Design of Machine Elements

TUTORIAL - 1

Q1. A cylindrical part of diameter d is loaded by axial force P causing stress of $\sigma = \frac{4P}{\pi d^2}$ Load is known with an uncertainty of ± 10%, the diameter is known with an uncertainty of ± 5% and the strength is known with an uncertainty of ±15%. Determine the minimum design factor to prevent the failure of the part.

Sol $n_d = \frac{\text{Minimum Breaking Strength (BS)}}{\text{Maximum Allowable Load (W)}}$

$$\sigma = \frac{4P}{\pi d^2}$$

$$\Rightarrow \frac{d\sigma}{\sigma} = \frac{dP}{P} + 2\frac{dd}{d}$$

$$\Rightarrow \frac{d\sigma}{\sigma} = (10 + 2\times 5)\% = 20\%$$

when uncertainty in breaking strength

$$\Rightarrow n_d = \frac{0.85}{W} \Rightarrow W = \frac{0.85}{n_d}$$

when uncertainty in Maximum allowable load

$$\Rightarrow n_d = \frac{BS}{1.2}$$

$$\Rightarrow BS = 1.2\, n_d$$

∴ Design factor when both uncertainties are considered

$$n_d = \frac{1.2}{0.85} \Rightarrow \boxed{n_d = 1.4118}$$

Q2 A solid circular rod of diameter d is subject to a bending moment M = 100 N·m. The resulting stress induced is $\sigma = \frac{32M}{\pi d^3}$. Using a material strength of 175 MPa and a design factor of 3, determine the minimum diameter of the rod. Using table A-17 select a preferred diameter and the resulting factor of safety

Sol $\frac{32M}{\pi d^3} = \frac{175\times 10^6}{3} \Rightarrow \frac{32\times 100}{\pi d^3} = \frac{175\times 10^6}{3}$

$$\Rightarrow d = 25.94 \text{ mm}$$

Using the table, we get preferred diameter of 28 mm.

$$\therefore \text{Factor of safety} = \frac{\sigma \pi d^3}{32M}$$

$$= \frac{175 \times 10^6 \times \pi \times (28 \times 10^{-3})^3}{32 \times 100}$$

$$\boxed{FOS = 3.771}$$

Q3 Select a suitable material along with brief justification for the following parts. State the material properties. State possible failure mechanism of the parts.

(a) Metal cutting saws. (Carbide abrasive, Diamond, CBN)
HSS – good wear resistance, hardness, tensile strength.

(b) Rolling contact bearings in your bicycle (Cr steel)
Wear resistant, Corrosion resistant

(c) Lathe Bed (Cast Iron)
High vibration dampening capacity, High strength, Cheap.

(d) Crankshaft of an IC engine (37C15 Alloy steel)
Creep and Corrosion resistant

(e) Pushrod for valve gear train of an IC engine (Medium Carbon Steel)
Wear resistant, Corrosion resistant, high fatigue life.

(f) Cam for valve gear train of an IC engine Plain Carbon Steel
Low friction, Wear resistance

(g) Spring for valve gear train of an IC engine (Oil tempered Chrome Silicon Steel)
High Fatigue strength

(h) Rim of locomotive wheels (Aluminium / Magnesium)
High Load carrying capacity, Corrosion resistant

(i) Door hinge Steel, Stainless Steel, Brass
Corrosion resistant, high compression strength, long working cycle.