- (iii) Crushing Failure of Pin in Eye When a
- cylindrical surface such as a pin is subjected to a
- force along its periphery, its projected area is taken
- into consideration to fi nd out the stress. As shown
- in Fig. 4.21, the projected area of the cylindrical

surface is ($l \times d$) and the compressive stress is given by,

$$\sigma_c = \frac{\text{force}}{\text{projected area}} = \frac{P}{(l \times d)}$$

As shown in Fig. 4.18, the projected area of the pin in the eye is (bd) and the compressive stress between the pin and the eye is given by,

$$\sigma_c = \frac{P}{bd} \qquad (4.26e)$$

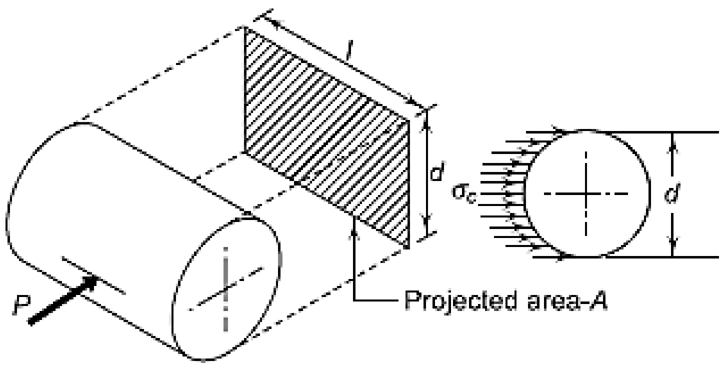

Fig. 4.21 *Projected Area of Cylindrical Surface*

(v) Bending Failure of Pin When the pin is tight in the eye and the fork, failure occurs due to shear. On the other hand, when the pin is loose, it is subjected to bending moment as shown in Fig. 4.22. It is assumed that the load acting on the pin is uniformly distributed in the eye, but uniformly varying in two parts of the fork. For triangular distribution of load between the pin and the fork,

$$x = \frac{1}{3}a \qquad \text{also,} \qquad z = \frac{1}{2}\left(\frac{1}{2}b\right) = \frac{1}{4}b$$

The bending moment is maximum at the centre. It is given by,

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

$$= \frac{P}{2}\left[\frac{b}{2} + \frac{a}{3}\right] - \frac{P}{2}\left[\frac{b}{4}\right] = \frac{P}{2}\left[\frac{b}{4} + \frac{a}{3}\right]$$

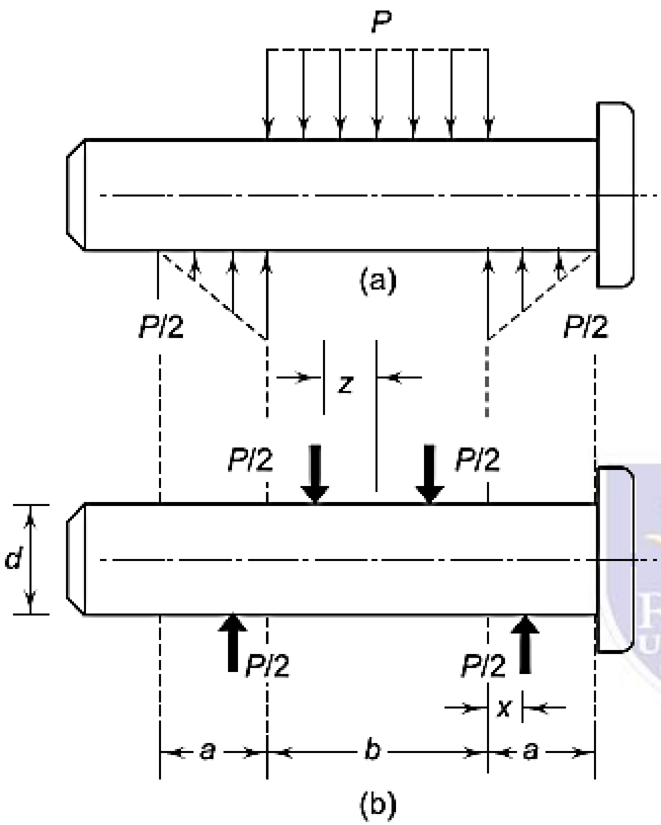

Fig. 4.22 *Pin Treated as Beam (a) Actual Distribution of Forces (b) Simplified Diagram of Forces*

Also, $I = \dfrac{\pi d^4}{64}$ and $y = \dfrac{d}{2}$

From Eq. (4.12),

$$\sigma_b = \frac{M_b y}{I} = \frac{\dfrac{P}{2}\left[\dfrac{b}{4} + \dfrac{a}{3}\right]\dfrac{d}{2}}{\dfrac{\pi d^4}{64}}$$

or
$$\sigma_b = \frac{32}{\pi d^3} \times \frac{P}{2}\left[\frac{b}{4} + \frac{a}{3}\right] \tag{4.26g}$$

(vi) Tensile Failure of Eye Section *XX* shown in Fig. 4.23(a) is the weakest section of the eye. The area of this section is given by,

$$\text{area} = b\,(d_0 - d)$$

The tensile stress at section *XX* is given by,

$$\sigma_t = \frac{P}{\text{area}} \quad \text{or} \quad \sigma_t = \frac{P}{b\,(d_0 - d)} \tag{4.26h}$$

(vii) Shear Failure of Eye The eye is subjected to double shear as shown in Fig. 4.23(b). The area of each of the two planes resisting the shear failure is

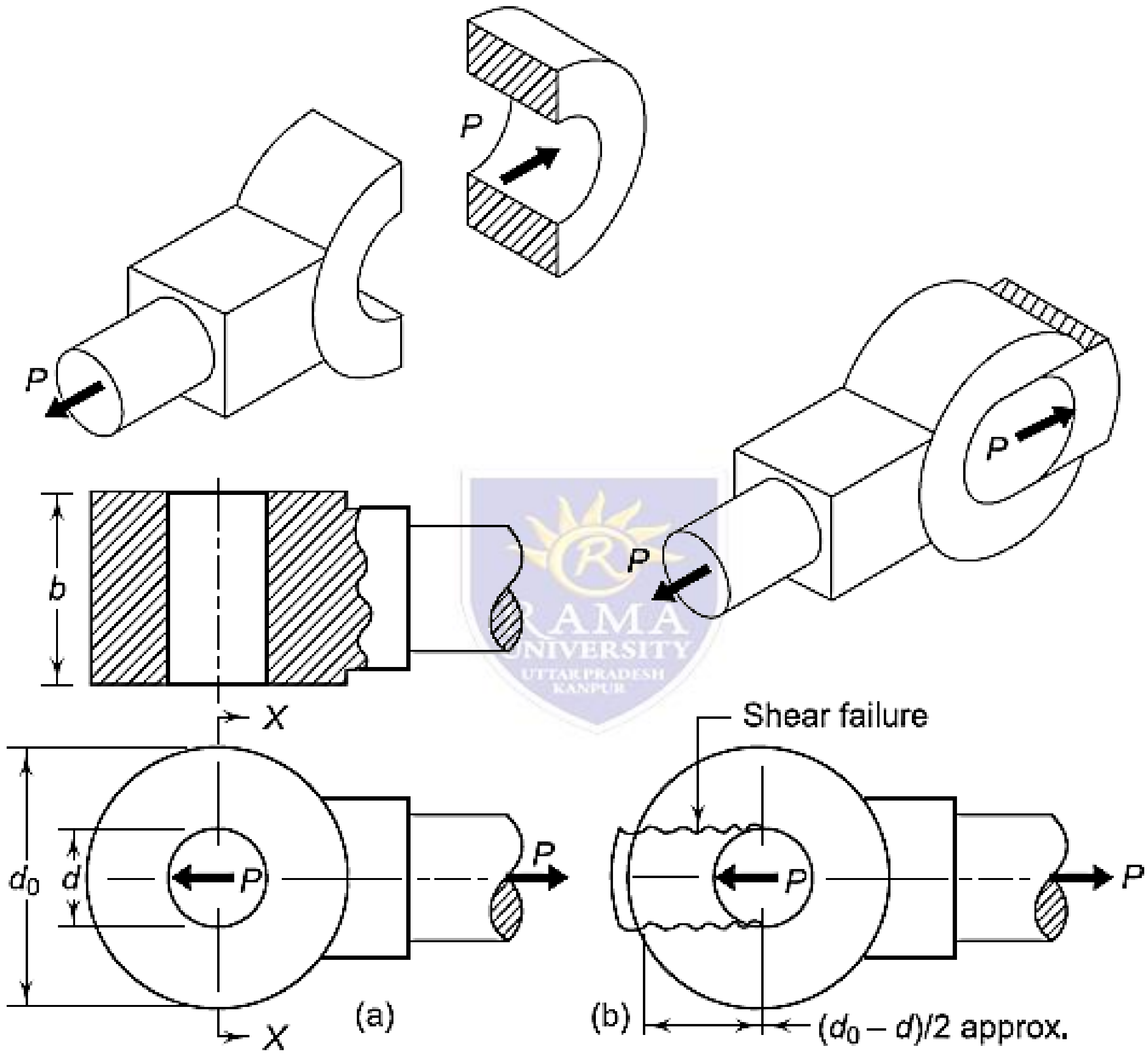

Fig. 4.23 *(a) Tensile Failure of Eye (b) Shear Failure of Eye*

$[b(d_0 - d)/2]$ approximately. Therefore, shear stress is given by,

$$\tau = \frac{P}{2[b(d_0 - d)/2]}$$

or $$\tau = \frac{P}{b(d_0 - d)} \qquad (4.26i)$$

Standard proportion for outside diameter of the eye or the fork is given by the following relationship,

$$d_0 = 2d \qquad (4.26j)$$

(viii) Tensile Failure of Fork Fork is a double eye and as such, Fig. 4.23 is applicable to a fork except for dimension b which can be modified as $2a$ in case of a fork. The area of the weakest section resisting tensile failure is given by

$$\text{area} = 2a(d_0 - d)$$

Tensile stress in the fork is given by

$$\sigma_t = \frac{P}{2a(d_0 - d)} \qquad (4.26k)$$

(ix) Shear Failure of Fork Each of the two parts of the fork is subjected to double shear. Modifying Eq. (4.26i),

$$\tau = \frac{P}{2a(d_0 - d)} \qquad (4.26l)$$

Standard proportions for the dimensions a and b are as follows,

$$a = 0.75\,D \qquad (4.26m)$$

$$b = 1.25\,D \qquad (4.26n)$$

The diameter of the pinhead is taken as,

$$d_1 = 1.5\,d \qquad (4.26o)$$

The gap x shown in Fig. 4.18 is usually taken as 10 mm.

$$\therefore \quad x = 10 \text{ mm} \qquad (4.26p)$$

The applications of strength equations from (4.26a) to (4.26l) in finding out the dimensions of the knuckle joint are illustrated in the next example. The eye and the fork are usually made by the forging process and the pin is machined from rolled steel bars.

- DESIGN PROCEDURE FOR KNUCKLE JOINT
- The basic procedure to determine the dimensions of the knuckle joint consists of the following steps:

(i) Calculate the diameter of each rod by Eq. (4.26a).

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

(ii) Calculate the enlarged diameter of each rod by empirical relationship using Eq. (4.26b).

$$D_1 = 1.1\,D$$

(iii) Calculate the dimensions a and b by empirical relationship using Eqs (4.26m) and (4.26n).

$$a = 0.75\,D \qquad b = 1.25\,D$$

(iv) Calculate the diameters of the pin by shear consideration using Eq. (4.26c) and bending consideration using Eq. (4.26g) and select the diameter, whichever is maximum.

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

(whichever is maximum)

(v) Calculate the dimensions d_o and d_1 by empirical relationships using Eqs (4.26j) and (4.26o) respectively.

$$d_o = 2d \qquad d_1 = 1.5d$$

(vi) Check the tensile, crushing and shear stresses in the eye by Eqs (4.26h), (4.26e) and (4.26i) respectively.

$$\sigma_t = \frac{P}{b\,(d_0 - d)}$$

$$\sigma_c = \frac{P}{bd}$$

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

(vii) Check the tensile, crushing and shear stresses in the fork by Eqs (4.26k), (4.26f) and (4.26l) respectively.

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

$$\sigma_c = \frac{P}{2ad}$$

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

The application of the above mentioned procedure is illustrated in the next example.