MANUFACTURING OF COMPOSITES

FINAL EXAM

April 22, 2005

19:00 to 22:00 hours

Closed book, Closed notes

Student name:---------- Student ID:----------

Part I: Problems.

1. Question 1: (10 marks)

A pressure vessel 30 cm in diameter was made by filament winding using both glass/epoxy and graphite epoxy. The layers from the inside to the outside of the thickness are as follows:

- 4 layers of graphite/epoxy at 90°.
- 3 layers of glass/epoxy at 45°.
- 3 layers of glass/epoxy at -45°.
- 2 layers of graphite/epoxy at 30°.
- 2 layers of graphite/epoxy at -30°.

The thickness of each layer is 0.3 mm. The strength of glass fiber is 1000 MPa and the strength of graphite fiber is 1500 MPa. Calculate the maximum pressure that can be contained assuming thin wall theory.

2. Question 2: (10 marks)

You are going to cure a laminate made of 12 plies of graphite epoxy where the fibers are AS4 (trade name of the fiber) and the resin is 3501-6 (trade name of the epoxy). You took the prepregs from the freezer and you left the prepregs in a room with a relative humidity of 50% for several hours before laying up.

Assuming that you are curing the graphite/epoxy laminate in an autoclave using a two-step cure cycle with the first dwell at 102 °C and the maximum temperature at 177 °C.

a) (5 marks). What would be the minimum pressure that you need to apply to avoid void formation?.
b) (5 marks). Assuming that the dwell period at 102 °C needs to be long enough so that the liquid resin can flow from the bottom of the laminate to the top of the laminate (to be absorbed by the bleeder materials). Calculate the minimum dwell period.

Volume fraction of fibers: $V_f = 0.65$
Radius of fibers: $r_f = 4$ μm
Kozeny constant: $k_o = 15$.
Thickness of one ply t = 0.127 mm.
Viscosity or resin at 102 °C for first 10 minutes = 0.8 Pa-seconds.
Viscosity of resin at 177 °C for first 10 minutes = 200 Pa-seconds.

3. Question 3:. (10 marks)

You are going to pultrude a rod made of graphite/epoxy such that the diameter of the product is 6 mm with a fiber volume fraction $V_f = 65\%$. Unidirectional tows are used. Assume that an axial pulling force of 3000 N is applied on the fiber bundles. In order to avoid void formation, a pressure of 0.69 MPa is required inside the die. Assume that the maximum attainable fiber volume fraction is $V_a = 0.8$. What would be the transverse strain in the material?

Fiber diameter : $d_f = 8$ μm.
Modulus E = 234 GPa.
$\beta = 200$

4. Question 4: (10 marks)

You want to make a laminate using Liquid Composite Molding. The dimensions of the piece are: 3 mm x 200 mm x 300 mm. You bought some plain weave fabric AS4/3501-6 material and you found that the dry fiber has an initial volume fraction of 50%. The final product should have a fiber volume fraction of 65%. Maximum fiber volume fraction = 0.8.

a) (5 marks) How much should the compressive force be to compress the fibers?
b) (5 marks) Assuming that you use edge injection (c = 0.5) such that the resin will flow along the length of the mold (dimension 300 mm). Estimate the time required for mold filling. The injection pressure is 0.69 MPa.

Viscosity = 0.2 Pa.sec.
E = 234 GPa
$K_o = 0.7$
$d_f = 8$ μm
$\beta = 200$

5. Question 5: (10 marks)

It is desired to filament wind a pipe of 10 cm in diameter and 200 cm in length. The winding angle is 40°. The band width of the fiber tows is 0.1 cm. The dwell angle is 120o of the rotation of the mandrel. You are allowed to adjust the parameters except the diameter, the length of the pipe and the winding angle. Specify:

a) (4 marks) Number of circuits per pattern.
b) (4 marks) Number of patterns per layer.
c) (2 marks) Number of circuits per layer.

6. Question 6: (10 marks)

You are making a composite with all fibers along one direction (unidirectional composite). The composite has 60% weight fraction of fibers. The properties of fibers and resins are:

E_f = 234 GPa
E_m = 3 GPa
Density of fibers = 2.5 g/cm^3
Density of resin = 1.8 g/cm^3.

a) (5 marks) Determine the modulus of the composite in the fiber direction.
b) (5 marks) Determine the density of the composite.

Part II: Multiple choices. 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) Polyester resin can be made by the reaction of isophthalic acid and maleic anhydride.
c) Polyester resin can be made by the reaction of maleic acid and ethylene glycol.
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 glycol group.
c) Methyl Ethyl Ketone Peroxide is one type of epoxy resin.
d) Diglycidyl 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 diluent.
b) For the curing of epoxy using hardener, if the amount of epoxy is more than that of the stoichiometric ratio, a weakened 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 completely processed at 177 °C.
b) The major advantage of BMI is that it can be processed at 177 °C and then post cured at 246 °C.
c) The good properties of BMI come 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 increase the ductility 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.

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. For polymeric composites, thermoset resins are used more than thermoplastic resins because:

a) The cured thermoset resin has lower viscosity than the cured thermoplastic resin.

b) At room temperature or at relatively high temperature, thermoset resins can appear in liquid form whereas thermoplastic resins can not.

c) Thermoset resins are more ductile than thermoplastic resins.

d) Thermoset resins can be recycled whereas thermoplastic resins can not be.

13. Which of the following fiber has orthotropic properties?

a) Glass fiber

b) Graphite fiber

c) Polyethylene fiber

d) Silicon carbide fiber

14. a) A yarn is a twisted tow.
b) Plain weave has less stability than 4-harness satin weave.
c) Chopped strand mate gives higher stiffness than woven fabrics.
d) A tape is a cross ply [0/90] fabric.

15. In producing a part made of carbon fiber/epoxy composites using an autoclave, which of the following material would be the best mold material in terms of dimensional stability?
a) Aluminum
b) Steel
c) Cast Iron
d) Invar

16. In pultrusion, the most important parameter that affects the pull force is:
a) the tensile strength of the fibers.
b) the compressive strength of the fibers.
c) The shear strength of the fibers.
d) the bulk compression of the fiber bundles

17. In liquid composite molding, to improve the surface finish, one good way to do it is:
a) to have a resin with low viscosity
b) to have fibers with low surface tension
c) to use resin with low shrinkage
d) to machine the surface of the part after it is molded.

18. The compression stress of the fiber bundles depends on:
a) the diameter of the fiber.
b) the viscosity of the resin.
c) the compression strength of the fiber
d) the volume fraction of the fiber bundle.

19. Which of the following has higher surface energy?
a) steel
b) glass
c) water
d) epoxy.

20. In manufacturing thermoplastic composites,

a) Faster cooling rate gives higher degree of crystallinity.
b) The time required for complete autohesion depends on the viscosity of the resin.
c) Thermoplastic liquid resin is Newtonian liquid.
d) The curing cycle is normally a two step curing cycle, similar to the case of thermoset resins.