

## 518 ■ A Textbook of Machine Design

**Solution.** Given :  $M = 3000 \text{ N-m} = 3 \times 10^6 \text{ N-mm}$  ;  $T = 10\,000 \text{ N-m} = 10 \times 10^6 \text{ N-mm}$  ;  
 $\sigma_{tu} = 700 \text{ MPa} = 700 \text{ N/mm}^2$  ;  $\tau_u = 500 \text{ MPa} = 500 \text{ N/mm}^2$

We know that the allowable tensile stress,

$$\sigma_t \text{ or } \sigma_b = \frac{\sigma_{tu}}{F.S.} = \frac{700}{6} = 116.7 \text{ N/mm}^2$$

and allowable shear stress,

$$\tau = \frac{\tau_u}{F.S.} = \frac{500}{6} = 83.3 \text{ N/mm}^2$$

Let  $d$  = Diameter of the shaft in mm.

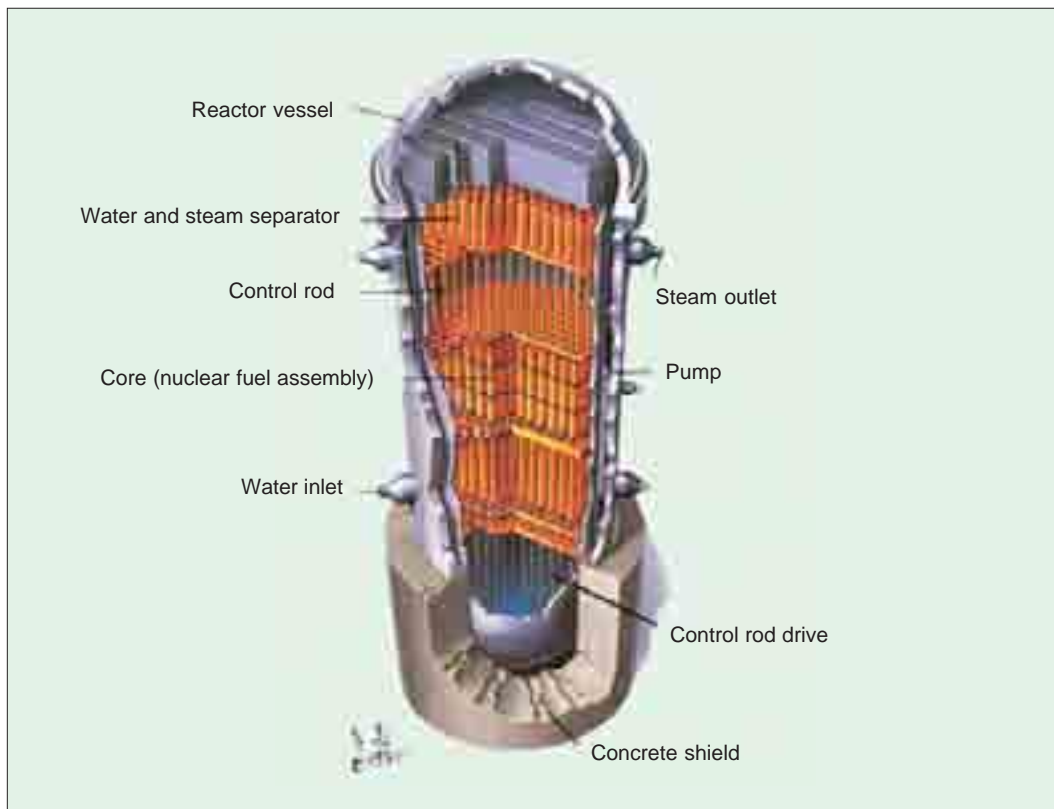
According to maximum shear stress theory, equivalent twisting moment,

$$T_e = \sqrt{M^2 + T^2} = \sqrt{(3 \times 10^6)^2 + (10 \times 10^6)^2} = 10.44 \times 10^6 \text{ N-mm}$$

We also know that equivalent twisting moment ( $T_e$ ),

$$10.44 \times 10^6 = \frac{\pi}{16} \times \tau \times d^3 = \frac{\pi}{16} \times 83.3 \times d^3 = 16.36 d^3$$

$$\therefore d^3 = 10.44 \times 10^6 / 16.36 = 0.636 \times 10^6 \text{ or } d = 86 \text{ mm}$$



*Nuclear Reactor*

Note : This picture is given as additional information and is not a direct example of the current chapter.

According to maximum normal stress theory, equivalent bending moment,

$$M_e = \frac{1}{2} \left( M + \sqrt{M^2 + T^2} \right) = \frac{1}{2} (M + T_e)$$

$$= \frac{1}{2} (3 \times 10^6 + 10.44 \times 10^6) = 6.72 \times 10^6 \text{ N-mm}$$

We also know that the equivalent bending moment ( $M_e$ ),

$$6.72 \times 10^6 = \frac{\pi}{32} \times \sigma_b \times d^3 = \frac{\pi}{32} \times 116.7 \times d^3 = 11.46 d^3$$

$$\therefore d^3 = 6.72 \times 10^6 / 11.46 = 0.586 \times 10^6 \text{ or } d = 83.7 \text{ mm}$$

Taking the larger of the two values, we have

$$d = 86 \text{ say } 90 \text{ mm Ans.}$$

**Example 14.6.** A shaft supported at the ends in ball bearings carries a straight tooth spur gear at its mid span and is to transmit 7.5 kW at 300 r.p.m. The pitch circle diameter of the gear is 150 mm. The distances between the centre line of bearings and gear are 100 mm each. If the shaft is made of steel and the allowable shear stress is 45 MPa, determine the diameter of the shaft. Show in a sketch how the gear will be mounted on the shaft; also indicate the ends where the bearings will be mounted? The pressure angle of the gear may be taken as  $20^\circ$ .

**Solution.** Given :  $P = 7.5 \text{ kW} = 7500 \text{ W}$  ;  $N = 300 \text{ r.p.m.}$  ;  $D = 150 \text{ mm} = 0.15 \text{ m}$  ;  $L = 200 \text{ mm} = 0.2 \text{ m}$  ;  $\tau = 45 \text{ MPa} = 45 \text{ N/mm}^2$  ;  $\alpha = 20^\circ$

Fig. 14.2 shows a shaft with a gear mounted on the bearings.

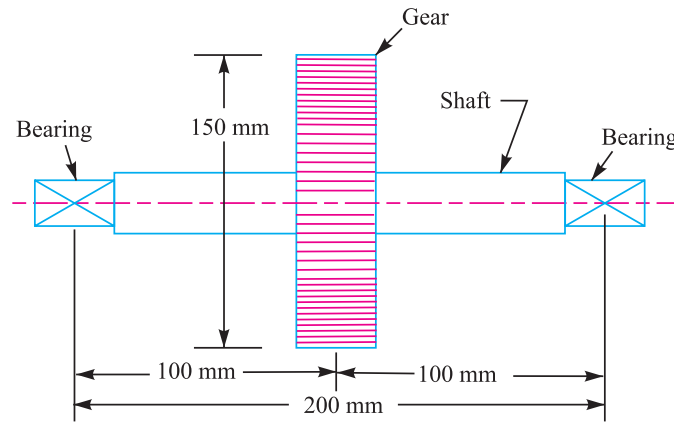


Fig. 14.2

We know that torque transmitted by the shaft,

$$T = \frac{P \times 60}{2\pi N} = \frac{7500 \times 60}{2\pi \times 300} = 238.7 \text{ N-m}$$

$\therefore$  Tangential force on the gear,

$$F_t = \frac{2T}{D} = \frac{2 \times 238.7}{0.15} = 3182.7 \text{ N}$$