for CSES library. room Ph

CARLETON UNIVERSITY

FINAL
EXAMINATION
December 1993

DURATION: 3 HOURS

No. of Students: **35**

Department Name & Course Number: **Mechanical & Aerospace Engineering 87.370A**
Instructor(s) **M. McDill**

AUTHORIZED MEMORANDA
One crib sheet, 8 1/2" x 11" (both sides), calculator.

Students **MUST** count the number of pages in this examination question paper **before** beginning to write, and report any discrepancy immediately to a proctor. This question paper has 5 pages.

This examination question paper **MAY** be taken from the examination room.

All questions have equal value. The mark distribution for each question is shown by [ ]. Read the exam paper carefully. Some questions are mandatory. Some questions may be chosen.

Do **BOTH** 1 and 2.

1 a) A carbon-reinforced epoxy composite is a candidate for a certain aerospace application. The room temperature properties and volume percent for the carbon fibre and epoxy are given below. **[5]**

Material	$E^{\parallel}$ (GPa)	ρ (g/cm^3)	v/o
C fibre	250	1.75	54
epoxy resin	3.72	1.35	46

If the composite uses unidirectional continuous fibres estimate its density and its elastic modulus parallel to the fibres.

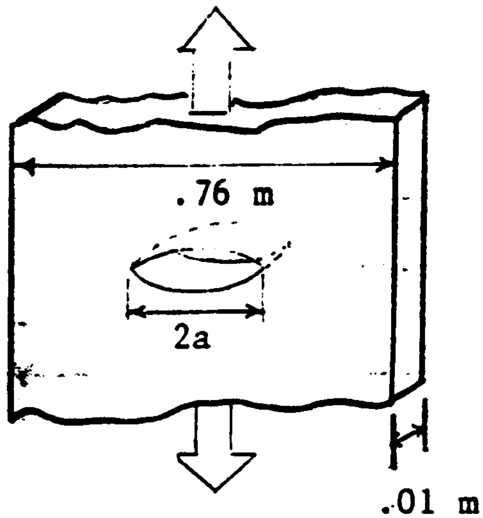
b) The composite in part (a) is to be compared to Ti-6Al-4V with E = 110 GPa and $\rho = 4.43$ g/cm^3.

The two candidate materials are to be used in compression for a member with a rectangular cross-section.

Use an appropriate relationship to rank the two materials, for this application, if $\frac{b}{t}$ is a constant. **[5]**

2. A large panel with a through-thickness centre crack ($2a = 2.54 \times 10^{-3}$ m) is cyclically loaded from 0 MPa to 97 MPa. The panel is 0.76 m wide and 0.01 m thick. The panel is fabricated from a material with a fracture toughness of $28\ MPa\sqrt{m}$. Fatigue crack growth can be approximated by the Paris Law, $\frac{da}{dN} = A\Delta K^{m}$. For this material

$$A = 3.4 \times 10^{-11} \frac{m/cycle}{\left(MPa\sqrt{m}\right)^{3}} \text{ and } m = 3. \text{ Assume } Y = 1.$$



a) Calculate the critical length. [3]

b) Determine the number of fatigue cycles to failure. [5]

c) Briefly discuss what is meant by damage tolerant design. [2]

Do <u>either</u> 3 <u>or</u> 4

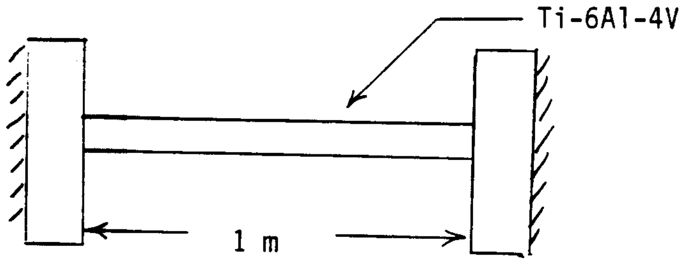
3. A 1 m piece of Ti-6Al-4V is carefully positioned, stress free, at 20°C between two endplates as shown below.

The Ti-alloy is heated and eventually yields in compression. On cooling it falls out of the end pieces and is found to be 2 mm shorter than its original length; i.e., there has been plastic strain.

Assume the material is elastic perfectly-plastic, so that it can be assumed that only plastic strain occurs after the yield point.

a) Determine the temperature reached during the heating cycle. **[7]**

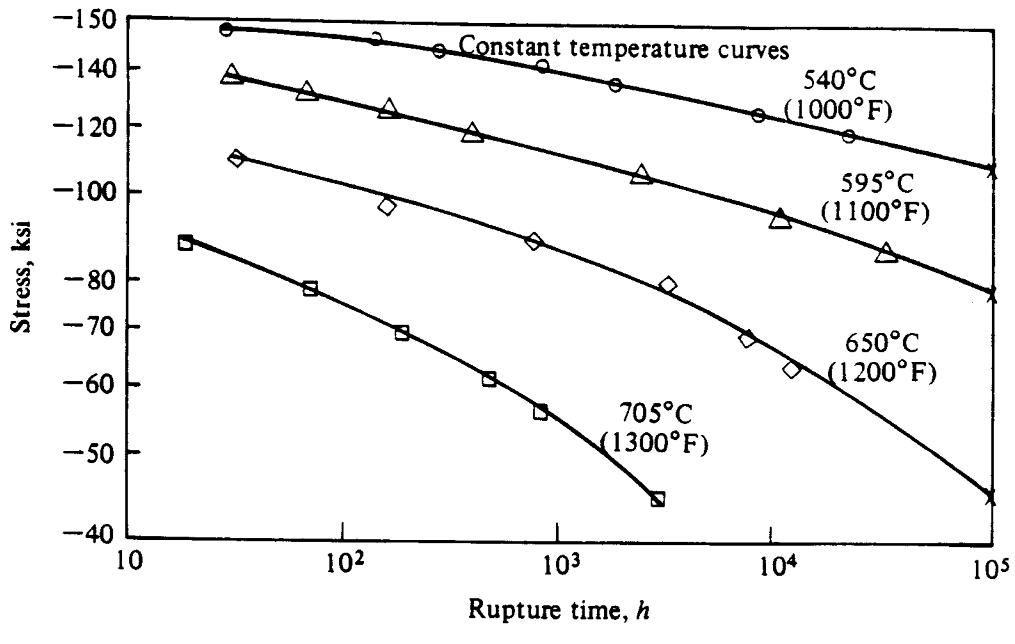
$$\alpha = 9x10^{-6}{}^{\circ}C^{-1}, \quad E = 110\ GPa, \quad Sy(compression) = 1100\ MPa$$



b) What assumption have you made in your solution for part (a)? **[1]**

c) List any difficulties this Ti-alloy might have at this service temperature. **[2]**

4. Creep rupture data for a nickel-based superalloy, Inconel 718, are given below. <u>Estimate</u> the temperature to which Inconel 718 could be subjected and still provide a service life of 10,000 hours under a service stress of 690 MPa before failing by creep rupture. Note: 1 ksi = 6.9 MPa. **[10]**



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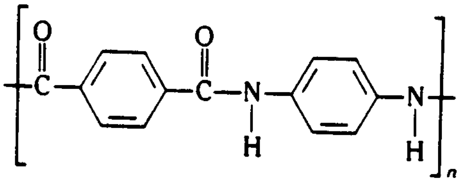
Do either 5 or 6

5 a) The repeating chemical structural unit for a certain polymer is shown below: **[2]**



Is the polymer a polycarbonate, a polyimide, a polyamide or a polysulfone? Clearly explain your choice.

b) Briefly explain why atomic oxygen is a problem for polymers in low earth orbit. **[3]**

c) Briefly explain how UV and X-ray radiation can degrade the properties of polymers in low earth orbit. **[3]**

d) Why is outgassing of polymers a problem in low earth orbit? **[2]**

6 a) A certain aerospace application requires a plastic with excellent optical qualities, which will be subject to regular exposure to outdoor weathering, and occasional exposure to mild cleaners such as windex with ammonia. The objects will also be immersed in water for long periods. Suggest a polymeric material suitable for this application. Briefly explain your choice. **[5]**

b) Three manufacturing methods are available for this application: i) casting plus machining; ii)injection molding, iii) thermoforming. Assuming the objects are shaped and sized much like a deep soup bowl, select an appropriate manufacturing method from the three. Briefly explain your choice. **[5]**

Do either 7 or 8

7. Briefly discuss the differences that exist between a typical fatigue failure in a metal component and a fatigue failure in a typical laminated composite component. **[10]**

8. An aircraft maintenance worker accidently drops a large 3 kg wrench on an Al-alloy wing skin panel. While examining the damage, a second wrench, also 3 kg, falls out of the worker's pocket onto a C-fibre reinforced polymer panel nearby.

Discuss the difference(s) in the types of damage, if any, which will have occurred to the Al-alloy panel and the CRP panel. **[10]**

Jm
PA

Do ALL remaining questions.

9 a) Briefly explain why partially stabilized ZrO_2 is tougher than many other ceramics. **[4]**

b) Sketch the stress-strain curve typical of most ceramics. Include the compressive and tensile ranges. Label all axes and important features. **[3]**

c) Why do ceramics tend not to yield and slip? **[3]**

10 a) Small diameter fibres are recommended as reinforcement in ceramic matrix composites. However, large diameter fibres are recommended for use in metal matrix composites. Briefly explain the reason(s) for this difference. **[5]**

b) What three toughening mechanisms are thought to play a role in toughening ceramic matrix composites? Briefly explain why each mechanism improves toughness. **[5]**

11 a) Briefly discuss the evolution of the design of the manufacturing processes used for turbine blades in aeroengines. **[6]**

b) What is the purpose of a thermal barrier coating on turbine blades in the hottest sections of gas turbine engines? **[2]**

c) Why are ceramics frequently used for thermal barrier coatings? **[2]**

12 a) Sketch the load-elongation curve typical of a ductile material at room temperature. Clearly show the region associated with diffuse necking. **[2]**

b) Sketch the load-elongation curve typical of superplastic forming. Clearly show the region associated with diffuse necking. **[2]**

c) Briefly list the requirements of a material which can be superplastically formed. **[4]**

d) Briefly list the attributes of diffusion bonding. **[2]**

13 Several video presentations dealing with manufacturing processes were given in class this year.

a) Which presentation did you find most interesting? Briefly discuss why you found it interesting. **[7]**

b) List three key points made during the video. **[3]**

ENJOY YOUR HOLIDAYS.