Experiment 4: Mechanical Testing

Objectives:

- Determine the flexural and tensile moduli for various thermoplastic and thermoset composite samples using the American Standard Test Methods (ASTM).

- Study the effect of processing conditions and annealing on the moduli and on fracture behavior.

- Study the effect of filler on the mechanical properties of thermoplastic materials.

Background

Tensile and flexural tests provide different measures of the material's mechanical properties. The tensile test gives a measure of the Young's modulus of the material as well as the tensile strength and yield point. The flexural or flex test provides the material properties in three-point bending. This is a more complex mode of deformation than the tensile test. The load required for the flex test is usually much lower. Injection-molded test coupons will be provided for this experiment. In order to give reproducible results, the tensile bars should not have notches or burrs on their edges and should be free of scratches.

Experimental Guide:

The experiments must be carried out as per ASTM specifications, these specifications are in the Engineering library reserve section. You must test five (5) samples for each material and each test (flex and tensile).

You will be responsible for the following values for each tensile test specimen as well as an average value of each set of samples:

- Young's Modulus
- Stress and strain at the yield point

You will be responsible for the following values for each flexural testing specimen as well as an average value for each material tested:

- Flexural Modulus
- Stress and strain at the yield point

Materials:

Polycarbonate (unfilled and 30% glass-filled)
Polypropylene (unfilled and 30% glass-filled and 30% talc-filled)

Equipment:

UTS (United Testing Systems) Machine with computer
Printer

UTS Operation

Start-up

1. Turn on the computer screen (the rest of the computer should be on already).
2. Log into windows as CHE 472, password: Polymer.
3. Double click on the icon labeled “UNITED test-man”.
4. Press the ON button and the START switch on the UTS machine.
5. Decide which test you will be performing: Flex or Tensile. Then notify the TA to insure that the proper grips and load cell are attached.

Tensile testing procedure (ASTM D3039) 20K load cell

1. Measure the width and thickness of the specimens at several locations along the narrower section in the middle. Record these numbers on a separate sheet of paper. They will be important in the analysis of your data.
2. Place the sample (tensile bar) in the lower grip, so that the wide part of the sample is within the grip.
3. Tighten the lower jaw grip firmly so that your specimen is secure within the grip.
4. Press the J key on the keyboard to enable the jog controls.
5. Press either the jog buttons on the machine panel or use the up/down arrow keys along with the shift key to lower the jaw grips, so that the narrower segment of the tensile bar is in between the two grips.
6. Tighten the upper grip firmly.
7. Hit F10 key and type L (Loadcell) and enter the capacity of the load cell, which is located on the upper grip.
8. Press the enter key.
9. Press any key to tare the load cell.
10. Type E and select C (crosshead) from the choices.
11. Now measure the length of your specimen between the edges of the jaw grips to determine the jaw separation.
12. Enter the grip separation you measured.
13. Type G (Graph)
14. Set Max. Load to 500 lbs.
15. Set Max. % Strain to 50%
16. Hit Esc to exit the Set-up Scales menu.
17. Hit the F1 key to select either tensile or compression (flexural) testing mode.

18. Verify the force units are in pounds, if not use the F3 key to select those units
19. Verify the linear units are in inches, if not use the F4 key to select those units.
20. Hit the F7 key and you will be prompted for a test speed, enter the speed which is in accordance to the ASTM standard method,

NOTE: the ASTM methods are in the Mechanical testing drawer in the laboratory and also in the engineering library.

21. Type T to test and the test will begin.
22. After the sample breaks, hit the S key to stop the crosshead.
23. Loosen the grips and remove the sample.
24. Type R to return the grips to the starting location.
25. Type Ctrl-W, this will write an ASCII file.

a) The computer will prompt you for a path to write to, hit C.
b) Then type " windows\CHE 472".
c) The ASCII file produced is named based on the time the test was run so keep a log of the tests and times the tests were run. The data recorded is the load (lb) and the percentage strain.

Flexural testing procedure (ASTM D790) 1K load cell

1. Measure the width and thickness of the specimen at several locations. Record these numbers on a separate sheet of paper. They will be important in the analysis of your data.
2. Determine the support span, which should be sixteen times the thickness of the specimen.
3. Align the sample midway between the supports.
4. Hit F10 key and type L (Loadcell) and enter the capacity of the load cell, which is located on the loadcell which is above the upper grip.
5. Press the enter key.
6. Press any key to tare the load cell.
7. Type E and select C (crosshead) from the choices. Enter the jaw separation, which is the span between the two supports.
8. Hit the Esc key to exit the set-up scales menu
9. Hit the F1 key to select either tensile or compression (flexural) testing mode.
10. Verify the force units are in pounds, if not use the F3 key to select those units
11. Verify the linear units are in inches, if not use the F4 key to select those units.
12. Hit the F7 key and you will be prompted for a test speed, enter the speed which is in accordance to the ASTM standard method
13. Lower the upper fixture using the jog controls so that it almost

touches the compression arm.
14. Type T to test and the test will begin
15. After the sample has yielded, type S to stop the crosshead and end the test.
16. Type R to return the crosshead to the starting location
17. Type Ctrl-W, this will write an ASCII file

a) The computer will prompt you for a path to write to, hit C
b) Then type " windows\CHE 472"
c) The ASCII file produced is named based on the time the test was run so keep a log of the tests and times. The data recorded is the load (lb) and the percentage strain.

Theory and Analysis

Tensile and flexural properties require different sets of calculations to find the modulus of elasticity.

Tensile Test Theory

The ASCII file will give values for the extension, Δl, and the force, P. In the tensile test, the tensile stress (S) is given by

$$S = \frac{P}{bh}$$

where:
P = load in pounds
b = width of the sample in inches
h = height or thickness of the sample in inches

Strain or elongation is defined as:

$$\varepsilon = \frac{\Delta l}{l_o}$$

where:
Δl = is the extension
l_o = the initial gage length

The Young's modulus in tension (E_t) is calculated using the following equation evaluated at small strains, which insures a constant value.

$$E_t = \frac{dS}{d\varepsilon}$$

where:
$(dS/d\varepsilon)$ = slope of the stress vs strain curve

The yield point is the maximum of the stress vs. strain curve.

$$\frac{dS}{d\varepsilon} = 0$$

Flexural Test Theory

The ASCII file for the flexural test will give you the percentage strain, and the load, P. The first step in calculating the flexural properties is to create a load vs. deflection curve. Deflection can be calculated from strain by multiplying it by the span L (the specimen length between the two support points).

The flexural properties can be found by the following equations (see pp 227-233 of the text by Mallick). The modulus of elasticity is calculated by finding the initial (within the first 1%) slope of the load vs. deflection curve and using the following equation:

$$E_b = \frac{mL^3}{4bh^3}$$

where:
E_b = Flexural modulus
m = initial slope of the load vs. deflection curve
b = width of beam tested
h = thickness of beam tested
L = specimen length between two support points

The maximum fiber stress for any point on the load-deflection curve is given by the following equation:

$$S = \frac{3PL}{2bh^2}$$

where
S= stress in the outer fibers at mid-span
P= load at a given point on the curve

Discussion Questions:

1. What are the differences and similarities between the results for the fiber-reinforced polymer versus neat polymer samples?
2. What are the differences and similarities between the polypropylene and the polycarbonate samples?
3. Do these results follow the trends seen in literature? If not, what could be some reasons why there are those dissimilarities?
4. What kind of trends do you expect if the fiber-loading increases to 40% for both the polypropylene and polycarbonate samples?
5. Were the modulus and stress values consistent from sample to sample? If not, why not? Was there more variability in the filled or unfilled samples? Why?

References:

1. ASTM standards.
2. L.A. Carlsson and R.B. Pipes, Experimental Characterization of Advanced Composite Materials, Chap 3 and 4.
3. Mallick, Fiber-reinforced Composites, Dekker, 1993.