
{here PFW $\rightarrow$ parallel filter weld}

$$\frac{15 \times 10^3}{0.707 \times 6 \times 60} = \tau_s$$

$\tau_S = 58.9344$ MPa
Given shear strength of material
= 200 MPa

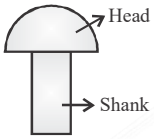
$$FOS = \frac{200}{58.9344} = 3.4$$

Sol 4. (c)

Steel beams undergoes both bending and shear loads.

CHAPTER - 4
RIVETED JOINTS

4.1 INTRODUCTION



Rivet is specified by the shank diameter. A 20mm rivet means a rivet having 20mm shank diameter.

4.1.1 Applications of Riveted Joints

1. Riveted joints are used where it is necessary to avoid the thermal after effects of welding.
2. Used for metals with poor weld ability such as aluminum alloys.
3. To join different materials like steel and asbestos.
4. Welded joints have poor resistance to vibrations and impact loads.

4.1.2 Advantages of Riveted Joint over Welded Joints

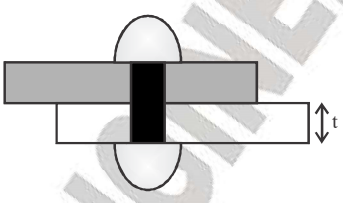
1. More reliable in case of vibration and impact loads.
2. Quality of riveted joint can be easily checked.
3. Can be dismantled work without much damaged parent material.

4.1.3 Disadvantages of Riveted Joints Compared to Welded Joint

1. More material cost, holes required for rivets weaker the plate and it is necessary to increase plate thickness to compensate this loss.
2. More labor cost and less productive process.
3. More weight of riveted joints due to overlapping straps requirement.
4. Noisy process
5. Strep concentration is there near holes in plates.

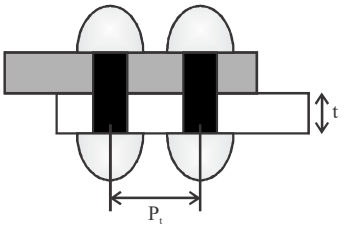
4.2 TYPES OF RIVETED JOINTS

1.



Single Riveted

2.



Double Riveted

CHAPTER - 5
FRICTION CLUTCHES

5.1 CLUTCH

It is a mechanical device, which is used to connect or disconnect the source of power from the remaining parts of the power transmission system at the will of operator.

5.1.1 Classification of Clutches

1. Positive Contact Clutches: They include square jaw clutches, spiral jaw clutches and toothed clutches. Power transmission is achieved by means of interlocking of jaws or teeth. No slip is there.

2. Friction Clutches: They include single and multi plate clutches, cone clutches and centrifugal clutches. Power transmission is achieved by means of friction between contacting surfaces.

3. Electromagnetic Clutches: They include magnetic particle clutches, magnetic hysteresis clutches and eddy current clutches. Power transmission is achieved by means of magnetic field.

4. Fluid Clutches and Couplings: Power transmission is achieved by means of hydraulic pressure.

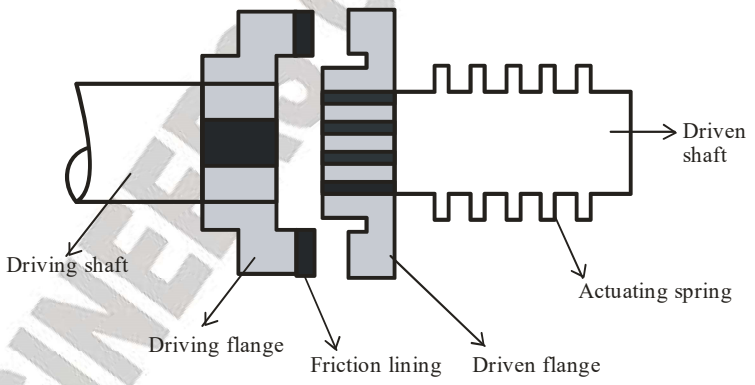
5.1.2 Advantages of Jaw Clutches

1. No slip and engagement is positive
2. No heat is generated during engagement or disengagement.

5.1.3 Disadvantages

1. It can be engaged only when both shafts are stationary or rotate with very small speed difference.
2. It cannot be engaged at high speeds

5.2 SINGLE PLATE FRICTION CLUTCH



1. One flange is rigidly hanged to the driving shaft, while the other is connected to the driven shaft by means of splines. The splines permit free axial movement of the driven flange with respect to driven flange shaft.
2. This axial movement is necessary for engagement and disengagement of the clutch.
3. The actually force is provided by a helical spring which forces the driven flange to move towards driving flange.
4. Power is then transmitted from driving flange to driven flange by means of frictional force.

GATE QUESTIONS

1. Single - plate clutch has a friction disc with inner and outer of 20 mm and 40mm, respectively. The friction lining in the disc is made is such a way that the coefficient of friction μ varies radially as $\mu = 0.01$ r, where r is in mm. The clutch needs to transmit a friction torque of 18.85 kN-mm. As per uniform pressure theory, the pressure (in MPa) on the disc is _____

[GATE - 2017]

2. A disc clutch with a single friction surface has coefficient of friction equal to 0.3. The maximum pressure which can be imposed on the friction material is 1.5 MPa. The outer diameter of the clutch plate is 200 mm and its internal diameter is 100 mm. Assuming uniform wear theory for the clutch plate, the maximum torque (in N.m) that can be transmitted is _____.

[GATE - 2014]

3. A clutch has outer and inner diameter 100 mm and 40 mm respectively. Assuming a uniform pressure of 2 MPa and coefficient of friction of liner material 0.4, the torque carrying capacity of the clutch is

[GATE - 2008]

(a) 148 Nm (b) 196 Nm
(c) 372 Nm (d) 490 Nm

4. A disk clutch is required to transmit 5 kW at 2000 rpm. The disk has a friction lining with coefficient of friction equal to 0.25. Bore radius of friction lining is equal to 25 mm. Assume uniform contact pressure of 1 MPa. The value of outside radius of the friction lining is

[GATE - 2006]

(a) 39.4 mm (b) 49.5 mm
(c) 97.9 mm (d) 142.9 mm

5. Axial operation claw clutches having self-locking tooth profile.

[GATE - 1987]

(a) Can be disengaged at any speed
(b) Can be disengaged only unloaded
(c) Can be engages only when unloaded
(d) Can work only with load.

CHAPTER - 6
BRAKES

6.1 BRAKES

A brake is a mechanical device, which is used to absorb energy passed by a moving system or mechanism by means of friction.

Brake capacity depends upon the following three factors.

1. The until presence between braking surfaces.
2. The contacting area of braking surfaces.
3. Radius of brake drum
4. μ
5. Ability of the brake to dissipate heat that is equivalent to the energy being absorbed.

6.2 ENERGY EQUATIONS

Consider a mechanical system of mass m, moving with velocity V_1 is slowed down to velocity V_2,

$\therefore$ During the period of breaking, the KE $= \frac{1}{2} m(V_1^2 - V_2^2)$

Similarly for a rotating body, KE $= \frac{1}{2} I(\omega_1^2 - \omega_2^2)$

$$KE = \frac{1}{2} mk^2(\omega_1^2 - \omega_2^2)$$

Where k is radius of gyration

In certain applications, like hoists, the brake absorbs the potential energy released by the moving weight during the braking period.

PE = mgh

Depending upon the type of applications, the total energy absorbed by the brake is determined by

$E = T \times \theta$

Where θ is angle through which brake drum rotates during the breaking period (rad)

Example. A solid CI disk, 1m in diameter and 0.2m thick is used as flywheel. It is rotating at 350rpm. It is brought to rest in 1.5s by means of a brake calculate

(a) The energy absorbed by the brake

(b) The torque capacity of the brake $P_a = 7200 kg/m^3$

Solution.

D = 1m, t = 0.2m, N_1 = 350rpm, N_2 = 0

t = 1.5s

(a) $E = \frac{1}{2} mk^2(\omega_1^2 - \omega_2^2)$

$$\omega_1 = \frac{2\pi(350)}{60} = 36.63 \text{ rad/sec}$$

$m = (\pi r^2 h)\ (7200)$

$m = \pi(.5)^2 \times (.2)\ (7200) = 1130.97 kg$

$k = \frac{d}{\sqrt{8}}$ (for solid disk about its axis of rotation)

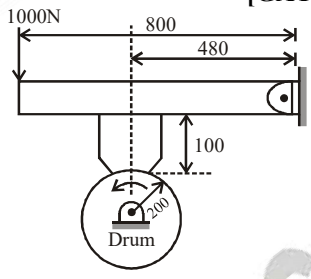
GATE QUESTIONS

1. A four-wheel vehicle of mass 1000 kg moves uniformly in a straight line with the wheels revolving at 10 rad/s. The wheels are identical, each with a radius of 0.2 m. Then a constant braking torque is applied to all the wheels and the vehicle experience a uniform deceleration. For the vehicle to stop in 10 s, the braking torque (in N.m) on each wheel is _____.

[GATE - 2014]

2. A drum brake is shown in the figure. The drum is rotating in anticlockwise direction. The coefficient of friction between drum and shoe is 0.2. The dimensions shown in the figure are in mm. The braking torque (in N-m) for the brake shoe is _____.

[GATE - 2014]



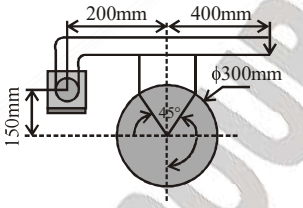
3. A band brake having bandwidth of 80 mm, drum diameter of 250 mm, coefficient of friction of 0.25 and angle of wrap of 270 degrees is required to exert a friction torque of 1000 N m. The maximum tension (in kN) developed in the band is

[GATE - 2010]

(a) 1.88 (b) 3.56
(c) 6.12 (d) 11.56

4. A block – brake shown below has a face width of 300 mm and a mean coefficient of friction of 0.25. For an activating force of 400N, the braking torque in Nm is

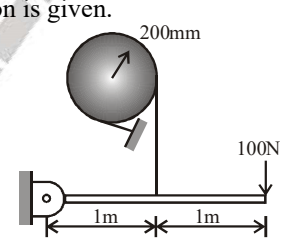
[GATE - 2007]



(a) 30 (b) 40
(c) 45 (d) 60

Linked statement for Q.5 & Q.6

A band brake consists of a lever attached to one end of the band. The other end of the band is fixed to the ground. The wheel has a radius of 200 mm and the wrap angle of the band is 270°. The braking force applied to the lever is limited to 100 N, and the coefficient of friction between the band and the wheel is 0.5 No other information is given.



5. The maximum tension that can be generated in the band during braking is

[GATE - 2005]

(a) 1200 N (b) 2110 N
(c) 3224 N (d) 4420 N

6. The maximum wheel torque that can be completely braked is

[GATE - 2005]

(a) 200 N.m (b) 382 N.m
(c) 604 N.m (d) 844 N.m

7. In a band brake the ratio of tight side band tension to the tension on the slack side is 3. If the angle of overlap of band on the drum is 180° the coefficient of friction required between drum and the band is

[GATE - 2003]

(a) 0.20 (b) 0.25
(c) 0.30 (d) 0.35

CHAPTER - 7
BELTS

7.1 BELT DRIVES

Belt, chain and rope drives are called flexible drives.
Gear drives are rigid drives.
Belts are used to transmit power between two shafts by means of friction.

7.1.1 Advantages of Belt Drives

1. Operation is smooth and silent
2. It can transmit power over considerable distance between the axes of driving and driven shafts.
3. They can transmit only a definite load, which if exceeded, will cause the belt to slip over the pulley.
4. It has ability to absorb shocks and damp vibration
5. It has low cost and simple design.

7.1.2 Disadvantages of Belt Drives

1. It has large dimensions and occupies more space.
2. The VR is not constant due to belt slip.
3. It has low efficiency
4. It has short life

Two types of cross section
(i) Flat belt (ii) V-belt

7.1.3 Advantages of Flat Belts Over V-Belts

1. Relatively cheap and easy to maintain
2. Their maintenance consists of periodic adjustment in the centre distance between shafts in order to compensate stretching.
3. Different VR can be obtained by using a stepped pulley, where the belt is shifts from one step to another, having different diameter.
4. Simple and inexpensive
5. Can be used for long distances up to 15m
6. Efficiency of flat belt is more than efficiency of V-belt

7.1.4 Disadvantages of Flat Belt Drives Over V-Belt Drives

1. The power transmitting capacity of flat belt is low.
2. VR is less than V-belt
3. Flat belts are nosier than V-belts
4. Only horizontal and not vertical.

7.1.5 Advantages of V-Belts

1. Force of friction between the surfaces of the belt and v-grooved pulley is high due to wedge action. This wedging action permits a smaller arc of contact, increases the pulling capacity of the belt and consequently results in increase in power transmitting capacity.
2. Shorter distance belts
3. High VR up to 7: 1
4. Smooth operation

GATE QUESTIONS

1. A wire rope is designated as 6 × 19 standard hoisting. The numbers 6 × 19 represent **[GATE - 2003]**

(a) Diameter in millimeter × length in meter
(b) Diameter in centimeter × length in meter
(c) Number of strands × number of wires in each strand
(d) Number of wires in each strand × number of strands

SOLUTIONS

Sol 1. (c)

CHAPTER - 8
CHAIN DRIVES

8.1 INTRODUCTION
A chain can be defined as a series of links connected by pin joints.
It has some features of belt drive and some of gear drive.

8.1.1 Advantages
1. It can be used for long as well as short distance range.
2. Number of shafts can be driven
3. Small overall dimensions
4. Positive drive and has no slip
5. High efficiency (96% to 98%).
6. No initial tension required
7. Easy to replace.

8.1.2 Disadvantages
1. More wear.
2. Less précised motion
3. Noisy operation

8.2 DESIGN OF SPUR GEARS
A mechanical drive is defined as a mechanism, which is intended to transmit mechanical power over a certain distance, usually involving a change in speed and torque.
Two groups of mechanical drives are
1. Mechanical drives that transmit power by means of friction e.g. belt and rope drive.
2. Mechanical drives that transmit power by means of engagement e.g. chain drive and gear drive.

1. Selection of a proper mechanical drive for a given application depends upon number of factors such as centre distance, VR, shifting arrangement, maintenance and cost.
2. Gear drive is a positive drive and has constant speed.

8.3 CHAIN
The belt drive is not a positive drive because of creep and slip .The chaibn drive is a positive drive .Like belts , chains can be used for larger centre distances .They are made of metal and due to this chain is heavier than the belt but they are flexible like belts .It also requires lubrication from time to time .The lubricant prevents chain from rusting and reduces wear.
The chain and chain drive are shown in figure .The sprockets are used in place of pulleys.The projected teeth of sprockets fit in the recesses of the chain .The distance between roller centers of two adjacent links is known as pitch .The circle passing through the pitch centrers is called pitch circle.

ESE OBJ QUESTIONS

1. For roller chain drive with sprocket having 10 teeth, the velocity of the driven shaft with respect to that of drive will be approximately.

[ESE - 2008]

(a) Same
(b) 5% above
(c) 5% below
(d) 5% above to 5% below

2. Source of power loss in a chain drive are given below:

1. Friction between chain and sprocket teeth.
2. Overcoming the chain stiffness.
3. Overcoming the friction in shaft bearing.
4. Frictional resistance to the motion of the chain in air or lubricant.

To correct sequence of descending order of power loss due to these sources is

[ESE - 1995]

(a) 1, 2, 3, 4 (b) 1, 2, 4, 3
(c) 2, 1, 3, 4 (d) 2, 1, 4, 3

SOLUTIONS

Sol 1. (d)

$$V_{max} - V_{min}\ \alpha\left[1-\cos\left(\frac{180}{z}\right)\right]$$

In order to reduce the variation in chain speed, the number of teeth on the sprocket should be increased. It has been observed that the speed variation is 4% for a sprocket with 11 teeth, 1.6% for sprocket with 17 teeth, and less than 1% for a sprocket with teeth.

For smooth operation at moderate and high speeds, it is considered a good practice to use a driving sprocket with at least 17 teeth. For durability and noise considerations, the minimum number of teeth on the driving sprocket should be 19 or 21.

Sol 2. (a)

This is the decreasing order in which losses takes place.

CHAPTER - 9
GEARS

9.1 GEAR DRIVES

Gears are defined as toothed wheels or multi lobed comes, which transmit power and motion from one shaft to another by means of successive engagement of teeth.

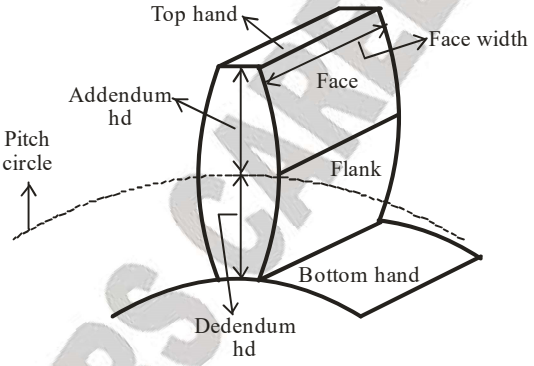
9.1.1 Advantages

1. It is a positive drive with constant VR
2. CD between shafts is small therefore compact construction
3. It can transmit very large power, even beyond the range of chain and belt drive
4. It can transmit motion at very low velocity which is not possible with belt drives
5. 99% efficiency
6. Provision of gear shifting is there in gear boxes.

9.1.2 Disadvantages

1. Gear drives are costly and their maintenance cost is also higher.
2. Precise alignment is also required.

9.2 TERMINOLOGY



1. Pinion: smaller of the two mating gear
2. Gear: larger of the two rotating gear
3. Pitch circle: Pitch circle is the curve of intersection of the pitch surface of revolution and the plane of rotation. It is an imaginary circle that rotates without slipping with the pitch circle of a mating gear corresponding diameter is pitch circle dia. (PCD)
4. Addendum (h_a): height of tooth above PCD
5. Ddendum (h_d): height of tooth below PCD
6. Clearance (C): Clearance is the amount by which dedendum of a given gear exceeds the addendum of its mating tooth.
7. Face width (b): It is width of tooth measured parallel to axis.
8. Tooth space: The width of the space between two adjacent teeth measured along the pitch circle is called the tooth space.
9. Working depth: Sum of addendum of gear is engagement.
10. C.D: It is the distance between centres of pitch circles of mating gears.
11. Pressure angle: It is the angle which the line of action makes with the common tangent to the pitch circles. The pressure angle is also called angle of obliquity.

CHAPTER - 10
BEARING

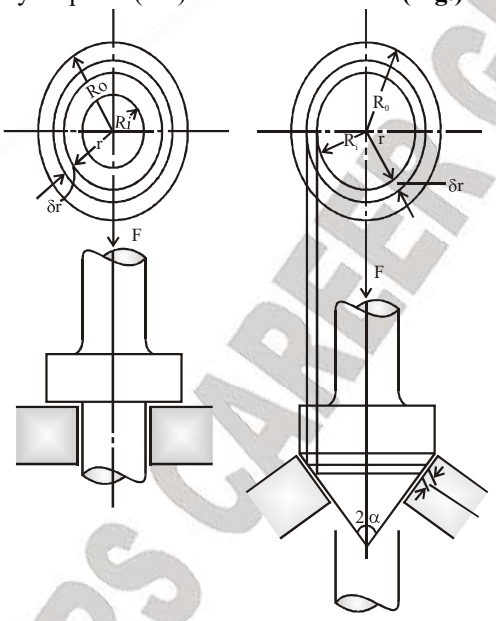
10.1 INTRODUCTION

When a rotating shaft is subjected to an axial load, the thrust (axial force) is taken either by a pivot or a collar. Examples are the shaft of a steam turbine and propeller shaft of a ship.

10.1.1 Collar Bearing

A collar bearing or simply a collar is provided at any position along the shaft and bears the axial load on a mating surface.

The surface of the collar may be plane (flat) normal to the shaft **(Fig.)** of conical shape **(Fig.).**



10.1.2 Pivot Bearing

When the axial load is taken by the end of the shaft which is inserted in a recess to bear the thrust, it is called a *pivot bearing* or simply a *pivot*. It is also known as *footstep bearing*.

$$= \int_{R_i}^{R_o} p \times 2\pi r dr \quad = \int_{R_i}^{R_o} \frac{C}{r} \times 2\pi r dr$$

$$= \int_{R_i}^{R_o} 2\pi C.dr = (2\pi Cr)_{R_i}^{R_o} = 2\,\pi\, C\,(R_o - R_i) = 2\,\pi\, pr\,(R_o - R_i)$$

or pressure intensity p at a radius *r* of the collar,

$$p = \frac{F}{2\pi r (R_o - R_i)}$$

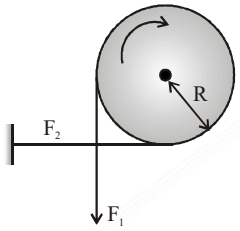
In a flat pivot, in which $R_i = 0$, the pressure would be infinity at the centre of the bearing (r = 0), which cannot be true. Thus, the uniform wear theory has a flaw in it.

Collars and pivots, using the above two theories, have been analysed below:

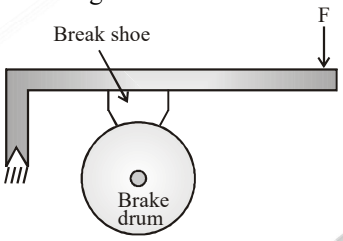
GATE QUESTIONS

1. The force F_1 and F_2 in a brake band and the direction of rotation of the drum are as shown in the figure. The coefficient of friction is 0.25. The angle of wrap is $3\pi/2$ radians. It is given that R = 1m and F_2 = 1N. the torque (in N-m) exerted on the drum is___

[GATE - 2016]



2. For the brake shown in figure, which one of the following is TRUE ?



[GATE - 2016]

(a) Self energizing for clockwise rotation of the drum
(b) Self energizing for anti – clockwise rotation of the drum
(c) Self energizing for rotation in either direction of the drum
(d) not of the self energizing type

3. A hydrodynamic journal is subjected to 2000 N load at a rotational speed of 2000 rpm. Both bearing bore diameter and length are 40 mm. If radial clearance is 20 μm and bearing is lubricated with an oil having viscosity 0.03 Pa.s, the sommerfeld number of the bearing is _____.

[GATE - 2014]

4. Ball bearings are rated by a manufacturer for a life of 10^6 revolutions. The catalogue rating of particular bearing is 16 kN. If the design load is 2 kN, the life of the bearing will be $p \times 10^6$ revolutions, where p is equal to _____.

[GATE - 2014]

5. A solid circular shaft needs to be designed to transmit a torque of 50 N.m. If the allowable shear stress of the material is 140 MPa, assuming a factor of safety of 2, minimum allowable design diameter in mm is

[GATE - 2012]

(a) 8 (b) 16
(c) 24 (d) 34

6. Two identical ball bearings P and Q are operating at loads 30 kN and 45 kN respectively. The ratio of the life of bearing P to the life of bearing Q is

[GATE - 2011]

7. A lightly loaded full journal bearing has journal diameter of 50 mm, bush bore of 50.05 mm and bush length of 20 mm. If rotational speed of journal is 1200 rpm and average viscosity of liquid lubricant is 0.03 Pa s, the power loss (in W) will be

[GATE - 2010]

(a) 37 (b) 74
(c) 118 (d) 237

8. A journal bearing has a shaft diameter of 40 mm and a length of 40 mm. The shaft is rotating at 20 rad/s and the viscosity of the lubricant is 20 MPa.s. The clearance is 0.020 mm. The loss of torque due to the viscosity of the lubricant is approximately.

[GATE - 2008]

(a) 0.040 Nm (b) 0.252 Nm
(c) 0.400 Nm (d) 0.652 Nm

9. A natural feed journal bearing of diameter 50 mm and length 50 mm operating at 20 revolution/sec. carries a load of 2.0 kN. The lubricant used has a viscosity of 20 MPa/s. The