FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF METALLURGICAL ENGINEERING

ENGINEERING FAILURE ANALYSIS

EMR 3101

Final Examination Paper

JUNE 2019

This examination paper consists of **3** pages

Time Allowed: 3 hours

Total Marks: 100

Examiner's Name: Mr. Quinton Dean Chingoka

INSTRUCTIONS

1. Answer **ANY FIVE QUESTIONS**
2. Each question carries 20 marks
3. Use of calculators is permissible

Additional Requirements

N/A

MARK ALLOCATION

Question 1 to 6	**20 Marks**
Part Questions	**As shown in each part question**
Total Attainable	**100**

Question 1

Using materials examples of your choice, briefly describe the difference between the following types of environmental degradation. (Note: Your answer should consider the condition(s) responsible for each type of attack and the expected appearance of the material (i.e. microstructure) during or following failure).

(a) Stress-corrosion cracking *(5 marks)*

(b) Hydrogen embrittlement *(5 marks)*

(c) Corrosion fatigue *(5 marks)*

(d) Cavitation erosion *(5 marks)*

Question 2

(a) Regarding fracture mechanics analysis, what is the difference between critical crack growth and stable crack growth? Give one example of each. Concise is good. (*10 marks*)

(b) Explain the failures in weldments and their remedies. (*10 marks*)

Question 3

(a) Consider a nominal stress-strain curve for a ductile material loaded in tension. At the point of plastic instability, the work hardening capability of the material is balanced by the applied stress. The work-hardening rate of materials is usually described by a power law of the form: $\sigma = K\varepsilon^{n}$ where σ and ε are the true stress and true strain respectively; K is a constant and n is the work hardening exponent. Show that plastic instability (i.e. necking) occurs when ε=n. *(10 marks)*

(b) A 1.5mm thick, 80mm wide sheet of magnesium that is originally 5m long is to be stretched to a final length of 6.2m. What should be the length of the sheet before the applied stress is released? (E=65GNm^{-2} and σ_y=200MNm-2). *(10 marks)*

Question 4

(a) Briefly describe the mechanical test procedures for creep and fatigue testing of a material of your choice and schematically illustrate how the mechanical property data is represented (i.e. compare a typical "creep curve" with a typical "fatigue curve").

(10

marks)

(b) A steel part can be made by powder metallurgy or by machining from a solid block. Which part is expected to have the higher toughness? Explain. *(10 marks).*

Question 5

(a) A relatively large sheet of steel with a fracture toughness, $K_c = 25 MPa\sqrt{m}$ is to be exposed to a cyclic tensile stress of 100 MPa. Prior to testing it has been determined that the component contains surface cracks up to as large as a=20mm in length. If the cyclic crack growth rate is under steady state conditions where,

$$\frac{da}{dN} = A(\Delta K)^n$$

Given $A = 1 \times 10^{-12} MPa^{-3} m^{-1/2}$ and n=3; estimate the fatigue life (i.e. the number of cycles to failure, Nr). *(10 marks)*

(b) The nominal stress-strain curve for a tough engineering material, as obtained from a tensile test for example, defines the stresses for the onset of general yielding (σ_y) and final fracture (σ_f). However, it is known that materials can catastrophically fail at stresses, $\sigma < \sigma_y$ such that the stress-strain curve becomes a poor measure of the integrity of a material. Describe in sufficient detail two different conditions and the associated mechanisms whereby a tough material can fail at stresses $\sigma < \sigma_y$. *(10 marks)*

Question 6

(a) Steel plate is to be used in the construction of a marine vessel. The steel has a fracture toughness (Kc) of $53 MNm^{-3/2}$ and a yield strength (σ_y) of $950 MNm^{-2}$. It is possible that surface cracks may be produced during construction and the smallest surface crack depth that can be detected by ultrasonic inspection methods is a=1.0mm. Assuming that the plate contains cracks at the limit of detection, determine whether the plate will undergo general yield or will fail by fast fracture before general yielding occurs. *(10 marks)*

(b) Why are large structures (e.g. ships, bridges and oil rigs) made of steel much more likely to fail in cold winter environments rather than in warm summer climates? *(5 marks)*

(c) Briefly explain why HCP metals are typically more “brittle” than FCC and BCC Metals. *(5 marks)*