22.314/1.56/2.084/13.14 Fall 2006

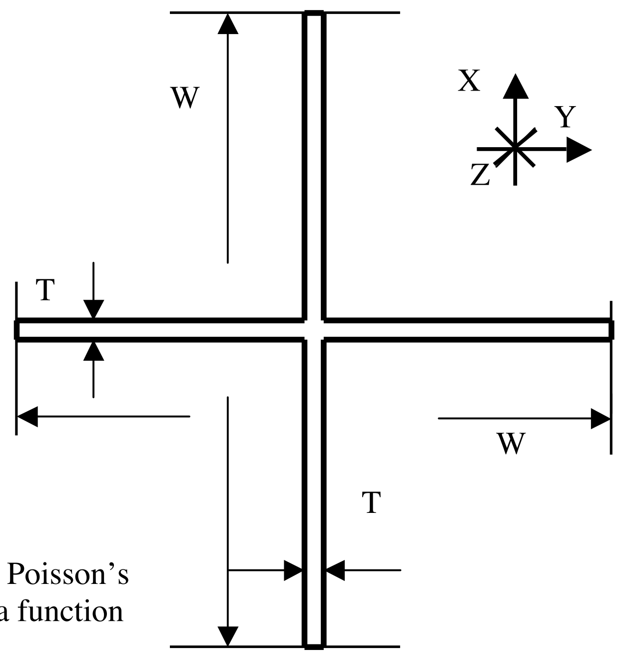
Problem Set VII

Due 11/02/06

This problem set illustrates applications of beam theory to Zircaloy Follower in a BWR for calculation of curvature caused by Zircaloy growth ; Consult Notes X on Beam Theory.

ZIRCALOY FOLLOWER

a) Geometry and Material properties :



Consider a BWR reactor core that has cruciform shaped control rods. When each control rod is fully withdrawn for power operation, it is replaced in the core by an attached "Zircaloy follower " to prevent excessive water hole peaking. The follower is also cruciform shaped and is shown in the adjacent figure. The dimensions are :

L = length in the z-direction = 2.4 m ; W = width or span = 200 mm ; and T = thickness = 7 mm.

The Zircaloy has a Young's Modulus of 75 GPa and a Poisson's Ratio of 0.25. The growth strain in the z-direction as a function of fast fluence is given by the following equation :

$$\varepsilon_{gz} = C_1 N + C_2 N^2 \quad ; \qquad (1.1)$$

where :

- the z-direction growth strain (ε_{gz}) is given in percent;
- the fast fluence (N) is given in the units of (10^{21} fast neutrons per cm^2) with the fast flux cutoff specified by E > 1 MeV; and
- the constants are $C_1 = 0.013$ and $C_2 = 0.0018$.

b) Notation and Support Information :

For points originally on the axial centerline (x = 0; y = 0), denote displacements in the x-direction, the y-direction, and the z-direction displacement, respectively, by u, v, and w.

At z = 0, the follower is supported so that u, v, and w are all zero and so that no moments are applied. At z = L, the follower is supported so that the z-direction force is zero, so that u and v are zero, and so that no moments are applied.

c) Fast Neutron Fluence:

After several refueling cycles, a follower has an accumulated fast fluence given by:

$$N = \left[N_x(x)\right]\left[N_z(z)\right] \quad ; \tag{1.2}$$

Where N is the fast fluence expressed in the units of Eq 1.1; where

$$N_x(x) \;=\; 15\left[1 + \frac{0.1\,x}{W}\right]; \text{ and where} \tag{1.3}$$

$$N_z(z) \;=\; 1.49\cos\left[\pi\frac{\left(z - \left(L/2\right)\right)}{L_e}\right] \;. \tag{1.4}$$

L_e is the extrapolated length of the core (2.54 m)

d) Questions : d.1) What is u as a function of z ? d.2) What is the value of w at z = L ?