Problems of Practices
Of
Mechanics of Solids
18- Thick Walled Cylinder

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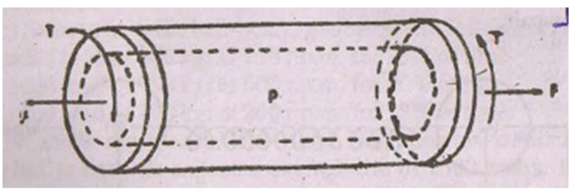
1. A compound cylinder is formed by shrinking a tube 16 cm external dia and 12 cm internal dia on to another tube which has an internal dia of 8 cm. If after shrinking, the radial compression at the common surface is 300 kgf/cm^2, find the circumferential stress at the inner and outer surfaces and at the common surface.

2. A thick walled cylindrical vessel with internal radius r_1 = 0.25 m and external radius r_2 = 0.35 m, has rigid end plates welded to its two ends (Fig. 2). It is subjected to a tensile load F = 1000 kN through the endplates, a twisting moment T = 100 kN-m, and, and internal pressure p = 60 MPa. Determine the principal stresses and the absolute maximum shear stress on the inside surface of the vessel. Neglect the end effect.



3. A compound cylinder is made by shrinking a jacket with outer diameter of 20 cm on a hollow cylinder with diameters 10 cm and 15 cm. When the compound cylinder is subjected to an internal pressure of 350 kgf/cm², the maximum circumferential stress in both the cylinders is same. Calculate the maximum stress developed and the internal diameter of the jacket. Take the value of $E = 2 \times 10^6$ kg/cm².

4. A steel cylinder having 12.5 cm outside diameter has a wall thickness of 1.5 cm. The cylinder is used as a pressure vessel to hold fluid at an internal pressure of 30 MPa. Assume that the ends of the cylinder are closed. Calculate

(i) the radial and tangential stress at the inner and outer surfaces,

(ii) the three principal normal strains at the inner surface, assuming that the material does not yield.

Take Young's modulus = 2×10^{11} N/m² Poisson's ratio = 0.3.

5. Find the ratio of thickness to internal diameter of a thick tube subjected to internal pressure when the pressure is 5/8 of the value of the maximum permissible circumferential stress. Find the increase in internal diameter of such a tube of 100 mm internal diameter when the internal pressure is 100 MN/m². $E = 200 \times 10^9$ N/m²; Poisson's ratio = 0.286.

6. A steel shaft of 7.5 cm diameter has an aluminum disc of 30 cm outside diameter shrunk on it. The shrink allowance is 1 part per 1000. Find the tangential and radial stresses al the interface due to shrink-fit. Calculate also the r.p.m. of rotation, at which the shrink-fit loosens up.

Neglect the expansion of the shaft caused by rotation. Take

Poisson's ratio for both metals = 0.3

E for steel = 210×10^3 MPa

E for aluminum = 71×10^3 MPa

Density of aluminum = 2.76 g/cm³.

7. On the outer surface of a closed thick cylinder of diameter ratio 2.5, were fixed strain gauges to measure the longitudinal and circumferential stains. At an internal pressure of 230 MN/m² these stains were recorded as 9.18×10^{-6} and 369×10^{-6} respectively. Determine the values of Young's modulus, modulus of rigidity and Poisson's ratio.

8. A thick spherical pressure vessel of inner radius 150 mm is subjected to an internal pressure of 80 MPa. Calculate its wall thickness based upon the (i) maximum principal stress theory, and (ii) total strain energy theory. Poisson's ratio = 0.30, yield strength = 300 MPa.

9. What are lame equations?

For a long hollow thick walled cylinder subjected to a high internal pressure, determine the radial and circumferential stresses throughout the vessel in terms of internal pressure 'p' and internal external radii.

10. A steel rotor disc of uniform thickness 50 mm has an outside diameter 800 mm and a central hole of diameter 150 mm. There are 200 blades each of weight 2 N at an effective radius of 420 mm pitched evenly around the outer periphery of the disc. Determine the maximum rotational speed such that maximum shearing stress in the disc does not exceed 375 MN/m². Take density (ρ) of the steel as 7470 kg/m³. Following basic relation for radial stress (σ_r) and hoop stress (σ_θ) at radius of routing disc at ω rad/sec can be used with usual

$$\sigma_r = A - \frac{B}{r^2} - (3-\gamma)\frac{\rho\omega^2 r^2}{8}$$
$$\sigma_\theta = A + \frac{B}{r^2} - (3-\gamma)\frac{\rho\omega^2 r^2}{8}$$

11. A compound cylinder is made by shrinking an outer tube of outside diameter 200 mm and inside diameter 150 mm onto an inner tube, internal diameter 100 mm with a radial interference of 0.2 mm. Both the tubes are made of steel with elastic modulus $E = 2 \times 10^6$ kg/cm² and Poisson's ratio $\mu = 0.3$.
Calculate the value of pressure at the interface and values of hoop stress in the two tubes at the interface. Work from the first principles assuming the basic Lame's equations.

$$\sigma_r = A - \frac{B}{r^2},\ \sigma_c = A + \frac{B}{r^2}$$

12. When two cylindrical parts are assembled by shrinking or by press fitting, a contact pressure is created between the two parts. If the radii of the inner cylinder are a and c and that of the outer cylinder are $(c - \delta)$ and b, δ being the radial interference, the contact pressure is given by:

$$P = \frac{E\delta}{c}\left[\frac{(b^2-c^2)(c^2-a^2)}{2c^2(b^2-a^2)}\right]$$

where E is the Young's modulus of the material. Can you outline the steps involved in developing this important design equation?

13. A steel rod of diameter 50 mm is forced into a bronze casing of outside diameter 90 mm, producing a tensile hoop stress of 30 MPa at the outside diameter of the casing.
(i) the radial pressure between the rod and the casing,
(ii) the shrinkage allowance and
(iii) the rise in temperature which would just eliminate the force fit.
Assume the following material properties: $E_S = 2 \times 10^5$ N/mm², $\mu_S = 0.25$; $\alpha_S = 1.2 \times 10^{-5}$ /°C and $E_b = 1 \times 10^5$ N/mm², $\mu_b = 0.3$, $\alpha_b = 1.9 \times 10^{-5}$ /°C.

14. A circular disc 50 cm outside diameter has a central hole and rotates at a uniform speed about an axis through its centre. The diameter of the hole is such that the maximum stress due to rotation is 85% of that in thin ring whose mean diameter is also 50 cm. If both are of the same material and rotate at the same speed, determine the diameter of the central hole and speed of the disc for the data given below:
Allowable stress = 900 kg/cm³, Specific weight = 7.8 gm/cm³, Poisson's ratio = 0.3

15. A compound cylinder is made by shrinking a cylinder of outer diameter 180 mm over another cylinder of inner diameter 90 mm. If the numerical value of the maximum hoop stress developed due to shrinkage fitting in both cylinders be same, find the junction diameter.

16. A compound cylinder is formed with inner diameter = 300 mm; the diameter at the junction = 400 mm and outer diameter = 500 mm. If the initial interference in diameters at the junction is 0.2 mm, find the radial pressure developed at the junction. Find also the minimum temperature to which the outer cylinder is to be heated to slip it onto the inner cylinder. Take $E = 2 \times 10^5$ N/mm² and $\alpha = 12.5 \times 10^{-6}$ /°C.

17. A copper rod 6 cm in diameter is placed within a steel tube, 8 cm external diameter and 6 cm internal diameter, of exactly the same length. The two pieces are rigidly fixed together by two transverse pins 20 mm in diameter, one at each end passing through both rod and the tube. Calculate the stresses induced in the copper rod, steel tube and the pins if the temperature of the combination is raised by 50°C. Take:
E_s = 210 GPa, α_s = 0.0000115 /°C
E_c = 105 GPa, α_c = 0.000017 /°C

18. A thick-walled steel cylinder having an inside diameter of 150 mm is to be subjected to an internal pressure of 40 N /mm^2. Find to the nearest mm the outside diameter required, if the hoop stress in the cylinder wall is not to exceed 125 N/mm^2.

19. A spherical shell of 150 mm internal diameter has to withstand an internal pressure of 30 Mega N/m^2. Calculate the thickness of the shell if the allowable stress is 80 MN/m^2. Assume the stress distribution in the shell to follow the law

$$\sigma_r = a - \frac{2b}{r^3}, \text{ and } \sigma_\theta = a + \frac{2b}{r^3}$$

20. What do you understand by a rotating disc of uniform strength?

21. A turbine disc is required to have a uniform stress of 150 MPa at a speed of 3200 rpm. The disc is to be of 30 mm thick at the centre. What will be its thickness at a radius of 40 mm?
Assume density of disc material = 7800 kg/m^3.

22. A cylindrical pressure vessel 200 cm in diameter and 350 cm in length is made of 1.30 cm thick plates. It is subjected to an internal pressure of 10 kg/cm^2. Calculate the longitudinal and circumferential stresses developed in the vessel.

23. A thick cylinder is made of 6 cm internal diameter. It is subjected to an internal pressure of 50 MPa. If the maximum tensile stress is limited to 100 MPa, find the thickness required. Also, show the variations of hoop and radial stresses across the thickness of the cylinder.

24. A thick cylinder is subjected to both internal and external pressure. The internal diameter of the cylinder is 200 mm and the external diameter is 250 mm. If the maximum permissible stress is 30 N/mm^2 and the external pressure is 8 N/mm^2, determine the intensity of internal radial pressure.