- It is required to design a knuckle
- joint to connect two circular rods subjected to an
- axial tensile force of 50 kN. The rods are co-axial
- and a small amount of angular movement between
- their axes is permissible. Design the joint and
- specify the dimensions of its components. Select
- suitable materials for the parts.
- Solution
- Given P = (50 X 103) N
- Part I Selection of material
- The rods are subjected to tensile force. Therefore,
- yield strength is the criterion for the selection of
- material for the rods. The pin is subjected to shear
- stress and bending stresses. Therefore, strength is
- also the criterion of material selection for the pin.
- On strength basis, the material for two rods and pin
- is selected as plain carbon steel of Grade 30C8 (Syt
- = 400 N/mm2). It is further assumed that the yield
- strength in compression is equal to yield strength
- in tension. In practice, the compressive strength of
- steel is much higher than its tensile strength.
- Part II Selection of factor of safety
- In stress analysis of knuckle joint, the effect of
- stress concentration is neglected. To account for
- this effect, a higher factor of safety of 5 is assumed
- in the present design.

Part III *Calculation of permissible stresses*

$$\sigma_t = \frac{S_{yt}}{(fs)} = \frac{400}{5} = 80 \text{ N/mm}^2$$

$$\sigma_c = \frac{S_{yc}}{(fs)} = \frac{S_{yt}}{(fs)} = \frac{400}{5} = 80 \text{ N/mm}^2$$

$$\tau = \frac{S_{sy}}{(fs)} = \frac{0.5\, S_{yt}}{(fs)} = \frac{0.5(400)}{5} = 40 \text{ N/mm}^2$$

Part IV *Calculation of dimensions*

The dimensions of the knuckle joint are calculated by the procedure outlined in Section 4.10.

Step I *Diameter of rods*

$$D = \sqrt{\frac{4P}{\pi\sigma_t}} = \sqrt{\frac{4(50\times 10^3)}{\pi\,(80)}} = 28.21 \text{ or } 30 \text{ mm}$$

Step II *Enlarged diameter of rods (D_1)*

$$D_1 = 1.1\,D = 1.1(30) = 33 \text{ or } 35 \text{ mm}$$

Step III *Dimensions a and b*

$a = 0.75\,D = 0.75(30) = 22.5$ or 25 mm

$b = 1.25\,D = 1.25(30) = 37.5$ or 40 mm

Step IV *Diameter of pin*

$$d = \sqrt{\frac{2P}{\pi\tau}} = \sqrt{\frac{2\,(50\times10^3)}{\pi\,(40)}} = 28.21 \text{ or } 30\text{ mm}$$

Also,

$$d = \sqrt[3]{\frac{32}{\pi\,\sigma_b}\times\frac{P}{2}\left[\frac{b}{4}+\frac{a}{3}\right]}$$

$$= \sqrt[3]{\frac{32}{\pi\,(80)}\times\frac{(50\times10^3)}{2}\left[\frac{40}{4}+\frac{25}{3}\right]}$$

$= 38.79$ or 40 mm

$\therefore\quad d = 40$ mm

Step V *Dimensions d_0 and d_1*

$d_0 = 2d = 2(40) = 80$ mm

$d_1 = 1.5d = 1.5(40) = 60$ mm

Step VI *Check for stresses in eye*

$$\sigma_t = \frac{P}{b\,(d_0-d)} = \frac{(50\times10^3)}{40\,(80-40)} = 31.25\text{ N/mm}^2$$

$\therefore\quad \sigma_t < 80$ N/mm^2

$$\sigma_c = \frac{P}{b\,d} = \frac{(50\times10^3)}{40\,(40)} = 31.25\text{ N/mm}^2$$

$\therefore\quad \sigma_c < 80$ N/mm^2

$$\tau = \frac{P}{b\,(d_0-d)} = \frac{(50\times10^3)}{40(80-40)} = 31.25\text{ N/mm}^2$$

$\therefore\quad \tau < 40$ N/mm^2

Step VII *Check for stresses in fork*

$$\sigma_t = \frac{P}{2a\,(d_0-d)} = \frac{(50\times10^3)}{2(25)(80-40)} = 25\text{ N/mm}^2$$

$\therefore\quad \sigma_t < 80$ N/mm^2

$$\sigma_c = \frac{P}{2ad} = \frac{(50\times10^3)}{2(25)\,(40)} = 25\text{N/mm}^2$$

$\therefore\quad \sigma_c < 80$ N/mm^2

$$\tau = \frac{P}{2a\,(d_0-d)}$$

$$= \frac{(50\times10^3)}{2(25)\,(80-40)} = 25\text{N/mm}^2$$

$\therefore\quad \tau < 40$ N/mm^2

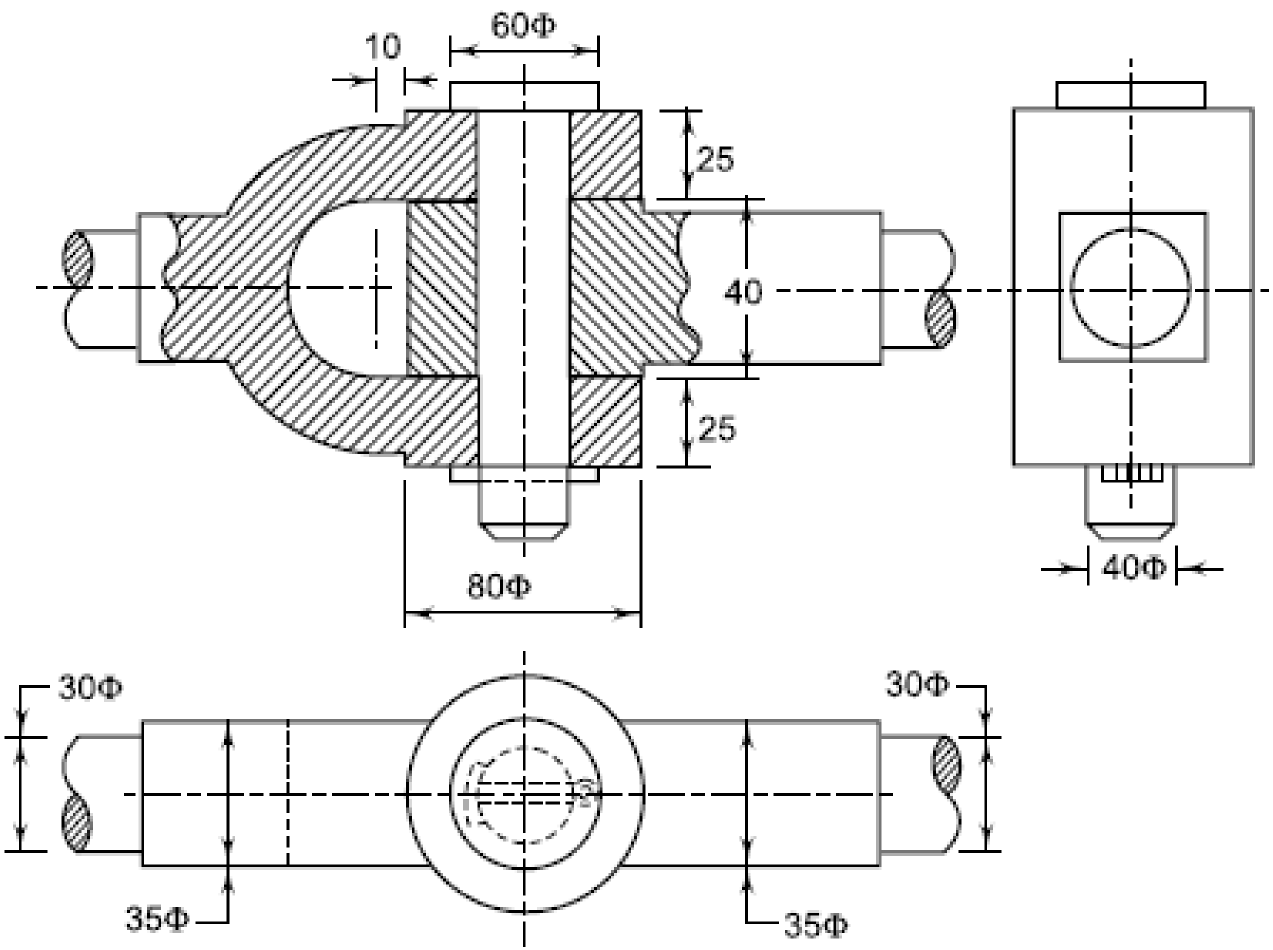

Fig 4.24 *Dimensions of Knuckle Joint*

Example 4.8 *An offset link subjected to a force of 25 kN is shown in Fig. 4.27. It is made of grey cast iron FG300 and the factor of safety is 3. Determine the dimensions of the cross-section of the link.*

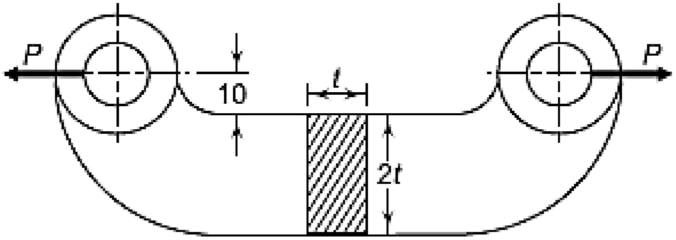

Fig. 4.27 *Offset Link*

Solution

Given $P = 25$ kN $\quad S_{ut} = 300$ N/mm^2 $\quad (fs) = 3$

Step I *Calculation of permissible tensile stress for the link*

$$\sigma_t = \frac{S_{ut}}{(fs)} = \frac{300}{3} = 100 \text{ N/mm}^2 \qquad \text{(a)}$$

Step II *Calculation of direct tensile and bending stresses*

The cross-section is subjected to direct tensile stress and bending stresses. The stresses are maximum at the top fibre. At the top fibre,

$$\sigma_t = \frac{P}{A} + \frac{M_b\, y}{I}$$

$$= \frac{25\times10^3}{t(2t)} + \frac{25\times10^3(10+t)(t)}{\left[\frac{1}{12}t(2t)^3\right]} \qquad \text{(b)}$$

Step III *Calculation of dimensions of cross-section*

Equating (a) and (b),

$$\frac{12500}{t^2} + \frac{37500\,(10+t)}{t^3} = 100$$

or, $t^3 - 500\,t - 3750 = 0$

Solving the above equation by trial and error method,

$$t \cong 25.5 \text{ mm}$$

- PRINCIPAL STRESSES
- In previous articles and examples, mechanical
- components, which are subjected to only one type of
- load, are considered. There are many components,
- which are subjected to several types of load
- simultaneously. A transmission shaft is subjected
- to bending as well as torsional moment at the same
- time. In design, it is necessary to determine the
- state of stresses under these conditions. An element
- of a plate subjected to two-dimensional stresses is
- shown is Fig. 4.30(a). In this analysis, the stresses
- are classifi ed into two groups—normal stresses and
- shear stresses. The normal stress is perpendicular to
- the area under consideration, while the shear stress
- acts over the area.

There is a particular system of notation for these stresses. The normal stresses are denoted by σ_x, σ_y and σ_z in the X, Y and Z directions respectively. Tensile stresses are considered to be positive, while compressive stresses as negative. The shear stresses are denoted by two subscripts, viz. τ_{xy} or τ_{yz}, as shown in Fig. 4.30(a). The first subscript denotes the area over which it acts and the second indicates the direction of shear force. As an example, consider the shear stress denoted by τ_{xy}. The subscript x indicates that the shear stress is acting on the area, which is perpendicular to the X-axis. The subscript y indicates that the shear stress is acting in the Y-direction. The shear stresses are positive if they act in the positive direction of the reference axis. It can be proved that,

$$\tau_{xy} = \tau_{yx} \quad (4.27)$$