MANGALORE INSTITUTE OF TECHNOLOGY & ENGINEERING

(A Unit of Rajalaxmi Education Trust®, Mangalore)
Autonomous Institute affiliated to VTU, Belagavi, Approved by AICTE, New Delhi,
Accredited by NAAC with A+ Grade & ISO 9001:2015 Certified Institution

Model Question Paper

Seventh Semester BE Degree Examination

Fatigue and Damage Tolerant Design of Structures

Time: 3 Hours **Max. Marks: 100**

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M: Marks, L: RBT (Revised Bloom's Taxonomy) level, C: Course outcomes.

		Module -1	**M**	**L**	**C**
Q1	a.	Explain the phases of fatigue failure: crack initiation, crack growth, and final fracture, with suitable examples	10	L2	CO1
	b.	A rod of a linkage mechanism made of steel 40Cr1 (S_{ut} = 550 N/mm^2) is subjected to a completely reversed axial load of 100 kN. The rod is machined on a lathe and the expected reliability is 95%. There is no stress concentration. Determine the diameter of the rod using a factor of safety of 2 for an infinite life condition	10	L3	CO2
		OR			
Q2	a.	Describe the difference between low-cycle fatigue and high-cycle fatigue and explain the role of the endurance limit in fatigue design	10	L2	CO1
	b.	A rotating bar made of steel 45C8 (S_{ut} = 630 N/mm^2) is subjected to a completely reversed bending stress. The corrected endurance limit of the bar is 315 N/mm^2. Determine the fatigue strength of the bar for a life of 90,000 cycles.	10	L3	CO2
		Module- 2			
Q3	a.	Explain the difference between monotonic stress–strain behavior and cyclic stress–strain behavior in metallic materials.	10	L2	CO1
	b.	Two specimens are tested under strain-controlled fatigue: one polished (mirror finish) and one rough-machined. Fatigue life at a strain amplitude of 0.005 is measured as 45,000 cycles for polished and 18,000 cycles for rough surface. Determine how surface finish and material conditions influence strain–life fatigue behavior, and recommend design considerations based on the results	10	L3	CO2
		OR			
Q4	a.	Describe the significance of mean stress effects in the strain–life (ε–N) fatigue approach and how it influences fatigue life prediction.	10	L2	CO1
	b.	A material has strain–life fatigue properties: fatigue strength coefficient f'=1000 MPa, fatigue ductility coefficient f'=0.25, exponents b=-0.09 and c=-0.55. Using the Coffin–Manson strain–life equation: $\varepsilon_a = \frac{\sigma'_f}{E}(2N)^b + \varepsilon'_f(2N)^c$ Assume E=210 GPa and strain amplitude a=0.006. Determine the fatigue life (N).	10	L3	CO2

<table>
<tr><th colspan="6">Module – 3</th></tr>
<tr><td rowspan="2">Q5</td><td>a.</td><td>Explain the different loading modes (Mode I, Mode II and Mode III) in Linear Elastic Fracture Mechanics and their relevance to crack propagation in structural components.</td><td>10</td><td>L2</td><td>CO3</td></tr>
<tr><td>b.</td><td>A compact tension (CT) specimen is tested under constant amplitude loading with an applied stress range such that $da/dN=C(\Delta K)^m$ and $\Delta K=22$ MPa √m Using the Paris Law equation with C=5×10-12and m=3.2, Determine the crack growth rate (da/dN). Based on the result, briefly interpret whether the crack is likely in the Paris region, threshold region, or unstable growth region of the fatigue crack growth curve.</td><td>10</td><td>L3</td><td>CO4</td></tr>
<tr><th colspan="6">OR</th></tr>
<tr><td rowspan="2">Q6</td><td>a.</td><td>Describe the significance of fracture toughness (K_c / K_{IC}) and its role in predicting failure in cracked structures under cyclic or static loading</td><td>10</td><td>L2</td><td>CO3</td></tr>
<tr><td>b.</td><td>A plate with a central through-thickness crack of 8 mm is subjected to a tensile stress of 120 MPa. Using the formula for Mode I stress intensity factor: $K=\sigma\pi a$ calculate the stress intensity factor (K) and determine whether crack propagation is expected if the material has a fracture toughness of K_{IC} = 55 MPa √m</td><td>10</td><td>L3</td><td>CO4</td></tr>
<tr><th colspan="6">Module – 4</th></tr>
<tr><td rowspan="3">Q7</td><td>a.</td><td>Explain the concept of spectrum loading and how it differs from constant-amplitude loading in fatigue analysis.</td><td>10</td><td>L2</td><td>CO3</td></tr>
<tr><td>b.</td><td>A component is subjected to variable-amplitude loading with the following load history: a) 3000 cycles at 250 MPa, where the fatigue strength at this stress level is 10,000 cycles. b) 5000 cycles at 180 MPa, where the fatigue strength at this level is 50,000 cycles. Using the Palmgren–Miner damage rule, determine the cumulative fatigue damage and state whether failure is expected?</td><td>05</td><td>L3</td><td>CO4</td></tr>
<tr><td>c.</td><td>A material follows the stress–life relation: $\sigma_a = \sigma_f'(2N)^b$ where the fatigue strength coefficient is $\sigma_f' = 950$ MPa and the fatigue strength exponent is $b = -0.12$. Determine the fatigue life (N) for an applied stress amplitude of 300 MPa. Determine the fatigue life and comment on its suitability for design under spectrum loading conditions.</td><td>05</td><td>L3</td><td>CO4</td></tr>
<tr><th colspan="6">OR</th></tr>
<tr><td rowspan="2">Q8</td><td>a.</td><td>Describe the purpose of the rainflow cycle-counting method in fatigue life estimation and why it is preferred over simpler counting techniques.</td><td>10</td><td>L2</td><td>CO3</td></tr>
<tr><td>b.</td><td>Steel component is subjected to the following variable-amplitude fatigue loading spectrum as given in the table. Using the Palmgren–Miner rule, determine: a) The cumulative fatigue damage? b) Whether failure is expected? c) The remaining life, if failure has not occurred?
<table>
<tr><th>Load Level</th><th>Stress Amplitude (MPa)</th><th>Number of Cycles Applied (N)</th><th>Fatigue Life from S–N Curve (N)</th></tr>
<tr><td>1</td><td>300 MPa</td><td>2,000 cycles</td><td>10,000 cycles</td></tr>
<tr><td>2</td><td>250 MPa</td><td>5,000 cycles</td><td>40,000 cycles</td></tr>
<tr><td>3</td><td>200 MPa</td><td>20,000 cycles</td><td>100,000 cycles</td></tr>
</table>
</td><td>10</td><td>L3</td><td>CO4</td></tr>
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Module - 5					
Q9	a.	Explain the Safe-Life design philosophy used in aircraft structures. Discuss its advantages, limitations, and typical applications.	07	L2	CO5
	b.	Discuss the recommended design practices used to improve fatigue resistance in aircraft structures. Provide suitable examples.	07	L2	CO5
	c.	Describe different types of fatigue loading experienced by aircraft structures. Explain their effect on structural components.	06	L2	CO5
OR					
Q10	a.	Explain how corrosion fatigue and fretting fatigue influence fatigue life and structural reliability in aerospace structures.	07	L2	CO5
	b.	Summarize how low-temperature fatigue and high-temperature fatigue affect fatigue behavior and influence design considerations for fatigue-critical components.	07	L2	CO5
	c.	Describe the Damage Tolerance design philosophy. Explain how crack detection and inspection intervals play a role in ensuring structural safety.	06	L2	CO5

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