## INDIAN INSTITUTE OF ENGINEERING SCIENCE & TECHNOLOGY SHIBPUR, HOWRAH - 3

## MECHANICAL ENGINEERING DEPARTMENT

M.E. (Mech.) Second Semester Examination, 2014 Fatigue, Creep and Fracture Mechanics (ME – 1013)

Time: 3 Hours Full Marks: 70

Answer FIVE questions
(taking TWO from Group - A & Group- B respectively
and Group C is compulsory to answer.)
The questions are of equal value.

## **GROUP A**

- 1. (a) Derive the expression for the principal creep strain,  $\varepsilon_1$  under the combined state of stresses.
  - (b) A thin walled pressure vessel of circular cross-section is subjected to an internal pressure of 8 MPa at an elevated temperature. It has a diameter of 70 cm. Determine the wall thickness based on an allowable creep strain of 0.006 m per m of diameter in two years. Given  $B_t = 6 \times 10^{-12}$  m per m per day, n = 8 and  $\sigma_0 = 7$  MPa.
    - 2. A thick walled cylinder having inner and outer radii of a and b respectively is subjected to an internal gas pressure of p. Assuming that there is no axial creep strain due to the constant volume of the cylinder, find the followings considering the octahedral shear stress:
      - (i) radial creep stress,  $\sigma_r$

- (ii) axial creep stress,  $\sigma_a$
- 3. (a) Establish the condition of fatigue failure by the octahedral shear stress theory in terms of principal stresses under the triaxial state of stress.
  - (b) Derive the above condition in terms of biaxial state of stress components.

## **GROUP B**

- 4. (a) Deduce the expression for the strain energy release rate in expanding of an elliptical shaped crack in a large plate subjected to an uniaxial tensile stress,  $\sigma$ .
  - (b) Derive the expressions for the stress components,  $\sigma_x$ ,  $\sigma_y$  and  $\tau_{xy}$  near the tip of a mode I crack assuming a suitable Westergaad's stress function. Given that  $\sigma_x = \text{Re } Z - y \text{ Im } Z'$ ,  $\sigma_y = \text{Re } Z + y \text{ Im } Z'$ ,  $\tau_{xy} = -y \text{ Re } Z'$  with the usual notations.
- 5. (a) Derive the principal stresses around the tip of a mode I crack for the case of plane stress.

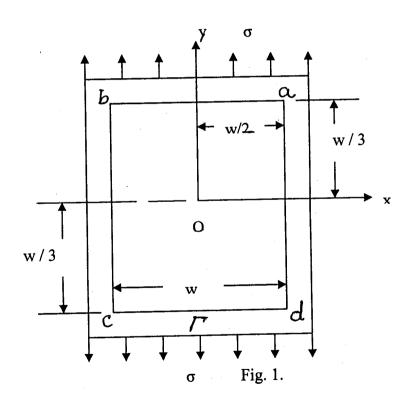
Explain Von – Mises' criterion of plane stress estimating the plastic zone size around the tip of a mode – I crack.

- (b) Explain the critical condition of a crack growth.
- 6. (a) What is Ramberg Osgood's relation for the strain under the condition of plastic flow?

Utilizing the above relation, estimate the total J-Integral for a rectangular path contour,  $\Gamma$  as the near – field contour in a single – edge notched specimen subjected to far – field stress,  $\sigma$ .

(c) Calculate the energy density, W and total J – Integral for the contour a – b – c –d – a in an Al – alloy plate as shown in Fig. 1. Use the following data:

Crack size,  $a_0 = 1.5$  mm, w = 21 mm,  $\sigma_{ys} = 65$  MPa, E = 80,000 MPa,  $\alpha = 0.35$ , n = 5, P = 1.5 kN,  $y_{23} = w/3$  and B = 1.0 mm.



- 7. Explain the following concepts:
  - (i) Stress intensity factor
  - (ii) J-Integral
  - (iii) Dugdale's approach for estimating the plastic zone size around the crack tip