27/11/19

Introduction:

The subject machine design is creation of new and better machines and improving the existing machines (or) objects.

Types of Machine design:

1) **Adoptive design:** In most cases the designers work is concentrated with adoptation of exisiting designs. The designers only makes minor alteration (or) Modification in the exisiting design of product.

2) **Development design:** This type of design needs considerable scientific training and design ability in order to modify the exisiting design into a new idea by adopting a new material or different methods of manufacture.

3) **New design:** This type of design needs lot of research, techniqual ability and creative thinking.

General procedure in machine design:

Need (or) Aim → Synthesis (Mechanisms) → Analysis of forces → Material selection → Design of elements → Modification → Detailed drawing → Production

Recognization of need (or) aim: First of all make a complete statement of the problem, indicating the need, aim (or) purpose for which machine is to be design.

Synthesis (Mechanisms): select the possible mechanisms or group of mechanisms which will give designed motions. The successful operation of any machine is depends upon the simpliest arrangement of links. which will give motions. The motions of the part may be rectilinear, curvelinear, constant velocity or variable acceleration.

Analysis of forces: Find the forces acting on each member of the machine and the energy transmitted by each member.

Material selection: It is the most important part while designing the machine components, select the best material suited of the each member of the machine.

It is essential that the designer should have a knowledge of the properties of a materials and they behaviour under working conditions. some of the important properties are.

Design of elements: Find the size of each no. of the machine by consedering forces acting on the member and the permissible stresses for the materials used. It should be kept in mind each member should not deflect or deformed then permissible link.

Modification: Modify the size of the member to agree with past experience and judgement to facilitate manufacture. The modification may also be necessary by consederation of manufacturing to reduce the overal task.

Detailed drawing: Draw the detailed drawing of each component and the assembly of machine with complete specification for the manufacturing process suggerted.

Production: the component as per the drawing is manufactured in the workshop.

General consideration of in Machine design:

(1) Type of load and stresses caused by the load. The load on the machine component may act in several ways due to which the internal stresses are to be setup.

(2) Motion of the parts (or) kinematics of the machine

(3) **Selection of materials:**

(4) Form and size of the parts.

(5) Frictional resistance and the lubrication.

(6) There is always a loss of power due to frictional resistance and it should be noted that the friction of starting is higher than the running friction. therefore the essential that a careful attention must be given to the matter of lubrication of all surfaces.

Scanned with CamScan

7) convinent and economical features in designing the operating features of the machines should be carefully studied. The starting, controlling and stopping levers should be located on the basis of convinient handling.

8) If parts are to be changed for different products are replaced on account of varying, brakage, easy access should be provided and the necessity of removing of other parts to accomplish should be avoided if possible.

29/11/19

9) <u>Use of Standard parts</u>: The use of standard parts is closly related to the cost, because of the cost of standard are stock parts is only the fraction of the cost of simillar product made to oder.

10) <u>Saftey of operations</u>: some machines are dangerous to operate, espacially those which are speed up into ensure production and maximum rate. so Therefore, necessary that a designer should always provide saftey devices for the saftey of the operater. The saftey appliances should in no way interface with operation of the machine.

11) <u>Work shop facilities</u>: A design engineer should be familier with the limitations of is employeer's work shop in order to avoid the necessary of having work done in some other workshop.

12) **Cost of construction:** The cost of construction of an article is most important consideration involve in design. The aim of the designer and all the conditions should be to reduce the manufacturing cost to the minimum.

13) **Assembling:** Every machine or structure must be assembled as a unit before it can function. The final location of any machine is important and the design engineer must anticipate the exact location and the local facilities for erruction.

Classification of Engineering materials:

Engineering Materials.

- **Non-metals**
  - → plastic
  - → wood
  - → Rubber
  - → leather.
- **Metals and alloys**
  - **Ferrousmetals**
    - **Iron**
      - * castiron
        - → Graycastiron
        - → Maliable castiron
        - → white cast iron
        - → Nodular castiron
        - → chilled castiron
      - * wrough Iron
      - * steel
        - → Dead mild steel
        - → low carbon steel
        - → Medium carbonsteel
    - **Iron alloy**
  - **Non-ferrous metals**
    - * copper
      - → copper alloys
    - * Aluminium
      - → Aluminiumalloys
    - * lead
    - * Tin
    - * Gun metal
    - copper alloys.
      - → Brass
      - → Bronze
    - Aluminium alloys
      - → Durallium
      - → Y-alloy
      - → magnalium.

Selection of Materials for Engineering purpose:

The selection of a proper material for Engineering purpose is one of the most difficulty problem for the designer. The following factors should be considered while selecting the materials.

1. Availability of materials.
2. Suitablety of materials for the working condition in service.
3. cost of the materials.

Important properties which determine the utility of the material. those are chemical properties, physical properties, mechanical propeties, Dimensional properties and technological properties.

i. chemical properties: This includes composition and structure of a materials the compositions makes up a material and their a relevant propeties. The structure is depends upon the arrangement of atoms in the material.

ii. physical property: It includes the electrical thermal and magnetic propeties its depands upon the electrical resistance of a material per unit length and unit weight.

iii. Mechanical propeties: With the help of these propeties deviation of the materials due to stress and strain can be observed.

iv. Dimensional propeties: It includes roughness, waviness and chamber → waveness is a wave like and variation from a perfect surface.

→ Roughness is findly spreaded surface irregularation height, width and direction of which establis a definite surface pattern.

→ chamber is a maximum deviation from edge straightness.

Technological properties: This includes machinability, wealdability, castability, forgedability, Bendability and Hardenability.

30|11|19

Mechanical properties of a materials:

1) Toughness: It is the property of a material to resist fraction give to high impact loads like hammer blows.

2) Hardness: It is the ability of a material to resist wear scratching and indintation and machining.

3) Resalence: It is the property of a material to absorb energy to resist shaft loads and Impact loads.

4) Creet: It is the property of a material to undergo slow and progress deformation over a period of time under constant stress.

Manfacturing process: The knowledge of manufacturing Process is of great importance for a design engineer. The following are various manufacturing process is used in mechanical engineering.

1) primary shaping process: This process is used for manufacturing proc prilivinary shaping of the component are known as primary shaping process.

→ The common operation used for this process are casting, forging, extruding, rolling, drawing, bending, shearing and spinning. etc.

2) Machining process: The process used for giving final shape of the machine components according to the planned dimensions are known as Machining process.

→ In the commonly used operations turning, plaining, shaping, drilling, boring, reaming, etc.

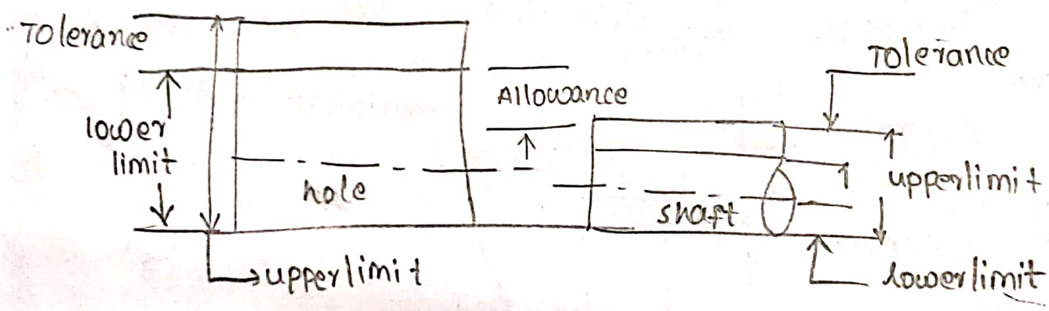
3) Finishing process: The process used to provide good surface finish for the machining components are known as surface Finishing process.

→ The common operations used for this process are polishing, Honing, Lapping, Abbressive belt grinding, super finishing, etc.

4 Joining processes: The process used for joining machine components are known as joining processes.

→ These operations are welding, rimitting, shouldering, brazing, screw fastening, etc.

Important terms used in limit system:



Nominal size: It is the size of a part specified in the drawing is called Nominal size.

Basicsize: It is the size of a part to which all limits of variation are applied to arrive at final dimensioning of the making parts.

Actualsize: It is the actual measured dimension of the part the difference b/w the basic size and actual size should not be exceed a certain link.

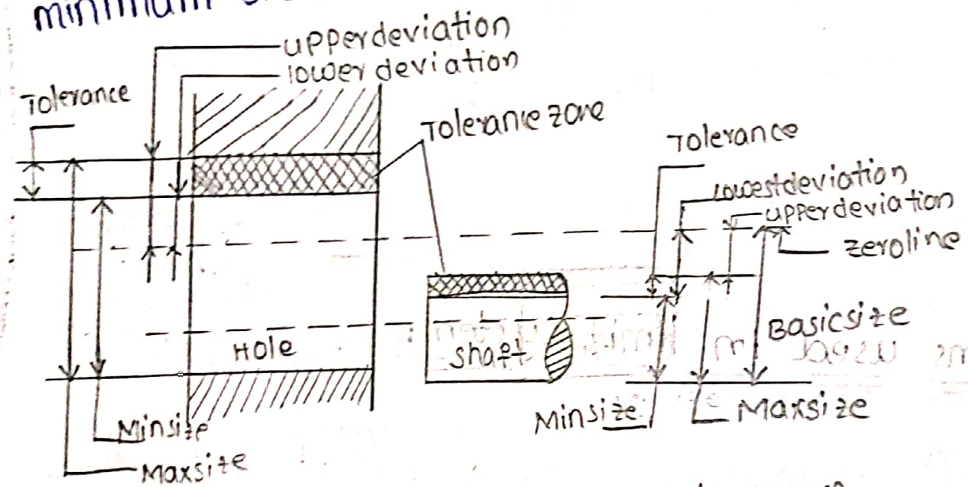
04/12/19

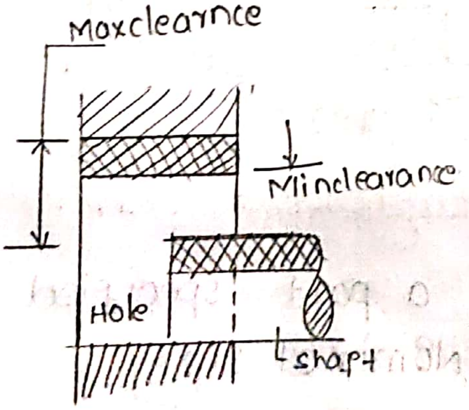
Allowance: The difference b/w the basic dimensions of the meeting Parts is called as allowance.

Tolerance: The difference b/w the upper limit and the lower limit of a dimensions is called as Tolerance.

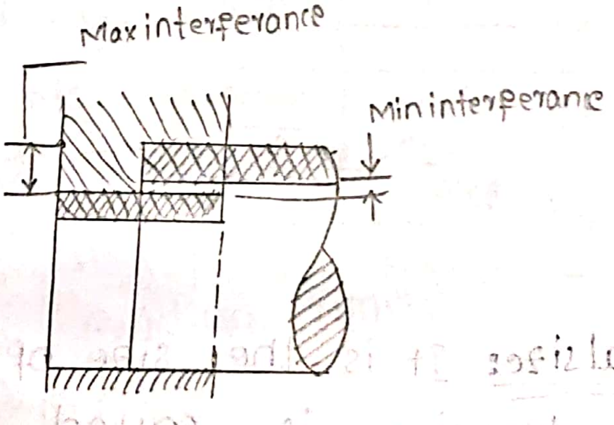
upper deviation: It is the algebric difference b/w the maximum size and the basic size.

Lower deviations: It is the algebric difference b/w the minimum size and the basic size.

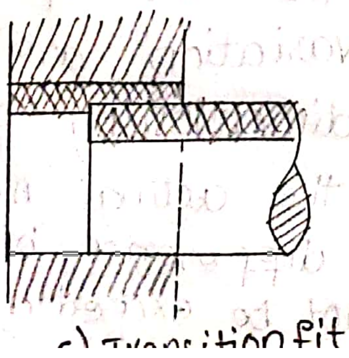




a) clearance fit



b) Inter ferance fit



c) Transition fit

Fits: The degree of tightness or looseness b/w the two meeting parts is known as fit.

The clearance is the amount by which the actual size of the shaft is less than the actual size of the hole in an assembly

Interferance: Interferance is the amount by which the actual size of shaft is larger than the actual size of hole. in an assembly.

05/12/19

Transition fit: In the type fit the size limits of the meeting part are so selected that either a clearance or interference may occur depends upon the actual size of the meeting parts.

→ The transition fit may be force fit tight fit, push fit.

1) A reciprocating steam engine connecting rod is subjected to maximum load of 65 kN. Find the diameter of the connecting rod of its thinner path If the permissible tensile stress 35 N/mm².

Sol. Given

$P = 65\ kN$

$\sigma_t = 35\ N/mm^2$

$d = ?$

$\sigma = \frac{P}{A}$

$A = \frac{\pi}{4} d^2$

$A = \cancel{65}$

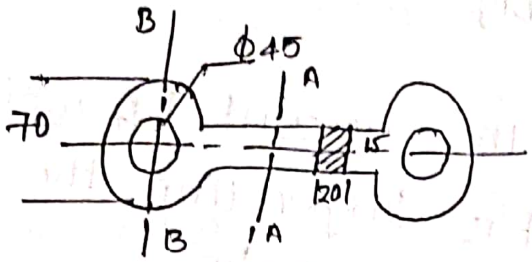
$35 = \frac{65 \times 10^3}{\frac{\pi}{4} d^2}$

$\frac{\pi}{4} d^2 = 1857.1$

$d^2 = 2364.5$

$d = 48.62\ mm$

(2) A cast iron link is required to transmit a study tensile load of 45 KN. Find the tensile stress induced in the link as shown in below the link material at section A-A, B-B.



Sol. $\sigma = ?$

$P = 45\ KN$

at A-A

$A = 20 \times 15$

$= 300\ mm^2$

at B-B

$A = 20 \times (70-45)$

$= 500\ mm^2$

$\sigma_{A-A} = \frac{45 \times 10^3}{300} = 150\ N/mm^2$

$\sigma_{B-B} = \frac{45 \times 10^3}{500} = 90\ N/mm^2$

(3) A Hydraulic press exerts a load 35 M.N this load is carried by two steel rods supporting the upper head of the press. If the safe stress is 85 M.Pascal $E = 210\ KN/mm^2$. Find diameter of each rod

(ii) Extend in each rod in a length of 25 m

Sol. $P = 35\ MN$

$\sigma = 85\ M.Pa$

$d = ?$

$\delta l = ?$

$l = 25\ m$

$E = 210\ KN/mm^2$

$P = 35\ MN = 35 \times 10^6\ N$

$\sigma = 85\ MPa = 85 \times 10^6\ N/m^2$

$= 85 \times \frac{10^6\ N}{1000^2\ mm^2}$

$= 85\ N/mm^2$

$P_1 = P/2$

$= 35 \times \frac{10^6}{2}$

$= \cancel{175}\ 17.5 \times 10^6$

$\sigma' = \frac{P_1}{A}$

$85 = \frac{17.5 \times 10^6}{\frac{\pi}{4} \times d^2}$

$\frac{\pi}{4} \times d^2 = \frac{17.5 \times 10^6}{8.5}$

$\frac{\pi}{4} d^2 = 2058823.5$

$d^2 = 262137.55$

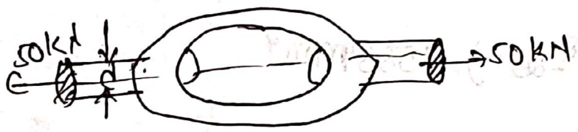
$\boxed{d = 511.99}$ mm

$\delta l = \frac{PL}{AE}$

$\delta l = \frac{35 \times 10^6 \times 2.5}{\frac{\pi}{4}(511.99)^2 \times 210}$

$\delta l = 2.02101$ mm

3 A coil chain of a plane required to carry a maximum load of 50 KN as shown in figure. Find the diameter of link, the permissible tensile strength is not exceed 75 Mg



$P = 50\,KN$

$\sigma = 75\,MPa$

$d = ?$

$P = \frac{\sigma}{A}$

$\frac{\pi}{4} d^2 = \cancel{75 \times}$

$50 \times 10^3 = \frac{75}{\frac{\pi}{4} d^2}$

$\frac{\pi}{4} d^2 = \frac{75 \times 4}{50 \times 10^3 \times \pi}$

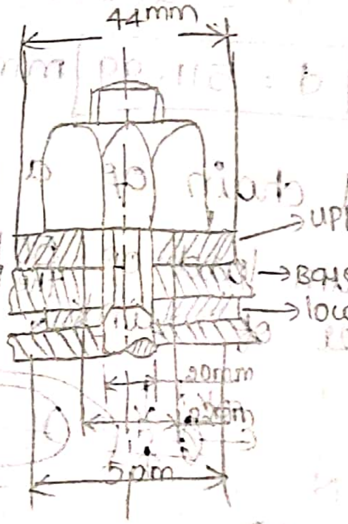
$\boxed{d = 29\,mm}$

Scanned with CamScanner

06/12/19

(4) A rectangular base plate is fixed at each of its 4 corners by 20mm diameter bolt and Nut as shown in fig. The plate rests on washers of 22mm internal diameter and 50mm external diameter. copper washers which are placed b/w the nut and the plate are of 22mm internal and 44mm external diameter. If the base plate carried in 120 of KN (including self weight which is equally distributed on the 4-corners) calculate the stress on the lower washers before the nuts are tightened.

What could be the stress in the upper and lower washers when the nuts are tightened. so as to produce and tension of 5KN on each bolt.



$U.W = A_1 = \frac{\pi}{4}(D_0^2 - D_i^2)$

$= \frac{\pi}{4}(44^2 - 22^2) = 1140mm^2$

$L.W = A_2 = \frac{\pi}{4}(D_0^2 - D_i^2)$

$= \frac{\pi}{4}(50^2 - 22^2) = 1583.9mm^2$

$P_1 = P/4 = 120/4 = 30kN$

Before tightened $\sigma_{L.W} = P/A = 30\times10^3/1586.9$

$= \underline{18.9}\ N/mm^2$

$\sigma_{U.W} = P/A = 5\times10^3/1140 = 4.38\ N/mm^2$

$\sigma_{L.W} = P/A$

$= \frac{30\times10^3 + 5\times10^3}{1586} = \underline{22.10}\ N/mm^2$

combine bending and Tortion:

$\frac{T}{J} = \frac{fs}{R} = \frac{G\theta}{l}$

$\frac{T}{J} = \frac{fs}{R} = \frac{q}{R}$

$\frac{q}{R} = \frac{T}{J}$

$q = \frac{T}{J} \times R$

$= \frac{T}{\frac{\pi}{\cancel{32}_{16}} d^{\cancel{4}3}} \times \frac{\cancel{d}}{\cancel{2}}$

$\boxed{q = \frac{16T}{\pi d^3}}$

$\frac{M}{I} = \frac{E}{R} = \frac{\sigma_b}{y}$

$\frac{\sigma_b}{y} = \frac{M}{I}$

$\sigma_b = \frac{M}{I} \cdot y$

$= \frac{M}{\frac{\pi}{\cancel{64}_{32}} \cdot d^{\cancel{4}3}} \cdot \cancel{d}/\cancel{2}$

$\boxed{\sigma_b = \frac{32M}{\pi d^3}}$

Maximum principle stress-

$\frac{\sigma_b}{2} + \sqrt{\left(\frac{\sigma_b}{2}\right)^2 + fs^2}$

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

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

$= \frac{16}{\pi d^3}\left[M + \sqrt{M^2 + T^2}\right]$

$= \frac{16}{\pi d^3}\left[M - \sqrt{M^2 + T^2}\right]$

1) A solid shaft of diameter 80mm is subjected to a twisting moment of 8MN mm and bending moment of 5MN mm at a point determine the principle stresses and the position of the plane on which they act.

$M = 5MN\text{-}mm$
$= 5 \times 10^6 N\text{-}mm$

$T = 8MN\text{-}mm$
$= 8 \times 10^6 N\text{-}mm$

$D = 80mm$

Max pri stress $= \frac{16}{\pi d^3}\left(M + \sqrt{M^2 + T^2}\right)$

$= \underline{143.54}$ N/mm^2 (Tensile)

Min pri stree $= \frac{16}{\pi d^3}\left[M - \sqrt{M^2 + T^2}\right]$

$= \frac{16}{\pi d^3}\left[5 \times 10^6 - \sqrt{2.5 \times 10^{3} + 6.4 \times 10^{13}}\right]$

$= \underline{44.10}$ N/mm^2

Position of the plane

$\tan 2\theta = \frac{2fs}{\sigma b} = \frac{2 \times \frac{16T}{\pi d^3}}{\frac{32M}{\pi d^3}}$

$\tan 2\theta = T/m$

$\tan 2\theta = \frac{8 \times 10^3}{5 \times 10^3}$

$\boxed{\theta = 28.1}$

Scanned with CamScan

The maximum allowable shear stress in a hallow shaft of external diameter Equal to, twice of the internal diameter determine the diameter of the shaft if it is subjected to a torque of 4×10^6 N-mm and bending moment of 3×10^6 N-mm. stress 80N/mm²

$D_0 = A$
$D_i = B$
$M = C$
$T = D$.

sol. $D_0 = 2D_i$

$M = 3$ MN-mm
$= 3\times10^6$ N-mm

$d_i = \cancel{16}$mm 40.6
$d_o = \cancel{32}$ 81.2

$T = 4$ MN-mm
$= 4\times10^6$ N-mm

D_0 & D_i = ?

M.A Pri stress $= \frac{16 D_0}{\pi(D_0^4 - D_i^4)}\left[M + \sqrt{M^2+T^2}\right]$ (Tensile)

$= \frac{16\times2 D_i}{\pi\left[(2\times D_i)^4 - D_i^4\right]}\left[3\times10^6 + \sqrt{(3\times10^6)^2 + (4\times10^6)^2}\right]$

$80 = \frac{16\times2\times D_i\times10^6}{\pi\left[(16\times D_i^4) - D_i^4\right]}\left[3 + \sqrt{3^2+4^2}\right]$

07/12/19

Theories of failure: When the load is acting on the body If the generated tensile stress is directly proportional to tensile strain with in the elastic limit. Beyond the elastic limit if the tensile stress increases the failure of the bar takes place. not only tensile stress the failure of the bar will also due to other quantities such as shear stress and strain energy also attain definite value, and any one of these may be deciding factor of the failure of bar. certain theories have advanced to explain the causes of failure those are
1. Maximum principle stress theory. (or) Normal stress theory
2. Maximum shear stress theory.
3. Maximum principle strain theory.

4. Maximum strain theory

5. Maximum shear strain energy theory.

1. Maximum principle stress theory: A/c to this theory the failure of a material will occur for the maximum principle tensile stress. in the complex system reaches the value of maximum stress at the elastic limit in simple tension (or) The minimum principlo stress reaches the value of maximum stress at the elastic limit. in simple compression.

A/c to this theory $\sigma_t \geq \sigma_{yt}$ When consider the factor of saftey $\boxed{\sigma_t = \frac{\sigma_{yt}}{\text{factor of saftey}}}$

$$\boxed{(\sigma_t)_{max} = \frac{\sigma_1}{2} + \frac{1}{2}\sqrt{\sigma_1^2 + 4\tau^2}}$$

Minimum principle stress $\boxed{(\sigma_t)_{min} = \frac{\sigma_1}{2} - \frac{1}{2}\sqrt{\sigma_1^2 + 4\tau^2}}$

2. Maximum principle shear stress theory: This theory is also known as guest theory. A/c to this theory the failure of a material will occur when the maximum value of shear stress in a material reaches the value at the elastic limit in simple tention maximum shear stress. This maximum principle stress is Equal to half of the difference b/w the maximum and minimum principle stress.

$$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_3)$$

$$\tau_{max} = \frac{1}{2}(\sigma_y)$$

$$\tau_{max} = \frac{\sigma_y}{2 \times FOS}$$

$$\tau_{max} = \frac{1}{2}\left[\sqrt{\sigma_1^2 + 4\tau^2}\right]$$

1, The total load of a bolt consists of an axial load of 10 KN together with a transverse shear force of 5 KN. Find the diameter of bolt required according to maximum principle stress theory. Assume permissible tensile stress at elastic limit 100 MPa

Sol $P = 10\,KN$

$P_s = 5\,KN$

$\sigma_{yt} = 100\,MPa$

$d = ?$

$A = \frac{\pi}{4} d^2$

$\sigma_t = P/A \Rightarrow \frac{10\times10^3}{\frac{\pi}{4}\times d^2} = \frac{12732.39}{d^2}$

$$\sigma_t = \frac{12732.39}{d^2}$$

$$\tau = P/A = \frac{5\times10^3}{\frac{\pi}{4} d^2} = \frac{6366.9}{d^2}$$

$$(\sigma_{max}) = \frac{\sigma_1}{2} + \frac{1}{2}\left[\sqrt{\sigma_1^2 + 4\tau^2}\right]$$

$$= \frac{12732.39}{2.d^2} + \frac{1}{2}\left[\sqrt{\left(\frac{12732.39}{d^2}\right)^2 + 4\left(\frac{6366.9}{d^2}\right)^2}\right]$$

$$= \frac{6366.195}{d^2} + \frac{1}{2}\left[\sqrt{\frac{(12732.39)^2}{(d^2)^2} + \frac{4(6366.9)^2}{(d^2)^2}}\right]$$

$$= \frac{6366.195}{d^2} + \frac{1}{2}\cdot\frac{1}{d^2}\sqrt{(12732.39)^2 + 4(6366.9)^2}$$

$$= \frac{1}{d^2}\left[6366.195 + \frac{1}{2}\times 18006.311\right]$$

$$= \frac{15369.34}{d^2}$$

$$100 = \frac{15369.34}{d^2}$$

$$\boxed{d = 12.39\,mm}$$

2 The load on the shaft 15KN and 8KN of shear stress load acting on the member find the diameter of the shaft. If factor of saftey equal 4 and maximum permissible yield stress 120 N/mm².

Sol. $P = 15KN$

$P_s = 8KN$

$d = ?$

$FOS = 4$

$\sigma_{yt} = 120 N/mm^2$

$$\sigma_t = P/A = \frac{15\times10^3}{\frac{\pi}{4}\times d^2} = \frac{19098.59}{d^2}$$

$$\tau = P/A = \frac{8\times10^3}{\frac{\pi}{4}\times d^2} = \frac{10185.91}{d^2}$$

$$(\sigma_{max}) = \frac{\sigma_t}{2} + \frac{1}{2}\left[\sqrt{\sigma_t^2 + 4\tau^2}\right]$$

$$= \frac{19098.59}{2.d^2} + \frac{1}{2}\left[\sqrt{\left(\frac{19098.59}{d^2}\right)^2 + 4\left(\frac{10185.91}{d^2}\right)^2}\right]$$

$$= \frac{9549.29}{d^2} + \frac{1}{2}\cdot\frac{1}{d^2}\sqrt{(19098.59)^2 + 4(10185.91)^2}$$

$$= \frac{1}{d^2}\left[9549.29 + \frac{1}{2}(27924.311)\right]$$

$$= \frac{23511.44}{d^2}$$

$$\frac{120}{4} = \frac{23511.44}{d^2}$$

$$d^2 = 783.714$$

$$\boxed{d = 27.99 mm}$$

(3) A cylindrical shaft made of steel of yield strength 700 MPa is subjected to static load of bending moment 10 KNm and Tortional moment 30 KNm. Determine the diameter the shaft using principle stress theory.

sol. $\sigma_y = 700 MPa$

$M = 10 KN-mt$

$T = 30 KN-mt$

$d = ?$

$$\frac{M}{I} = \frac{\sigma}{y} \Rightarrow \sigma_b = \frac{M}{I} \cdot y$$

$$= \frac{10 \times 10^6}{\frac{\pi}{\cancel{64}_{32}} \cdot d^{\cancel{4}3}} \times \cancel{d}/\cancel{2}$$

$$\sigma_b = \frac{10 \times 10^6 \times 32}{\pi \times d^3} = \frac{101.85 \times 10^6}{d^3}$$

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\tau = \frac{T}{J} \cdot R \Rightarrow \frac{T}{\frac{\pi}{\cancel{32}_{16}} d^{\cancel{4}3}} \cdot \cancel{d}/\cancel{2} = \frac{16 \times 30 \times 10^6}{\pi \times d^3}$$

$$\tau = \frac{152.788 \times 10^6}{d^3}$$

$$(\sigma_{max}) = \frac{\sigma_1}{2} + \frac{1}{2}\sqrt{\sigma_1^2 + 4 \cdot \tau^2}$$

$$= \frac{101.85 \times 10^6}{2 \cdot d^3} + \frac{1}{2}\sqrt{\left(\frac{101.85 \times 10^6}{d^3}\right)^2 + 4\left(\frac{152.78 \times 10^6}{d^3}\right)^2}$$

$$= \frac{50.91 \times 10^6}{d^3} + \frac{1}{2} \cdot \frac{1}{d^3}\sqrt{(101.85 \times 10^6)^2 + 4(152.78 \times 10^6)^2}$$

$$= \frac{1}{d^3}\left(50.91 \times 10^6 + \frac{1}{2}(101.85 \times 10^6)\right)$$

$$= \frac{101.83}{d^3} \times 10^6$$

9/12/19

4) A machine element is loaded so that the max principle stress $\sigma_1 = 120$ M.Pa, $\sigma_2 = 70$ M.Pa, $\sigma_3 = -90$ M.Pa. the material has maximum yield strength in compression and tension of 360 M.Pa. Find the FOS of each following theories maximum stress theory and maximum shear stress theory.

$\sigma_{yt} = 360$ M.Pa

$\sigma_1 = +120$ MPa

$\sigma_2 = +70$ M.Pa

$\sigma_3 = -90$ M.Pa

$\sigma_t = \frac{\sigma_{yt}}{FOS}$

$120 = \frac{360}{FOS}$

$\boxed{FOS = 3}$

$\tau_{max} = \frac{\sigma_y}{F.S}$

$\tau_{max} = \frac{1}{2}(120-(-90))$

$105 = \frac{360}{FS}$

$\boxed{FOS = 3.42 \simeq 4}$

5) The principle stresses that point in the elastic member are $100 N/mm^2$, $80 N/mm^2$, $50 N/mm^2$ compressing. If the stresses at the elastic limit is simple tension is $200 N/mm^2$ of failure a/c to determine the FOS. Determine the material will occur. If not determine the max. principle stress theory. i.e 100 N/mm² ($200 N/mm^2$)

statement: The max. principle tensile stress is less than the ultimate so the material will safe under given working conditions.

$\boxed{\sigma_1 < \sigma_{yt}}$

$\sigma_{yt} = 200 N/mm^2$

$\sigma_1 = +100 N/mm^2$

$\sigma_2 = +80 N/mm^2$

$\sigma_3 = -50 N/mm^2$

$\sigma_t = \frac{\sigma_{yt}}{FOS}$

$100 = \frac{200}{FOS} \Rightarrow \boxed{FOS = 2}$

$\tau_{max} = \frac{\sigma_y}{FOS}$

$\tau_{max} = \frac{1}{2}(100-(-50))$

$= \frac{1}{2}(150) = 75$

$75 = \frac{200}{FS} \Rightarrow \boxed{FS = 2.67 \simeq 3}$

Scanned with CamScan

6, At a section of mild steel shaft the max. Torque 8437.5 N-m and maximum bending moment is 5062.5 N-m the diameter of the shaft 90 mm and the stress at elastic limit in the simple tension for the material of shaft is 220 N/mm². calculate the FOS a/c to max. shear stress theory.

Sol. $T_{max} = 8437.5$ N-m

$M = 5062.5$ N-m

$d = 90$ mm

$\sigma_F = 220 N/mm^2$

$F.S = ?$

$\frac{T}{J} = \frac{F_s}{R}$

$F_S = \frac{T}{J} \times R$

$= \frac{T}{\frac{\pi}{32} \times d^4} \cdot \frac{d}{2}$

$F_S = \frac{8437.5}{\frac{\pi}{32} \times 90^4} \cdot \frac{90}{2} \Rightarrow 0.059 N/mm^2$

$= 59 \times 10^{-3} N/mm^2$

$\frac{M}{I} = \frac{\sigma_b}{y}$

$\sigma_b = \frac{M}{I} \cdot y$

$= \frac{M}{\frac{\pi}{64} \cdot d^4} \cdot \frac{d}{2}$

$= \frac{5062.5}{\frac{\pi}{64} \cdot (90)^4} \cdot \frac{90}{2}$

$\sigma_b = 0.072 N/mm^2$

$= 72 \times 10^{-3} N/mm^2$

$\tau_{max} = \frac{1}{2}\left[\sqrt{(\sigma_b)^2 + 4\tau^2}\right]$

$\tau_{max} = \frac{1}{2} \sqrt{(\cancel{0.072})^2 + 4(\cancel{0.059})^2}$ (72×10^{-3}, 59×10^{-3})

$= \frac{1}{2} \sqrt{72 \times 10}$

$\cancel{= \frac{1}{2}(0.504)}$

$\tau_{max} = 0.25$

$\tau_{max} = \cancel{25} \, 122 \times 10^{-3}$

11/12/19

Maximum principle strain theory: The failure will occur in a material when the maximum principle strain reaches the strain due to yield stress in a simple tension (or) minimum principle strain reaches the strain due to yield stress in simple compression

→ The simple strain in direction of simple stress

$$e_1 = \frac{\sigma_1}{E} - \mu \frac{\sigma_2}{E} - \mu \cdot \frac{\sigma_3}{E}$$

$$e_1 = \frac{1}{E} \cdot \left[\sigma_1 - \mu(\sigma_2 + \sigma_3)\right]$$

→ The principle strain in the direction of stress 'σ_3' is

$e_3 = \frac{\sigma_3}{E} - \mu \frac{\sigma_1}{E} - \mu \frac{\sigma_2}{E}$

$e_3 = \frac{1}{E}(\sigma_3 - \mu(\sigma_1 + \sigma_2))$

→ strain due to yield stress in simple tension

$$\boxed{e_y = \frac{\sigma_y}{E}}$$

→ A/c to this theory the failure of a material when

$e_1 \geq e_{yield}$ (Tensile)

$e_3 \geq e_{yield}$ (comp)

$e_1 = e_{yield}$

$e_3 = e_{yield}$

1) The principle stresses at a point in a elastic material are 200 N/mm² tensile 100 N/mm² tensile 50 N/mm² tensile if the stress at the elastic limit in a simple tension is 200 N/mm² take a poison's ratio = 0.3 Determine whether body will failure or not

sol: $\sigma_1 = 200\,N/mm^2$ (T); $\sigma_2 = 100\,N/mm^2$ (T); $\sigma_3 = 50\,N/mm^2$ (comp).

$\sigma_y = 200\,N/mm^2$; $\mu = 0.3$

$e_1 \geq e_{yield}$

$\sigma_1 - \mu(\sigma_2 + \sigma_3) = \sigma_y / F.S$

$200 - 0.3(100 - 50) = e_1$

$e_1 = 185$

$185 \geq 200$

2) Determine the dia of a bolt which is subjected to an axial pull of 9 kN together with a transfer shear force of 4.5 kN. A/c to max principle strain theory elastic limit in Tension 225 N/mm² FS is 3

$\mu = 0.3$

P = 4.5 KN

Sol. $\mu = 0.3$ F.S = 3

Tension = 225 N/mm²

$$\tau = P/A = \frac{4.5\times10^3}{\frac{\pi}{4}\times d^2} = \frac{5.72\times10^3}{d^2}$$

$$\sigma = P/A = \frac{9\times10^3}{\frac{\pi}{4}\times d^2} = \frac{11.45\times10^3}{d^2}$$

$$\sigma_{max} = \frac{\sigma}{2} + \frac{1}{2}\left[\sqrt{\sigma_1^2+4\tau^2}\right]$$

$$= \frac{11450}{2d^2} + \frac{1}{2}\left[\sqrt{4\left(\frac{5720}{d^2}\right)^2+\left(\frac{11450}{d^2}\right)^2}\right]$$

$$= \frac{1}{2d^2}\left[11450+\sqrt{4(5720)^2+(11450)^2}\right]$$

$$\sigma_{max} = \frac{13817.83}{d^2}$$

$$\sigma_{min} = \frac{\sigma}{2} - \frac{1}{2}\sqrt{\sigma^2+4\tau^2} = \frac{-2367.3}{d^2}$$

3. A mild steel of 50mm dia is subjected to a bending moment of 2000 N/m & a Torque T if the yield point of steel in tension is 200 mpa. Find the max value of his torque without causing yielding of the shaft according to max shear strain theory

Sol. d = 50mm

m = 2000N-m

σ_y = 200 mPa

T = ?

$$\frac{T}{J} = \frac{f_s}{R}$$

$$f_s = \frac{T}{J}\times R$$

$$= \frac{T}{\frac{\pi}{\cancel{32}_{16}}\times 50^{\cancel{4}3}}\times\frac{\cancel{50}}{\cancel{2}}$$

$$= \frac{T}{24,543.69}$$

$$\frac{m}{J} = \frac{\sigma_b}{y}$$

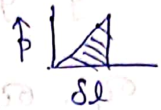
$$= \frac{2000\times10^3}{\frac{\pi}{64}\times50^4}\times 50/2$$

$$\sigma_b = 162.9 \text{ N/mm}^2$$

18/12/19

Maximum strain energy theory: A/c to this theory the failure of a material occurs when the total strain energy for unit volume in the material reaches the strain energy per unit volume of the material at the elastic limit in simple tension.

Work done by the load in straining the material and is



equal to $= \frac{1}{2} \cdot P \times \delta l$

$= \frac{1}{2} (\sigma \cdot A) \cdot e \cdot l$

$= \frac{1}{2} \cdot \sigma \times e \cdot \cancel{A} \cancel{l} / \cancel{A} \cancel{l}$

$$\boxed{U = \frac{1}{2} \cdot \sigma \cdot e}$$

For a ~~#~~ 3-dimensional stress the principle stresses acting at a point are $\sigma_1, \sigma_2, \sigma_3$. The corresponding strains are e_1, e_2 & e_3.

$$e_1 = \frac{\sigma_1}{E} - \frac{\sigma_2}{mE} - \frac{\sigma_3}{mE}$$

$$e_1 = \frac{1}{E}\left(\sigma_1 - \mu(\sigma_2 + \sigma_3)\right)$$

$$e_2 = \frac{1}{E}\left(\sigma_2 - \mu(\sigma_1 + \sigma_3)\right)$$

$$e_3 = \frac{1}{E}\left(\sigma_3 - \mu(\sigma_2 + \sigma_1)\right)$$

The total strain energy per unit volume in 3-dimensional system.

$$U = \frac{1}{2} \cdot \sigma_1 \cdot \frac{1}{E}\left(\sigma_1 - \mu(\sigma_2 + \sigma_3)\right) + \frac{1}{2}\sigma_2 \cdot \frac{1}{E}\left(\sigma_2 - \mu(\sigma_3 + \sigma_1)\right) + \frac{1}{2} \cdot \sigma_3 \cdot \frac{1}{E}\left(\sigma_3 - \mu(\sigma_1 + \sigma_2)\right)$$

$$U = \frac{1}{2E} \left[(\sigma_1^2 - \mu\sigma_1 \cdot \sigma_2 - \mu\sigma_1 \cdot \sigma_3) + (\sigma_2^2 - \mu \cdot \sigma_2 \cdot \sigma_3 - \mu \cdot \sigma_2 \cdot \sigma_1) + (\sigma_3^2 - \mu\sigma_3\sigma_1 - \mu\sigma_3 \cdot \sigma_2)\right]$$

$$U = \frac{1}{2E}\left[(\sigma_1^2 + \sigma_2^2 + \sigma_3^2) - 2\mu\sigma_1\sigma_2 - 2\mu\sigma_1\cdot\sigma_3 - 2\mu\sigma_2\cdot\sigma_3\right]$$

$$U = \frac{1}{2E}\left[(\sigma_1^2 + \sigma_2^2 + \sigma_3^2) - 2\mu(\sigma_1\cdot\sigma_2 + \sigma_1\cdot\sigma_3 + \sigma_2\cdot\sigma_3)\right] \geq \frac{1}{2}E\cdot\sigma_y^2$$

The strain energy per unit volume corresponding to stress at elastic limit in simple tension.

$$U = \frac{1}{2}\cdot\sigma_y\cdot e_y$$

$$= \frac{1}{2}\cdot\sigma_y\cdot\frac{\sigma_y}{E}$$

$$= \frac{1}{2}E\cdot\sigma_y^2$$

For the failure of a material.

$$U = \frac{1}{2E}\left[(\sigma_1^2 + \sigma_2^2 + \sigma_3^2) - 2\mu(\sigma_1\cdot\sigma_2 + \sigma_1\cdot\sigma_3 + \sigma_2\sigma_3\right] \geq \frac{1}{2}E\sigma_y^2$$

1) Given,

$\sigma_1 = 200\ N/mm^2$ (T)

$\sigma_2 = 100\ N/mm^2$ (T)

$\sigma_3 = 50\ N/mm^2$ (C)

$\sigma_y = 220\ N/mm^2$

$\mu = 0.3$

$$U = \frac{1}{2E}\left[((200)^2 + (100)^2 + (-50)^2) - 2(0.3)((200\times100) + (100\times-50) + (-50\times200))\right]$$

$$= 44250 \geq 24200$$

The calculated value is less than yield stress value so the material will safe.

2) Given

$P_t = 9\ kW$

$P_s = 4\ kW$

$\mu = 3$

$\sigma_3 = 200\ N/mm^2$

Maximum shear strain energy theory: This theory is due to misses and Henky, and is known as Misses Henky theory.
This theory is also called as Maximum energy distortion theory. [von Misses theory] {Maximum distortion energy theory}

A/c to this theory the failure of a material occurs when the total shear strain energy per unit volume in the stressed material reaches a value equal to the shear strain energy per unit volume at the elastic limit in simple tension.

The total shear strain energy per unit volume due to principle stresses σ_1, σ_2 & σ_3 in a stressed material is equal to $= \frac{1}{12C}\left[(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2\right]$

In simple tension test is a uniaxial stress system which means $\sigma_1 = \sigma_y$ & $\sigma_2, \sigma_3 = 0$

$$= \frac{1}{12C}\left[(\sigma_y-0)^2 + (0-0)^2 + (0-\sigma_y)^2\right]$$

$$= \frac{1}{12C}\left[(\sigma_y)^2 + 0 + (-\sigma_y)^2\right] \Rightarrow \frac{1}{12C}(2\sigma_y^2)$$

For the failure of a material

$$= \frac{1}{12C}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right] \geq \frac{1}{12C}(2\sigma_y^2)$$

For two dimensional $\sigma_3 = 0$

$\sigma_3 = 0$

$$= \frac{1}{12C}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-0)^2+(0-\sigma_1)^2\right]$$

$$= \frac{1}{12C}\left[\sigma_1^2+\sigma_2^2-2\sigma_1\sigma_2+\sigma_2^2+\sigma_1^2\right]$$

$$= \frac{1}{12C}\left[2\sigma_1^2+2\sigma_2^2-2\sigma_1\sigma_2\right]$$

$$= \frac{1}{12C}\times 2\left[\sigma_1^2+\sigma_2^2-\sigma_1\sigma_2\right] \geq \frac{1}{12C}\times 2\sigma_y^2$$

Note: All theories formulae:

(1) Normal stress theory:

$$\sigma_t \geq \sigma_y$$

$$\sigma_t = \frac{\sigma_y}{FOS}$$

(2) Max shear stress theory

$$\tau_{max} = \frac{1}{2}\sigma_y$$

$$\tau_{max} = \frac{\sigma_y}{2.FOS}$$

(3) Max. principle strain theory:

$$\frac{1}{E}(\sigma_1-\mu(\sigma_2+\sigma_3)) \geq \frac{1}{E}\cdot\sigma_y$$

$$\frac{1}{E}(\sigma_3-\mu(\sigma_1+\sigma_2)) \geq \frac{1}{E}\cdot\sigma_y$$

(4) Max. strain energy:

$$U = \frac{1}{2E}\left[(\sigma_1^2+\sigma_2^2+\sigma_3^2)-2\mu(\sigma_1\cdot\sigma_2+\sigma_2\cdot\sigma_3+\sigma_3\cdot\sigma_1)\right] \geq \frac{1}{2}E\cdot\sigma$$

(5) Max shear strain energy:

$$= \frac{1}{12C}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right] \geq \frac{1}{12C}(2\sigma_y^2)$$

$$= \cancel{\frac{1}{12C}\left[(\sigma_1+\sigma_2\right.}$$

$$= \frac{1}{12C}\times 2\left[\sigma_1^2+\sigma_2^2-\sigma_1\cdot\sigma_2\right] \geq \frac{1}{12C}\times 2\sigma_y^2$$

problem:

The principle stresses at a point in an elastic material 220 N/mm² (T), 110 N/mm² (T), 55 N/mm² (C) If the elastic limit in simple tension is 220 N/mm² and $\mu = 0.3$ then determine wheather the failure of a material will occur or not according to all theories.

Sol. Given

$\sigma_1 = 220\ N/mm^2 (T)$

$\sigma_2 = 110\ N/mm^2 (T)$

$\sigma_3 = -55\ N/mm^2 (C)$

$\sigma_y = 220\ N/mm^2$

$\mu = 0.3$

(i) Maximum principle stress theory:

$\sigma_t \geq \sigma_y$

$220 \geq 220$

The maximum principle stress is equal to yieldstress so the material will fail.

(ii) Maximum shear stress theory:

$$\boxed{\tau_{max} = \frac{1}{2}\sigma_y}$$

$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_3)$

$= \frac{1}{2}(220 - (-55))$

$= 137.5$

$\because \tau_{max} \geq \frac{\sigma_y}{2}$

$137.5 \geq 220/2$

$137.5 \geq 110$

The maximum shear stress theory is greater than yield stress. so the material will fail.

iii) Maximum principle strain energy theory:

$$\Rightarrow \frac{1}{E}(\sigma_1 - \mu(\sigma_2+\sigma_3)) \geq \frac{1}{E}\cdot\sigma_y$$

$$\Rightarrow (220 - 0.3(110+55)) \geq \cdot 220$$

$$\Rightarrow 203.5 \geq 220$$

The material will safe.

iv) Maximum strain theory:

$$U = \frac{1}{2E}\left[(\sigma_1^2+\sigma_2^2+\sigma_3^2) - 2\mu(\sigma_1\cdot\sigma_2+\sigma_2\cdot\sigma_3+\sigma_3\cdot\sigma_1)\right] \geq \frac{1}{2E}\cdot\sigma_y^2$$

$$= \left((220^2+110^2+55^2) - 2(0.3)\left[(220\times110)+(110\times55)+(55\times220)\right]\right) \geq 220^2$$

$$= 63525 - 2(\overset{6050}{\cancel{12705}}) \geq 48400$$

$$= \overset{51425}{\cancel{38115}} \geq 48400$$

Fail

v) Maximum shear strain energy theory:

$$= \frac{1}{12C}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right] \geq \frac{1}{12C}(2\sigma_y^2)$$

$$= \cancel{f}\ 12100 + \overset{27225}{\cancel{3025}} + 75625 \geq 96800$$

$$114950 \geq 96800$$

~~safe~~ fail.

Determine the diameter of bolt which is subjected to an axial load of 12 kN and together with a transverse shear force of 6 kN when the elastic limit in tension is 300 N/mm². FOS = 3, $\mu = 0.3$ using all theories

Given

$(P_t) = 12\times10^3$ N

P_s = 6 kN

F.S = 3

$\mu = 0.3$

$$\sigma_t = \frac{P_t}{A} = \frac{12\times10^3}{\frac{\pi}{4}\times d^2} = \frac{15278.8}{d^2}$$

$$\tau_s = \frac{P_s}{A} = \frac{6\times10^3}{\frac{\pi}{4}\times d^2} = \frac{\cancel{5092.9}\ 7639.4}{d^2}$$

$$\sigma_1 = \frac{\sigma_t}{2} + \frac{1}{2}\sqrt{(\sigma_t)^2 + 4(\tau)^2}$$

$$= \frac{15278.8}{2\times d^2} + \frac{1}{2}\sqrt{\left(\frac{15278.8}{d^2}\right)^2 + 4\left(\frac{7639.4}{d^2}\right)^2}$$

$$= \frac{7639.4}{d^2} + \frac{1}{2}\cdot\frac{1}{d^2}\sqrt{(15278.8)^2 + 4(7639.4)^2}$$

$$= \frac{7639.4}{d^2} + \frac{1}{2d^2}(21.6\times10^3)\ \sqrt{21607.4}$$

$$\sigma_1 = \frac{7639.4}{d^2} + \frac{\cancel{10.8\times10^6}\ 73.49}{d^2} \Rightarrow \frac{\cancel{7712.8}\ 1844.29}{d^2}$$

$$\sigma_2 = \frac{\sigma_t}{2} - \frac{1}{2}\sqrt{(\sigma_t)^2 + 4(\tau)^2}$$

$$= \frac{7639.4}{d^2} - \frac{1}{2}\cdot\frac{1}{d^2}\sqrt{21607.4} \Rightarrow \frac{7639.4}{d^2} - \frac{73.49}{d^2}$$

$$= \frac{-3164.35}{d^2}$$

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

$$= \frac{1}{2}\sqrt{\left(\frac{15286.6}{d^2}\right)^2 + 4\left(\frac{7643.3}{d^2}\right)^2}$$

$$= \frac{10803.7}{d^2}$$

1) $\sigma_1 = \sigma_y$

$$\frac{18443.29}{d^2} = \frac{300}{3}$$

$$\frac{18443.29 \times 3}{300} = d^2$$

$$\boxed{d = 13.5}$$

2) $\tau_{max} = \frac{1}{2} \cdot \sigma_y$

$$\frac{\sigma_y}{\cancel{2}FS} = \cancel{\frac{1}{2}\cdot}\sigma_y$$

$$\frac{10803.7}{d^2} = \frac{300}{2 \times 3}$$

$$\boxed{d = 14.69}$$

3) $(\sigma_1 - \mu(\sigma_2 + \sigma_3)) \geq \sigma_y / FS$

$$\left(\frac{18443.29}{d^2} - (0.3)\left(\frac{-3164.35}{d^2}\right)\right) \geq \frac{10\cancel{803.7}}{\cancel{d^2}} \frac{300}{\cancel{FS}3}$$

$$\frac{18443.29}{d^2} - \frac{949.30}{d^2} = \frac{\overset{100}{\cancel{300}}}{\cancel{3}}$$

$$\frac{17493.99}{d^2} = 100$$

$$\boxed{d = 13.1}$$

4) $(\sigma_1^2 + \sigma_2^2 + \sigma_3^2) - 2(\mu)(\sigma_1 \cdot \sigma_2 + \sigma_2 \cdot \sigma_3 + \sigma_3 \cdot \sigma_1)$

$$\left[\left(\frac{18443.29}{d^2}\right)^2 + \left[\left(\frac{-3164.35}{d^2}\right)^2\right] - 2(0.3)\left[\left(\frac{18443.29}{d^2}\right)\left(\frac{-3164.35}{d^2}\right)\right]\right] = \frac{\sigma_y^2}{FS^2} = \frac{\overset{300}{\cancel{900}}}{\cancel{3}}$$

$$\frac{1}{d^2}(350168056.9) - \frac{1}{d^2}(-35016614.8) = 30000$$

$$= \frac{\cancel{3058}\; 385184671.7}{d^2} = 30000$$

$$= \overset{42.7}{\cancel{12839488.8}} = d^2$$

$$\boxed{\cancel{d = 1133.1}}$$

$$\boxed{d = 6.5}$$

A cast iron pully transmit a 10kw power at 400rpm the diameter of the pully is 1.2m and it has a four straight arms of eliptical cross section in which major axis is twice the minor axis. Determine the dimension of the each arm. If the allowable bending stress is 15MPa.

Sol.
$d = 1.2\,mt$
$P = 10\,kW$
$N = 400\,rpm$
$\sigma_b = 15\,MPa$
4 arms
$\boxed{a = 2b}$

$P = \frac{2\pi NT}{60}$

$10\times10^3 = \frac{2\pi\times400\times T}{60}$

$T = 238.71\ N\text{-}mt$

$T = W\times R$

$W = T/R$

$= \frac{238.7\times10^3}{0.6\times10^3}$

$W = \frac{396.8}{4} = 99.47\ N$

$\boxed{\sigma_b = \frac{M}{Z}}$ $\boxed{M = W\times R}$

$M = 99.47\times0.6\times10^3$

$M = 59682\ N\text{-}mm$

$\boxed{Z = \frac{\pi}{4}a^2b \text{ elliptical}}$

Rough
$\frac{M}{I} = \frac{\sigma_b}{y} = \frac{E}{R}$

$\sigma_b = \frac{M}{I}\cdot y$

$\boxed{\frac{I}{y} = Z}$

$\boxed{\sigma_b = \frac{M}{Z}}$

$15 = \frac{59682}{\frac{\pi}{4}\cdot a^2 b}$

$15 = \frac{59682}{0.785\times(2b)^2\cdot b}$

$\boxed{b = 10.81\,mm}$

$a = 2(10.81)$

$\boxed{a = 21.62\,mm}$

A pully transmit 20kw power at 300rpm the diameter of the pully is 550mm and it has 4arms which is in elliptical shape. In which major axis is twice the minor axis. calculate the dimension If allowable bending stress is 15 M.Pa.

Sol.
$d = 550\,mm$
$P = 20\,kW$
$N = 300\,rpm$
$\sigma_b = 15\,MPa$
4arms
$\boxed{a = 2b}$

$P = \frac{2\pi NT}{60}$

$20\times10^3 = \frac{2\pi\times300\times T}{60}$

$\boxed{T = 636.9\ N\text{-}m}$

$T = W\times R$

$W = T/R$

$= \frac{636.9\times\cancel{10^3}}{275\times\cancel{10^3}}$

$\boxed{W = 2.316\ N}$

$W = 0.579\ N$

$\sigma_b = \frac{M}{Z}$

$M = \cancel{6}\times\cancel{R}\ \cancel{2.316\times275}$

$= \cancel{15\times10}$

$\cancel{M = 636.9}$

$M = 159.22\ N\text{-}m$

$\sigma_b = \frac{M}{Z}$

$15 = \frac{159.22}{\frac{\pi}{4}\times(2b)^2\cdot b}$

$15 = \frac{159.22}{0.785\times2b^{2}b}$

$\cancel{15} \quad \frac{\cancel{101.41}}{\cancel{53}}$

$2b^2\cdot b = 202.82$

$b^3 = 101.41$

$\boxed{b = 4.66}$

$a = 2(4.66)$

$\boxed{a = 9.32}$

Scanned with CamScan