Problems of Practices
Of
Mechanics of Solids
17- Thin Walled Cylinder

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1. A one mm diameter steel wire is wound around a copper tube with external and internal diameters of 140 mm and 120 mm respectively, to increase the strength of the tube against internal pressure. Find, what initial tension must be given to the wire, so that maximum allowable stresses for the tube and wire materials namely 90 and 200 MPa respectively are reached simultaneously. Assume 'μ' for copper and steel to be 0.3 and wire winding as a thin cylinder. Modulus of elasticity for copper and steel may be assumed as 10^6 and 2×10^6 MPa respectively. The tube is open at the ends.
2. What should be the ratio of thickness of a thin cylindrical shell to the thickness of its hemispherical end for a pressure vessel subjected to internal fluid pressure so that the junction section remains free from unequal deformation?
3. A thin cylindrical vessel of internal diameter d and thickness t is closed at both ends and is subjected to an internal pressure p. How much would be the hoop and longitudinal stress in the material?
4. The pressure within the cylinder of a hydraulic press is 9 MPa. The inside diameter of the cylinder is 25 mm. Determine the thickness of the cylinder wall, if the permissible tensible stress is 18 N/mm^2.

5. Derive a formula for increase in volume of a thin metallic sphere when it is subjected to an internal pressure p.

6. A thin spherical shell of copper has a diameter of 400 mm and a wall thickness of 2 mm and is just full of water at atmospheric pressure. Calculate the volume of water pumped in to raise the inside pressure to 1.5 N/mm^2. The modulus of elasticity for copper is 1×10^5 N/mm^2. K (Bulk Modulus) is 2.5×10^2 N/mm^2 and Poisson's ratio is 0.25.

7. Distinguish between thin and thick cylinders. A thin cylindrical shell having hemispherical ends is subjected to internal pressure 'p'. The internal diameter is 'd' and thicknesses of cylinder and hemisphere are t_1 and t_2 respectively. Assuming Poisson's ratio $\nu = 0.3$, prove the following:

(i) For no distortion of juncture, $t_2/t_1 = 7/17$.

(ii) For equal maximum stresses in cylindrical and hemispherical portions, $t_2/t_1 = 0.5$.

8. A thin cylinder 150 mm internal diameter and 2.5 mm thick has its ends closed by rigid plates and is then filled with water. When an external axial pull of 37 kN is applied to the ends, the water pressure is observed to fall by 0.1 N/mm2. Determine the value of Poisson's ratio. Assume E = 140000 N/mm^2; K = 2200 N/mm^2.

9. A thin cylindrical pressure vessel of inside radius r and thickness of metal t is subjected to an internal fluid pressure p. What are the values of –

(i) maximum normal stress;

(ii) maximum shear stress?

10. A cylindrical shell has the following dimensions:

Length = 3 m

Inside diameter = 1 m

Thickness of metal = 10 mm

Internal pressure = 1.5 MPa

Calculate the change in dimensions of the shell and the maximum intensity of shear stress induced. Take E = 200 GPa and Poisson's ratio = $\mu = 0.3$.

11. A steel sleeve is pressed onto a solid steel shaft which has 5 cm diameter. The radial pressure between shaft and sleeve is 1800 N/cm^2 and hoop stress at the inner surface of the sleeve is 4500 N/cm^2. If an axial compressive load of 50 kN is applied to the shaft, determine change in radial pressure at the interface of shaft and sleeve. Assume $\mu = 0.3$.

12. A thin cylindrical shell of diameter 200 mm, wall thickness t is subjected to an internal pressure of 2 N/mm^2. The longitudinal joint efficiency of the shell is 80%. What should be the minimum wall thickness of shell, if allowable stress in shell is limited to 100 MPa?

13. Considering principal stresses in a steam boiler drum as P, $0.5P$, 0 and Poisson's ratio $\mu = 0.30$, equivalent stress in simple tension as σ, find P in terms of σ due to (i) maximum shear stress theory, (ii) strain energy theory, (iii) distortion energy theory.

14. How will you distinguish between a thin-walled and a thick walled pressure vessel? What advantage you obtain by wire winding a thin cylinder?

15. What largest internal pressure can be applied to a cylindrical tank 1.8 meter in diameter and 14 mm wall thickness if the ultimate tensile strength of steel used is 467 MPa and a factor of safety of 7 is desired?

16. The cylinder of a hydraulic ram has 160 mm internal diameter. Find the thickness required to withstand an internal pressure of 60 MPa, if the maximum tensile stress is limited to 90 MPa and the maximum shearing stress to 80 MPa. Use Lame's formula for thick cylinders under internal pressure.

17. A thin cylindrical shell is 5 m long, has 200 mm internal diameter and has thickness of metal 10 mm. It is filled completely with a fluid at atmospheric pressure. If an additional 25000 mm^3 fluid is pumped in, find the pressure inside the shell and hoop stress developed. Find also the changes in diameter and length. Take $E = 200$ MPa and $\nu = 0.3$.

18. A thin cylindrical shell with hemispherical ends is subjected to internal fluid pressure. For equal maximum stress to occur in both the cylindrical and the spherical portions, what would, be the ratio of thicknesses of the spherical portion to that of the cylindrical portion?

19. Derive expressions for longitudinal and hoop stresses in a thin walled pressure vessel. Using the above expressions, determine hoop and longitudinal stresses in a household LPG cylinder, assuming it to be a thin walled pressure vessel with following dimensions: *OD* = 315 mm thickness: 2.8 mm. Take end caps to be flat and the pressure in the cylinder is 1.4 MPa at room temperature.

20. The internal diameter of the cylinder of a hydraulic ram is 10 cm. Find the thickness required to withstand an internal pressure of 500 atm (1 atm = 98.07 kPa), if the yield point for the material (in tension as well as compression) is σ_y = 500 MPa. Use a Factor of safety of 2.

21. A spherical gas container made of steel has 5.4 m outer diameter and wall thickness of 10 mm. Knowing that the internal pressure is 400 kPa, determine the hoop stress and longitudinal stress in the container.

22. A thin cylindrical shell with hemispherical ends as thickness of cylindrical portion t_1 and thickness of hemispherical portion t_2. The internal pressure for both is same. For no distortion of the junction under pressure what will be the value of ratio of thickness (t_2/t_1) if the material has a Poisson's ratio $\nu = 0.3$.

23. A thin cylinder is turning about its axis. Find the safe number of revolutions for a rotor of 3 metres in diameter if the hoop stress is not to exceed 1300 kg/cm^2. Take density as 6500 kg/cm^3.

24. A thin cylinder with closed ends has an internal pressure of 6 MN/m^2. The cylinder is of 50 mm internal diameter and 2.5 mm thick. It is also subjected to an axial pull of 10 kN and a torque of 500 Nm.
Determine the principal stresses in the cylinder and maximum shear stress.

25. A thin spherical vessel of 1000 mm diameter and 2 mm thickness is subjected to an internal pressure of 4 MPa. The Young's modulus and Poisson's ratio are 200 GPa and 0.3 respectively. Find the following:
(i) Hoop stress,
(ii) Change in volume of the vessel.

26. A thin cylindrical shell has an external diameter of 500 mm and wall thickness of 10 mm. The length of the cylinder is 1.7 m. Determine the increase in its internal diameter and also the increase in length when the inside pressure is 1 MPa. Given

E = 210 GPa and Poisson's ratio = 0.3. Hence determine the change in volume of the cylinder if the ends are closed with flat plates.

27. A thin cylindrical shell is 3 m long, 1 m in diameter, thickness of wall is 10 mm. The internal fluid pressure is 1.5 N/mm^2. Calculate the change in dimensions of the shell and hence change in its volume. Also calculate the maximum intensity of shear stress. Given: E = 200 GPa and ν = 0.3.