MANUFACTURING OF COMPOSITES

MECH 425/MECH 6521

FINAL EXAM

April 16, 2004

7:00 to 10:00 pm- H 937

Student name: ---

Student I.D: ---

Part I: Multiple choice part.

For each question, circle the most correct statement: Each question is worth 1 mark.

1.

a) Polyester resin can be made by the reaction between maleic acid and formaldehyde.

b) Polyestesr resin can be made by the reaction of orthophthalic acid and ethylene glycol.

c) Polyester resin can be made by the reaction of isophthalic acid and maleic anhydride.

d) Polyester resin can be made by the reaction between cobalt naphthenate and Dimethyalinine.

2.

a) Epoxy resin can be crosslinked by using styrene.

b) Epoxy resin can be recognized by the presence of the glycidyl group.

c) Methyl Ethyl Ketone Peroxide is one type of epoxy resin.

d) Triglycidyl ether of bisphenol A is a common type of epoxy resin.

3.

a) For the curing of epoxy using hardener, the stoichiometric ratio is when 50% by weight of resin is mixed with 50% by weight of hardener.

b) For the curing of epoxy using hardener, if the amount of epoxy is more than that of the stoichiometric ratio, a non-crosslinked product is formed.

c) For the curing of epoxy using hardener, if the amount of hardener is more than that of the stoichiometric ratio, there is no effect on the physical properties of the product.

d) For the curing of epoxy using hardener, the stoichiometric ratio is not important.

4.

a) Polyimide has temperature stability up to 350 °F.
b) Polyimide has temperature stability up to 350 °C.
c) Polyimide has temperature stability up to 600 °C.
d) Polyimide has temperature stability up to 800 °C.

5.

a) Bismaleimide (BMI) can be processed at 100 °C.
b) The major advantage of BMI is that it can be processed at 100 °C and then post cured at 250 °C.
c) The good properties of BMI comes from the presence of many aromatic diamines.
d) BMI resins are commonly used for automotive applications.

6.

a) Phenolics are formed by the reaction between phenol and ethylene glycol.
b) The formation of phenolics is a condensation process where alcohol is the condensate.
c) Compared to epoxy resins, phenolics have low shrinkage.
d) Compared to epoxy resins, phenolics have higher temperature resistance.

7.

a) In carbon/carbon composites, carbon fibers are mixed in bulk carbon matrix.
b) Carbon/carbon composites are most often made from carbon fiber reinforced epoxy.
c) Carbon/carbon composites have the highest energy absorption (specific heat capacity) than any known material.
d) Carbon/carbon composites are not used very much due to poor bonding between carbon fiber and carbon matrix.

8.

a) For advanced thermoplastic composites, the thermoplastic matrix is usually polyethylene, polypropylene, or nylon.
b) For advanced thermoplastic composites, the thermoplastic matrix resin is usually polyetheretherketone, or polyphenylene sulfide.
c) The advantage of thermoplastic composites over thermoset composites is that thermoplastic composites have less void content as a result of manufacture.
d) The disadvantage of thermoplastic composites as compared to thermoset composites is that thermoset composites have higher fracture toughness.

? 9.

a) Low profile additives are added to polyester to reduce the coefficient of expansion of the material.

b) Low profile additives are added to polyester to reduce water absorption of the material.

b) Carbon black or titanium oxide are usually added into the resin to absorb ultraviolet light to reduce the degradation of the resin.

c) Fillers usually cost more than the resin.

10.

a) A common metal matrix composite is steel reinforced with silicon carbide.

b) There are not many types of metal matrix composites due to the low surface tension of the metal.

c) There are not many types of metal matrix composites due to the high surface tension of the metal.

d) Most metal matrix composites have long fiber reinforcement.

Surface energy = surface tension?

11.

a) Glass fibers used in composite materials are made of pure silica.

~~b)~~ The reason why metal oxides are added to silica is to reduce the viscosity of the material for easier processing.

~~c)~~ E glass has more silica content than S glass.

d) A glass fiber which has more silica content is weaker than a glass fiber with has less silica content.

12.

a)

$$t_f = \frac{(0.5)(1)(0.3)^2(0.3)}{(50\times10^3)(1\times10^{-9})} = 270\,s$$

$\downarrow$

4.5 mins

Part II: Problems:

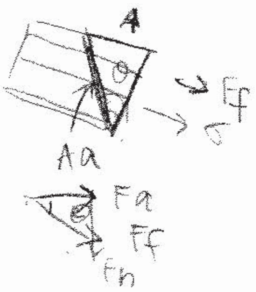
Question 1: (5 marks)

In a liquid composite molding process, an edge injection is used to fill the mold with the preform. The viscosity of the resin is 1 Pa-sec, the length of the mold is 300 mm, the porosity is 0.3, the permeability if 1×10^{-9} m^2 and the injection pressure is 50 kPa. Calculate the time required to fill the mold.

Question 2: (5 marks):

For a cylindrical vessel made of composite material, derive the equation that relates the hoop stress to the stress in the fiber and the winding angle.

Similarly, derive the equation that relates the axial stress to the stress in the fiber and the winding angle.



$$\sigma_a = \frac{F_a}{A_a} = \frac{F_f\cos\theta}{A/\cos\theta} = \frac{F_f\cos^2\theta}{A} = \sigma_f\cos^2\theta$$

$$\sigma_h = \frac{F_h}{A_h} = \frac{F_f\sin\theta}{A/\sin\theta} = \frac{F_f}{A}\sin^2\theta = \sigma_f\sin^2\theta$$

$\sigma_h (t_1 + t_2) = \sigma_f \cos 60^2 t_1 + \sigma_f t_2 \cos 45^2$

$\sigma_a (t_1 + t_2) = \sigma_f t_1 \sin 60^2 + \sigma_f t_2 \sin 45^2$

For a composite vessel made up of two different layers of the same material and same thickness but with different fiber orientations: $\theta_1 = 60°$ and $\theta_2 = 45°$, write the following equations:

- Relation between the hoop stress with the stress in the fiber.
- Relation between the axial stress with the stress in the fiber.

Question 3: (5 marks)

What is the flow rate of the resin through a bed of fiber perform along the x direction given the following information:

Fiber volume fraction = 0.62
Fiber radius = 3.5 μm
Kozeny constant = 0.7
Pressure gradient = 1.2 x 10 ^{5} Pa/m.
Viscosity = 100 Poise
1 Poise = 0.1 Pa.sec.

$$K = \frac{(3.5\times10^{-6})^2}{4(0.7)} \frac{(1-0.62)^3}{0.62^2} = 6.23\times10^{-13}$$

$$\mu = \frac{(6.23\times10^{-13})}{10} \times 1.2\times10^5 \rightarrow 7\times10^{-9}\ \frac{m}{s}$$

Question 4 (5 marks)

A graphite/epoxy bed has an initial fiber volume fraction of 0.55. The maximum attainable fiber volume fraction is 0.85. The coefficient $3\pi E/\beta^4 = 0.06$ psi. What would be the required pressure to compress the fiber bed to have a volume fraction of 0.65?

$V_0 = 0.55$ $\quad \frac{3\pi E}{\beta^4} = 0.06.$

$V_a = 0.85$

$V_f = 0.65$

$$\sigma = 0.06 \frac{\left(1 - \sqrt{\frac{0.65}{0.55}}\right)}{\underbrace{\left(\sqrt{\frac{0.85}{0.65}} - 1\right)^4}_{0.003496}} = 1.495\ \cancel{Pa}\ Psi$$