

Chapter 4. Axial Members and Pressure Vessels (Biaxial)

الفصل الرابع العناصر المحورية وأوعية الضغط (ثنائية المحور)

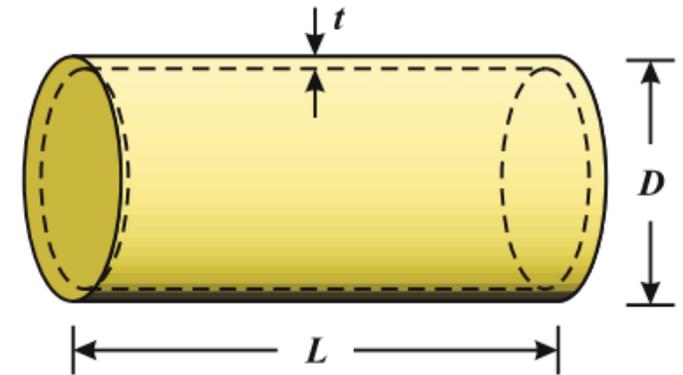
Pressure Vessels Problems

1. A steel cylindrical pressure vessel at an industrial plant has a diameter of $D = 1.60 \text{ m}$ and wall thickness of $t = 20.0 \text{ mm}$. The cylinder body has length $L = 6.00 \text{ m}$. For steel, $E = 200 \text{ GPa}$, $S_y = 480 \text{ MPa}$, and Poisson's ratio $\nu = 0.30$.

(a) Using a factor of safety against yielding of 3.0, determine the allowable (maximum working) pressure of the contained gas.

(b) If the contained pressure is 600 kPa, determine the change in length of the cylinder from its unpressurized (unloaded) state.

(c) If the contained pressure is 600 kPa, determine the change in radius of the cylinder from its unpressurized (unloaded) state.



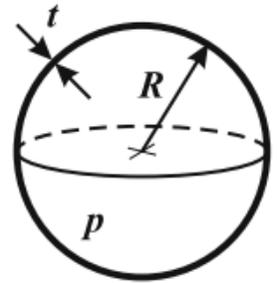
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2. A spherical propane tank has radius $R = 400 \text{ mm}$ and a thickness of $t = 5 \text{ mm}$. The material has yield strength $S_y = 400 \text{ MPa}$, modulus $E = 200 \text{ GPa}$, and Poisson's ratio $\nu = 0.3$.

(a) Determine the stresses in the walls of the vessel if $p = 1.0 \text{ MPa}$. Draw the stresses on a plane–stress, stress element.



b) If the factor of safety against yielding is 2.0, determine the allowable pressure that can be contained in the vessel.

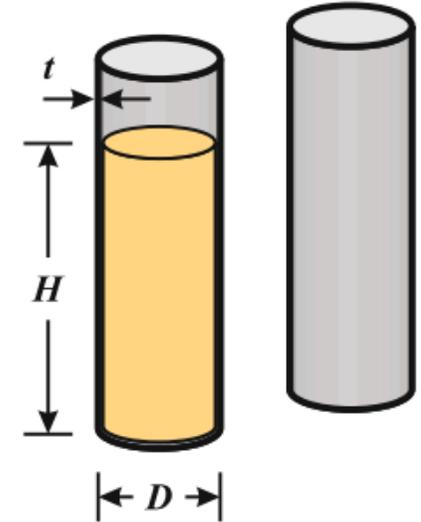
c) If $p = 1.0 \text{ MPa}$, determine the strain around the circumference of the vessel.

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3. Grain silos are large thin-walled cylinders. As with water, the pressure increases linearly with depth below the surface of the “fluid” (the grain). The mass density of the grain is ρ .

Derive formulas for the hoop stress and axial stress anywhere in the wall of the silo, distance x below the surface of the grain. Note that silos are not pressurized like gas cylinders.



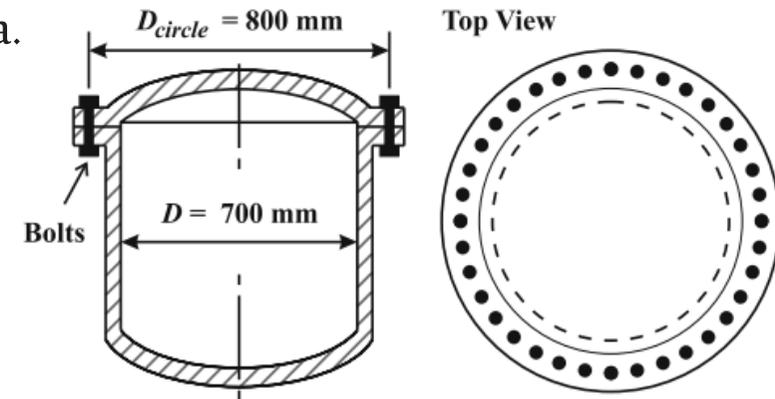
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4. A factory uses a cylindrical pressure vessel with an inner diameter of 700 mm. The vessel operates at an internal pressure of 6.0 MPa. The steel used in the construction of the vessel has an allowable tensile stress of 280 MPa (the factor of safety has already been applied). The lid of the pressure vessel is attached to the body using 36 equally spaced bolts on a circle of diameter $D_{\text{circle}} = 800$ mm around the circumference of the pressure vessel. The allowable stress in tension for the bolts is 245 MPa.

- (a) Calculate the minimum allowable wall thickness to support the load.
- (b) Determine the minimum bolt diameter at the root of the threads of the bolts (*hint*: what force does each bolt need to carry)? Assume the bolt-heads and nuts are strong enough.

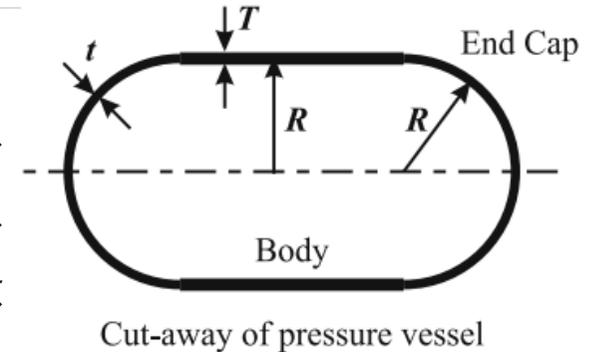


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5. A pressure vessel has a cylindrical body and hemispherical end caps. The body and end caps are made of the same material and have radius R . The thickness of the body is T and the thickness of the end caps is t . Young's modulus is E and Poisson's ratio is ν .



- (a) Determine the ratio of the thicknesses t/T if the hoop strain at the cylinder/end cap joint is to be the same in each part (i.e., so the hoop strain is the same as the spherical strain at the joint). Matching these strains prevents excessive stresses at the joint.
- (b) If the yield strength is S_y , determine the pressure required to cause yielding p_y in the vessel. Based on the results of *Part (a)*, does failure occur in the cylindrical body or in the spherical end-cap?

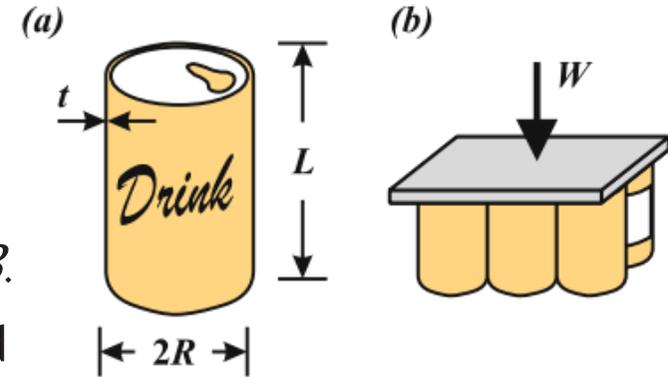
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6. A six-pack is shaken so that the pressure in each can is $p = 140 \text{ kPa}$. A board is placed on the six pack and a student(s) weighing W stands on the board so his weight is evenly distributed to the six cans.

The aluminum properties are $E = 70 \text{ GPa}$, $S_y = 240 \text{ MPa}$, and $\nu = 0.33$. Each can has an average radius of $R = 3.2 \text{ cm}$, thickness $t = 2.5 \text{ mm}$, and length $L = 12 \text{ cm}$.



- (a) Determine the critical weight of the student, W_{cr} , so that a stress element on the surface of the can is in a state of uniaxial stress. Assume that no support is provided by the contained liquid and the cans do not fail by buckling (being crushed).
- (b) Determine the strain in the longitudinal direction of the can due to pressure $p = 140 \text{ kPa}$ and force W_{cr} .
- (c) Determine the strain in the hoop direction of the can due to pressure $p = 140 \text{ kPa}$ and force W_{cr} .

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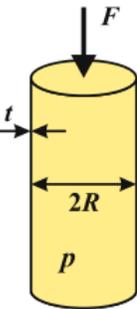
Pressure Vessels Problems

7. Pressurized air in inflatable structures allows them to be roughly handled. Without air pressure, a basketball can be crumpled into a relatively small space. Another application of inflatable structures are bounce-houses that give children untold hours of joy. Air pressure may also be used to deploy space structures such as unfolding antennae.

Air beams are large pressurized cylinders made of industrial plastic fabric, and are used as support frames in temporary structures. After inflation, the unfolded structure becomes a thin wall pressure vessel. Failure occurs under two circumstances:

- (1) when the stress in the fabric membrane becomes compressive, causing the membrane to wrinkle or kink;
- (2) when the tensile stress in the fabric reaches the fabric strength, S_u .

A pressurized fabric tube is subjected to a compressive axial force F . Determine the load that causes compressive failure of the tube. Assume the load does not cause bending.



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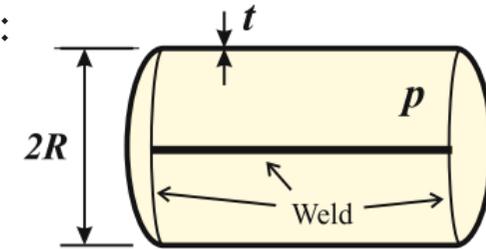
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8. A thin-walled cylindrical pressure vessel is made by rolling a steel plate, and welding along a longitudinal line. End caps are also welded onto each end of the cylinder body. Material Properties:

Steel: $S_{y,s} = 550 \text{ MPa}$, $E = 200 \text{ GPa}$. Weld: $S_{y,w} = 450 \text{ MPa}$, $E = 200 \text{ GPa}$

Geometry Diameter: $2R = 1.6 \text{ m}$. Thickness: $t = 12.0 \text{ mm}$.



(a) For a factor of safety is 2.0, determine the allowable pressure, p_{allow} .

(b) A Pressure release valve (safety valve) is attached to the pressure vessel. The valve is a hollow cylinder, encasing a piston (or plug) attached to a spring. Assume there is no leakage around the piston, and friction between the piston and the cylinder is negligible. With no pressure, the bottom of the piston is aligned with the inner wall of the vessel. The valve cylinder has inner length $L = 120 \text{ mm}$ and inner diameter $b = 20 \text{ mm}$. The pressure release opening is $\Delta = 20 \text{ mm}$ above the inside wall of the vessel.

If the valve is to release the gas when the internal pressure is $p_{rel} = 4.0 \text{ MPa}$, determine the required stiffness k of the spring.

Safety Valve, Part (b)

