Master of Mechanical Engg 2nd Semester Examination, 2019

Design of Industrial pressure vessel

Time: Three Hours Full Marks: 100

Answer any five

All questions carry equal marks

1. Prove that, for a thick Spherical pressure vessel which is subjected to internal pressure p_i,

$\sigma_r = \frac{p_i a^3}{b^3 - a^3}\left(1 - \frac{b^3}{r^3}\right)$ and $\sigma_t = \frac{p_i a^3}{b^3 - a^3}\left(1 + \frac{b^3}{2r^3}\right)$, where the terms have usual meaning.

2. (a) An industrial pressure vessel is to be designed based on various failure theories. Internal pressure = 150 MN/m^2.Internal diameter : 800 mm. Yield point stress 450 MN/m^2. Calculate the wall thicknesses required according to Maximum normal stress theory, Maximum shear theory. Maximum strain theory, maximum strain energy theory.

   (b)Derive the expression of wall thickness as per maximum distortion energy theory & calculate the thickness with the help of data given in 2(a)

3. A cylinder of outer radius 'a' and inner radius b is subjected to autofrettage where entire cylinder wall has been plastically penetrated. Derive the expression for the residual stress and explain graphically assuming b/a=2.

4. Derive the expression of thermal stress for radial(σ_r), tangential(σ_t) and axial stress (σ_z)developed in a cylinder [outer radius '**b**' and inner radius '**a**'] for a steady state logarithmic thermal gradient having inner temperature T_i (at r = a)and outer temperature being 0 (at r = b) ,E is the young's modulus and **α** is the coefficient of linear thermal expansion.

5. Prove that thermal stress developed in a hollow cylindrical pressure vessel for logarithmic temperature distribution is given by: [r_e and r_i are inner and outer radius $a = r_e/r_i$]

$$\sigma_t = \frac{E\alpha\Delta t}{2(1-\mu)}\left[\frac{a^2 + \left(\frac{r_e}{r}\right)^2}{a^2 - 1} - \frac{1 + \ln\left(\frac{r}{r_i}\right)}{\ln a}\right] \quad \sigma_r = \frac{E\alpha\Delta t}{2(1-\mu)}\left[\frac{a^2 - \left(\frac{r_e}{r}\right)^2}{a^2 - 1} - \frac{\ln\left(\frac{r}{r_i}\right)}{\ln a}\right]$$

Draw the stress distribution for centrifugal heat flux and centripetal heat flux. Find the resultant stress distribution by superimposing the mechanical stress due to internal pressure p_i. 20

6. Prove that the thermal stress in a long hollow cylinder, when heated uniformly throughout its thickness is given by

$$\sigma_r = \frac{\alpha E}{(1-\mu)r^2}\left[\frac{r^2-a^2}{b^2-a^2}\int_a^b Trdr - \int_a^r Trdr\right]$$

$$\sigma_t = \frac{\alpha E}{(1-\mu)r^2}\left[\frac{r^2+a^2}{b^2-a^2}\int_a^b Trdr - \int_a^r Trdr - Tr^2\right]$$

Where 'T' represents temperature distribution and other terms have the usual meaning.

7. Prove that thermal stress developed in a hollow spherical pressure vessel for logarithmic temperature distribution is given by: [r_e and r_i are inner and outer radius $a = r_e/r_i$]

$$\sigma_t = \frac{E\alpha\Delta t}{(1-\mu)}\left[\frac{r_e}{(a-1)r} - \frac{2a}{a^2-1}\right] \text{and } \sigma_r = 0$$

. Plot the variation of stress distribution both for centrifugal and centripetal heat flux. Also study the combined effect of mechanical stresses and thermal stresses for σ_t. 20

8. A pipe made of C.I. [inner diameter 250 mm, 15 mm thick] is wound closely with a single layer of circular steel wire of 5 mm diameter, under a tension of 70 N/mm^2. Find the compressive stress in the pipe section. Also find the stresses set up in the pipe and steel wire, when water under a pressure of 3.5N/mm^2 is admitted into the pipe. Take Young's modulus E for castiron (C.I.) is 10^5 N/mm^2 and E for steel is 2X10^5 N/mm^2. Poission's ratio is 0.3.