2.0 DESIGN OF FASTENING ELEMENTS

The method of joining two or more machine elements by using any permanent or temporary fastener is called fastening. So design of fastening element includes prepare specification of a particular fastener, preparation of drawing and finally decision towards manufacturing methodology.

Fastening is of two types: - (1) **Permanent Fastening**. (2) **Temporary Fastening**.

Permanent Fastening:- The method of fastening in which the joints can disassembled only by braking the fastener is called permanent fastening method.

Example: - Riveting, Brazing, Soldering, Welding etc.

Temporary Fastening:- The method of fastening in which the joints can be readily engage or disengage without braking the fastener is called Temporary fastening.

Example: - Screw joint, Nut and Bolt joint, Stud and nut joint etc.

2.1 State Nomenclatures, Form of threads and specification:-

A screw thread is obtained by cutting a continuous helical groove on a cylindrical surface by the help of lathe machine. A screw thread fastener is formed by a nut and bolt assembles. The threads formed on the surface of screw are of two types: - (1) V-Thread.

(2)Square-Thread.

The following are the terms that are associated with screw threads.

1. **Major (nominal)diameter**:- This is the largest the largest diameter of a screw thread , touching the crests on external thread or the roots on external thread or the roots on internal thread.
2. **Minor (core or root) diameter**:-This is the smallest diameter of a screw thread, touching the roots or core of an external thread or the crest of internal thread.
3. **Pitch diameter**:-This is the diameter of imaginary cylinder, passing through the threads at the points where the width of thread is equal to the space between thread.
4. **Pitch**: - It is the distance measured parallel to the axis, between corresponding points on adjacent screw threads.
5. **Lead**:-It is the distance; a screw advances axially in one turn. For a single threaded screw, the pitch and lead are equal; for a double thread screw, the lead is twice the pitch and so on.

THREAD DESIGNATION (SPECIFICATION):-

Bureau of Indian Standards (BIS) adopts ISO (International Organization for standards) metric threads which are followed by a number of countries, including India.

BIS recommends two thread series: Course and fine series, based on the relative values of the pitches.

- ISO metric screw thread is designated by the letter 'M' followed by the value of the nominal diameter and pitch, the two values separated by the sign '×'.
- For example, a diameter, pitch combination of nominal diameter 10 mm and pitch 1.25 is designated as **M10 × 1.25.**
- If there is no indication of pitch in the designation, it shall mean the course pitch. For example,
- **M10** means that the nominal diameter of the thread is **10** mm and pitch is **1.5** mm.
- Following are the other designations, depending on the shape of the thread profile.
- **SQ 40× 10** – **SQUARE** thread of nominal diameter 40 mm and pitch 10 mm.
- **ACME 40 × 8- ACME** threads of nominal diameter **40** mm and pitch **8**mm.
- **WORM 40× 10 –Worm** thread of nominal diameter 40 mm and pitch 10 mm.

2.2 DESCRIBE NATURE OF LOADS AND FAILURE OF BOLT SUBJECTED TO DIFFERENT STRESS CONDITION: -

The following are the types of stresses that are induced in bolted joint under static loading:

I. Stresses due to initial tightening (screwing up) of the nut.
II. Stresses due to external forces.
III. Stresses due to the combination of above.

(I).STRESSES DUE TO INITIAL TIGHETING (screwing up) OF THE NUT:-

When a bolt is tightened by a nut initially; the following are the types of stresses induced:

I. Tensile stress due to stretching of the bolt.
II. Compressive stress on the threads.
III. Shear stress across the threads.
IV. Tensional shear stress induced by frictional resistance between the threads in engagement.
V. Bending stress, if the surfaces under the bolt head and nut are not perfectly normal to the bolt axis.

Hence, in actual practice, the bolts are designed on the basis of tensile stress induced due to stretching of the bolt; but with a high factor safety.

An empirical relation arrived at from experimental results , used to determine the initial tension , F1 in a bolt , to make the joint leak proof (Fluid tight), is given

$$F1 = 2840d, \text{ N.}$$

Where d= nominal diameter of the in mm.

For ordinary fastening purpose, the initial tension in a bolt may be reduced to half of the above value, i.e**.., F1 = 1420d, N.**

(II) Stresses due to external forces:-

The following stresses are induced in a bolt when it is subjected to an external load.

1. **Tensile stress**: - The bolts, studs and screws usually carry a load in the direction of the bolt axis which induces a tensile stress in the bolt.
   Let **dc** = Root or core diameter of the thread, and
   σ_t= Permissible tensile stress for the bolt material.
   We know that external load applied,
   $$P = \frac{\pi}{4} \times (d_c)^2 \times \sigma_t$$

Now from Data Book **(SMJ)**, the value of the nominal diameter of bolt corresponding to the value of d_c may be obtained.

2. **Shear stress: -** Sometimes, the bolts are used to prevent the relative movement of two or more parts, as in case of flange coupling, and then the shear stress is induced in the bolts. In some cases, the bolts may be relieved of shear load by using shear pins. The shear stresses should be avoided as far as possible.

   Let d= Major diameter of the bolt, and
   n= Number of bolts.

   ∴ Shearing load carried by the bolts,
   $$P_s = \frac{\pi}{4} \times d^2 \times \tau \times n$$

3. **Combined tension and shear stress**: - When the bolt is subjected to tension and shear loads, as in case of coupling bolts or bearings, then the diameter of the shank of the bolt is obtained from the shear load and that of threaded part from the tensile load. So to obtained the value we use the following two theories of failure ,

Maximum principal shear stress,

$r_{Max} = \frac{1}{2} \times \sqrt{(\sigma_t)^2 + 4 \times r^2}$

And

Maximum principal tensile stress,

$\sigma_{t\,(max)} = (\sigma_{t}/2) + (1/2)\sqrt{(\sigma_t)^2 + 4 \times r^2}$

(iii) Stresses due to combined forces:-

Generally, studs are used to fasten cylinder head to the cylinder body of an I.C. engine. Here the studs are subjected to initial tightening load as well as gas or steam load. The resultant load on the studs depends upon the following factors:

1. The initial tension due to tightening of the bolt.
2. The external load.
3. The relative elastic yielding of the studs and connected bodies.

In order to determine the resultant load (P) on the stud (bolt), the following equation may be used.

$$P = P_1 + KP_2$$

Where P_1 = Initial tension due to tightening of the bolt,

P_2 = External load on the bolt, and

K= Stiffness constant for the connected parts.

The values of k for various types of joints are obtained from Design data book. (**S. MD. JALALUDEEN**).

The design equation is then given by,

$$P = \frac{\pi \times dc}{4} \times \sigma_t$$

Using the above equation, the value of $\mathbf{d_c}$ and then **d** may be determined from the table.

(iv) Stresses due to Transverse shear:-

Bolts subjected to shear stress should be avoided as for as possible, by the use of dowel pins, after fitting the bolts. When bolts are subjected transverse shear, the plane of shear should never be across the threaded portion of the bolt. Further, it is advisable to have the diameter of the shank slightly larger than the threaded part of the bolt.

Let, Q_t = Total shear load.

n = number of bolts.

$r =$ It is Permissible shear stress.

d = Shank diameter.

d_c= Core diameter

Assuming that transverse shear stress is uniformly distributed across the shank area.

$$Q_t = n \times \frac{d}{4} \times r$$

Assuming the number of bolts, n, the shank diameter of the bolt may be determined.

2.5 Types of welded joints:-

A welded joint is a permanent joint which is obtained by the fusion of the edges of the two parts to be joined together; with or without the application of pressure and a filler material. The heat required for the fusion of the material may be obtained by burning of gas (in case of gas welding) or by an electric arc (in case of electric arc welding).

From practical point view, following types of welded joints are important:

1. **Lap joint or Fillet joint**
2. **Butt joint.**

Lap Joint: - The lap joint or fillet joints are obtained by overlapping the plates and then welding the edges of the plates. The cross-section of the fillet is approximately triangular. The fillet joints may be:-

1. Single Transverse Fillet.
2. Double Transverse Fillet.
3. Parallel Fillet Joints.

Butt Joint: -

The butt joint is obtained by placing the plates edge to edge.

The Butt joints may be,

1. Square butt joint.
2. Single v- butt joint.
3. Single U- Butt joint.
4. Double V- Butt joint.
5. Double U- butt joint.

2.6 Advantages of welded Joints over Riveted joints:-

Following are the advantages and disadvantages of welded joints over riveted joints.

1. The welded structures are usually lighter than riveted structures. This is due the reason, that in welding, gussets or other connecting components are not used.
2. The welded joints provide maximum efficiency which is not possible in case of riveted joints.
3. Alterations and additions can be easily made in the existing structures.
4. As the welded structure is smooth in appearance, therefore it looks pleasing.
5. In welded connections, the tension members are not weakened as in the case of riveted joints.
6. A welded joint has a great strength. Often a welded joint has the strength of parent metal itself.
7. Sometimes, the members are of such a shape that they afford difficulty for riveting. But they can be easily welded.
8. The welding provides very rigid joints. This is in line with the modern trend of providing rigid frames.
9. It is possible to weld any part of a structure at any point. But riveting requires enough clearance.
10. The process of welding takes less time than the reverting.

2.7 Eccentrically loaded welded joints:-

An eccentric load may be imposed on welded joints in many ways. The stresses (shear and bending stress) induced on the joint may be of different nature or of the same nature. We shall now discuss two cases of eccentric loading as follows:

Case: 1 Consider a T- joint fixed at one end and subjected to an eccentric load ‘P’ at distance ‘e’.

Consider a T-joint fixed at one end and subjected to an eccentric load ‘***P***’ at a distance e as shown in fig.

Let S= Size of weld.

l = length of weld, and

t = Throat Thickness.

The joint will be subjected to the following two types of stresses:

1. Direct shear stress due e to the shear force ‘P ’acting at the welds , and
2. Bending stress due to the bending moment (P× e).

We know that area at the throat,

A= Throat thickness × Length of weld.

= t×l×2 = 2t × l...(For double fillet

= 2× 0.707 s × l = 1.414 s × l....................................($\therefore t = s\cos 45^0 = 0.707\, s$)

∴ Shear stress in the weld (assuming uniformly distributed),

$$\tau = \frac{P}{A} = \frac{P}{1.141 s \times l}$$

Section modulus of the weld metal through the throat,

$$Z = \frac{t \times l^2}{6} \times 2 \ldots \text{........................(For both sides weld)}$$

$$= \frac{0.707 s \times l^2}{6} \times 2 = \frac{s \times l^2}{4.242}$$

Bending moment, **M=** ***P*×*e*,**

∴Bending Stress, $\sigma_b = \frac{M}{Z} = \frac{P \times e \times 4.242}{s \times l^2} = \frac{4.242\, P \times e}{s \times l^2}$

We know that the maximum normal stress,

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

And maximum shear stress,

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

<u>Case-2:-</u> When a welded joint is loaded eccentrically as shown in figure, the following two types of the stresses are induced:

1. Direct or Primary shear stress.
2. Shear stress due to turning moment.

Let P= Eccentric load,

e=Eccentricity *i.e.* perpendicular distance between the lines of action of load and centre of gravity (G) of the throat section or fillets

l=Length of single

s= Size or leg of weld, and

t= Throat Thickness.

Let two loads P_1 and P_2 (each equal to P) are introduced at the centre of gravity 'G' of the w system. The effect of load P_1 = P is to produce direct shear stress which is assumed to be uniform over the entire weld length. The effect of load P_2 =P is to produce a turning moment of magnitude $\boldsymbol{P \times e}$ which is tends to rotate the joint about the centre of gravity 'G' of the weld system. Due to turning moment, secondary shear stress is produced.

We know that the direct or primary shear stress,

$$r_1 = \frac{load}{Throat\ area.} = \frac{P}{A} = \frac{P}{2t \times l}$$

$$= \frac{P}{2 \times 0.707 s \times l} = \frac{P}{1.414 s \times l}$$

$(\therefore Throat\ area\ for\ a\ single\ fillet\ weld = t \times l = 0.707 s \times\ )$

Shear stress due to the turning moment i.e. secondary shear stress,

$$r_2 = \frac{T \times r_2}{J} = \frac{P \times e \times r_2}{J},$$

In order to find the resultant stress, the primary and secondary shear stresses are combined vectorially.

∴Resultant shear stress at 'A'

$$r_A = \sqrt{\ _1^2 + \ _2^2 + 2\ _1 \times\ _2 \times \cos\theta}$$

θ= Angle between $r_1$and r_2

$\text{Cos}\theta = \frac{r1}{r_2}$

....

: RIVETED JOINTS:

Introduction: A rivet is a short cylindrical bar with a head integral to it. The cylindrical portion of the rivet is called shank or body and lower portion of shank is known as tail, as shown in the figure.

Riveting is the process of forming a riveted joint. For, this a rivet is first placed in the hole drilled through the two parts to be joined.

Area of Application:-

The rivets are used to make permanent fastening between the plates such as in structural work, ship building, bridge, tanks and boiler shells. The riveted joints are widely used for joining light metals.

Methods of Riveting:-

The function of rivets in a joint is to make a connection that has strength and tightness. The strength is necessary to prevent leakage as in a boiler or in a ship hull. Hot riveting produces better results, compared to cold riveting. This is because, after hot riveting, the contraction in the shank length tends to pull the parts together, making a tight joint.

Caulking and Fullering:-

Normally, the outer edges of the plates used in boilers and other pressure vessels are beveled. To produce air tight joints, these beveled edges are caulked. Caulking is an operation in which the outer beveled edges of the plates are hammered and driven –in by a caulking tool, which is in the form of a blunt edged chisel.

Fullering operation is also used to produce air tight joints. However, unlike the caulking tool, the width of the fullering tool is equal to the width of the beveled edges of the plates.

2.8 Types of Riveted Joint:-

Following are the two types of riveted joints, depending upon the way in which the plates are connected.

Lap Joint: - A lap joint is that in which one plate overlaps the other and the two plates are then riveted together.

Butt Joint: - A butt joint is that in which the main plates are kept in alignment butting (e.i.touching) each other and a cover plate (i.e. strap) is placed either on one side or on both sides of the main plates. The cover plate is then riveted together with the main plates. Butt joints are of following two types.

1. Single strap butt joint , and
2. Double strap butt joint.

In a ***single strap butt joint***, the edges of the main platers butt against each other and only one Cover plate is placed on one side of the main plates and then riveted together.

In a ***double strap butt joint***, the edges of the main plates butt against each other and two cover plates are placed on both sides of the main plates and then riveted together.

In addition to the above, following are the types of riveted joints depending upon the number rows of the rivets.

1. **Single riveted joint** and
2. **Double riveted joint.**

A ***single riveted joint*** is that in which there is a single row of rivets in a lap joint and there is a single row of rivets on each side in a butt joint.

A ***double riveted joint*** is that in which there are two rows of rivets in a lap joint and there are two rows of rivets on each side in a butt joint.

When the rivets in the various rows are opposite to each other, then the joint is said to be ***chain riveted.***

On the other hand, if the rivets in the adjacent rows are staggered in such a way that every rivet in the middle of the two rivets of the opposite row, then the joint is said to be ***Zig - Zag riveted.***

2.9 Failures of a Riveted joint:-

A riveted joint may fail in the following ways:-

1. **Tearing of the plate at an edge: -** A joint may fail due to tearing of the plate at an edge as. This can be avoided by keeping the margin, **m= 1.5d,** where d is the diameter of the rivet hole.
2. **Tearing of the plate across a row of rivets:** - Due to the tensile stresses in the main plates, the main plate or cover plates may tear off across a row of rivets. In such cases, we consider only one pitch length of the plate, since every rivet is responsible for that much length of the plate only.

The resistance offered by the plate against tearing is known as ***tearing resistance*** or ***tearing strength*** or ***tearing value of the plate.***

Let, p = Pitch of the rivets.
d = diameter of the rivet hole.
t= Thickness of the plate.
σ_t = Permissible tensile stress for the plate material.

We know that tearing area per pitch length,

$$A_t = (p-d).\, t$$

∴Tearing resistance or pull required to tear off the plate per pitch length,

$$P_t = A_t.\sigma_t = (p-d).\, t.\, \sigma_t$$

When the resistance (P_t) is greater than the applied load (p) per pitch length, then this type of failure will not occur.

3. **<u>Shearing of the rivets</u>: -** The plates which are connected by the rivets exert tensile stress on the rivets, and if the rivets are unable to resist the stress, they are sheared off. The resistance offered by a rivet to be sheared off is known as ***shearing resistance*** or ***shearing strength*** or ***shearing value*** of the rivet.

   Let, d= Diameter of the rivet hole,
   r = Safe permissible shear stress for the rivet material, and
   n = Number of rivets per pitch length.

   We know that shearing area,

   $$\mathbf{A_s = \frac{}{4} \times d^2} \text{.........................} \textbf{(In single shear)}$$
   $$\mathbf{= 2 \times \frac{}{4} \times d^2} \text{............................} \textbf{(In double shear)}$$
   $$\mathbf{= 1.875 \times \frac{}{4} \times d^2} \text{..................} \textbf{(In double shear, according to IBR)}$$

   ∴ Shearing resistance or pull required to shear off the rivet per pitch length,

   $$\mathbf{P_s = n \times \frac{}{4} \times d^2 \times} r \text{............................} \textbf{(In single shear)}$$
   $$\mathbf{= n \times 2 \times \frac{}{4} \times d^2 \times} r \text{..................} \textbf{(In double shear)}$$
   $$\mathbf{= n \times 2 \times \frac{}{4} \times d^2 \times} r \text{..................} \textbf{(In double shear, according to IBR)}$$

   When the shearing resistance (P_s) is greater than the applied load (p) per pitch length, then this type of failure will occur.

4. **<u>Crushing of the plate or rivets</u>: -** Sometimes, the rivets do not actually shear off under the tensile stress, but are crushed. Due to this, the rivet hole becomes of an oval bearing failure. The area which resists this action is the projected area of the hole or rivet on diametric plane.

   The resistance offered by a rivet to be crushed is known as ***crushing resistance*** or ***crushing strength*** or ***bearing value*** of the rivet.

   Let d= Diameter of the rivet hole.
   t= Thickness of the plate,
   σ_c= Safe permissible crushing stress for the rivet or plate material
   n= Number of rivets per pitch length under crushing.

   We know that crushing area per rivet (*i.e.* projected area per rivet)

   $$\mathbf{A_c} = \boldsymbol{d.t}$$

   ∴ Total crushing area= ***n.d.t***

   And crushing resistance or pull required crushing the rivet per pitch length,

   $$\mathbf{P_c} = \boldsymbol{n.d.t.\sigma_c}$$

When the crushing resistance (**P_c**) is greater than the applied load (**p**) per pitch length, then this type of failure will occur.

<u>Strength &Efficiency of a Riveted:-</u>

The strength of a joint may be defined as the maximum force, which it can transmit, without causing it to fail. We are come to conclude from the above discussion that P_t, P_S and P_c are the pulls required to tear off the plate, shearing off the rivet and crushing off the rivet. A little consideration we show that if we go on increasing the pull on a riveted joint, it will fail when the least of these three pulls is reached, because a higher value of the other pulls will never reach since the joint has failed, either by tearing off the plate, shearing off the rivet or crushing off the rivet

Efficiency of a Riveted joint:-

The efficiency of a riveted joint is defined as the ration of the strength of riveted joint to the strength of the un-riveted or solid plate.

We have already discussed that strength of the riveted joint

= Least of P_t, P_s and Pc

Strength of the un-riveted or solid plate per pitch length,

$$\mathbf{P= p\times t\times \sigma_t}$$

∴Eefficiency of the riveted joint,

$$y = \frac{least\ of\ P\ ,s\ and\ Pc}{p\times t\times \sigma t}$$

P= Pitch of the rivets,
t = Thickness of the plate of the plate, and
σ_t= Permissible tensile stress of the plate material.

2.10 Design of Boiler Joints: - (Pressure Vessel)

The boiler has a longitudinal joint as well as circumferential joint. The ***longitudinal joint*** is used to join the ends of the plate to get the required diameter of a boiler. For this purpose, a butt joint with two cover plates is used. The ***circumferential joint*** is to get the required length of the boiler. For this purpose, a lap joint with one ring overlapping the other alternately is used.

Since a boiler is made up of rings, therefore the longitudinal joints are staggered for convenience of connecting rings at places where both longitudinal and circumferential joints occur.

Before going to design we should conversant with the use of Design Data Book. Here we use a standard Data book written by **S.MD. JALALUDEEN (IN SI UNITS)**.

Design of longitudinal Butt joint for a Boiler:

According Indian boiler regulations (I.B.R), the following procedure should be adopted for the design of longitudinal butt joint for a boiler. Steps are as follows.

1. *Thickness of boiler shell*:- **t =** $\frac{P.D}{2.\sigma_t \eta_l}$

Where t= Thickness of the boiler shell,

P= Steam pressure in boiler,

D= Internal diameter of boiler shell,

σ_t= Permissible tensile stress, and

5_l = Efficiency of the longitudinal joint.

The following point may be noted:
The thickness of the boiler shell should not less than 7 mm.

2. *Diameter of rivet* for t > 8mm, d' = $6.05\sqrt{t}$ (Unwin's formula).

Then refer table no. 9.5 and page no- 9.18 to get d= diameter of rivet hole.

(For t < 8mm, obtain d by equating the shear strength to crushing strength of rivets).

3. *Pitch of rivets*: - The pitch of the rivets is obtained by equating the tearing resistance of the plate to the shearing resistance of the rivets. It may noted that

   (a) **The pitch of the rivets should not be less than 2d, which is necessary for the formation of head**.

   (b) The maximum value of the pitch of rivets for a longitudinal joint of a boiler as per I.B.R. is

   $$P_{max} = c \times t + 41.28 \text{ mm}$$

   Where t = thickness of the shell plate in mm

   C= Constant.

   (The value of the constant C is given in table 9.7)

   $$P_{min} = (2.25 \text{ to } 2.5)\, d$$

4. *Distance between rows of rivet*: - According to Indian Boiler Code to find the above said dimension follow page no 9.4.
5. *Thickness of butt strap:* According to I.B.R. , the thickness for butt strap(t_1) are as given below:
   a. The thickness of butt strap, in no case, shall be less than 10 mm.
   b. For wide cover placed inside boiler t_1 = o.75t and for further requirement we may use equation 9.6, 9.7, 9.8, 9.9, 9.11.

6. *Margin*: - The margin (m) is taken as 1.5d.

7. *Efficiency of the longitudinal butt joint of boiler can be calculated by formula (9.*21) design data book S.Md. Jalaludeen. To calculate the above said factor, the pre-requisite are 9.13, 9.14, 9.15 equations of page no 9.6 .

Design for circumferential Lap Joint:-

The following procedure is adopted for the design of circumferential lap joint for a boiler.

1. Total number of rivets for the circumferential joint,

$$n' = \left[\frac{D}{d}\right]^2 \times \left[\frac{\;}{s_s}\right],$$ P= Steam pressure

2. *Number of rows of rivets,* $n = \frac{n'p'}{\pi(D+t)}$, **p'= Pitch of lap joint**

t = Thickness of boiler plate.

3. *Efficiency of circumferential joint,* $\eta_c = \frac{p'-d}{p'}$.

<u>3. O DESIGN OF SHAFT, KEYS</u>

3.1. Function of Shaft:-

Shaft is a rotating machine element which supports transmission elements (like gear, pulley, flywheels etc) and transmits power.

3.2. Shaft material: - It should have,
(I) Strength
(ii)Machinability
(iii) Withstand heat treatment and case hardening, wear resistance, resistance to stress.

The material generally used for manufacturing of shaft is Carbon steel and of different grade- C25, C30, C35, C40.

IMPORTANT REMARK:-
Shafts are generally design on the basis of loads acting on it. And the loads are as follows:-

1. Axial tensile force
2. Bending load and bending moment
3. Twisting force and twisting moment.

Before entering into the design problem of shaft, whatever the formulas we are going to be used according to the above said condition, kindly refer design Data book of S.MD. JALALUDEEN. Page no:-4.4, 4.5

3.3. DESIGN OF SOLID AND HOLLOW SHAFTS TO TRANSMIT A GIVEN POWER AT GIVEN RPM BASED ON:-

The shafts may be designed on the basis of
1. Strength. 2. Rigidity and Stiffness

In designing shafts on the basis of strength, the following cases may consider:
(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.

(a) When Shafts are subjected to Twisting moment only:-
When the shaft is subjected to a twisting moment only, then the diameter of the shaft may be obtained by using the torsion equation. We know that

$$\frac{T}{I_P} = \frac{\tau}{R} = \frac{C\theta}{L}$$

T = Twisting moment acting upon the shaft.
I_P=Polar moment of inertia of the shaft about the axis of rotation= $\frac{\pi}{32} \times D^4$
τ= Torsional shear stress, and
r= Distance from neutral axis to the outer most fibre. ($\frac{D}{2}$; where D, is the diameter of the shaft).
D= Outer diameter of hollow shaft
d= Inner diameter of hollow shaft
From torsion equation, $\frac{T}{I_P} = \frac{\tau}{R}$

We know that $T = \frac{\pi}{16} \times \tau \times D^3$ (…......... Solid Shaft)

Similarly, $T = \frac{\pi}{16} \tau \times \left[\frac{D^4 - d^4}{D}\right]$ (........... Hollow Shaft)

(b) Shafts subjected to Bending moment only:-
When Shaft is subjected to a bending moment only, then the maximum stress (tensile or compressive) is given by the bending equation. We know that

From bending equation, $\frac{M}{I} = \frac{\sigma_b}{y}$
M= Bending Equation.
I= Moment inertia of cross sectional area of the shaft about the axis of rotation=$\frac{\pi}{64} \times D^4$
σ_b =Bending stress, and

Y= Distance from neutral axis to the outer most fibre= $\frac{D}{2}$.

We know that, $M = \frac{\sigma_b . \pi D^3}{32}$ (… .... Solid Shaft)

Similarly, $M = \frac{\pi}{32} \times \sigma_b \times \left[\frac{D^4 - d^4}{D}\right]$ (.............. Hollow shaft)

(c) ***Shafts subjected to combined Twisting and Bending:-***

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. Various theories are proposed to account the elastic failure of the materials when they are subjected to various types of combined stresses. The following two theories are important from the subjected point of view.

1. Maximum shear stress theory or Guest's theory. It is used or 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 r = Shear stress induced due to twisting moment, and

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

K = $\frac{d}{D}$, Ratio of inner diameter to outer diameter of the shaft

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

$$\tau_{max} = \frac{1}{2}\sqrt{(\sigma_b)^2 + 4^{\;2}} \text{ .... } \mathbf{(1)}$$

If we put the value of r and σ_b in the above equation, then,

$$\tau_{max} \times \frac{\pi D^3}{16} = \sqrt{(M)^2 + (T)^2} \text{ .... } \mathbf{(2)}$$

$$\Rightarrow \quad \mathbf{T_e} = \sqrt{(M)^2 + (T)^2} \text{ .... } \mathbf{(3)}$$

Where $\mathbf{T_e}$ is known as equivalent twisting moment.

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

$$\sigma_{b\,Max} = \frac{\sigma b}{2} + \frac{1}{2}\sqrt{(\sigma_b)^2 + 4\tau^2} \text{ ------------------------- } (1)$$

$$\sigma_{bmax} \times \frac{\pi D^3}{32} = \frac{M}{2} + \sqrt{\left(\frac{M}{2}\right)^2 + \left(\frac{T}{2}\right)^2} \text{ ------------------ } (2)$$

$$\Rightarrow M_e = \frac{M}{2} + \sqrt{\left(\frac{M}{2}\right)^2 + \left(\frac{T}{2}\right)^2} \text{ --------------------------- } (3)$$

$$\therefore \quad Me = \frac{M + \sqrt{M^2 + T^2}}{2} \text{ ------------------- } (4)$$

Where $\mathbf{M_e}$ is known as equivalent bending moment.

In case of a hollow shaft, the equations may be represented as,

$$\mathbf{T_e} = \sqrt{(M)^2 + (T)^2} = \tau \times \frac{\pi D^3}{16}(1 - k^4)$$

$$Me = \frac{M + \sqrt{M^2 + T^2}}{2} = \sigma_b \times \frac{\pi D^3}{32}(1 - k^4)$$

2. Shafts designed on the basis of Rigidity:-

Sometimes shafts should be designed on the basis of rigidity. We shall consider the following case of rigidity,

(a) Torsional Rigidity:-The torsional rigidity is important in the case of camshaft of an I.C. Engine where the timing of the valves would be affected. The permissible amount of twist should not exceed 0.25° per meter length of such shafts. The torsional deflection may be obtained by using the torsion equation,

$$\frac{T}{I_P} = \frac{G.\theta}{L}$$

$$\Rightarrow \theta = \frac{T.L}{I_{P}.G}$$

Where, θ=**Torsional deflection or angle of twist in radians,**

T= twisting moment or torque on the shaft,

I_p=**Polar moment of inertia of the cross-sectional area about the axis of rotation**

$= \frac{\pi D^4}{32}$ ------------------------------ (Solid shaft)

$= \frac{\pi}{32}(D^4 - d^4)$ ---------- (Hollow shaft)

G= modulus of rigidity for the shaft material, and

L= Length of the shaft.

(b) Lateral Rigidity:-

IT is important in case of Transmission shafting and shafts running at high speed, where small lateral deflection would cause huge out-of-balance forces. The lateral rigidity is also important for maintaining proper bearing clearances and for correct gear teeth alignment.

3.4 Standard sizes of shafts: -

Standard available sizes of shaft(in mm) are 5, 6,7,8,9,10,11,12,14,16,18,20, 22, 25, 28, 32, 36, 40, 45, 50, 56, 63, 71, 80, 90, 100,110, 125, 140, 160, 180 and 200**.**

Advantages of hollow shaft:-

For same weight, more strength, more stiffness, higher natural frequency. So that moment of inertia (I) increases.

Disadvantages:-
Taking more space and also in the same time it is expensive.

- ***N.B.***

All the components are weak in tension. During tension of the element the elongation of the molecular length increases which give rise the problem of yielding of the component, but in compression molecular length reduces which gives the strength in component.

When the shaft is subjected to both twisting moment as well as bending moment the diameter of the shaft is to be calculated by using theories of failure. *i.e.*, maximum shear stress theory and maximum distortion energy theory.

Power transmitted by a shaft:

Work done by the shaft per minute = Torque × angle turned in one minute

$$= T_{mean} \times 2\,\pi\,N \text{ N-m}$$

Power transmitted by the shaft (P) $= \frac{\text{Work done per minute}}{60000}$ KW

$$\Rightarrow \mathbf{P} = \frac{T_{mean} \times 2\ \ N}{60000} \text{ kW}$$

3.5 <u>State function of Keys, Types of keys and Material of keys:-</u>

Key is defined as a machine element which used to connect the transmission, Shaft to the rotating element like flywheel, pulley, Gear, Sprocket.

Different Types of Keys:-

(1) Sunk key:-

a. Square Key
b. Rectangular Key

In the sunk key it fits half of the thickness on to the shaft and half of the thickness to the flywheel.

(2)Saddle Key:-
It fits the key way of the flywheel only and there is no key way on the shaft. It transmits less power than the sunk key.

(3)Feather key:-
It is parallel key i.e.; fixed either to the shaft or to the flywheel and it permits relative axial relative axial movement between them.

(2) Woodruff Key:-
It is a semicircular uniform thickness disc which is used on the papered shaft.
Generally the material of key is same of shaft i.e. plain carbon steel and alloy steel.

3.7 Design analysis of a rectangular sunk key:-

The key will fail by (1) Shear, (2) Crushing.

(1) For Shear Failure:-

P= Force acting on key

P= r_k × (Shear area)

= r_k× (b×l)

$r_k < r_{Permissible}$ (*If not, then increase the length*).

(2) For Crushing Failure:-

P= σ_{ck} × ($\frac{h}{2}$ ×l)

$\sigma_{ck} < r_{permissible}$ (If not, then increase the length).

3.8 Design rectangular sunk key by using empirical relation for given diameter of shaft:-

Let T= torque transmitted by the shaft

F= Tangential force acting at the circumference of the shaft,

d= diameter of the shaft,

L= Length of the key,

w= Width of the key,

t= Thickness.

r And r_c= Shear and crushing stresses for the material of key

The key is equally strong in shearing and crushing, if

$L \times w \times r \times \frac{d}{2} = L \times \sigma_c \times \frac{t}{2} \times \frac{d}{2}$ -- (1)

$\frac{w}{t} = \frac{\sigma_c}{2c}$ -- (2) or

The permissible crushing stress for the usual key material is at least twice the permissible shearing stress. Therefore from the above equation, we have w= t. In the words, a square key is equally strong in shearing and crushing.

In order to find the length of the key to transmit full power of the shaft, the shearing strength of the key is equal to the torsional shear strength of the shaft.

By equating shearing strength and torsional shear strength, we have

$L \times w \times r \times \frac{d}{2} = \tau_1 \times \frac{\pi d^3}{16}$

∴ L= 1.571 d $\times \frac{c1}{c}$ -------- (taking w= d/4, and taking r =shear stress for the shaft material)

When the key material is same as that of the shaft, then $r = r_1$,

∴ L= 1.571 d.

EFFECT OF KEYWAY:-

A little consideration will show that key way cut into the shaft reduces the load carrying capacity of the shaft. This is due to the stress concentration near the corners of the key way and reduction in the cross-sectional area of the shaft. In other way the torsional strength of the shaft is reduced.

3.9 State specification of keys:-

- **Sunk key:-**
  - (a) Rectangular sunk key: - The usual proportions of this key are: width of key, w= d/4; And thickness of key. t= 2w/3 = d/6, d= diameter of the shaft or diameter of the hole in the hub.
  - (b) Square sunk key:- Here w=t= d/4

- **Gib- head key:-**
  The usual proportions of the gib head key are: width, w= d/4;
  And thickness at large end, t= 2w/3 = d/6

- **Parallel sunk key:-**
  The parallel sunk keys may be of rectangular or square section uniform in width and thickness throughout.

4.0-: DESIGN OF BELT DRIVES AND PULLEYS:-

4.1 Types of belt drives:

1. Light drives 2. Medium drives 3. Heavy drives

Types of flat belt drives:

Generally the belt drives are known as - 1. Open belt drive
2. Crossed or twist belt drive

Types of Belts:

Generally there is different form of belts are available-1. Flat Belt
2. V-belt

5. DESIGN OF CLOSED COIL HELICAL SPRING OF ROUND ROD

Introduction:-

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. The important field of applications of springs is as follows:

- To cushion, absorb or control energy due to either shock or vibration as in car springs, railway buffers, air-craft landing gears, shock absorbers and vibration damping.
- To apply forces, as in brake, clutches and spring-loaded valves.
- To control motion by maintaining contact between two elements as in cams and followers.
- To measure forces, as in spring balances and engine indicators.
- To store energy, as in watches, toys, etc.

Types of springs:-

There are many types of the springs, yet the following, according to their shape, are important.

1. Helical spring. 2. Conical and volute springs. 3. Torsion springs. 4. Laminated or leaf springs. 5. Disc or Bellevile springs. 6. Special purpose springs.

5.1 Material for Helical springs:-

The material of the spring should have high fatigue, strength, high ductility, high resilience and it should be creep resistant. It largely depends upon the service for which they are used. The springs are mostly made from oil-tempered carbon steel wires containing 0.60 to 1.0 per cent manganese. Non-ferrous materials like phosphor bronze, beryllium copper, monelmetal, brass etc, may be used in special cases to increase fatigue resistance, temperature resistance and corrosion resistance.

5.2 Standard size spring wire:-

'*SWG'* stands for standard wire gauge number.

5.3 Terms used in compression spring:--

The following terms used in connection springs are important from subject point of view.

(1) ***Solid length: -*** When the compression spring is compressed until the coils come in contact with each other, then the spring is said to be solid. The solid length of a spring is the product of total number of coils and the diameter of the wire. Mathematically,

$L_s = n'.d$, Where n'= Total number of coils, and d= Diameter of the wire.

(2) Free length:-

The free length of a compression spring is the length of the spring in the free or unloaded condition. It is equal to the solid length plus the maximum deflection pr compression of the spring and the clearance between the adjacent coils.(when fully compressed).

Mathematically, Free length of the spring,

L_f = solid length + Maximum compression + clearance between adjacent coils

= n'.d + δ_{max} + 0.15 δ_{max}

The following relation may also be used to be finding the free length of the spring, i.e.

L_f = n'.d + δ_{max} + (n'-1) ×1 mm.

In this expression, the clearance between the two adjacent coils is taken as 1 mm.

(3) Spring index:-

Spring index is defined as the ratio of the mean diameter of the coil to the diameter of the wire. Mathematically, spring index, C= D/d,

Where, D= Mean diameter of the coil,

And d= Diameter of the wire.

(4) ***Spring Rate: -*** The spring rate (or stiffness or spring constant) is defined as the load required Per unit deflection of the spring. Mathematically, Spring rate,

Spring rate, K= W/δ, Where, W= Load, and δ= Deflection of the spring.

(5) ***Pitch: -*** The pitch of the coil is defined as the axial distance between adjacent coils in uncompressed state. Mathematically,

Pitch of the coil, P= $\frac{Free\ length}{n^{F}-1}$,

The pitch of the may also be obtained by using the following relation, i.e.

Pitchy of the coil, P= $\frac{L_f - L_S}{n'}$ + d

Where, L_f = Free length of the spring,

Ls= Solid length of the spring,

n'= Total number of coils, and

d= Diameter of the wire.

5.4 Stress in helical spring of a circular wire:-

Consider a helical compression spring made of circular wire and subjected to an axial load W.

Let D= Mean diameter of the spring coil,

d= Diameter of the spring wire,

n= Number of active coils,

G= Modulus of rigidity for the spring material,

W= Axial load on the spring,

r= Maximum shear stress induced in the wire,

C= spring index= D/d,

P= Pitch of the coils, and

δ = Deflection of the spring, as a result of an axial load W, The load w tends to rotate the wire due to the twisting moment (T) set up in the wire. Thus torsional shear stress is induced in the wire. The spring is in equilibrium under the action of two forces W and the twisting moment T. We know that the twisting moment,

$$T = W \times \frac{D}{2} = \frac{\pi}{16} \times r_1 \times d^3$$

$$r_1 = \frac{8W.D}{\pi d^3},$$

In addition to the torsional shear stress (r_1) induced in the wire, the following stresses also act on the wire:

1. Direct shear stress due to the load W, and
2. Stress due to curvature of wire.

We know that direct shear due to the load W,

$$r_2 = \frac{Load}{Cross-sectional\ area\ of\ the\ wire.}$$

$$= \frac{W}{\frac{\pi}{4} \times d^2} = \frac{4w}{\pi d^2} \text{ ------------------------ (ii)}$$

We know that the resultant shear stress induced in the wire,

$$r = r_1 \pm r_2 = \frac{8W.D}{\pi d^3} \pm \frac{4}{\pi d^2},$$

The positive sign is used for the inner edge of the wire and negative sign is used for the outer edge of the wire. Since the stress is maximum at the inner edge of the
Wire, therefore:

Maximum shear stress induced in the wire,
= Torsional shear stress + Direct shear stress

$$= \frac{8W.D}{\pi d^3} \pm \frac{4W}{\pi d^2} = \frac{8W.D}{\pi d^3}\left(1 + \frac{d}{2D}\right)$$

$$= \frac{8W.D}{\pi d^3}\left(1 + \frac{1}{2C}\right) = K_s \times \frac{8W.D}{\pi d^3} \text{ ---------------------------- (Substituting D/d=C)}$$

5.5 Deflection of Helical springs of circular Wire:-

We know that, total active length of wire,
L= Length of one coil × No. of active coils = πD × n
Let, θ= Angular deflection of the wire when acted upon by the torque T.
∴ Axial deflection of the spring, = $\theta \times D/2$

We also know that, $\frac{T}{J} = \frac{c}{D/2} = \frac{G.\theta}{l}$

$$\therefore \theta = \frac{T.l}{J.G} \;;$$

Where J= Polar moment of inertia of the spring wire.

$= \frac{\pi}{32} \times d^4$, **d** being the diameter of spring wire.

And G= Modulus of rigidity for the material of the spring wire.

Now substituting the values of ***l*** and ***J*** in the above equation, we have

$$\theta = \frac{T.l}{J.G} = \frac{[W \times \frac{D}{2}]\pi \; .D\, n}{\frac{\pi}{32} \times d^4 G} \times D/2 = \frac{8.W.D^3.n}{G.d^4} = \frac{8.W.C^3.n}{G.d} \quad (\therefore C = D/d)$$

And the stiffness of the spring or spring rate, $\frac{W}{\delta} = \frac{G.d^4}{8.D^3.n} = \frac{G.d}{8C^3.n}$ = Constant

5.6 Eccentric Loading of springs:-

Sometimes, the load on the springs does not coincide with the axis of the spring, i.e. the spring is subjected to an eccentric load. In such cases, not only the safe load for the spring reduces, the stiffness of the spring is also affected. The eccentric load on the spring increases the stress on one side. When the load is offset by a distance 'e' from the spring axis; then the safe load on the spring may be obtained by multiplying the axial load by the factor, $\frac{D}{2e+D}$,Where D is the mean diameter of the spring.

5.7 Buckling of compression springs: - It has been found experimentally that when the free length of the spring (L_f) is more than four times the mean or pitch diameter (D), then the spring behaves like a column and may fail by buckling at comparatively low load. The critical axial load (W_{cr}) that causes buckling may be calculated by using the following relation, i.e.

W_{cr} = k × K_B × L_f

Where, k= spring rate or stiffness of the spring= W/δ

L_f= Free length of the spring, and

K_B= Buckling factor depending upon the ratio $\frac{L_f}{D}$,

The buckling factor (K_B) for the hinged end and built –in –end springs may be taken from the Data book **(S.MD.Jalaludeen)**. In order to avoid the buckling of spring, it is either mounted on a central rod or located on a tube. When the spring is located on a tube, the clearance between the tube walls and the spring should be kept as small as possible, but it must be sufficient to a allow for increase in spring diameter during compression.

5.8 Surge in springs:-

When one end of a helical spring is resting on a rigid support and the other end is loaded suddenly, then all the coils of the spring will not suddenly deflect equally, because some time is required for the propagation of stress along the spring wire. In the beginning, the end coils of the spring in contact with the applied load take up whole of the deflection and then it transmits a large part of its deflection to the adjacent coils. In this way a wave of propagation travels along the spring. This produces a very high amount of stresses and cause failure. This phenomenon is called surge. The surge in springs may be eliminated by using the following methods:

1. By using friction dampers on the centre coils so that the wave propagation dies out.
2. By using springs of high natural frequency.
3. By using springs having pitch of the coils near the ends different than at the centre to have different natural frequencies.

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DESIGN OF MACHINE ELEMENTS

TWO MARK QUESTIONS & ANSWERS

UNIT- I

INTRODUCTION:

1. **Define Design**.

   Creating a plan or drawing for a product using intellectual ability and scientific knowledge is called design. A product so designed should permit economical manufacture, and it should meet the specification requirements.

2. What are the classifications of machine design?

a) Adaptive design
b) Development design
c) New Design

3. What are the general considerations to be considered in designing of a machine component?

1. Type of load and stresses caused by the load
2. Motion of the parts or kinematics of machines
3. Selection of materials
4. Form and size of the parts
5. Frictional resistance and lubrication
6. Convenient and economical features
7. Use of standard parts
8. Safety of operation
9. Workshop facilities
10. Number of machines to be manufactures
11. Cost of construction
12. Assembling

4. Write down the general procedure in Machine Design.

a) Recognition of need.
b) Specifications & Requirements – Design Synthesis.
c) Feasibility Study.
d) Creative Design Synthesis.
e) Preliminary Design and Development.
f) Analysis of forces
g) Material Selection
h) Detailed Design of elements
i) Prototype Building, Testing and Modification
j) Detailed drawing and design for production

5. What are the factors to be considered during design?

a) Efficiency of machine
b) Absence of noise
c) Reliability
d) Life

e) Ease of control
f) Overload capacity
g) Maintenance
h) Space requirement
i) Weight
j) Size
k) Cost of manufacture
l) Ergonomics
m) Safety

6. What are the factors to be considered for the selection of materials for the design of machine elements?

a) Properties of materials
b) Manufacturing ease and cost
c) Quantity required
d) Availability of material
e) Space available
f) Cost

7. What are the different properties of materials and discuss?

a) **Strength**:

It is the ability of a material to resist the externally applied forces without breaking or yielding. The internal resistance offered by a part to an externally applied force is called stress.

b) **Stiffness**:

It is the ability of a material to resist deformation under stress. The modulus of elasticity is the measure of stiffness

c) **Elasticity**:

It is the property of a material to regain its original shape after deformation when the external forces are removed. This property is desirable for materials used in tools and machines. It may be noted that steel is more elastic than rubber.

d) **Plasticity**:

It is property of a material which retains the deformation produced under load permanently. This property of the material is necessary for forgings, in stamping images on coins and in ornamental work.

e) **Ductility**:

It is the property of a material enabling it to be drawn into wire with the application of a tensile force. A ductile material must be both strong and plastic. Mild steel, copper, aluminum, nickel, zinc, tin and lead are the ductile materials

f) **Brittleness**:

It is the property of a material opposite to ductility. It is the property of breaking of a material with little permanent distortion. Cast Iron is a brittle material.

g) **Malleability**:
It is a special case of ductility which permits materials to be rolled or hammered into thin sheets. A malleable material should be plastic but it is not essential to be so strong. Lead, soft steel, wrought iron, copper and aluminum.

h) **Toughness**:
It is the property of a material to resist fracture due to high impact loads like hammer blows. The toughness of the material decreases when it is heated. This property is desirable in parts subjected to shock and impact loads.

i) **Machinability**:
It is the property of a material which refers to a relative case with which a material can be cut.

j) **Resilience**:
It is the property of a material to absorb energy and to resist shock and impact loads. It is measured by the amount of energy absorbed per unit volume within elastic limit. This property is essential for spring materials.

k) **Creep**:
When a part is subject to a constant stress at high temperature for a long period of time, it will undergo a slow and permanent deformation called creep. This property is considered in designing internal combustion engines, boilers and turbines.

l) **Fatigue**:
When a material is subjected to repeated stresses, it fails at stresses below the yield point stresses. Such type of failure of a material is known as fatigue.This property is considered in designing shafts, connecting rods, springs, gears etc.

m) **Hardness**:
It is a very important property of the metals and has a wide variety of meanings. It embraces many different properties such as resistance to wear, scratching, deformation and machinability etc. It also means the ability of a metal to cut another metal. The hardness is usually expressed in numbers which are dependent on the method of making the test.

8. What is impact strength?

Impact strength is a measure of the resistance of metals to impact loads. Also defined as the energy required bringing a specimen to rupture and calculated per unit area of its section.

9. What are the effects of chromium, nickel and molybdenum on steel?

Chromium improves hardenability, corrosion resistance and increases wear resistance and hardness.

Nickel increases strength without decreasing ductility.

Molybdenum improves hardenability and creep strength, molybdenum is used in all creep resisting steel.

10. What do you mean by factor of safety?

Factor of safety is defined, as the ratio of the maximum stress to the working stress or ultimate stress to the working/design stress or yield stress to the working/design stress.

11. What is design stress?

Permissible stress or design stress of a material is defined as the ratio between maximum stress (yield stress in case of brittle material / ultimate stress in case of ductile material) to the factor of safety.

12. Explain the following a)Stress concentration b)Size factor c)Surface finish factor d)Notch sensitivity

a) **Stress Concentration**:

Stress concentration may occur due to abrupt changes of cross section of the member due to the presence of discontinuities like holes, notches, grooves or shoulders. It may also be due to the presence of internal cracks or air holes in the materials.

b) **Surface finish factor**:

Nature of the surface has a great influence on the endurance strength of materials. Perfectly smooth, polished surfaces have the highest endurance strength. Grinding gives lesser strength and rough finish reduces further.

c) Notch Sensitivity:

It is defined as the degree to which the theoretical effect of stress concentration is actually reached.

13. What is meant by fatigue failure?

Many machine and structural members are subjected to loads that vary in magnitude. This induces cyclic or fatigue stresses in members and the members fail at a stress much less than the yield point stress. This is known as fatigue failure.

14. What are the different types of varying loads? Give one example.

Completely Reversed Loading – Shafts carrying pulleys
Repeated Loading – Gears, Chain
Fluctuating Loading – Vehicle springs, Engine valve springs
Alternating Loading – IC engine connecting rods

15. Differentiate between sudden and impact loads.

Suddenly applied loads – as produced by combustion in an engine or by an explosion.
Impact loads- As produced by the dropping of a weight by a ram in a forging press, by a pile driver or by vehicle crash.

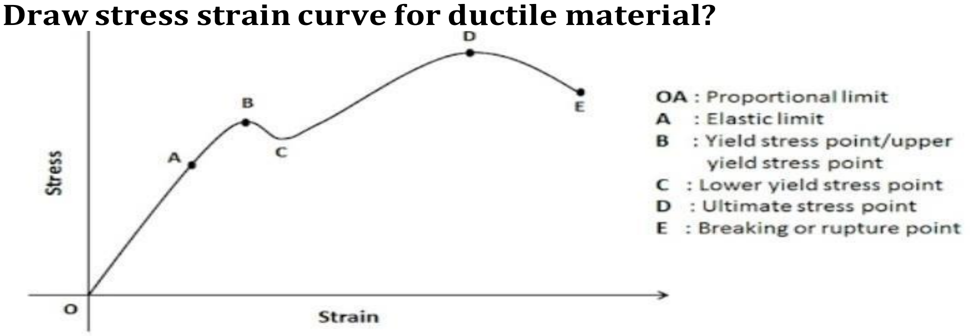
16. **What is meant by eccentric loading and eccentricity?**
An external load, whose line of action is parallel but does not coincide with the centroidal axis of the machine component, is known as an eccentric load. The distance between the centroidal axis of the machine component and the eccentric load is called eccentricity.

17. **Define stress concentration factor.**
Theoretical or form stress concentration factor is defined as the ratio of Maximum stress and Nominal stress.

18. **What is ratio for factor of safety for fatigue loading?**
The ratio between the endurance limit of a material to the working/design stress of the material is called as Factor of safety for fatigue loading.

19. **What do you mean by Adaptive Design?**
This type of design needs no special knowledge or skills and can be attempted by designers of ordinary technical training. The designer only makes minor alternation or modification in the existing designs of the product.

20. **Draw stress strain curve for ductile material?**



UNIT- II
Design of Shafts and Keys

1. Define shaft?

A shaft is a rotating machine element which is used to transmit power from one place to another. It is used for the transmission of torque and bending moment.

2. Differentiate between shaft and axle?

An axle though similar in shape to the shaft is a stationary machine element and is used for transmission of bending moment only. It simply acts as a support for some rotating body.

3. What is a spindle?

A spindle is a short shaft that imparts motion either to a cutting tool or to a work piece.

4. What are the materials used for shafts?

For ordinary shaft - mild steel

For high strength shafts - alloy steel such as nickel,

Ni-Cr steel and Cr-v steels

5. What are the types of shafts and give their importance?

a) Transmission shafts

These shafts transmit power between the source and the machine absorbing power. These shafts carry machine parts such as pulleys gears etc. They are subjected to bending in addition to twisting.

b) Machine shafts

These shafts form an integral part of the machine itself. The crankshaft is an example of machine shaft.

6. What are the various types of stresses induced in the shafts?

The various types of stresses induced in the shafts are

- Shear stress due to transmission of torque
- bending stresses
- stresses due to combined tensional and bending loads

7. What are the standard sizes of transmission shafts?

The standard size of transmission shafts are,

a) 25 mm to 60 mm with 5 mm steps

b) 60 mm to 110 mm with 10 mm steps

c) 110 mm to 140 mm with 15 mm steps

d) 140mm to 500 mm with 20 mm steps

Standard length - 5 m, 6 m, and 7 m.

8. On what basis shafts are designed?

a) Based on rigidity and stiffness

b) Based on strength

c) Based on critical speed.

9. Differentiate the hollow shaft over a solid shaft?

The hollow shafts are used in marine work. These shafts are stronger per kg of material and they may be forged on a mandrel, thus making the material more homogeneous than a solid shaft.

11. What are the desirable properties for the material for shaft and axles?

The desirable properties for the material for shaft and axles are

a) Sufficient high strength

b) A low sensitivity to stress concentration.

c) Ability to withstand heat and case hardening treatment.

d) Good machinability.

12. How the shafts are designed when it is subjected to twisting moment only?

When the shaft is subjected to torque only, then it is designed based on torsion equation.

13. Write the formula for equivalent torque and bending moment when the shafts are subjected to fluctuating loads.

Equivalent torque T_e= $(_M)^2 + (T)^2)^{1/2}$

Equivalent bending moment M_e = $1/2[M + (M)^2 + (T)^2)^{1/2}]$

Where
k_m=combined shock and fatigue factor for bending

K_t=combined shock and fatigue factor for torsion

15. Define tensional stiffness of a shaft.

Tensional stiffness of shaft is defined as the resisting strength of a shaft to tensional load. Mathematically it can be calculated by the formula T/180=GJ/I

16. What are the ways of improving lateral rigidity of shafts?

The ways of improving lateral rigidity of shafts are,

a) Maintaining proper bearing clearances
b) Correct gear teeth alignment

18 State any two reasons for preferring hollow shafts over solid shafts.

The two reasons for preferring hollow shafts over solid shafts are

a) For same weight of shaft, hollow shaft can transmit 1.5 times the torque transmitted by solid shaft.
b) For a particular power transmission, hollow shaft requires minimum weight.

19. What is a key?

Key is an element which is used to connect two machine parts for preventing relative motion of rotation with respect to each other.

20. Name the stresses induced in a taper key.

The stresses induced in taper key are,

a) Shear stress
b) Crushing stresses

21. Give the specifications of a parallel key.

The specifications of a parallel key is given as,

L x b x h

Where,

L - Length of the key

b – Width of the key

h - Height of the key

22. Name the types of keys.

The types of keys are,

a) saddle key
b) tangent key
c) sunk key
d) round key and taper pin

23. How Sunk keys are provided?

Sunk keys are provided half in the keyway of the shaft and half in the keyway of the hub or boss of the pulley.

24. List out the various types of sunk keys.

The various types of sunk keys are,

a) rectangular sunk key
b) square sunk key
c) parallel sunk key
d) gib head key
e) feather key
f) woodruff key

25. What is a keyway?

Keyway is a slot or recess in a shaft and hub of the pulley to accommodate a key.

26. Give the difference between square sunk key and rectangular sunk key.

	Rectangular sunk key	Square sunk key
Width	d/4	d/4
thickness	d/6	d/4

27. What is a gib head key? What is its advantage?

A rectangular sunk key with a head at one end is known as gib head key.

It is usually provided to facilitate the removal of key.

28. What is a feather key?

A key attached to one member of a pair and which permits relative axial movements is known as feather key.

It is a special type of parallel key which transmit a turning moment and also permits axial movements.

29. What is a woodruff key?

Woodruff key is a piece from a cylindrical disc having segmental cross section. A woodruff key is capable of tilting in a recess milled out in the shaft by a cutter having the same curvature as the disc from which the key is made.

They are largely used in machine tools and automobile constructions.

30. What are the advantages and dis advantages of a woodruff key?

The advantages and dis advantages of a woodruff key are,

It accommodates itself to any taper in the hub or boss of the mating piece.

a) It is useful on tapering shaft end. Its extra depth in the shaft prevents any tendency to turn over in its keyway.

31. What are the two types of saddle keys?

The two types of saddle keys are,

a) Flat saddle key
b) Hollow saddle key

32. What are splines?

The keys are made integral with the shaft which fits in the keyways broached in the hub. Such shafts are known as splined shafts. These shafts usually have four, six, ten or sixteen splines. These splined shafts are relatively stronger than shaft having a single keyway.

33. What are round keys?

The round keys are circular in section and fit into holes drilled partly in the shaft and partly in the hub.

34. List the advantages of splines over keys?

The advantages of splines over keys are,

Splines can be used when both axial movements as well as positive drive is to obtained.

a) It is used when the force is to be transmitted is large in proportion to the size of the shaft as in automobile transmission and sliding gear transmission.

35. What are the various forces acting on sunk key?

The various forces acting on sunk key are,

a) Force due to fit of the key in its keyway

b) Forces due to torque transmitted by the shaft

36. Write the formula for the shaft subjected to constant torque and bending moment?

Equivalent torque $T_e = (M^2 + \tau^2)^{1/2}$

Equivalent bending moment

$M_e = 1/2[\ M + (M^2 + T^2)^{1/2}\ ]$

37. List any two methods used for manufacturing of shaft?

The two methods used for manufacturing of shaft are,

a) cold rolling
b) hot rolling
c) turning or grinding from rough bars

38. What is the effect of keyway cut into shaft?

The keyway cut into the shaft reduces the load carrying capacity of the shaft. This is due to the stress concentration near the corners of the keyway and reduction in cross sectional area of the shaft. In other words the tensional strength of the shaft is reduced.

UNIT- III
DESIGN OF FASTENERS AND WELDED JOINTS

1. Define pitch and lead of a thread?

Axial distance from a point on one thread to corresponding point to next thread is called pitch. Lead is the distance the screw moves in one turn.

2. What are stresses that act on screw fastening?

Stresses that act on screw fastening are,

a) initial stresses due to screwing up
b) Stresses due to external forces.
c) Combined stresses

3. Give some examples for temporary joints and permanent joints?

Some examples for temporary joints and permanent joints are,

Permanent joints – Riveted joints, Welded joints, bonded joints.

Temporary joints – Threaded joints, cotter joints, knuckle joints

4. List the advantages of screwed joints

The advantages of screwed joints are,

- Highly reliable.
- Convenient to assemble and disassemble.
- Relatively cheap to produce due to standardization and highly efficient manufacturing processes.

5. What are the various forms of screw threads?

The various forms of screw threads are,

a) British standard Whitworth (BSW) thread
b) British association thread
c) Unified standard thread
d) American national standard thread
e) Square method
f) Acme thread
g) Metric thread

6. Define pitch diameter of a screw thread?

Pitch diameter of a screw thread is the diameter of an imaginary cylinder on which screw thread surface would pass through the thread at such points make equal width of thread and equal width of spaces between threads.

7. How screw threads are formed?

A screw thread is formed by cutting a continuous helical groove on a cylindrical surface.

8. What is the difference between a stud and a bolt?

Stud is a round bar threaded at both ends

Bolt is a cylindrical bar with threads for nut at one end and head at the other end.

9. What do you mean by single start threads?

When a nut is turned on a bolt having a single continuous thread cut on it by one full turn, it advances axially through a distance equal to pitch. Hence in a single continuous thread, called single start thread, the lead is equal to pitch.

10. List one of the locking devices.

Some of the locking devices are,

a) lock nut
b) castle nut
c) sawn nut
d) grooved nut

11. What are the ways to produce bolts of uniform strength?

a) Reducing shank diameter equal to root diameter
b) Drilling axial holes

12. By what materials threaded fasteners are made?

Steel is the material of which most of the fasteners are made. For improving their properties alloy steels like, nickel steel, Ni-Cr steel and Cr-V steel are performed.

17. In what way coarse thread is different from fine thread?

Fine and coarse threads are having same major and minor diameters except their pitch values. Fine threads having smaller pitches than coarse threads.

20. Define self locking in power screws

If the friction angle is greater than the helix angle of the power screw, the torque required to lower the load will be positive, indicating that an effort is applied to lower the load.

22. What are the main types of welding?

23. Define the following the terms?

a) Major diameter b) Minor diameter c) Pitch d) Angle of thread

Major diameter- it is the diameter of an external or internal screw thread. It is also known as outside or nominal diameter.

Minor diameter- it is the smallest diameter of an external or internal screw thread. It is also known as core or root diameter.

Pitch- it is the distance from a point on one thread to the corresponding point on the next.

Pitch = 1/ no of threads per unit length of screw.

Angle of thread- it is the angle included by the flanks of the thread.

24. What are the types of threads used?

- British standard whitworth thread (B.S.W)
- British association thread (B.A)
- American national standard thread.

UNIT- V
DESIGN OF SPRINGS

1. What is spring and where it is employed?
A spring is an elastic body, which distorts when loading and recover its original shape when the load is removed. It finds application in many places such as automobiles, railway wagons, brakes, clutches, watches and so on.

2. By what materials the springs can be made?
Springs are made of oil tempered carbon steel containing 0.6 to 0.7% carbon and 0.6 to 1% manganese. Phosper bronze, Monel metal, beryllium copper are used for special purpose.

3. What type of spring is used in rams bottom safety valve?
Helical tension spring is used in rams' bottom safety valve.

4. What are the functions of spring?
The functions of the spring are,

To measure forces in spring balance, meters and engine indicators.

To store energy

5. What is spring and where it is employed?
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6. By what materials the springs can be made?
Springs are made of oil tempered carbon steel containing 0.6 to 0.7% carbons and 0.6 to 1% manganese. Phosper bronze, Monel metal, beryllium copper are used for special purpose.

7. Name the various types of springs?

Helical springs, spiral springs, leaf springs and disc or Belleville springs are the various types of springs.

8. What is spring index?

Spring index is the ratio of mean pitch diameter to the diameter of the wire

11. What are active and inactive coils?

The coils which are free to deflect under load is called active coils and the coils which do not take part in deflection of a spring is called inactive coils.

12. Define the term spring rate?

Spring rate is defined as the load required per unit deflection. It is also called as stiffness of the spring.

13. Define surging of springs?

The spring material is subjected to higher stresses, which may cause earlier fatigue failure of springs. This effect is called as surging of springs.

14. How will you find weather the given helical spring is a compression spring or tension spring?

The ends of compression springs are flat whereas for tension springs, hooks will be provided at the ends.

Coils will be slightly open for compression springs to facilitate compression whereas in tension springs the coils are very close.

15. What material is used for leaf spring?

Plain carbon steel having 0.9 to 1% carbon in annealed condition is normally used for leaf springs. Chrome vanadium and silica manganese steels are used for the better grade springs.

16. What is nipping of laminated leaf spring? Discuss its role in spring design?

Pre stressing of leaf springs is obtained by a difference of radii of curvature known as nipping.

The initial gap can be adjusted so that under maximum load conditions the stress in all the leaves will be same or, if desired the stress in the full length leaves may be less.

17. What are the functions of a rebound clip and a U-clip in a leaf spring?

A rebound and are used for holding the leaves of the spring together.

18. What are the end conditions of springs?

The end conditions of springs are,

a) Plain end.

b) Plain and ground end.

c) Squared end.

d) Squared and ground end.

Why whale's factor is to be considered in the design of helical compression spring?

When wire wound in the form of helix, compressive stress is induced in the inner side of the spring and tensile stress is induced in the outer side of the spring. Due to this stress concentration is produced in the outer side of the spring .so whales' factor is to be considered in the design of helical compression spring.

19. What is buckling of springs?

The helical compression springs behave like a column and buckles at a comparative small load when the length of the spring is more than four times the mean coil diameter.

20. Why leaf springs are made in layers instead of a single plate?

Leaf springs are made in layer only for distributing the shear forces and bending moment evenly.

21. Define solid length of helical spring.

When compression spring is compressed until the coils come in contact with each other, then the spring is said to be solid and resulting length is called solid length.

22. Define free length of a helical spring.

It is the length of the spring in free on unloading condition.

23. Why the clearance is provided between adjacent of the helical spring ?

To prevent closing of the coils during service with maximum working load.

24. Define the term spring stiffness or spring rate?

Spring stiffness or spring rate is defined as the load required per unit deflection of the spring.

25. Define pitch of the spring coil?

It is defined as the axial distance between adjacent coils in uncompressed state.

26. What are the points to be considered in choosing the pitch of spring coils?

a) It should be such that if the spring is accidently carelessly compressed, the stress does not increase the yield stress in torsion.

b) Spring should not close up before maximum service load is reached.

27. What are the methods used for elimination of surges in springs?

a) By using friction dampers on the centre coils so that the waves propagation dies out.

b)By using springs of high natural frequency.

c)By using springs having pitch of coils near the ends different at the centre to have different natural frequencies.

28. How to avoid buckling of springs?

In order to avoid buckling of spring, it is either mounted on a central rod or located on a tube

29. What are the disadvantages in helical springs of non-circular wire?

a) The quality of material used for springs is not so good.

b) The shape of the wire does not remain square or rectangular while forming helix resulting in trapezoidal cross sections. It reduces the energy absorbing capacity of the spring.

c) The stress distribution is not favorable as for circular wires.

30. How equalized stress in leaf spring leaves is achieved?

a) By making the full length of leaves of smaller thickness than the graduated leaves.

b) By giving greater radius of curvature to the full length leaves than graduated leaves.

31. What is meant by initial tension in helical torsion springs?

In tension helical springs it is necessary to apply from 20 to 30% of the maximum load before the coils begin to separate during close coil windings.

32. Name few applications of helical springs.

a) Door hinge springs.

b) Springs for starters in automobiles.

c) Springs for brush holders in electric motors.

34. What are torsion springs?

Torsion springs may be of helical or spiral type. The helical type may be used only in applications where the load tends to wind-up the spring and are used in various electrical mechanisms. The spiral type is also used where the load tends to increase the number of coils and when made of flat strips are used in watches and clocks.

35. How the stiffness of the spring can be increased?

The stiffness of the spring can be increased by decreasing the number of turns.

36. What types of stresses are induced in the wires of helical compression spring and tensional spring?

Compressive or tensile stresses in helical compression spring and both tensile and compressive stresses in case of tensional spring are due to bending.

37. What are the advantages of leaf springs over helical springs?

Leaf springs are made out of flat plates. The advantages of leaf spring over the helical spring is that the end of the spring may be guided along a defined path as it deflects to act as a structural member in addition to energy absorbing device.

38. How concentric springs are obtained?

Two or more springs are joined to form a nest and thus concentric springs are obtained.

39. What factors are considered for design of spring?

Deflection criteria, material strength properties, service environment, desired life, manufacturing cost, etc.

40. How the load is made to act concentric with spring axis in helical spring?

By making the two ends of spring as squared and ground ends, the load can be made to act concentric with spring axis.

41. List the basis on which the design of pin or rocker arm of an IC engine is made?

The pin or rocker arm of an IC engine is made on the basis of bearing, shearing and bending failure.

42. Name the various types of springs?

Helical springs, spiral springs, leaf springs and disc or Belleville springs are the various type of springs.