Fits And Tolerance

Series	Series Factor.
R5	$\sqrt[5]{10} = 1.58$
R10	$\sqrt[10]{10} = 1.26$.
R20	$\sqrt[20]{10} = 1.12$
R40	$\sqrt[40]{10} = 1.06$
R80	$\sqrt[80]{10} = 1.03$

Fits:-

When two parts are to be assembled the relationship between shaft & hole is called fit

Theory of failures under Static Load:-

Maximum Principle Stress Theorey (or) Rankine Theory:-

$$\sigma_1 = \sigma_y$$

$$\sigma_1 \text{ (or) } \sigma_2 \text{ (or) } \sigma_3 = \sigma_y .$$

Maximum Shear Stress Theory (Guest or Coulomb's Theory).

$$(\sigma_1 - \sigma_2) \text{ (or) } (\sigma_2 - \cancel{\sigma_3}) \text{ (or) } (\cancel{\sigma_3} - \sigma_1) = \sigma_y$$

Maximum Strain Theory (St. Venant's)

$$\sigma_1 - \gamma(\sigma_2 + \sigma_3) \text{ (or) } \sigma_2 - \gamma(\sigma_3 + \sigma_1) = \sigma_y$$

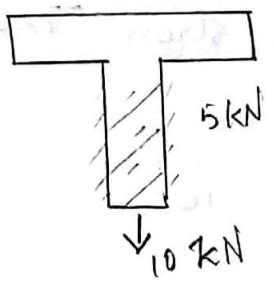
$$\sigma_3 = 0.$$

Maximum Strain Energy Theory

$$\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\gamma(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) = (\sigma_y)^2$$

$$\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - \sigma_1\sigma_2 - \sigma_2\sigma_3 - \sigma_3\sigma_1 = (\sigma_y)^2$$

1. The load on the bolt consists of axial pull of 10 kN together with shear force of 5 kN. Find the diameter of bolt according to maximum principle stress theory. Maximum shear stress theory, maximum strain theory, max. strain energy theory, maximum distortion energy theory. Tensile stress at elastic limit is 100 MPa $\nu = 0.3$



$$\sigma_x = \sigma_t$$

$$\sigma_t = \frac{10 \times 10^3}{\pi/4\, d^2} = \frac{12.73}{d^2} \text{ kN/mm}^2$$

$$\tau = \frac{\text{shear Load}}{\text{shear Area}}$$ (only for bolt)

$$= \frac{5}{\pi/4\, d^2} = \frac{6.36}{d^2} \text{ kN/mm}^2$$

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

$$= \frac{1}{2}\left[\frac{12.73}{d^2} + \sqrt{\left(\frac{12.73}{d^2}\right)^2 + 4\left(\frac{6.36}{d^2}\right)^2}\right]$$

$$= \frac{1}{2}\left[\frac{12.73}{d^2} + \frac{17.99}{d^2}\right]$$

$$\sigma_1 = \frac{15.362}{d^2} \text{ KN/mm}^2$$

$$\sigma_2 = \frac{1}{2}\left[\sigma_x - \sqrt{(\sigma_x)^2 - 4(\tau xy)^2}\right]$$

$$= \frac{-2.635}{d^2} \text{ KN/mm}^2$$

Case 1: Maximum Principle Stress Theory.

$$\frac{15.365 \times 10^3}{d^2} = 100 \qquad (\sigma_1 = \sigma_y)$$

$$d = 12.39 \text{ mm}$$

Case 2: Maximum Shear Stress Theory.

$$\sigma_1 - \sigma_2 = \sigma_y$$

$$\left(\frac{15.365}{d^2} + \frac{2.635}{d^2}\right) 10^3 = 100.$$

$$\frac{18}{d^2} = \frac{100}{10^3}$$

$$d = 13.41 \text{ mm}.$$

Case 3: Maximum Strain Theory

$$\sigma_1 - \gamma(\sigma_2 + \sigma_3) = \sigma_y.$$

$$\frac{15.362}{d^2} - 0.3\left(-\frac{2.635}{d^2}\right) = 100.$$

$$d = 12.7 \text{ mm}$$

Case 4 Maximum Strain Energy

$$\sigma_1^2+\sigma_2^2+\sigma_3^2-2\gamma(\sigma_1\sigma_2)=(\sigma_y)^2$$

$$\frac{235\times10^6}{d^4}+\frac{6.943\times10^6}{d^4}+0.6\left(\frac{40.47}{d^4}\right)10^6=10^4$$

$$\frac{(235+6.943+24.28)10^{6}}{10^4}=d^4$$

$$d=12.77\text{ mm}$$

Case 5 : Octahedral theory.

$$\sigma_1^2+\sigma_2^2-\sigma_1\sigma_2=\sigma_y$$

$$\frac{235\times10^6}{d^4}+\frac{6.943\times10^6}{d^4}+\frac{40.47\times10^6}{d^4}=10^4$$

$$d=12.96\text{ mm}$$

2. A cylindrical shaft made of steel yield strength of 700 MPa is subjected to a static load consisting of bending moment 10 KN/m and torsional moment of 30 kN·m. Determine the dia of shaft using any 3 theory of failures and assuming FOS = 2. Take Young's Modulus = 210 GPa $\gamma=0.3$.

Soln:-

$M=10\text{ kN}\cdot\text{m}$

$T=30\text{ kN}\cdot\text{m}$

$$\sigma_b = M/Z$$

$$= \frac{10 \times 10^6}{\pi/32 \, d^3}$$

$$= \frac{101.85}{d^3} \times 10^6 \ N/mm^2$$

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

$$= \frac{16 \times 30 \times 10^6}{\pi d^3} = \frac{152.78 \times 10^6}{d^3} \ N/mm^2.$$

$$\sigma_1 = 1/2 \left[\sigma_x + \sqrt{(\sigma_x)^2 + 4(\tau_{xy})^2} \right]$$

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

$$= 1/2 \left[\frac{101.85 \times 10^6}{d^3} + \frac{322.08 \times 10^6}{d^3} \right]$$

$$= \frac{211.96 \times 10^6}{d^3} \ N/mm^2.$$

$$\sigma_2 = 1/2 \left[\frac{101.85 \times 10^6}{d^3} - \frac{322.08 \times 10^6}{d^3} \right]$$

$$= \frac{-110.11 \times 10^6}{d^3} \ N/mm^2$$

1. Maximum Principle Stress theory.

$$\frac{211.96 \times 10^6}{d^3} = \frac{700}{2}$$

2. Maximum Shear stress Theory.

$$(\sigma_1 - \sigma_2) = \sigma_y/n$$

$$\frac{211.96 \times 10^6}{d^3} + \frac{110.11 \times 10^6}{d^3} = \frac{700}{2}$$

$$d = 97.2 \text{ mm}$$

3. Maximum Strain Theory.

1, 2, 5, 11, 14, 15, 16
22, 24, 33, 41, 42
48, 54, 501, 504
505

$$\sigma_1 - \nu(\sigma_2) = \sigma_y/n$$

$$\frac{211.96 \times 10^6}{d^3} + 0.3\left(\frac{110.11 \times 10^6}{d^3}\right) = \frac{700}{2}$$

$$d = 88.78 \text{ mm}$$

4. Strain Energy Theory

$$\sigma_1^2 + \sigma_2^2 - 2\nu(\sigma_1 \sigma_2) = \left(\frac{\sigma_y}{n}\right)^2$$

$$\frac{44927.04 \times 10^{12}}{d^6} + \frac{12124.21 \times 10^{12}}{d^6} + \frac{14003.3 \times 10^{12}}{d^6} = 122500.$$

$$d = 91.3 \text{ mm}$$

3. Mild steel shaft of 50 mm dia is subjected to bending moment of 2000 N-m and Torque T. The Yield point of the steel in tension is 200 MPas. Maximum Value of torque without causing yielding of shaft according to max. principal stress theory. Max. shear