AML-852 Engineering Failure Analysis and Prevention

Major Test-Session (2009-2010)

Time: 2 hours **M.Marks:80**

Note: Attempt all the questions. Marks of each question are indicated in RHS

Q.1 To be answered separately and **in the beginning** on the question paper itself (20)

2. A high strength Al-Alloy has yield strength = 410 MPa, tensile strength = 550 MPa and elastic modulus = 70 GPa. The expected plane strain fracture toughness of the alloy lies in the ragne of 25-30 MPa m. (a) Suggest dimensions of a standard 3-point bend specimen to evaluate K_{Ic} toughness. (b) A test conducted using 20 mm thick standard bend specimen of the alloy with cracklength =22 mm, resulted a P-CMOD diagram with fracture load = 4950 N preceded by little nonlinearity. Evaluate the fracture toughness of material and also the size of plastic zone at fracture. (12)

Given $K_I = \frac{PS}{BW^{1.5}}\left[2.9\alpha^{0.5} - 4.6\alpha^{1.5} + 21.8\alpha^{2.5}\right]$ $(\alpha = a/W)$

3. A cylindrical steel pressure vessel of diameter (D)= 1000 mm and thickness= 20 mm is found the contain an axial crack on the inner surface of the vessel having depth= 5 mm and length = 100 mm. The crack lies along the longitudinal weld line which was not stress relieved. The yield strength and tensile strength of steel are 420 MPa and 620 MPa respectively. Using the failure assessment diagram approach(Level-1) find the maximum pressure to which the vessel could be subjected without causing brittle fracture and plastic collapse. Given, K_{IC} of steel = 90 MPa$\sqrt{m}$ (12)

$\sigma_{net} = 1.2\, M_s.\sigma_h$ where $M_s = \left[1 - \frac{a}{BM_T}\right] / \left[1 - \frac{a}{B}\right]$

$M_T = \left[1 + 3.2\left(\frac{c^2}{DB}\right)\right]^{1/2}$, $K_I = 1.12\,\sigma\sqrt{\pi a}/\phi$, $\phi = \frac{3\pi}{8} + \frac{\pi}{8}\left(\frac{a}{c}\right)^2$

4. A heat exchanger tube of Ti alloy (K_{Ic}= 135 MPa$\sqrt{m}$) was found to undergo SCC by absorption of hydrogen under a constant thermal stress of 125 MPa which was just sufficient to cause the cracking. The failure was found to be initiated through a crack like defect of 135 μm size. The crack growth rate obeys the relationship:

   $da/dt = 2.4 \times 10^{-16} (K_I)^{5.4}$ Where K_I is in MPa $\sqrt{m}$ and da/dt in m/s.

   (i) Evaluate the safe life of the tube. (ii) If the minimum inspectable size of defect is 5 mm , how much reduction in residual stress is needed to prevent the occurrence of stress corrosion cracking . Given $K_I = 1.1\sigma\sqrt{\pi a}$ where 'a' is the defect size. (12)

5. A large nuclear pressure vessel is fabricated from a 250 mm thick plate of A533 steel with an yield strength of 700 MPa. The fatigue crack propogation in the material is given as,

   $$da/dN = \frac{1.25 \times 10^{-10} (\Delta K)^{2.0}}{\sqrt{(1-R)}}$$

   Where da/dN is in m/cycle and Δ K in MPa$\sqrt{m}$.

   For a semi elliptical surface crack of depth = 5 mm and a/2c ratio =0.25, compute the number of cycles required for the crack to grow to half the thickness of the vessel when the maximum and minimum stresses in the constant amplitude loading cycle are 420 and 210 MPa respectively. The K_I expression is , $K_I = 1.12\,\sigma\sqrt{\pi a}/\phi$

   The terms have usual meaning (12)