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# Mechanical Design 1

04 Assignment

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Mechanical Design 1

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**Problem 1**

A seamless cylinder with a storage capacity of 0.025 m$^3$ is subjected to an internal pressure of 20 MPa. The length of the cylinder is twice its internal diameter. The cylinder is made of plain carbon steel 20C8 ($S_{ut}$ = 390 MPa) and the factor of safety is 2.5. Determine the dimensions of the cylinder.

**Solution:**

For this question, we are asked to determine the dimensions of the cylinder.

$$\frac{\pi D^2}{4} \times (2D) = 0.025\ \text{m}^3$$

Therefore, I can know that the diameter of the cylinder is equal to

$$D = 0.2515\ \text{m}$$

And the length of the cylinder is equal to

$$L = 2D = 0.5031\ \text{m}$$

For the limitation of the thickness,

$$\frac{pr}{t} \le \frac{S_{ut}}{FS}$$

$$t \ge \frac{prFS}{S_{ut}} = \frac{(20\ \text{MPa}) \times \left(\frac{0.2515\ \text{m}}{2}\right) \times 2.5}{390\ \text{MPa}}$$

Solving the inequation above yields that

$$t \ge 0.01612\ \text{m}$$

Therefore, the dimensions of the cylinder is that

1. The diameter is 0.2515 m.
2. The length is 0.5031 m.
3. The thickness is 0.01612 m.

**Problem 2**

The maximum recommended speed for a 250-mm-diameter abrasive grinding wheel is 2000 rev/min. Assume that the material is isotropic; use a bore of 20 mm, ν = 0.24, and a mass density of 3320 kg/m$^3$, and find the maximum tensile stress at this speed

**Solution:**

For this question, we are asked to find the maximum tensile stress at this speed.

$$\sigma_{max} = \rho\omega^2\left(\frac{3+v}{8}\right)\left(r_i^2 + r_o^2 + \frac{r_i^2 r_o^2}{r_i^2} - \frac{1+3\nu}{3+\nu}r_i^2\right)$$

$$= (3320\ \mathrm{kg/m^3}) \times \left[\frac{2\pi \times 2000}{60}\ \mathrm{rad/s}\right]^2 \times \left(\frac{3}{8}\right)$$

$$\times \left[(10\ \mathrm{mm})^2 + (125\ \mathrm{mm})^2 + \frac{(10\ \mathrm{mm})^2 \times (125\ \mathrm{mm})^2}{(10\ \mathrm{mm})^2}\right.$$

$$\left. - \frac{1 + 3 \times 0.24}{3 + 0.24} \times (10\ \mathrm{mm})^2\right] = 1.85\ \mathrm{MPa}$$

**Problem 3**

The 50H7/p6 designated fit table for 50 mm basic size involves the following: Maximum and minimum hole diameters are $D_{\max} = 50.025\text{mm}$ and $D_{\min} = 50.000\text{mm}$; while maximum and minimum shaft diameters are $d_{\max} = 50.042\text{mm}$ and $d_{\min} = 50.026\text{mm}$; The materials are both hot-rolled steel. Find the maximum and minimum values of the radial interference and the corresponding interface pressure. Use a collar diameter of 100 mm

**Solution:**

For this question, we are asked to the maximum and minimum values of the radial interference and the corresponding interface pressure.

$$p = \frac{E\delta}{2R^2}\left[\frac{(r_o^2 - R^2)(R^2 - r_i^2)}{r_o^2 - r_i^2}\right]$$

$$= \frac{(207\ \text{GPa})\delta}{2 \times (25\ \text{mm})^2} \times \left\{\frac{[(50\ \text{mm})^2 - (25\ \text{mm})^2] \times [(25\ \text{mm})^2 - (0\ \text{mm})^2]}{[(50\ \text{mm})^2 - (0\ \text{mm})^2]}\right\}$$

$$= (3.105\ \text{GPa/mm})\ \delta$$

And from the question, I can know that

$$\delta_{max} = \frac{1}{2}(d_{max} - D_{\min}) = \frac{1}{2} \times [(50.042\ \text{mm}) - (50.000\ \text{mm})] = 0.021\ \text{mm}$$

$$\delta_{min} = \frac{1}{2}(d_{min} - D_{\max}) = \frac{1}{2} \times [(50.026\ \text{mm}) - (50.025\ \text{mm})] = 0.0005\ \text{mm}$$

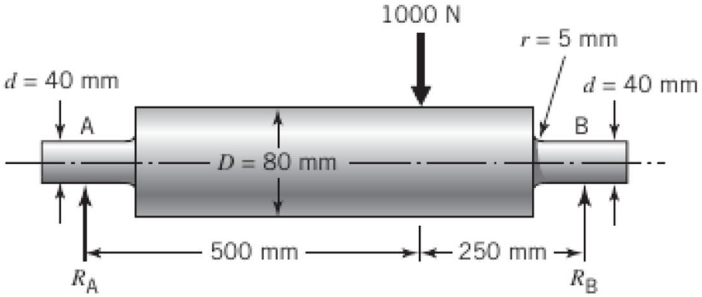
Therefore, I can know that

$$p_{max} = (3.105\ \text{GPa/mm})\ \delta_{max} = (3.105\ \text{GPa/mm}) \times (0.021\ \text{mm}) = 62.5\ \text{MPa}$$

$$p_{min} = (3.105\ \text{GPa/mm})\ \delta_{min} = (3.105\ \text{GPa/mm}) \times (0.0005\ \text{mm}) = 1.55\ \text{MPa}$$

**Problem 4**

A shaft is supported by bearings at locations $A$ and $B$ and is loaded with a downward 1000N force as shown. Find the maximum stress at the shaft fillet. The critical shaft fillet is 70 mm from $B$




**Solution:**

For this question, we are asked to find the maximum stress at the shaft fillet.

$$\circlearrowleft \sum M_A = 0 \Rightarrow -(1000\text{ N}) \times (500\text{ mm}) + R_B \times (750\text{ mm}) = 0 \Rightarrow R_B = 666.6\text{ N}$$

$$M_f = R_B x = (666.6\text{ N}) \times (0.070\text{ m}) = 46.67\text{ N}\cdot\text{m}$$

$$\sigma = \frac{My}{I} = \frac{Mr}{\frac{\pi r^4}{4}} = \frac{4M}{\pi r^3} = \frac{4 \times (46.67\text{ N}\cdot\text{m})}{\pi \times (0.02)^3} = 7.427\text{ MPa}$$

From the graph, I can know that the stress concentration factor is equal to

$$K_t = 1.6$$

Therefore, I can know that the maximum stress at the shaft fillet is equal to

$$\sigma_{max} = K_r\sigma = 1.6 \times (7.427\text{ MPa}) = 11.88\text{ MPa}$$

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