- The applications of strength equations from
- (4.25a) to (4.25j) in fi nding out the dimensions
- of the cotter joint are illustrated in the next
- example and the design project. In some cases, the
- dimensions of a cotter joint are calculated by using
- empirical relationships, without carrying out detail
- stress analysis. In such cases, following standard
- proportions can be used,
- d1 = 1.75d d2 = 1.21d
- d3 = 1.5 d d4 = 2.4 d
- a = c = 0.75 d b = 1.6 d
- t = 0.31 d t1 = 0.45 d
- Clearance = 1.5 to 3 mm
- Taper for cotter = 1 in 32

$$M_b = \frac{P}{2}\left[\frac{d_2}{2} + x\right] - \frac{P}{2}(z)$$

$$= \frac{P}{2}\left[\frac{d_2}{2} + \frac{d_4 - d_2}{6}\right] - \frac{P}{2}\left[\frac{d_2}{4}\right]$$

$$= \frac{P}{2}\left[\frac{d_2}{4} + \frac{d_4 - d_2}{6}\right]$$

Also, $I = \frac{tb^3}{12}$ $y = \frac{b}{2}$

and $\sigma_b = \frac{M_b y}{I}$

Therefore,

$$\sigma_b = \frac{\frac{P}{2}\left[\frac{d_2}{4} + \frac{d_4 - d_2}{6}\right]\frac{b}{2}}{\left(\frac{tb^3}{12}\right)} \qquad (4.25j)$$

- DESIGN PROCEDURE FOR COTTER
- JOINT
- The basic procedure to calculate the dimensions of
- the cotter joint consists of the following steps:
- (i) Calculate the diameter of each rod by Eq.
- (4.25a),

$$d = \sqrt{\frac{4P}{\pi \sigma_t}}$$

ii) Calculate the thickness of the cotter by the empirical relationship given in Eq. (4.25c),

$$t = 0.31\, d$$

(iii) Calculate the diameter d_2 of the spigot on the basis of tensile stress. From Eq. (4.25b),

$$P = \left[\frac{\pi}{4} d_2^2 - d_2\, t\right] \sigma_t$$

When the values of P, t and σ_t are substituted, the above expression becomes a quadratic equation.

(iv) Calculate the outside diameter d_1 of the socket on the basis of tensile stress in the socket, from Eq. (4.25d),

$$P = \left[\frac{\pi}{4}(d_1^2 - d_2^2) - (d_1 - d_2)\, t\right] \sigma_t$$

When values of P, d_2, t and σ_t are substituted, the above expression becomes a quadratic equation.

(v) The diameter of the spigot collar d_3 and the diameter of the socket collar d_4 are calculated by the following empirical relationships,

$$d_3 = 1.5\, d$$

$$d_4 = 2.4\, d$$

(vi) The dimensions a and c are calculated by the following empirical relationship,

$$a = c = 0.75\, d$$

(vii) Calculate the width b of the cotter by shear consideration using Eq. (4.25e) and bending consideration using Eq. (4.25j) and select the width, whichever is maximum between these two values.

$$b = \frac{P}{2\tau t} \quad \text{or} \quad b = \sqrt{\frac{3P}{t\sigma_b}\left[\frac{d_2}{4} + \frac{d_4 - d_2}{6}\right]}$$

(viii) Check the crushing and shear stresses in the spigot end by Eqs. (4.25h) and (4.25f) respectively.

$$\sigma_c = \frac{P}{t d_2}$$

$$\tau = \frac{P}{2 a d_2}$$

(ix) Check the crushing and shear stresses in the socket end by Eqs (4.25i) and (4.25g) respectively.

$$\sigma_c = \frac{P}{(d_4 - d_2)\, t}$$

$$\tau = \frac{P}{2(d_4 - d_2)\, c}$$

(x) Calculate the thickness *t*1 of the spigot collar by the following empirical relationship,
*t*1 = 0.45 *d*
The taper of the cotter is 1 in 32.

- It is required to design a cotter joint to connect two steel rods of equal diameter. Each rod is subjected to an axial tensile force of 50 kN. Design the joint and specify its main dimensions.

- Solution Given P = (50 × 103) N Part I Selection of material The rods are subjected to tensile force and strength is the criterion for the selection of the rod material. The cotter is subjected to direct shear stress and bending stresses. Therefore, strength is also the criterion of material selection for the cotter. On the basis of strength, the material of the two rods and the cotter is selected as plain carbon steel of Grade 30C8 (Syt = 400 N/mm2). Part II Selection of factor of safety In stress analysis of the cotter joint, the following factors are neglected: (i) initial stresses due to tightening of the cotter; and (ii) stress concentration due to slot in the socket and the spigot ends. To account for these factors, a higher factor of safety is used in the present design. The factor of safety for the rods, spigot end and socket end is assumed as 6, while for the cotter, it is taken as 4. There are two reasons for assuming a lower factor of safety for the cotter. They are as follows: (i) There is no stress concentration in the cotter. (ii) The cost of the cotter is small compared with the socket end or spigot end. If at all, a failure is going to occur, it should occur in the cotter rather than in the spigot or socket end. This is ensured by assuming a higher factor of safety for the spigot and socket ends, compared with the cotter. It is assumed that the yield strength in compression is twice the yield strength in tension. Part III Calculation of permissible stresses The permissible stresses for rods, spigot end and socket end are as follows:

$$\sigma_t = \frac{S_{yt}}{(fs)} = \frac{400}{6} = 66.67 \text{ N/mm}^2$$

$$\sigma_c = \frac{S_{yc}}{(fs)} = \frac{2S_{yt}}{(fs)} = \frac{2(400)}{6} = 133.33 \text{ N/mm}^2$$

$$\tau = \frac{S_{sy}}{(fs)} = \frac{0.5S_{yt}}{(fs)} = \frac{0.5\,(400)}{6}$$

$$= 33.33 \text{ N/mm}^2$$

Permissible stresses for the cotter are as follows:

$$\sigma_t = \frac{S_{yt}}{(fs)} = \frac{400}{4} = 100 \text{ N/mm}^2$$

$$\tau = \frac{S_{sy}}{(fs)} = \frac{0.5S_{yt}}{(fs)} = \frac{0.5(400)}{4} = 50 \text{ N/mm}^2$$

Part IV Calculation of dimensions

The dimensions of the cotter joint are determined by the procedure outlined in Section 4.10.

Step I Diameter of rods

$$d = \sqrt{\frac{4P}{\pi\sigma_t}} = \sqrt{\frac{4(50 \times 10^3)}{\pi(66.67)}} = 30.90 \text{ or } 32 \text{ mm}$$

Step II Thickness of cotter

$$t = 0.31\,d = 0.31(32) = 9.92 \text{ or } 10 \text{ mm}$$

Step III Diameter (d_2) of spigot

$$P = \left[\frac{\pi}{4}d_2^2 - d_2 t\right]\sigma_t$$

$$50 \times 10^3 = \left[\frac{\pi}{4}d_2^2 - d_2(10)\right](66.67)$$

or

$$d_2^2 - 12.73d_2 - 954.88 = 0$$

Solving the above quadratic equation,

$$d_2 = \frac{12.73 \pm \sqrt{12.73^2 - 4(-954.88)}}{2}$$

$\therefore \quad d_2 = 37.91$ or 40 mm

Step IV Outer diameter (d_1) of socket

$$P = \left[\frac{\pi}{4}(d_1^2 - d_2^2) - (d_1 - d_2)t\right]\sigma_t$$

$$50 \times 10^3 = \left[\frac{\pi}{4}(d_1^2 - 40^2) - (d_1 - 40)\ (10)\right](66.67)$$

or $\qquad d_1^2 - 12.73d_1 - 2045.59 = 0$

Solving the above quadratic equation,

$$d_1 = \frac{12.73 \pm \sqrt{12.73^2 - 4(-2045.59)}}{2}$$

$\therefore \quad d_1 = 52.04$ or 55 mm

Step V Diameters of spigot collar (d_3) and socket collar (d_4)

$d_3 = 1.5d = 1.5(32) = 48$ mm

$d_4 = 2.4d = 2.4(32) = 76.8$ or 80 mm

Step VI Dimensions a and c

$a = c = 0.75d = 0.75(32) = 24$ mm

Step VII Width of cotter

$$b = \frac{P}{2\tau t} = \frac{50 \times 10^3}{2(50)(10)} = 50 \text{ mm} \qquad \text{(a)}$$

or

$$b = \sqrt{\frac{3P}{t\sigma_b}\left[\frac{d_2}{4} + \frac{d_4 - d_2}{6}\right]}$$

$$= \sqrt{\frac{3\ (50 \times 10^3)}{(10)\ (100)}\left[\frac{40}{4} + \frac{80 - 40}{6}\right]}$$

$$= 50 \text{ mm} \qquad \text{(b)}$$

From (a) and (b),

$b = 50$ mm

Step VIII Check for crushing and shear stresses in spigot end

$$\sigma_c = \frac{P}{td_2} = \frac{50 \times 10^3}{(10)(40)} = 125 \text{ N/mm}^2$$

$$\tau = \frac{P}{2\ ad_2} = \frac{50 \times 10^3}{2(24)(40)} = 26.04 \text{ N/mm}^2$$

$\therefore \quad \sigma_c < 133.33$ N/mm^2 and $\tau < 33.33$ N/mm^2

Step IX Check for crushing and shear stresses in socket end

$$\sigma_c = \frac{P}{(d_4 - d_2)t}$$

$$= \frac{50 \times 10^3}{(80 - 40)(10)} = 125 \text{ N/mm}^2$$

$$\tau = \frac{P}{2(d_4 - d_2)\ c}$$

$$= \frac{50 \times 10^3}{2(80-40)(24)} = 26.04 \text{ N/mm}^2$$

$\therefore \quad \sigma_c < 133.33 \text{ N/mm}^2 \quad \text{and} \quad \tau < 33.33 \text{ N/mm}^2$

The stresses induced in the spigot and the socket ends are within limits.

Step X *Thickness of spigot collar*

$$t_1 = 0.45d = 0.45(32) = 14.4 \text{ or } 15 \text{ mm}$$

The taper for the cotter is 1 in 32.

Part V *Dimensioned sketch of cotter joint*

The dimensions of various components of the cotter joint are shown in Fig. 4.17.

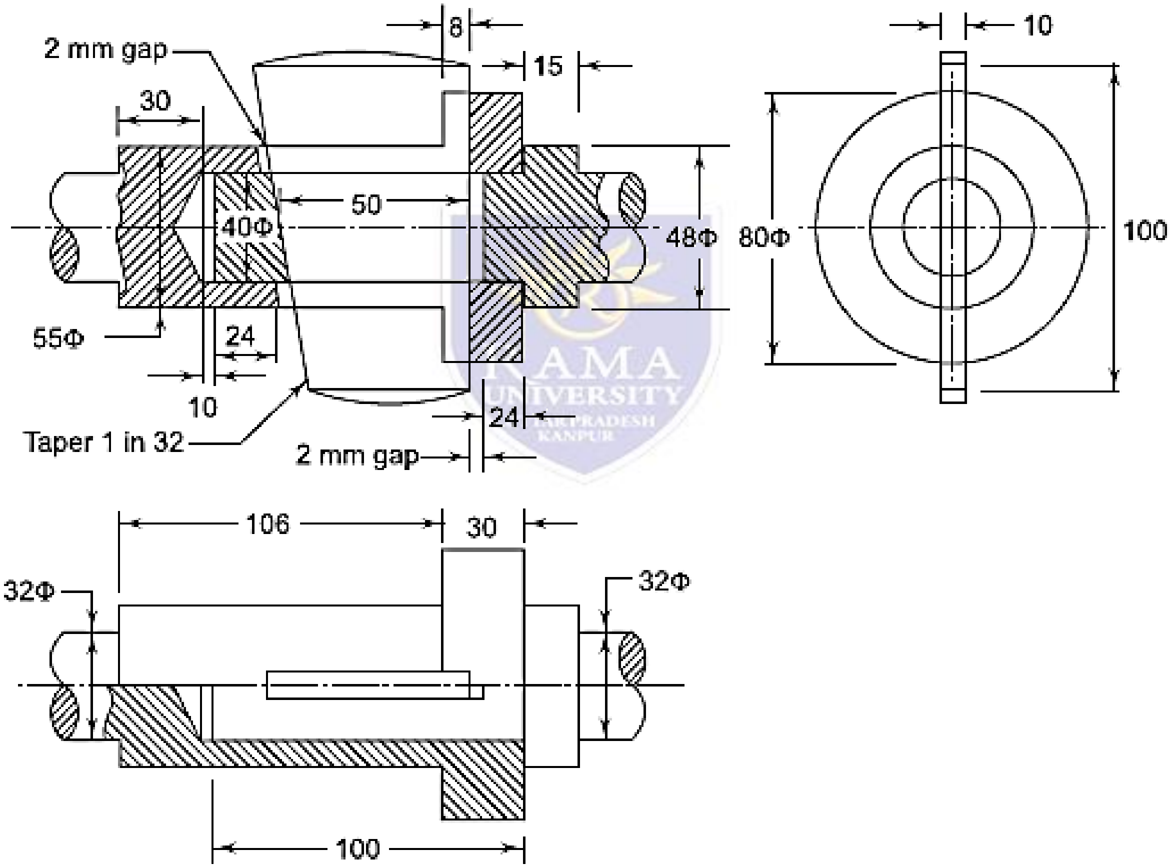

Fig. 4.17 *Dimensions of Cotter Joint*