POSTAL Book Package 2023

Mechanical Engineering

Conventional Practice Sets

Machine Design

Contents

MADE EASY Publications

9 CHAPTER Cotter and Knuckle Joints

Practice Questions

Q.1 Design a sleeve and cotter joint to resist a tensile load of 60 kN. All parts of the joint are made of the same material with the following allowable stresses :

σ_t = 60 MPa; τ = 70 MPa; and σ_c = 125 MPa.

Solution:

Given data: $\sigma_t = 60$ MPa = 60 N/mm^2; $\tau = 70$ MPa = 70 N/mm^2; $P = 60$ kN = 60×10^3 N; $\sigma_c = 125$ MPa = 125 N/mm^2

1. Diameter of the rods

Let d = Diameter of the rods.

Considering the failure of the rods, in tension. We know that load (P),

$$60 \times 10^3 = \frac{\pi}{4} \times d^2 \times \sigma_t = \frac{\pi}{4} \times d^2 \times 60 = 47.13\, d^2$$

$\therefore$ $d^2 = 60 \times 10^3/47.13 = 1273$ or $d = 35.7$ say 36 mm **Ans.**

2. Diameter of enlarged end of rod and thickness of cotter

Let d_2 = Diameter of enlarged end of rod, and

t = Thickness of cotter. It may be taken as $d_2/4$.

Considering the failure of the rod in tension across the weakest section (i.e, slot). We know that load (P),

$$60 \times 10^3 = \left[\frac{\pi}{4}(d_2)^2 - d_2 \times t\right]\sigma_t = \left[\frac{\pi}{4}(d_2)^2 - d_2 \times \frac{d_2}{4}\right]60$$

$$= 32.13\,(d_2)^2$$

$\therefore$ $(d_2)^2 = 60 \times 10^3/32.13 = 1867$ or $d_2 = 43.2$ say 44 mm **Ans.**

and thickness of cotter, $t = \frac{d_2}{4} = \frac{44}{4} = 11$ mm **Ans.**

Let us now check the induced crushing stress in the rod or cotter. We know that load (P),

$$60 \times 10^3 = d_2 \times t \times \sigma_c = 44 \times 11 \times \sigma_c = 484\,\sigma_c$$

$\therefore$ $\sigma_c = 60 \times 10^3/484 = 124$ N/mm^2

Since the induced crushing stress is less than the given value of 125 N/mm^2, therefore the dimensions d_2 and t are within safe limits.

3. Outside diameter of sleeve

Let d_1 = Outside diameter of sleeve.

Considering the failure of sleeve in tension across the slot. We know that load (P)

$$60 \times 10^3 = \left[\frac{\pi}{4}[(d_1])^2 - (d_2)^2] - (d_1 - d_2)t\right]\sigma_t$$

$$= \left[\frac{\pi}{4}[(d_1])^2 - (44)^2] - (d_1 - 44)11\right]60$$

or $\quad (d_1)^2 - 14d_1 - 2593 = 0$

$$\therefore \quad d_1 = \frac{14 \pm \sqrt{(14)^2 + 4 \times 2593}}{2} = \frac{14 \pm 102.8}{2}$$

$= 58.4$ say 60 mm **Ans.** ...(Taking +ve sign)

4. Width of cotter

Let $\quad b =$ Width of cotter

Considering the failure of cotter in shear. Since the cotter is in double shear, therefore load (P).

$$60 \times 10^3 = 2b \times t \times \tau = 2 \times b \times 11 \times 70 = 1540\ b$$

$\therefore \quad b = 60 \times 10^3/1540 = 38.96$ say 40 mm **Ans.**

5. Distance of the rod from the beginning to the cotter hole (inside the sleeve end)

Let $\quad a =$ Required distance.

Since the rod end is in double shear, therefore load (P),

$$60 \times 10^3 = 2a \times d_2 \times \tau = 2a \times 44 \times 70 = 6160\ a$$

$\therefore \quad a = 60 \times 10^3/6160 = 9.74$say 10 mm **Ans.**

6. Distance of the rod end from its end to the cotter hole

Let $\quad c =$ Required distance.

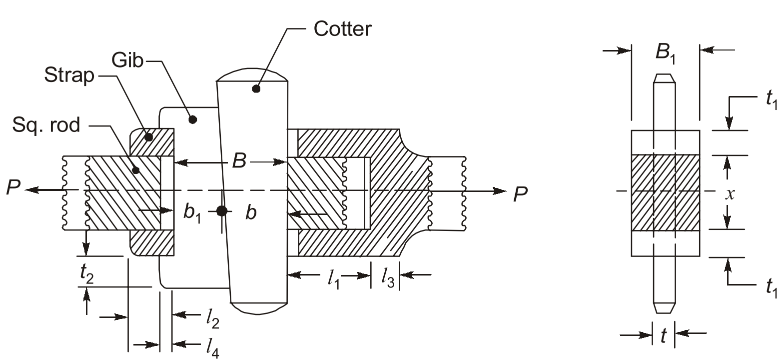
Considering the failure of the sleeve end in shear. Since the sleeve end is in double shear, therefore load (P),

$$60 \times 10^3 = 2(d_1 - d_2)c \times \tau = 2\,(60 - 44)c \times 70 = 2240\ c$$

$\therefore \quad c = 60 \times 10^3/2240 = 26.78$ say 28 mm **Ans.**

Q.2 Design a gib and cotter joint as shown in Figure, to carry a maximum load of 35 kN. Assuming that the gib, cotter and rod are of same material and have the following allowable stresses:

$$\sigma_t = 20 \text{ MPa};\ \tau = 15 \text{ MPa; and } \sigma_c = 50 \text{ MPa}$$



Solution:

Given data: $P = 35$ kN $= 35000$ N; $\sigma_t = 20$ MPa $= 20$ N/mm^2; $\tau = 15$ MPa $= 15$ N/mm^2; $\sigma_c = 50$ MPa $= 50$ N/mm^2

1. Side of the square rod

Let $\quad x =$ Each side of the square rod

Considering the failure of the rod in tension. We know that load (P),

$$35000 = x^2 \times \sigma_t = x^2 \times 20 = 20x^2$$

$\therefore \quad x^2 = 35000/20 = 1750$ or $x = 41.8$ say 42 mm **Ans.**

Other dimensions are fixed as follows:

Width of strap, $\quad B_1 = x = 42$ mm **Ans.**

Thickness of cotter, $\quad t = \dfrac{B_1}{4} = \dfrac{42}{4} = 10.5$ say 12 mm **Ans.**

Thickness of gib = Thickness of cotter = 12 mm **Ans.**

Height (t_2) and length of gib head (l_4) = Thickness of cotter = 12 mm **Ans.**

2. **Width of gib and cotter**

Let B = Width of gib and cotter

Considering the failure of the gib and cotter in double shear. We know that load (P),

$$35\,000 = 2B \times t \times \tau = 2\,B \times 12 \times 15 = 360\,B$$

$\therefore$ B = 35000/360 = 97.2 say 100 mm **Ans.**

Since one gib is used, therefore

Width of gib, $b_1 = 0.55\,B = 0.55 \times 100 = 55$ mm **Ans.**

and width of cotter, $b = 0.45\,B = 0.45 \times 100 = 45$ mm **Ans.**

3. **Thickness of strap**

Let t_1 = Thickness of strap.

Considering the failure of the strap end in tension at the location of the gib and cotter. We know that load (P),

$$35\,000 = 2(x \times t_1 - t_1 \times t)\sigma_t = 2(42 \times t_1 - t_1 \times 12)20 = 1200\,t_1$$

$\therefore$ t_1 = 35000/1200 = 29.1 say 30 mm **Ans.**

Now the induced crushing stress may be checked by considering the failure of the strap or gib in crushing. We know that load (P),

$$35000 = 2t_1 \times t \times \sigma_c = 2 \times 30 \times 12 \times \sigma_c = 720\,\sigma_c$$

$\therefore$ σ_c = 35000/720 = 48.6 N/mm^2

Since the induced crushing stress is less than the given crushing stress, therefore the joint is safe.

4. **Length (l_1) of the rod**

Considering the failure of die rod end in shearing. Since the rod is in double shear, therefore load (P),

$$35\,000 = 2l_1 \times x \times t = 2l_1 \times 42 \times 15 = 1260\,l_1$$

$\therefore$ l_1 = 35 000 /1260 = 27.7 say 28 mm **Ans.**

5. **Length (l_2) of the rod**

Considering the failure of the strap end in shearing. Since the length of the rod (l_2) is in double shear, therefore load (P),

$$35\,000 = 2 \times 2l_2 \times t_1 \times \tau = 2 \times 2l_2 \times 30 \times 15 = 1800\,l_2$$

$\therefore$ l_2 = 35 000 /1800 = 19.4 say 20 mm **Ans.**

Length (l_3) of the strap end $= \frac{2}{3} \times x = \frac{2}{3} \times 42 = 28$ mm **Ans.**

and length of cotter $= 4x = 4 \times 42 = 168$ mm **Ans.**

Q.3 **Design a knuckle joint to transmit 150 kN. The design stresses may be taken as 75 MPa in tension, 60 MPa in shear and 150 MPa in compression.**

Solution:

Given data: P = 150 kN = 150 × 10^3 N; σ_t = 75 MPa = 75 N/mm^2; τ = 60 MPa = 60 N/mm^2; σ_c = 150 MPa = 150 N/mm^2

The knuckle joint is shown in Figure. The joint is designed by considering the various methods of failure as discussed below:

1. **Failure of the solid rod in tension**

Let d = Diameter of the rod.

We know that the load transmitted (P),

$$150 \times 10^3 = \frac{\pi}{4} \times d^2 \times \sigma_t = \frac{\pi}{4} \times d^2 \times 75 = 59\,d^2$$

$\therefore$ $d^2 = 150 \times 103/59 = 2540$ or $d = 50.4$ say 52 mm **Ans.**

Now the various dimensions are fixed as follows :

Diameter of knuckle pin, $d_1 = d = 52$ mm

Outer diameter of eye, $d_2 = 2d = 2 \times 52 = 104$ mm

Diameter of knuckle pin head and collar,

$$d_3 = 1.5d = 1.5 \times 52 = 78 \text{ mm}$$

Thickness of single eye or rod end,

$$t = 1.25\, d = 1.25 \times 52 = 65 \text{ mm}$$

Thickness of fork, $t_1 = 0.75\, d = 0.75 \times 52 = 39$ say 40 mm

Thickness of pin head, $t_2 = 0.5d = 0.5 \times 52 = 26$ mm

2. **Failure of the knuckle pin in shear**

Since the knuckle pin is in double shear, therefore load (P),

$$150 \times 10^3 = 2 \times \frac{\pi}{4} \times (d_1)^2 \tau = 2 \times \frac{\pi}{4} \times (52)^2 \tau = 4248\,\tau$$

$$\therefore \quad \tau = 150 \times 10^3/4248 = 35.3 \text{ N/mm}^2 = 35.3 \text{ MPa}$$

3. **Failure of the single eye or rod end in tension**

The single eye or rod end may fail in tension due to the load. We know that load (P),

$$150 \times 10^3 = (d_2 - d_1)t \times \sigma_t = (104 - 52)65 \times \sigma_t = 3380\, \sigma_t$$

$$\therefore \quad \sigma_t = 150 \times 10^3/\, 3380 = 44.4 \text{ N/mm}^2 = 44.4 \text{ MPa}$$

4. **Failure of the single eye or rod end in shearing**

The single eye or rod end may fail in shearing due to the load. We know that load (P),

$$150 \times 10^3 = (d_2 - d_1)t \times \tau = (104 - 52)65 \times \tau = 3380\, \tau$$

$$\therefore \quad \tau = 150 \times 10^3/3380 = 44.4 \text{ N/mm}^2 = 44.4 \text{ MPa}$$

5. **Failure of the single eye or rod end in crushing**

The single eye or rod end may fail in crushing due to the load. We know that load (P),

$$150 \times 10^3 = d_1 \times t \times \sigma_c = 52 \times 65 \times \sigma_c = 3380\, \sigma_c$$

$$\therefore \quad \sigma_c = 150 \times 10^3/3380 = 44.4 \text{ N/mm}^2 = 44.4 \text{ MPa}$$

6. **Failure of the forked end in tension**

The forked end may fail in tension due to the load. We know that load (P).

$$150 \times 10^3 = (d_2 - d_1)2t_1 \times \sigma_t = (104 - 52)2 \times 40 \times \sigma_t = 4160\, \sigma_t$$

$$\therefore \quad \sigma_t = 150 \times 10^3/4160 = 36 \text{ N/mm}^2 = 36 \text{ MPa}$$

7. **Failure of the forked end in shear**

The forked end may fail in shearing due to the load. We know that load (P),

$$150 \times 10^3 = (d_2 - d_1)2t_1 \times \tau = (104 - 52)2 \times 40 \times \tau = 4160\, \tau$$

$$\therefore \quad \tau = 150 \times 10^3/4160 = 36 \text{ N/mm}^2 = 36 \text{ MPa}$$

8. **Failure of the forked end in crushing**

The forked end may fail in crushing due to the load. We know that load (P),

$$150 \times 10^3 = d_1 \times 2t_1 \times \sigma_c = 52 \times 2 \times 40 \times \sigma_c = 4160\, \sigma_c$$

$$\therefore \quad \sigma_c = 150 \times 10^3/4180 = 36 \text{ N/mm}^2 = 36 \text{ MPa}$$

From above, we see that the induced stresses are less than the given design stresses, therefore the joint is safe.

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