UNIVERSITI SAINS MALAYSIA

Course Examination During Long Vacation
Academic Session 2008/2009
Peperiksaan Kursus Semasa Cuti Panjang
Sidang Akademik 2008/2009

June 2009
Jun 2009

ESA 423/3 – Aerospace Materials & Composite
Bahan Aeroangkasa & Komposit

Duration : 3 hours
Masa : [3 jam]

ARAHAN KEPADA CALON :
INSTRUCTION TO CANDIDATES

Please ensure that this paper contains **TEN (10)** printed pages and **FIVE(5)** questions before you begin examination.
Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH (10)** *mukasurat bercetak dan* ***LIMA(5)*** *soalan sebelum anda memulakan peperiksaan ini.*

Answer **ALL** questions.
Jawab ***SEMUA*** *soalan.*

All questions carry the same marks.
Semua soalan membawa jumlah markah yang sama

Student have to answer the question in English.
Pelajar perlu menjawab soalan dalam Bahasa Inggeris.

Each questions must begin from a new page.
Setiap soalan mestilah dimulakan pada mukasurat yang baru.

Appendix/Lampiran

1. Table 1.1 Tensile properties of Some Metallic and Structural Composite Materials [2 pages/mukasurat]
2. Table 2.1 Properties of Selected Commercial Reinforcing Fibers [1 pages/mukasurat]

1. (a) What are the differences between steel, aluminium and brittle materials with respect to tensile stresses? Explain them by using the respective stress-strain diagrams.

Apakah perbezaan di antara keluli, aluminium dan bahan rapuh terhadap tegasan tegangan? Terangkan dengan menggunakan rajah tegasan-terikan.

(20 marks/*markah*)

(b) In aircraft and aerospace applications, the obligation to obtain high specific material properties is mandatory as the mass/weight is a key design of the structures. Please discuss **three (3)** available methods to enhance the mechanical properties in metals.

Dalam aplikasi-aplikasi kapal terbang dan aero-angkasa, keperluan untuk mencapai ciri-ciri spesifik bahan yang tinggi adalah keutamaan kerana jisim/berat adalah kunci kepada rekabentuk sesuatu struktur. Bincangkan ***tiga (3)*** *kaedah sedia ada untuk meningkatkan ciri-ciri mekanikal bagi logam-logam.*

[30 marks/*markah*]

(c) Alloys material can be classified into two main categories; namely solid solutions and intermediate phases.

Bahan aloi boleh dibahagikan kepada dua kategori utama; iaitu penyelesaian pepejal dan fasa pertengahan.

(i) Discuss the definition of the alloys and their categories in respect to the compositions of the single-phase structure.

Bincangkan definisi aloi dan kategori-kategorinya berdasarkan komposisi struktur fasa-tunggal.

(ii) Discuss the intermediate phase with respect to the discrepancies from the solid solutions.

Bincangkan kategori fasa pertengahan berdasarkan perbezaan–perbezaan berbanding kategori penyelesaian pepejal.

(iii) The significance and application of the inverse lever rule in the alloys system; and

Kepentingan dan aplikasi hukum "inverse lever" dalam sistem aloi; dan

[50 marks/*markah*]

2. (a) In fabrication of polymer matrix composite (PMC), the selection of matrix between thermosets and thermoplastic proved to be a key element in determining the performance of the material. Discuss comprehensively the design requirements for fabrication of the high performance composites. The discussion may include the mechanical requirements, advantages and disadvantages, thermal and dimensional stabilities.

Dalam fabrikasi komposit polimer matriks (PMC), pemilihan matriks di antara set-terma dan plastik-terma telah terbukti sebagai satu elemen penting dalam menentukan prestasi bahan tersebut. Bincangkan secara menyeluruh keperluan rekabentuk untuk pembikinan komposit berprestasi tinggi. Perbincangan tersebut hendaklah merangkumi keperluan mekanikal, kebaikan dan keburukan, terma dan stabiliti dimensi.

(40 marks/*markah*)

(b) In a certain application, a steel beam (AISI 4340 steel) of round cross section (diameter = 10 mm) is to be replaced by a unidirectional fiber-reinforced epoxy beam of equal length. The composite beam is designed to have a natural frequency of vibration 50% higher than that of the steel beam. Among the fibers to be considered are high-strength carbon fiber, high-modulus carbon fiber and Kevlar 49. By using the given table, select one of these fibers on the basis of minimum weight for the beam and the design requirement.

Satu rasuk besi (AISI 4340 besi) yang mempunyai keratan rentas bulatan (diameter = 10 mm) bakal digantikan dengan satu rasuk epoksi bertetulang fiber eka-arah yang mempunyai panjang yang sama. Rasuk komposit tersebut direkabentuk untuk mempunyai frekuensi asli getaran 50% lebih tinggi daripada rasuk besi. Antara fiber yang sesuai adalah fiber karbon kekuatan tinggi, fiber karbon modulus tinggi dan Kevlar 49. Dengan menggunakan jadual yang diberi, pilih salah satu fiber yang dinamakan di atas berdasarkan penentuan berat minimum rasuk dan keperluan rekabentuk.

Note that the natural frequency of vibration of a beam is given by the following equation:

Nota: Frekuensi asli getaran rasuk adalah seperti persamaan di bawah:

$$\omega_n = C\left(\frac{EI}{mL^4}\right)^{1/2}$$

Where:
Di mana:

ω_n = fundamental natural frequency
ω_n = *frekuensi asli asas*

C = a constant that depends on the beam support conditions
C = *pemalar yang bergantung kepada keadaan penyokong rasuk*

E = modulus of the beam material
E = *modulus rasuk bahan*

I = moment of inertia of the beam cross section
I = *momen inersia keratan rentas rasuk*

m = mass per unit length of the beam
m = *jisim per unit panjang rasuk*

L = beam length
L = *panjang rasuk*

(60 marks/*markah*)

3. (a) Assume that the area under the stress-strain diagram of a material is a measure of its toughness. Using the stress-strain diagram shown in Figure 3(a), compare the toughnesses of three matrix resins considered. Explain how the toughness values contribute to the performance of the materials.

Andaikan luas di bawah rajah tegasan-terikan sesuatu bahan adalah ukuran kekuatan. Dengan menggunakan rajah tegasan-terikan seperti ditunjukkan dalam Rajah 3(a), bandingkan kekuatan ketiga-tiga damar matriks yang ditunjukkan. Terangkan bagaimana nilai kekuatan menyumbang kepada prestasi bahan-bahan tersebut.

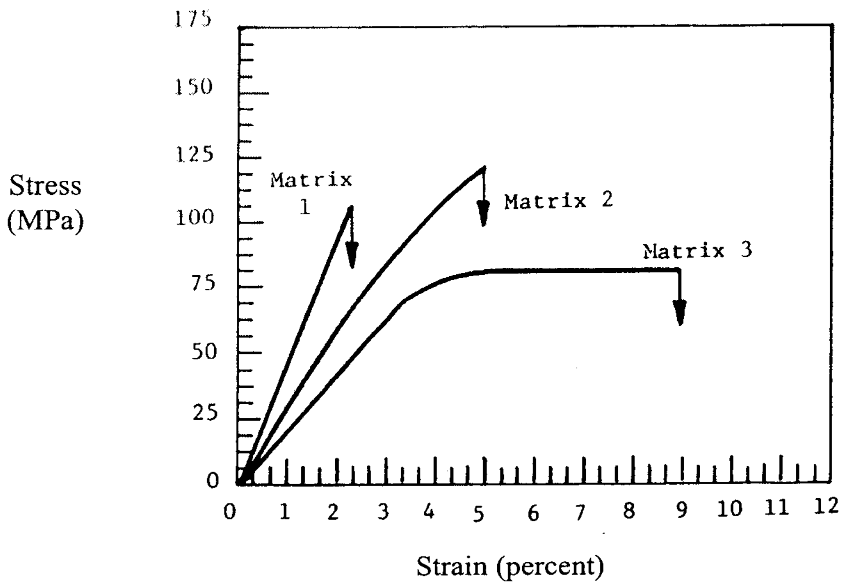

Figure 3(a)/*Rajah 3(a)*

[40 marks/*markah*]

(b) Tensile stress-strain diagram of a $[0/90_4]_S$ AS-4 carbon fiber/epoxy laminate is shown in Figure 3(b). The longitudinal and transverse modulus of a 0^0 unidirectional laminate of the same material are 142 and 10.3 GPa, respectively.

Rajah tegangan tegasan-terikan $[0/90_4]_S$ AS-4 gentian karbon/epoksi yang berlapis ditunjukkan dalam Rajah 3(b). Modulus longitud dan melintang untuk 0^0 eka-arah bahan berlapis yang sama bahannya adalah 142 dan 10.3 GPa.

(i) Determine the initial axial modulus of the $[0/90_4]_S$ laminate and compare it with the theoretical value. How would this value change if the 90^0 layers are at the outside or the laminate construction is changed to $[0_2/90_3]_S$?

Tentukan modulus awal paksi bagi $[0/90_4]_S$ berlapis dan bandingkan dengan nilai yang dapat secara teori. Bagaimana nilai ini berubah sekiranya 90^0 lapisan ini berada di luar atau pembinaan berlapis diubah menjadi $[0_2/90_3]_S$?

(ii) The knee in the stress-strain diagram is at a strain of 0.005 mm/mm. However, the ultimate longitudinal and transverse strains of the 0^0 unidirectional laminate are at 0.0146 and 0.006 mm/mm, respectively. Explain what might cause a lower strain at the knee.

Lutut dalam rajah tegasan-terikan berada pada terikan 0.005 mm/mm. Bagaimanapun, terikan muktamad longitud dan melintang 0^0 eka-arah berlapis berada pada 0.0146 dan 0.006 mm/mm. Terangkan, apakah punca yang menyebabkan terikan yang rendah pada lutut.

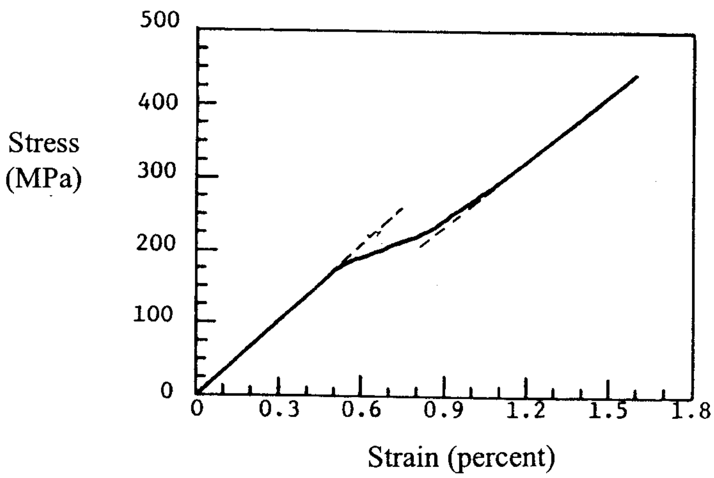

Figure 3(b)/*Rajah 3(b)*

(60 marks/*markah*)

4. (a) Figure 4(a) shows two types of stress-strain behaviors of a CFRP composite consisting of unidirectional carbon fibers and epoxy matrix. Discuss the behaviors of the material regarding the relative magnitudes of the ultimate tensile strains of the constituents and effects to the overall load distribution and energy absorbing capabilities of the composites.

Rajah 4(a) menunjukkan dua jenis sifat bagi tegasan-terikan komposit CFRP yang mengandungi gentian karbon eka-arah dan matrik epoksi. Bincangkan sifat-sifat bahan tersebut berdasarkan nilai-nilai relatif tegangan terikan akhir bahan-bahan komponen dan kesan-kesan kepada keseluruhan daya agihan dan keupayaan tenaga penyerapan bagi komposit.

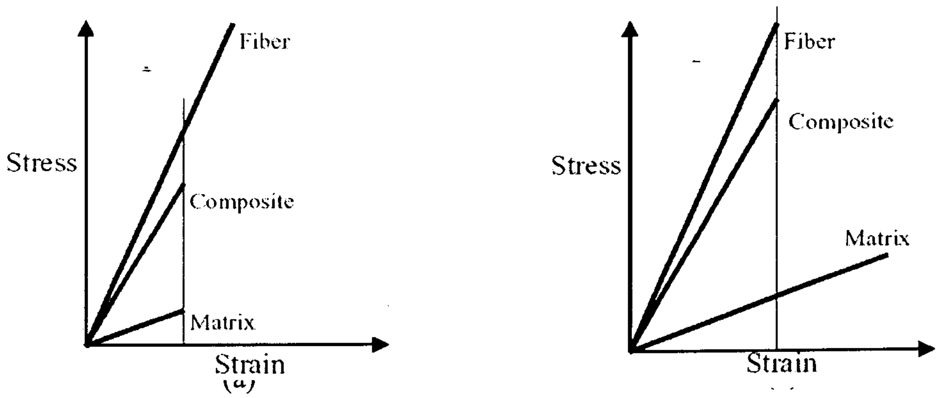

Figure 4(a)/*Rajah 4(a)*

[50 marks/*markah*]

(b) Figure 4(b) provides a schematic of the failure sequences observed in quasi-static and low-velocity tests on sandwich beams composite. The figure outlines four different cases in respect to the type of failures.

Rajah 4(b) menunjukkan satu lukisan skematik urutan kegagalan yang ditemui ketika ujian quasi-statik dan halaju-rendah pada rasuk-rasuk komposit sandwich. Rajah tersebut menggariskan empat kes yang berlainan berdasarkan jenis-jenis kegagalan.

(i) Discuss types of the failure mechanisms for each case.

Bincangkan jenis-jenis mekanisme kegagalan bagi setiap kes.

(ii) Determine the best failure modes for energy absorption and explain the reason.

Tentukan mod kegagalan terbaik bagi serapan tenaga dan terangkan sebab-sebabnya.

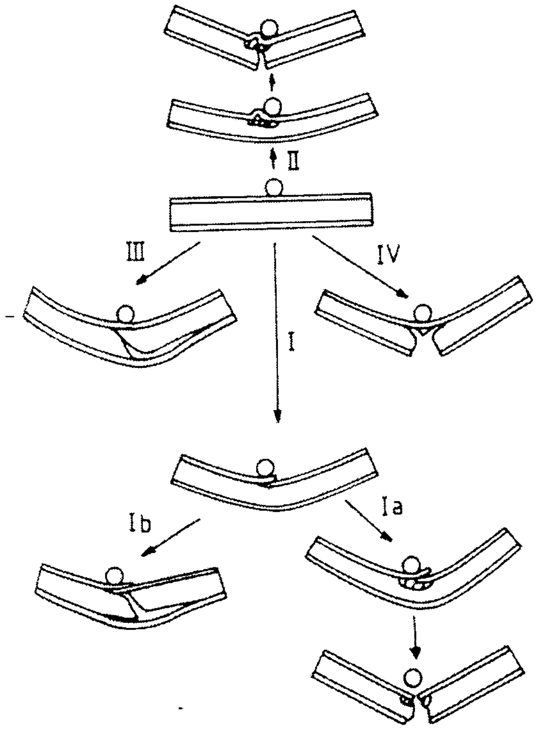

Figure 4(b)/*Rajah 4(b)*

[50 marks/*markah*]

5. (a) Name **TWO (2)** manufacturing processes of composite materials. For each process, discuss its main advantages and disadvantages.

*Namakan **DUA (2)** proses pembuatan dalam bahan komposit. Untuk setiap proses, bincangkan kebaikan dan keburukan.*

[20 marks/*markah*]

(b) What manufacturing process would you recommend to produce a cylindrical tube for **EACH** of the following configurations of the reinforcement? Elaborate your answer on the criteria you applied for the decision of the processes.

*Proses pembuatan manakah yang anda memperakukan dalam menghasilkan tiub selinder untuk **SETIAP** konfigurasi yang berikut untuk tetulang? Terangkan dengan terperinci jawapan anda untuk criteria yang anda telah pilih untuk proses-proses tersebut?*

(i) A combination of unidirectional and $\pm 45^0$ (angle measured with respect to the axis of the tube).

Satu kombinasi eka-arah dan $\pm 45^0$ (sudut diukur daripada paksi tiub tersebut)

(ii) Only chopped or CSM reinforcement.

Hanya tertulang potong atau CSM

[40 marks/*markah*]

(c) What manufacturing process would you recommend to produce a large quantity of the following parts while minimizing cost? Discuss your decision in term of the suitability of the process, productivity and the cost.

Proses pembuatan manakah yang anda akan memperakukan dalam penghasilan satu kuantiti besar untuk yang berikut sambil meminimumkan kos? Terangkan dengan terperinci dalam bentuk kesesuaian proses, produktiviti dan kos.

(i) Automotive door panel where structural performance is not critical but surface finish must be excellent.

Panel pintu automotif di mana prestasi struktur adalah tidak kritikal tetapi kemasan permukaan mestilah bagus.

...10/-

(ii) Aircraft door panel where structural performance is critical but surface finish is not important.

Panel pintu pesawat di mana prestasi struktur adalah kritikal tetapi permukaan adalah tidak penting.

[40 marks/*markah*]

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APPENDIX/*LAMPIRAN*

Table 1.1 Tensile Properties of Some Metallic and Structural Composite Materials

Material[a]	Specific gravity	Modulus, GPa (Msi)	Tensile strength, MPa (ksi)	Yield strength, MPa (ksi)	Ratio of modulus to weight,[b] 10^6 m	Ratio of tensile strength to weight,[b] 10^3 m
SAE 1010 steel (cold-worked)	7.87	207 (30)	365 (53)	303 (44)	2.68	4.72
AISI 4340 steel (quenched and tempered)	7.87	207 (30)	1722 (250)	1515 (220)	2.68	22.3
AL 6061-T6 aluminum alloy	2.70	68.9 (10)	310 (45)	275 (40)	2.60	11.7
AL 7178-T6 aluminum alloy	2.70	68.9 (10)	606 (88)	537 (78)	2.60	22.9
Ti-6A1-4V titanium alloy (aged)	4.43	110 (16)	1171 (170)	1068 (155)	2.53	26.9
17-7 PH stainless steel (aged)	7.87	196 (28.5)	1619 (235)	1515 (220)	2.54	21.0
INCO 718 nickel alloy (aged)	8.2	207 (30)	1399 (203)	1247 (181)	2.57	17.4

Table 1.1 (continued)

Material[a]	Specific gravity	Modulus, GPa (Msi)	Tensile strength, MPa (ksi)	Yield strength, MPa (ksi)	Ratio of modulus to weight,[b] 10^6 m	Ratio of tensile strength to weight,[b] 10^3 m
High-strength carbon fiber-epoxy (unidirectional)	1.55	137.8 (20)	1550 (225)	—	9.06	101.9
High-modulus carbon fiber-epoxy (unidirectional)	1.63	215 (31.2)	1240 (180)	—	13.44	77.5
E-glass fiber-epoxy (unidirectional)	1.85	39.3 (5.7)	965 (140)	—	2.16	53.2
Kevlar 49 fiber-epoxy (unidirectional)	1.38	75.8 (11)	1378 (200)	—	5.60	101.8
Boron fiber-6061 Al alloy (annealed)	2.35	220 (32)	1109 (161)	—	9.54	48.1
Carbon fiber-epoxy (quasi-isotropic)	1.55	45.5 (6.6)	579 (84)	—	2.99	38

[a]For unidirectional composites, the reported modulus and tensile strength values are measured in the direction of fibers.
[b]The modulus-weight ratio and the strength-weight ratios are obtained by dividing the absolute values with the specific weight of the respective material. Specific weight is defined as weight per unit volume. It is obtained by multiplying density by the acceleration due to gravity.

Table 2.1 Properties of Selected Commercial Reinforcing Fibers

Fiber	Typical diameter, (μm)[a]	Specific gravity	Tensile modulus, GPa (Msi)	Tensile strength, GPa (ksi)	Strain to failure, (%)	Coefficient of thermal expansion ($10^{-6}/^{\circ}C$)[b]	Poisson's ratio
Glass							
E-glass	10 (round)	2.54	72.4 (10.5)	3.45 (500)	4.8	5	0.2
S-glass	10 (round)	2.49	86.9 (12.6)	4.30 (625)	5.0	2.9	0.22
PAN carbon							
T-300[c]	7 (round)	1.76	231 (33.5)	3.65 (530)	1.4	−0.6 (longitudinal) 7–12 (radial)	0.2
AS-1[d]	8 (round)	1.80	228 (33)	3.10 (450)	1.32		
AS-4[d]	7 (round)	1.80	248 (36)	4.07 (590)	1.65		
T-40[c]	5.1 (round)	1.81	290 (42)	5.65 (820)	1.8	−0.75 (longitudinal)	
IM-7[d]	5 (round)	1.78	301 (43.6)	5.31 (770)	1.81		
HMS-4[d]	8 (round)	1.80	345 (50)	2.48 (360)	0.7		
GY-70[e]	8.4 (bilobal)	1.96	483 (70)	1.52 (220)	0.38		
Pitch carbon							
P-55[c]	10	2.0	380 (55)	1.90 (275)	0.5	−1.3 (longitudinal)	
P-100[c]	10	2.15	758 (110)	2.41 (350)	0.32	−1.45 (longitudinal)	
Aramid							
Kevlar[f] **49**	11.9 (round)	1.45	131 (19)	3.62 (525)	2.8	−2 (longitudinal) 59 (radial)	0.35

[1/1]