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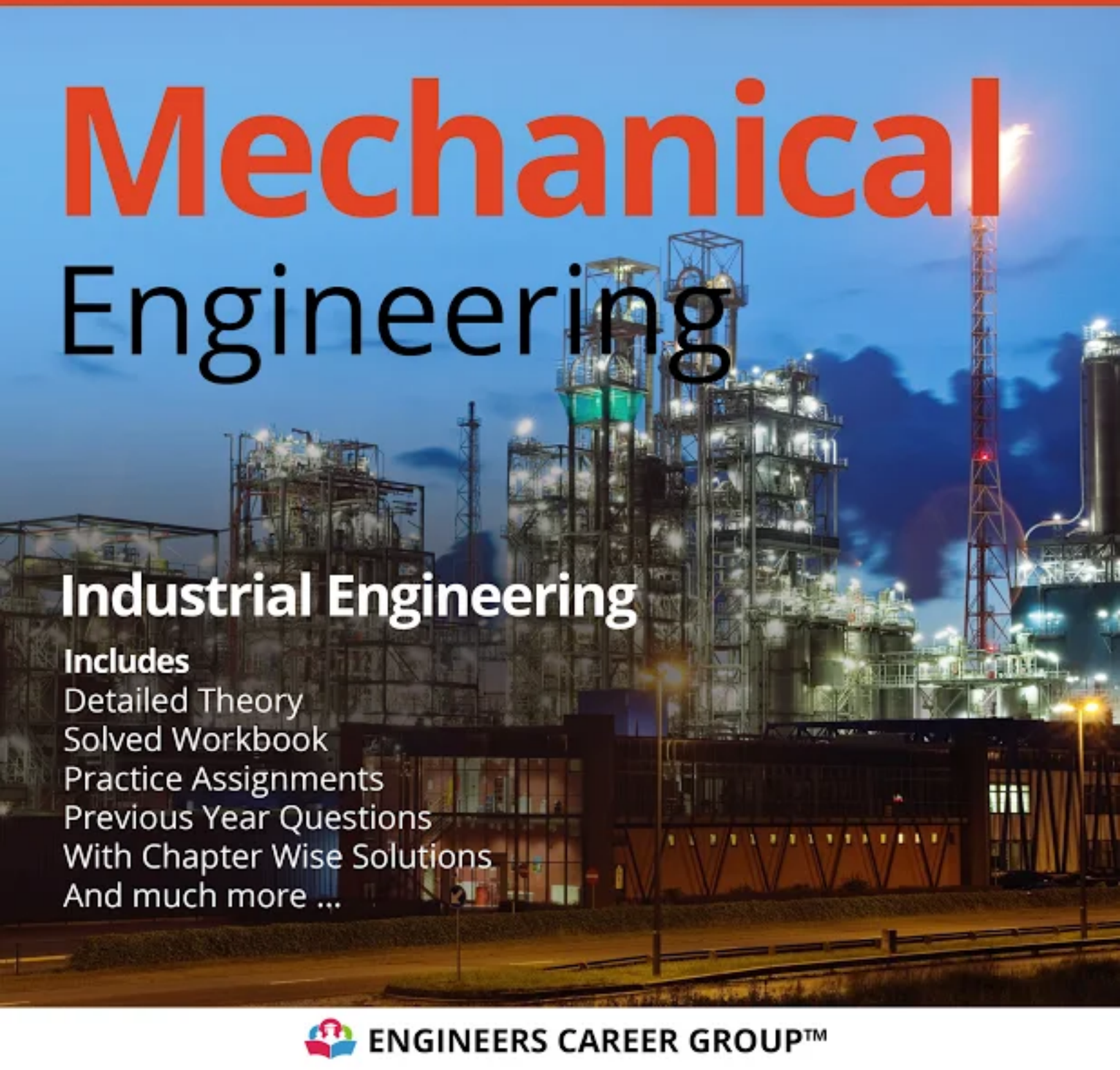

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MACHINE DESIGN

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. Pre-tensioning of a bolted joint is used to
(a) Strain harden the bolt head
(b) Decrease stiffness of the bolted joint
(c) Increase stiffness of the bolted joint
(d) Prevent yielding of the thread root

[GATE - 2018]

2. Fatigue life of a material for a fully reversed loading condition is estimated from $\sigma_a = 1100\ N^{-0.15}$ where σ_a is the stress amplitude in MPa and N is the failure life in cycles. The maximum allowable stress amplitude (in MPa) for a life of 1×10^5 cycles under the same loading condition is _____(correction to two decimal places).

[GATE - 2018]

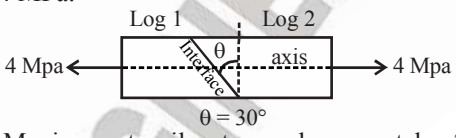
3. If σ_1 and σ_3 are maximum and minimum values of principle stresses algebraically then the maximum value of shear stress is ?

[GATE - 2018]

(a) $\frac{\sigma_1-\sigma_3}{2}$ (b) $\sqrt{\frac{\sigma_1-\sigma_3}{2}}$

(c) $\left(\frac{\sigma_1+\sigma_3}{2}\right)$ (d) $\sqrt{\frac{\sigma_1+\sigma_3}{2}}$

4. Two wooden pieces are attached as shown in figure below. Their attached with figure so the angle (θ) is given in the diagram is 30° and the whole assembly experience 10 in tensile stress of 4 MPa.



1. Maximum tensile stress glue can take 2.5 Mpa
2. Shear stress glue can take 1.5 Mpa

Assume that failure will be happen in glue not in wood ?

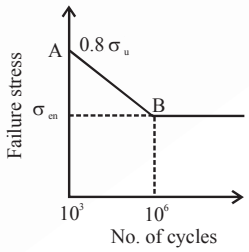
[GATE - 2018]

(a) It fails by two tensile stress not shear stress
(b) It fails by shear stress not tensile ?
(c) Fail by both of them
(d) Fail by none of them

5. A bar is subjected to a combination of a steady load of 60 kN and a load fluctuating between – 10 kN and 90 kN. The corrected endurance limit of the bar is 150 MPa. The yiled strength of the material is 480 MPa and he ultimate strength of the material is 600 MPa. The bar cross-section is square with side a. if the factor of safety is 2, the value if a (in mm), according to the modified Goodman's criterion, is_____ (correct to two decimal places).

[GATE - 2017]

6. 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]

7. The principal stresses at a point in a critical section of machine component are $\sigma_1 = 60$ MPa, $\sigma_2 = 5$ MPa and $\sigma_3 = -40$ MPa. For the material of the component, the tensile yield strength is $\sigma_y = 200$ 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

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
(b) Keeping the magnitude of bending moment small by reducing the unsupported length of the pin

CHAPTER - 2
POWER SCREWS

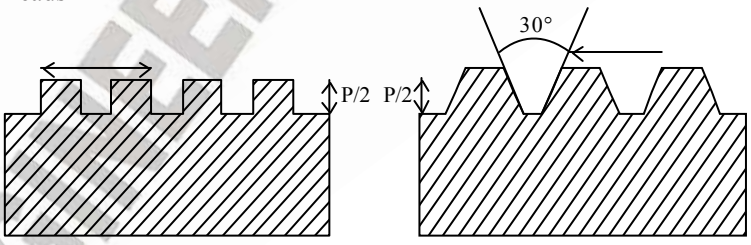
2.1 INTRODUCTION
A power screw is a mechanical device used for converting rotary motion into linear motion and transmitting power. Example; screw jack, lead screw of lathe, vice etc.

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



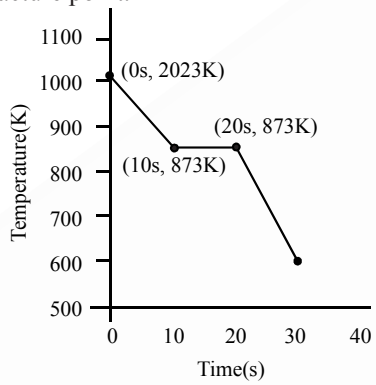
2.2.1 Square Threads
2.2.1.1 Advantages
1. Its efficiency is more than trapezoidal threads.
2. There is no radial pressure or side thrust on the nut.

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.



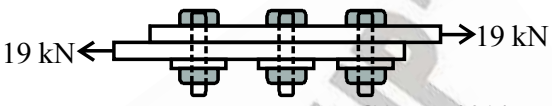
The toughness of the material (in MJ/m^3) is __

[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]

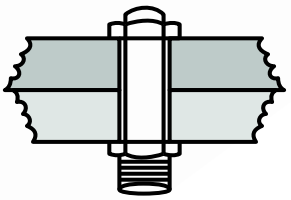
(a) M 8 (b) M 10
(c) M 12 (d) M 16

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.

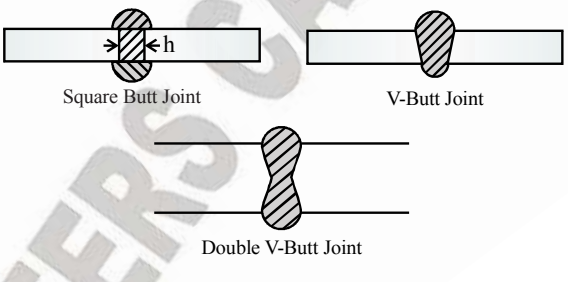
CHAPTER - 3
WELDED JOINTS

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

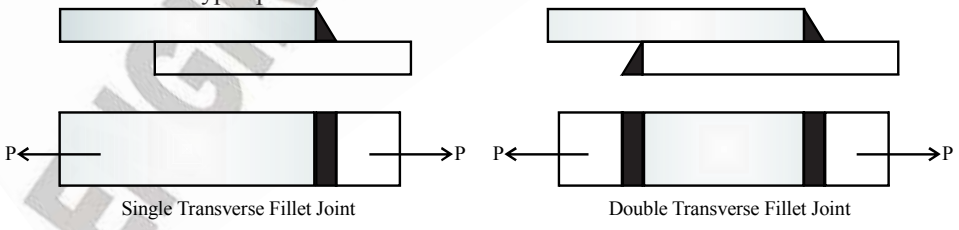
3.1.1 Advantages of Welded Joints
1. Lighter assemblies as compared to riveting where additional cover plates, gussets plates are required
2. Lower cost
3. Changes can be easily made
4. Leak-proof joints
5. Lesser production time
6. Drilling holes in reverted points reduces strength of material.
7. Bad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

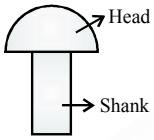


3.3 FILLET JOINTS
It is also called a lap joint, is a joint between two overlapping plates or components. A fillet weld consists of an approximately triangular cross-section joining two surfaces at right angles to each other. It is of two types parallel and transverse.



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

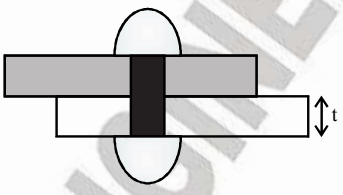
1. More reliable in case of vibration and impact loads.
2. Quality of riveted joint can be easily checked.
3. Can be dismantled work without much damaged parent material.

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.

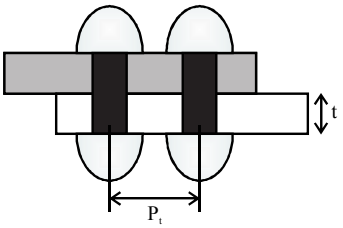
4.2 TYPES OF RIVETED JOINTS

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.

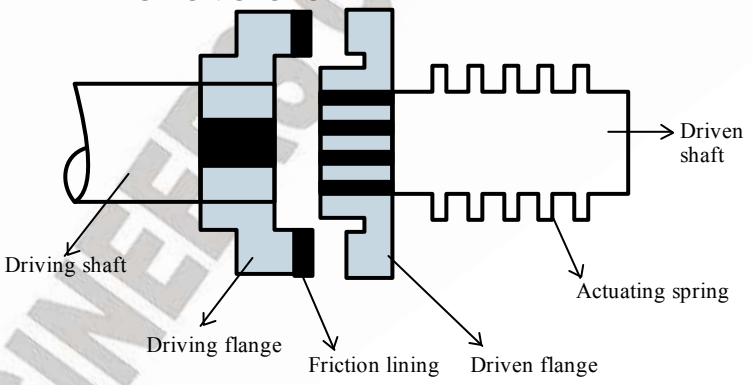
5.1.2 Advantages of Jaw Clutches

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, $N_1 = 350$rpm, $N_2 = 0$

t = 1.5s

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

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

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

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

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

$$k = \frac{1}{\sqrt{8}} \Rightarrow k^2 = \frac{1}{8}$$

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

ESE OBJ QUESTIONS

1. Assertion (A): In chain drives, angle of articulation through which link rotates during engagement and disengagement, is greater for a small number of teeth.
Reason (R): The greater angle of articulation will increase the life of the chain.

[ESE - 2015]

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false.
(d) A is false but R is true.

2. If the velocity ratio o=for an open belt drive is 8 and the speed of driving pulley is 800 r.p.m, then considering an elastic creep of 2% the speed of the driven pulley is

[ESE - 2015]

(a) 104.04 r.p.m. (b) 102.04 r.p.m.
(c) 100.04 r.p.m. (d) 98.04 r.p.m.

3. If the angle of warp on smaller pulley od diameter 250 mm is 120° and diameter of larger pulley is twice the diameter of smaller pulley, then the center distance between the pulleys for an open belt drive is

[ESE - 2015]

(a) 1000 mm (b) 750 mm
(c) 500 mm (d) 250 mm

4. If T_1 and m represent the maximum tension and mass per unit length of a belt, the maximum permissible speed of the belt is given by

[ESE - 2014]

(a) $\sqrt{\frac{T_1}{3m}}$ (b) $\sqrt{\frac{3T_1}{m}}$
(c) $\sqrt{\frac{2T_1}{3m}}$ (d) $\sqrt{\frac{T_1}{m}}$

5. Which of the following statements are correct regarding power transmission through V-belts?
1. V-belts are used at the high-speed end.
2. V-belts are used at the low-speed end.
3. V-belts are standard lengths.
4.V-angles of pulleys and belts are standardized.
Select the correct answer using the code given below:

[ESE - 2014]

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

6. Statement (I): In short open-belt drives, an idler pulley is used in order to increase the angle of contact on the smaller pulley for higher power transmission.
Statement (II): The idler pulley facilitates changing the speed of the driven shaft, while the main or driven shaft runs at constant speed.

[ESE - 2014]

(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.

7. Considering the effect of centrifugal tension in a flat drive with T_1 = tight side tension and T_c = centrifugal tension and m = mass per unit length of belt, the velocity of the belt for maximum power transmission is given by:

[ESE - 2013]

(a) $V = \sqrt{\frac{T_1}{3m}}$ (b) $V = \sqrt{\frac{T_c}{3m}}$
(c) $V = \sqrt{\frac{(T_1 - T_c)}{3m}}$ (d) $V = \sqrt{\frac{(T_1 + T_c)}{3m}}$

8. Statement (I): Generally, for larger size pulleys, curved arms are used.

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.

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.

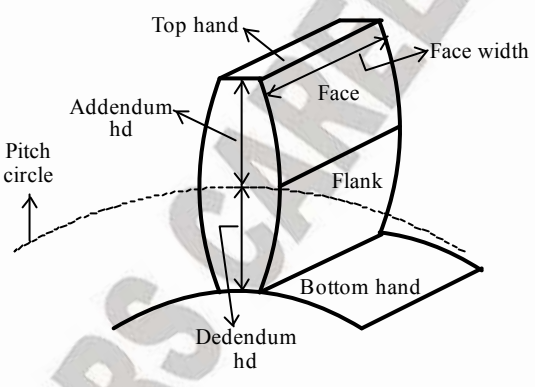
9.1.1 Advantages

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.

GATE QUESTIONS

1. A spur pinion of pitch diameter 50 mm rotates at 200 rad/s and transmits 3 kW power. The pressure angle of the tooth of the pinion is 20°. Assuming that only one pair of the teeth is in contact, the total force (in newton) exerted by a tooth of the pinion on the tooth on a mating gear is _____.

[GATE - 2014]

2. A pair of spur gears with module 5 mm and a center distance of 450 mm is used for a speed reduction of 5: 1. The number of teeth on pinion is _____.

[GATE - 2014]

3. Which one of the following is used to convert a rotational motion into a translational motion?

[GATE - 2014]

(a) Bevel gears
(b) Double helical gears
(c) Worm gears
(d) Rack and pinion gears

4. For the given statements:
I. Mating spur gear teeth is an example of higher pair.
II. A revolute joint is an example of lower pair.
Indicate the correct answer.

[GATE - 2014]

(a) Both I and II are false
(b) I is true and II is false
(c) I is false and II is true
(d) Both I and II are true.

5. Two cutting tools are being compared for machining operation. The tool life equation are:
Carbide tool: $VT^{1.6} = 3000$
HSSS tool: $VT^{0.6} = 200$
Where V is the cutting speed in m/min and T is the tool life in min. The carbide tool will provide higher tool life if the cutting speed in m/min exceeds.

[GATE - 2013]

(a) 15.0 (b) 39.4
(c) 49.3 (d) 60.0

Linked Statement for Q.6 & Q.7
A 20° full depth involute spur pinion of 4 mm module and 21 teeth is to transmit 15 kW at 960 rpm. It face width is 25 mm.

6. The tangential force transmitted (in N) is

[GATE - 2009]

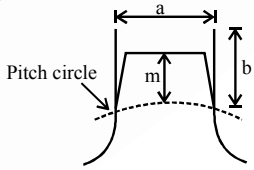
(a) 3552 (b) 2611
(c) 1776 (d) 1305

7. Given that the tooth geometry factor is 0.32 and the combined effect dynamic load and allied factors intensifying the stress is 1.5; the minimum allowable stress (in MPa) for the gear material is

[GATE - 2009]

(a) 242.0 (b) 166.5
(c) 121.0 (d) 74.0

8. One tooth of a gear having 4 module and 32 teeth is shown in the figure. Assume that the gear tooth and the corresponding tooth space make equal intercepts on the pitch circumference. The dimensions 'a' and 'b', respectively, are closest to:



[GATE - 2008]

(a) 6.08 mm, 4 mm (b) 6.48 mm, 4.2 mm
(c) 6.28 mm, 4.3 mm (d) 6.28 mm, 4.1 mm

9. Match the type of gears with their most appropriate description.

Type of gear
A. Helical
B. Spiral Bevel
C. Hypoid
D. Rack and pinion

Description
(i) Axes non parallel and non intersecting
(ii) Axes parallel and teeth are inclined to the axis

CHAPTER - 10
BEARING

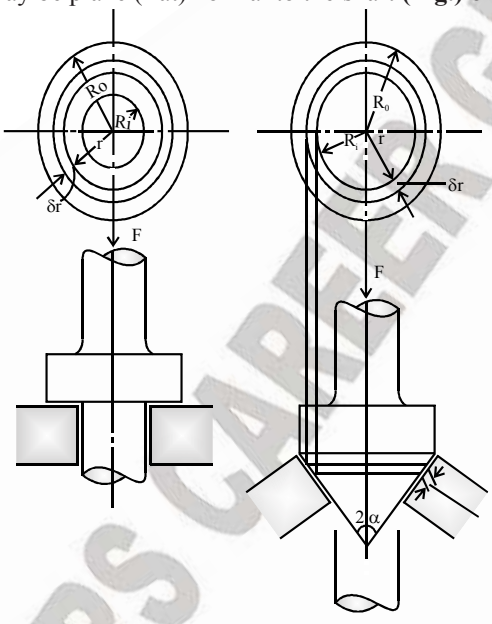
10.1 INTRODUCTION

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:

ESE OBJ QUESTIONS

1. In a journal bearing, the diameter of the journal is 0.15m , its speed is 900rpm and the load on the bearing is 40kN. Considering μ = 0.0072, the heat generated will be nearly

[ESE - 2018]

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

2. The bearing modulus for a bearing is 1628. What is the bearing characteristic number considered for bearing design?

[ESE - 2016]

(a) 1628 (b) 3256
(c) 4884 (d) 6512

3. A thick lubrication is

[ESE - 2016]

(a) a stable lubrication and there is no metal to metal contact
(b) a stable lubrication because there is some amount of metal to metal contact
(c) an unstable lubrication because there is some amount of metal to metal contact
(d) an unstable lubrication because there is no metal to metal contact

4. A journal bearing sustains a radial load of 3672 N. The diameter of the bearing is 50 mm and the length is 0.1m. The diametral clearance is 0.1m. The diametral clearance is 0.1 mm and the shaft rotates at 500 r.p.m. If the absolute viscosity of the oil is 0.06 kg/m-s, the value of Sommerfeld number is

[ESE - 2016]

(a) 5.2×10^6 (b) 10.3×10^6
(c) 15.2×10^6 (d) 20.3×10^6

5. If the dynamic load capacity of a ball bearing is increased to 1.5 times its earlier value without changing its equivalent load, the life of the bearing increase to

[ESE - 2016]

(a) 6.4 times its earlier life
(b) 5.2 times its earlier life
(c) 4.2 times its earlier life
(d) 3.4 times its earlier life

6. If the equivalent load in case of radial ball bearing is 500 N and the basic dynamic load ration is 62500 N, then L_{10} life of this bearing is

[ESE - 2015]

(a) 1.953 million of revolutions
(b) 3.765 million of revolutions
(c) 6.953 million of revolutions
(d) 9.765 million of revolutions

7. Consider the following statements in connection with thrust bearings:
1. Cylindrical thrust bearing have higher coefficient of friction than ball thrust bearings.
2. Taper rollers cannot be employed for thrust bearings.
3. Double row thrust ball bearing is not possible.
4. Lower race, outer race and retainer and readily separable in thrust bearings.
Which of these above statements are correct?

[ESE - 2015]

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

8. Consider that modern machines mostly use short bearings due to the following reasons:
1. ℓ/d of the most modern bearings is in the range of $\frac{1}{4}$ to 2.
2. No end leakage of oil form the bearing
3. Shaft deflection and misalignment do not affect the operation.
4. Can be applied to both hydrodynamics and hydrostatic cases.
Which of the above are correct?

[ESE - 2015]

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

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