Exam Date & Time: 05-Dec-2023 (02:30 PM - 05:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

SEVENTH SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV-DEC 2023

Fatigue and Fracture [MME 4067]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates:
1. Answer ALL the questions
2. Additional data (if any) may be suitably assumed

1) A) A mirror polished uniaxial loaded rod of diameter 56 mm is experiencing mean force of 180 kN. It is made from a structural steel material (S_y = 550 MPa, S_u = 670 MPa, S_f = 720 MPa, E = 200 GPa) which has completely reversed endurance strength of 300 MPa. Determine what is the allowable maximum and minimum fluctuating force that will not cause failure of the rod in 10^5 cycles. (5)

B) i) Construct schematic stress-life plot for steel (S_y = 490 MPa, S_u = 690 MPa, σ_f' = 850 MPa, E = 202 GPa) specimens for following cases.

Specimen A: 6 mm diameter, notch free, mirror polished finish, subjected to completely reversed bending.

Specimen B: 50 mm diameter, notch free, mirror polished finish subjected to completely reversed axial loading. (3)

ii) Compare and comment on observed changes in stress-life plots for above case with relevant reasoning.

C) In fracture surface analysis, when you would conclude that resulted fracture could be due to fatigue? With the help of neat sketches illustrate. (2)

2) A) It is required to design a solid circular link made of 4340 steel which is to be subjected to a spectrum of axial loads. The S-N design data based on experimental test results is shown in Table below for completely reversed cyclic stresses. (5)

S (MPa)	N (cycles)		S (MPa)	N (cycles)
1037	3500		622	216000
968	7100		553	440000
898	14200		484	1980000
829	28000		470	Infinite

The link is to be subjected to the following spectrum of completely reversed loading during each duty cycle: 970 MPa for 1000 cycles, 550 MPa for 7500 cycles. The duty cycle is repeated 2 times. After this, how many load cycles of 970 MPa could be applied as per Manson's double linear damage rule.

B) Demonstrate crack tip plasticity and the effect of plate thickness on the size and shape of plastic zone at the crack front. Draw relevant sketches. (3)

C) Draw representational monotonic and cyclic stress-strain curves showing cyclically hardening and cyclically softening behaviour in engineering materials and discuss the reasons for same. (2)

3) Listed below are the strain-life properties for high and low strength steel.

A)

Steel	σ_f' (MPa)	ε_f'	b	c	E (GPa)
Low strength (A)	800	1	− 0.1	− 0.5	200
High strength (B)	2700	0.1	− 0.08	− 0.7	200

Determine the following:

i) Transition life for both the steels (5)

ii) Strain amplitude of both the steels for a life of 500 cycles.

iii) Strain amplitude of both the steels for a life of 3×10^4 cycles.

iv) How the results obtained in i), ii) and iii) could be used by the designer to select steels A & B for an application.

v) Did the materials A & B, cyclically harden or soften?

B) A steel plate (S_y = 300 MPa, E = 198 GPa, Fracture toughness = 28.3 MPa √m) of thickness 30 mm, width 120 mm and 2 m long (in tensile stress direction) is loaded with normal tensile stress of 50 MPa. If a 64 mm long central crack (in transverse direction w.r.t. loading direction) is present, estimate the tensile stress at which catastrophic failure will occur. Also, compare it with the yield strength of the material and comment. Geometry constant f(α) may be assumed as 1. (3)

C) With relevant sketches discuss intergranular and intragranular crack propagation in metals. (2)

4) Develop an expression for critical crack length using Griffith's energy balance principle. (5)

A)

B) A centre crack detected on a large steel plate is of length 6 mm. It is assumed that the crack size is negligible as compared to the thickness of the plate and can be modelled as $da/dN = 7 \times 10^{-12} (\Delta K)^{3.2}$. The plate is subjected to constant amplitude fatigue loading of σ_{max} = 300 MPa and σ_{min} = 160 MPa. If the fracture toughness for steel material is 150 MPa√m, determine the crack length at failure and life of the component. Geometry constant β = f(α) may be assumed as 1.12. (3)

C) An axle subjected to constant amplitude cyclic service loads has been detected with a central crack during routine checks. It is now proposed to apply an overload cycle prior (2)

to continuing with previous service loads. With relevant sketches, demonstrate the implications of this overload cycle on the crack growth rate?

5) A) A notched component made up of Copper-Aluminum alloy (σ_f' = 1000 MPa, ε_f' = 1.0, b = - 0.08, c = - 0.6, E = 104 GPa) has a theoretical stress concentration factor of 2.9 and notch sensitivity factor of 0.95. It is subjected to a cyclic loading of 230 MPa to 25 MPa. Predict the life of the component using strain-life approach. (5)

B) An Aluminium alloy rod subjected to static load at elevated temperature undergoes deformation over a long period of time. Recognize the failure mode and illustrate the mechanism of such failure phenomenon in engineering materials with the help of deformation verses time curve. (3)

C) Write a note on Bauschinger effect. (2)

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