UNIVERSITY OF NAIROBI

DEPARTMENT OF MECHANICAL & MANUFACTURING ENGINEERING

FME 301: SOLID & STRUCTURAL MECHANICS III

TUTORIAL SHEET NO. 3

1. A cast iron water main, 300 mm internal diameter, is to resist 225 m head of water. If the maximum tensile stress in the cast iron is not to exceed 15 MN/m^2, calculate the necessary wall thickness of the cast iron water pipe:

   a) By the approximate thin cylinder formulae using internal radius, and

   b) By the use of the thick cylinder formulae.

   The density of water is 1,000 kg/m^3.

   (ANS. a) 21.4 mm, b) 23.2 mm)

2. A hub is shrunk onto a shaft. The final dimensions of the hub-shaft assembly are: common radius 100 mm and outer radius of hub is 300 mm. If the maximum shear stress on the inner surface of the hub is not to exceed that in a rod made of the same material as the hub and subjected to a maximum tensile strain of 0.001, calculate:

   a) The maximum contact pressure between the hub and the shaft, and

   b) The original difference between the common diameters of the hub and the shaft to produce the contact pressure calculated in a), if the shaft and the hub are made of steel of Young's modulus, E = 207 GN/m^2 and Poisson's ratio, $\upsilon = 1/3$.

   Neglect the axial frictional forces between hub and the shaft.

   (ANS. a) 92 MN/m^2, b) 0.2 mm)

3. The equations for the radial, σ_r, and circumferential, σ_θ, stresses at any radius r from the centre in a thick-walled cylinder subjected to internal or external pressure or both, are given by the general expressions:

   $$\sigma_r = A + B/r^2 \quad \text{and} \quad \sigma_\theta = A - B/r^2$$

   Where A and B are constants derived from boundary conditions.

Using these expressions, derive the equations for, σ_r, and, σ_θ , t any radius r from the centre in a closed-ended thick-walled cylinder of internal radius R_i and external radius R_o subjected to an internal pressure, p_i. If the axial stress, σ_a, is assumed uniform, derive its value.

In a particular closed-ended cylinder with diameter ratio 2.5, the axial and circumferential strains at the outer surface were measured to be 91.8×10^{-6} and 369×10^{-6} respectively when the internal pressure applied was 230 MN/m^2. Determine the values of the Young's modulus, E, and the Poisson's ratio, υ, for the material of the cylinder.

(ANS. E = 203 GN/m^2 and υ = 0.286)

4. A brass sleeve of 60 mm internal diameter and 75 mm external diameter is shrink-fitted into a steel hub of outer diameter 110 mm to give a common interface pressure of 35 MN/m^2.

   a) Determine the initial difference in diameter between the sleeve and the hub.

   b) Plot the residual stresses resulting from the shrinkage process.

   c) Assuming plane stress conditions, determine the circumferential stresses at the inner diameter of each component when a subsequent pressure of 100 MN/m^2 is applied in the shrunk assembly.

   Take Young's modulus and Poisson's ratio for brass to be 90 GN/m^2 and 0.33 respectively and Young's modulus and Poisson's ratio for steel to be 210 GN/m^2 and 0.29 respectively.

   (ANS. a) $\Delta d = 2u = 0.161$ mm, c) =)