Christopher King

Mechanical Design 1

07

Assignment

Christopher King

2018141521058

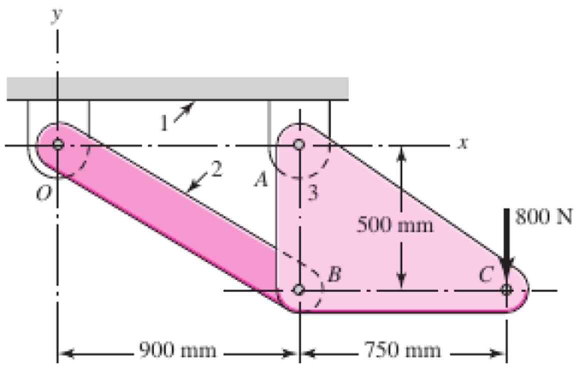
Mechanical Design 1

Class Section 01

11/04/2020

Problem 1

Link 2, shown in the figure, is 25 mm wide, has 12-mm-diameter bearings at the ends, and is cut from low-carbon steel bar stock having a minimum yield strength of 165 MPa. The end-condition constants are $C = 1$ and $C = 1.2$ for buckling in and out of the plane of the drawing, respectively.
Using a design factor $n_d = 4$, find a suitable thickness for the link.
Are the bearing stresses at O and B of any significance?



Solution:

For this question, we are asked to find a suitable thickness for the link using a design factor $n_d = 4$ and determine whether the bearing stresses at O and B are of any significance.

$$\circlearrowleft \sum M_A = 0 \Longrightarrow -(750\ \text{mm}) \times (800\ \text{N}) + F_{OB} \times \frac{(900\ \text{mm}) \times (500\ \text{mm})}{\sqrt{(900\ \text{mm})^2 + (500\ \text{mm})^2}} = 0$$

$$\Rightarrow F_{OB} = 1372.75\ \text{N}$$

$$k = \left(\frac{I}{A}\right)^{\frac{1}{2}} = \left(\frac{\frac{bh^3}{12}}{bh}\right)^{\frac{1}{2}} = \frac{h}{2\sqrt{3}} = \frac{25\text{ mm}}{2\sqrt{3}} = 7.217 \times 10^{-3}\text{ m}$$

$$\frac{l}{k} = \frac{\sqrt{(900\text{ mm})^2 + (500\text{ mm})^2}}{\frac{25\text{ mm}}{2\sqrt{3}}} = 142.66$$

$$\left(\frac{l}{k}\right)_{1in} = \sqrt{\frac{2\pi^2 CE}{S_y}} = \sqrt{\frac{2\pi^2 \times (1) \times (207.0\text{ GPa})}{(165\text{ MPa})}} = 157.4$$

Because $\left(\frac{l}{k}\right)_1 > \frac{l}{k}$, we can use Johnson formula.

$$\frac{n_d F_{OB}}{A} = S_y - \left(\frac{S_y}{2\pi}\frac{l}{k}\right)^2 \frac{1}{CE}$$

$$\frac{4 \times 1372.75\text{ N}}{(25\text{ mm})t} = (165\text{ MPa}) - \left[\frac{(165\text{ MPa})}{2\pi} \cdot \frac{\sqrt{(900\text{ mm})^2 + (500\text{ mm})^2}}{\frac{25\text{ mm}}{2\sqrt{3}}}\right]^2 \frac{1}{(1) \times (207.0\text{ GPa})}$$

$$\Longrightarrow t = 2.26 \times 10^{-3}\text{ m}$$

Assume $\left(\frac{l}{k}\right)_1 < \left(\frac{l}{k}\right)$

$$k = \left(\frac{I}{A}\right)^{\frac{1}{2}} = \left(\frac{\frac{hb^3}{12}}{bh}\right)^{\frac{1}{2}} = \frac{b}{2\sqrt{3}} = \frac{t}{2\sqrt{3}}$$

$$\frac{l}{k} = \frac{\sqrt{(900\text{ mm})^2 + (500\text{ mm})^2}}{\frac{t}{2\sqrt{3}}}$$

$$\left(\frac{l}{k}\right)_{1out} = \sqrt{\frac{2\pi^2 CE}{S_y}} = \sqrt{\frac{2\pi^2 \times (1.2) \times (207.0\text{ GPa})}{(165\text{ MPa})}} = 172.4$$

$$\frac{n_d F_{OB}}{A} = \frac{C\pi^2 E}{\left(\frac{l}{k}\right)^2}$$

$$\frac{4 \times 1372.75\ \text{N}}{(25\ \text{mm})t} = \frac{(1.2) \times \pi^2 \times (207.0\ \text{GPa})}{\left(\frac{\sqrt{(900\ \text{mm})^2 + (500\ \text{mm})^2}}{\frac{t}{2\sqrt{3}}}\right)^2}$$

$$\Rightarrow t = 10.445 \times 10^{-3}\ \text{m}$$

Verify:

$$\frac{l}{k} = \frac{\sqrt{(900\ \text{mm})^2 + (500\ \text{mm})^2}}{\frac{t}{2\sqrt{3}}} = 341.45 > \left(\frac{l}{k}\right)_1$$

This is Good.

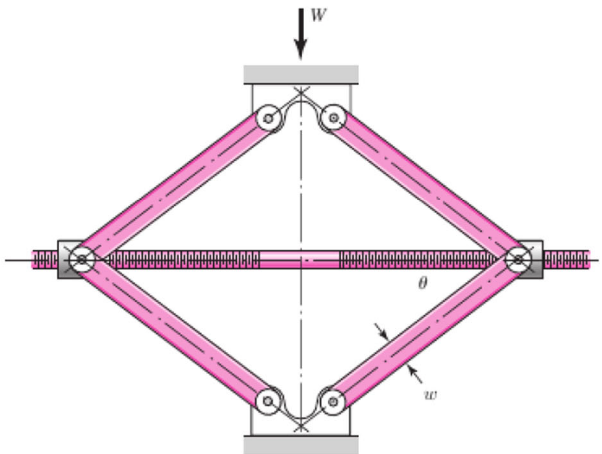
Therefore, the suitable thickness for the link using a design factor $n_d = 4$ is equal to 11 mm.

$$\sigma_b = -\frac{P}{td} = -\frac{1372.75\ \text{N}}{11 \times 10^{-3}\ \text{m} \times 0.012\ \text{m}} = -10.40\ \text{MPa}$$

No, the bearing stresses at O and B are not of any significance.

Problem 2

The figure shows a schematic drawing of a vehicular jack that is to be designed to support a maximum mass of 300 kg based on the use of a design factor $n_d = 3.50$. The opposite-handed threads on the two ends of the screw are cut to allow the link angle θ to vary from 15 to 70°. The links are to be machined from AISI 1010 hot-rolled steel bars. Each of the four links is to consist of two bars, one on each side of the central bearings. The bars are to be 350 mm long and have a bar width of w = 30 mm. The pinned ends are to be designed to secure an end-condition constant of at least C = 1.4 for out-of-plane buckling. Find a suitable preferred thickness and the resulting factor of safety for this thickness.



Solution:

For this question, we are asked to find a suitable preferred thickness and the resulting factor of safety for this thickness.

$$4F\ sin\theta = mg$$

$$\Rightarrow F = \frac{mg}{4\sin\theta}$$

Therefore, when $\theta = 15°$, F reaches the maximum.

$$F_{max} = \frac{mg}{4\sin\theta} = \frac{(300\text{ kg}) \times (9.81\text{ m/s}^2)}{4\sin 15°} = 2842.7\text{ N}$$

$$P_{cr} = n_d F_{max} = 3.5 \times 2842.7\text{ N} = 9949.52\text{ N}$$

Assume $\left(\frac{l}{k}\right)_1 < \left(\frac{l}{k}\right)$,

$$k = \left(\frac{I}{A}\right)^{\frac{1}{2}} = \left(\frac{\frac{hb^3}{12}}{bh}\right)^{\frac{1}{2}} = \frac{b}{2\sqrt{3}} = \frac{t}{2\sqrt{3}}$$

$$\frac{l}{k} = \frac{350\text{ mm}}{\frac{t}{2\sqrt{3}}}$$

$$\left(\frac{l}{k}\right)_1 = \sqrt{\frac{2\pi^2 CE}{S_y}} = \sqrt{\frac{2\pi^2 \times (1.4) \times (207.0\text{ GPa})}{(180\text{ MPa})}} = 178.27$$

$$\frac{n_d F_{OB}}{A} = \frac{C\pi^2 E}{\left(\frac{l}{k}\right)^2}$$

$$\frac{9949.52\text{ N}}{(30\text{ mm})t} = \frac{(1.4) \times \pi^2 \times (207.0\text{ GPa})}{\left(\frac{350\text{ mm}}{\frac{t}{2\sqrt{3}}}\right)^2}$$

$$\Rightarrow t = 5.55 \times 10^{-3}\text{ m}$$

Verify:

$$\frac{l}{k} = \frac{350\text{ mm}}{\frac{t}{2\sqrt{3}}} = 218.67 > \left(\frac{l}{k}\right)_1$$

This is Good.

Therefore, suitable preferred thickness is equal to 6 mm.

$$P_{cr} = A\frac{C\pi^2 E}{\left(\frac{l}{k}\right)^2} = (30\text{ mm})t \cdot \frac{(1.4) \times \pi^2 \times (207.0\text{ GPa})}{\left(\frac{350\text{ mm}}{\frac{t}{2\sqrt{3}}}\right)^2} = 12608.3\text{ N}$$

$$n_d = \frac{12608.3\text{ N}}{2842.7\text{ N}} = 4.43$$

Christopher King