Ans: 1 (a)

$$\sigma_\theta = -\sigma^* (1-3\eta^2) \quad \text{—(i)}$$

and, $$\sigma^* = \frac{\alpha E (T_0 - T_s)}{4(1-v)} \quad \text{—(ii)}$$

$$T_0 - T_s = \frac{LHR}{4\pi k}$$

$$= \frac{250 \text{ W/cm}}{4 \times 3.1416 \times 0.1 \text{ W/cm-K}}$$

$$= \frac{250 \text{ W/cm}}{1.2567 \text{ W/cm-K}}$$

$$= 198.934 \text{ K}.$$

From (ii) ⇒ $$\sigma^* = \frac{(8.2 \times 10^{-6})\,1/K \times 29 \times 10^4 \times 198.934\,k}{4(1-0.3)}$$

$$= \frac{461.528688}{2.8} \text{ MPa}$$

$$= 164.831 \text{ MPa}$$

∴ Maximum stress, $\sigma_\theta = -\sigma^* (1-3\eta^2)$.

$$= -164.831 (1 - 3 (1)^2)$$

$$= -164.831 \cancel{(1-0.6075)} (1-3) \quad [\because \eta = 1 \text{ when max}]$$

$$= \cancel{-697}\ 329.662 \text{ MPa}$$

Ans: 329.662 MPa.

Ans: 1 (b)

$\sigma_{frea} = 120\,MPa$.

we get, $\sigma^* = 164.831\,MPa$

$$\eta = \sqrt{\frac{(1+\sigma_{frea})/\sigma^*}{3}}$$

$$= \sqrt{\frac{\frac{1+120\,MPa}{164.831\,MPa}}{3}}$$

$$= \sqrt{\frac{0.7341}{3}}$$

$$= \sqrt{0.2447}$$

$$= 0.4947.$$

Ans: 0.4947.

Ans: TO THE Q. NO. 2.

$p = 50\,MPa$.

$\bar{R} = R = 5.4mm$

$\delta = 1.2\,mm$.

(a) Three components of stress in thin-walled cylinders, Hoop's stress. $\sigma_\theta = \frac{pR}{\delta}$

$$= \frac{50 MPa \times 5.4 mm}{1.2 mm}$$

$$= 225 MPa$$ **Ans:**

Radial stress, $\sigma_r = -\frac{p}{2}$

$$= -\frac{50 MPa}{2}$$

$$= -25 MPa$$ **Ans:**

Axial stress, $\sigma_z = \frac{pR}{2\delta}$

$$= \frac{50 MPa \times 5.4 mm}{2 \times 1.2 mm}$$

$$= 112.5 MPa.$$

Ans.

Given: $r = 5.6 mm$

(b) Three components of stress for thick-walled cylinder are →

$$\bar{R} = \frac{R_i + R_o}{2}$$

$$5.4 mm = \frac{5.6 mm + R_o}{2} \quad [\because r = R_i].$$

or, $10.8 mm - 5.6 mm = R_o$

or, $R_o = 5.2 mm$

$$\sigma_{rr} = \frac{-P\left(\frac{R_o}{r}\right)^2 - 1}{\left(\frac{R_o}{R_i}\right)^2 - 1}$$

$$= -P\,\frac{\cancel{\left(\frac{R_o}{r}\right)^2 - 1}}{\cancel{\left(\frac{R_o}{r}\right)^2 - 1}} \quad [\because r = R_i]$$

$$= -P$$

$$= -50\,MPa$$

Ans:—

$$\sigma_{\theta\theta} = P\,\frac{(R_o/r)^2 + 1}{(R_o/R_i)^2 - 1}$$

$$= 50\,MPa \times \frac{\left(\frac{5.2\,mm}{5.6\,mm}\right)^2 + 1}{\left(\frac{5.2\,mm}{5.6\,mm}\right)^2 - 1}$$

$$= 50\,MPa \times \frac{0.862 + 1}{0.862 - 1}$$

$$= 50\,MPa \times \left(\frac{1.862}{-0.138}\right)$$

$$= -674.637\,MPa$$

Ans —

$$\sigma_{zz} = P \frac{1}{(R_o/R_i)^2 - 1}$$

$$= 50\,MPa \frac{1}{(5.2mm/5.6mm)^2 - 1}$$

$$= 50\,MPa \frac{1}{-0.138}$$

$$= -362.32\ MPa.$$

/Ans:—

(d)

Maximum strain, $\epsilon_{\theta\theta} = \frac{1}{E}\{\sigma_{\theta\theta} - \nu(\sigma_{rr} + \sigma_{zz})\}$

$$= \frac{1}{180\times10^3\,MPa} \times \left[(-674.637\,MPa) - [0.28\{-50\,MPa + (-362.32\,MPa)\}]\right]$$

$$= \frac{1}{180\times10^3\,MPa}(-674.637\,MPa + 115.45\,MPa)$$

$$= \frac{-559.19\,MPa}{180\times10^3\,MPa}$$

$$= -0.003.$$

/Ans: →

ANS TO THE Q. NO.3

We know, change in the thickness of our gap,

$$\Delta \delta g = \bar{R}_C \alpha_C \Delta T - \bar{R}_F \alpha_F \Delta T_F \quad -(1).$$

$\cancel{Av(R_c) = R_f + \delta gap + \frac{t_c}{2}}$.

$\cancel{= 0.52 cm +}$

$$\bar{R}_c = Av(R_c) = R_f + t_{gap} + \frac{t_{clad}}{2}.$$

$$= 0.52 cm + 0.005 cm + \frac{0.08 cm}{2}.$$

$$= 0.565 cm$$

$$\Delta T = T_c - T_{ref} = (550-300)\,K = 250\,K.$$

$$\Delta T_F = T_f - T_{ref} = 300K - 300K = 0.$$

$\therefore$ From (1) $\Rightarrow$

$$\Delta \delta g = (0.565 cm \times 4.5 \times 10^{-6}\,1/K \times 250\,K) - 0$$

$$= 6.5 \times 10^{-4}\ cm$$

Ans: 6.5×10^{-4} cm.

(4)

$a = 8 \times 10^{-4}$

$D = 2 \times 10^{-15}$ cm²/s.

$t = 2$ years.

$y = 0.3017$.

$\dot{F} = 2 \times 10^{13}$ fission/cm³-s.

$\tau = \frac{Dt}{a^2}$.

$= \frac{1.26 \times 10^{-7}}{6.4 \times 10^{-7}}$

$= 0.196$

$\tau > \pi^{-2}$

gas production $= y \dot{F} t$.

$= 0.3017 \times 2 \times 10^{13} \times (63072000)$ s fissi/cm³-s.

$= 3.8 \times 10^{10}$ atoms

gas released = gas production × time fraction.

$= (3.8 \times 10^{10}) \times \left(1 - \frac{6}{\pi^2} e^{-\pi^2 \frac{Dt}{a^2}}\right)$

$= (3.8 \times 10^{10}) \times \{1 - (0.608 \times e^{-1.934})\}$.

$= (3.8 \times 10^{10}) \times (1 - 0.089)$ (longer time fraction.)

$= 3.46 \times 10^{10}$ atoms

Ans.

5

→ Strain hardening happens when a metal is strained beyond its ~~yie~~ yield point.

Cause:

When a metal is strained, dislocations will happen in the metal. Gradually these dislocation will interact with each other as furthere strain is applied and they will become pinned or tangled together. At this point, strain hardening will happen. If the matter is strained furthere, it will reach to the necking point and eventually rapture.

6

Three points →

1. Lattice constant decrease with increase of stoichiometry.

2. Vacancy formation energy also change with sto...

3. Solution energy of Xe, Cs and Sr in UO_2

depends on stoichiometry.

(7)

Fuel performance code:—

i) Need to have tem profile and measure volumetric change within the fuel.

ii) Must have tem profile and evaluates stress in cladding.

iii) Need to able to handle heat transport, mechanical interaction betn fuel and cladding, and pressure in the gap.

(8)

Three stages fission gas release:

(1) Gas atoms are produced due to fission and are diffused toward the grain boundaries. Small intergranular bubbles within the grains. These gas atoms never get trapped within the intragranular bubbles migrate to the GB.

ii) Nucleation happens for bubbles on the ~~gates to~~ GB and grow and interconnect.

iii) finally, the gas transports through interconnected bubbles ~~to~~ to a free surface.

(9)

High burn up leads to instability in crystalline ~~ox~~ structure and initiate a restructuring in the material. In UO_2 grain subdivide from 10mm ~~to~~ (100-200) mm size and porous structure of porosity 20%. This increase of relative porosity degrades material conductivity and the mean grain size.

(10)

Zero-D (0-D) defects: happens when there are lattice imperfections in one or two lattice sites.

Ex: In ZnS the smaller ion moves out

its place and creates 0-D effect.

3-D defects: point defects cluster and formed 3-D defect.

Ex: Often void space appear inside the metal and create 3-D defects.

(11)

Cause:

Fuel densification → evacuation of leftover pores.

Grain Growth → GB migration caused by annealing/heat treating.

(12)

Valence state of ~~UO_2 is~~ U in UO_2 is U^{4+}. Other possible states are U^{3+}, U^{4+}, U^{5+}, U^{6+}.