ENGR 240 – Science of Materials

Laboratory Report Grade Sheet

Names: Yifan Ge, Kaixiang You, Ahmed Mahmood

Lab Report Title: Impact and Tensile Testing of Polymers

Format: (all of the following are worth 1 point per occurrence)

\_\_\_ Report title, group member names, and date appear in that order, centered at top of page

\_\_\_ Page setup: all margins 0.5”, 2 column format for all report text after title and authors

\_\_\_ Text is left & right justified

\_\_\_ All text 10 or 11 pt. font, single spacing

\_\_\_ All table titles and figure captions are 9 - 10 pt. font (one font size smaller than text), bold

\_\_\_ All tables have titles (above)

\_\_\_ All figures have captions (below) and NO TITLES

\_\_\_ Pages are numbered, bottom center

\_\_\_ All sections have appropriate headings (as listed in rubric)

\_\_\_ Headings immediately precede corresponding section (not split bottom/top of next page)

\_\_\_ Significant figures are consistent

\_\_\_ Plots/Tables have error bars/report standard deviation (when appropriate)

\_\_\_ All values have appropriate units

\_\_\_ Non-breaking space used between values and units (hold ctrl-shift-space simultaneously)

\_\_\_ Symbols for units used where appropriate

\_\_\_ No constants in tables (e.g., π or common sample dimension)

\_\_\_ Table column headings contain units

\_\_\_ Table column headings contain common multipliers (exponents, etc.)

\_\_\_ Figure axes are labeled

\_\_\_ Figure axes contain units

\_\_\_ Figure axes contain common multipliers or log scale if appropriate

\_\_\_ Figures have white background

\_\_\_ Each data set in a figure is clearly marked and easily distinguishable

\_\_\_ Table and figures appear intact and are not split at the bottom/top of next page

\_\_\_ Consecutive tables and figures do not contain redundant information

\_\_\_ Limited use of personal pronouns

\_\_\_ Limited use of direct quotes from the textbook

\_\_x\_ Experimental values are compared to values reported in the literature (when appropriate)

\_\_\_ Proper use of Appendices

\_2\_\_ Style (scale of 1 to 4) Please proofread to avoid redundant sentences, subject-verb disagreement, etc.

=\_25\_\_/28

Content: (each of the following is out of 4 points)

Abstract \_2\_\_ x 1 = \_2\_\_

Introduction \_3.5\_\_ x 2 = \_7\_\_Should have explained elastomeric, plastic, brittle behavior and ductile-to-brittle transition.

M&M \_3.5\_\_ x 3 = \_10.5\_\_

Results \_3.5\_\_ x 4 = \_14\_\_Some fits for linear elastic region are not good. Also, post-fracture data shown on stress-strain diagram should have been removed.

Discussion \_3\_\_ x 5 = \_15\_\_There was no calculation of or comparison to accepted values for any properties (modulus, ductility, yield strength, etc.)

Conclusions \_4\_\_ x 2 = \_8\_\_

References \_0\_\_ x 1 = \_0\_\_

\_56.5\_\_/72 Total grade: 81.5

**LAB 3: IMPACT AND TENSILE TESTING OF POLYMERS**

Members: Ahmed Mahmood, Kaixiang You, Yifan Ge

Date: September 14, 2010

**Abstract:-**

Impact and tensile testing was performed on various types of polymers. Impact testing was performed to determine the brittleness of the materials at various temperatures. The High Impact Polystyrene (HIPS) samples were found to be more brittle as they were exposed to cooler temperatures. Tensile testing was performed on polymers to determine several mechanical properties. The properties of different polymers were also found to be different from each other during tensile testing.

**Introduction:-**

Impact energy is the energy that can cause fracture in a specific material. The more brittle a material is the less energy is required to cause fracture. A material can be hard but at the same time also brittle. That is, it will not resist much force before it breaks at a point. In our experiment, we used the pendulum tester, which uses the swinging motion of a pendulum to fracture the material. The resistance to the motion of the pendulum is measured as the energy required to cause fracture.

In tensile testing, tensile forces are applied on the polymers and they are forced to stretch. The more brittle material will resist this at first and then break at a certain point. This point would be where the atomic lattice is stretched so thin over each other that keeping the material intact would no longer be possible by inter-atomic and inter-molecular forces. The tension forces here exceed the combined inter-molecular and inter-atomic forces. We used Tinius Olsen tensile tester for this purpose.

**Materials and Methods:-**

The material used for the impact testing experiment was high impact polystyrene (HIPS), with a ‘v’ notch cut on the side. This allowed the easy, calibrated fitting on the testing equipment. A pendulum based testing machine was used to calculate impact energy. The machine works on the principle of gravitational potential energy. The pendulum has a certain amount of gravitational potential energy and hence when it impacts the test material, a resistance to the motion occurs. The decrease in the potential energy is the impact energy for the material. Three HIPS samples were tested at each of five different temperatures: room temperature (20°C), cooled by immersion in ice (0°C), immersion in liquid nitrogen (-196°C), and placed in ovens at 70°C and at 90°C. The impact energy results were displayed on the screen of the impact tester (J).

We performed tensile testingusing the Tinius Olsen tensile tester. We placed each sample between two grips of the machine. One grip remains stationary while the other one moves in the upward vertical direction. The concept here is to impart tension on the sample until it breaks. Different materials exhibit different mechanical properties. Materials that tend to extend a lot, exhibit ‘elastomeric’ stress-strain behavior. Materials that have a moderate extension show ‘plastic’ stress strain behavior, while materials that resist any form of extension, exhibit brittle behavior, that is, they are hard and stiff but crack when subjected to tensile forces. We used six polymers: nylon 6, polypropylene (PP), polymethyl methacrylate (PMMA), polycarbonate (PC), polyvinyl chloride (PVC) and high impact polystyrene (HIPS). The physical dimensions of the six samples were measured with caliper. We then repeated the measurements after the samples had been subjected to tensile testing.

**Result:-**

**Figure 1.** Impact energy of HIPS vs. temperature. Error bars indicate range of three measurements.

**Figure 2.** Engineering stress-engineering strain curve for each specimen tested.

**Figure 3.** Expanded view of the elastic regions for each specimen tested. The linear equations are the linear trend line of each specimen.

**Discussion:-**

Figure 1 shows that impact energy increases as the temperature increases. From these trends, our best estimation of the result is that impact energy (breaking energy) is exponentially related to the temperature. Also, during the experiment, we can notice that the sample gets softer as its temperature increases.

Figure 2, from the tensile testing experiment, shows that most materials went up to their maximum stress and then had a dramatic drop on the stress, except Nylon which had its maximum stress just before it broke. This linear elastic period at the beginning is relatively short for all materials. All materials’ stress increased before they broke. In all, Nylon has the best elastic property and has the lowest slope of linear elastic region, which indicates it is easy to be stretched and has good elastic extension; Polypropylene has the longest extension under stress and relatively low slope of linear elastic region, which shows it has good plastic extension; both PMMA and PVC have very large slope of linear elastic region and break very fast, which presents they are hard be extended and very brittle; Polycarbonate and HIPS both shows a drop of stress after maximum stress achieved, but the stress keeps increases until they break. (Detailed data is in Table 3 of Appendix)

**Conclusion:-**

* Impact energy of polymers increases exponentially as temperature increases
* Most polymers achieve their maximum stress after the linear elastic region
* All polymers show an increase in their stress before they break
* Due to different structure and order of their molecules, polymers have different characteristics.

Appendix:-

Table1. Data for Impact Test

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Impact Testing |  |  |  |  |  |  |
|  | °C | Trial1 (J) | Trial2 (J) | Trial3 (J) | Average (J) | Stdev (J) |
| Liquid Nitrogen | -195.79 | 0.0033 | 0.0033 | 0.0040 | 0.0035 | 0.0004 |
| Ice Water | 0 | 0.1076 | 0.1090 | 0.1054 | 0.1073 | 0.0018 |
| Room Temperature | 24 | 0.1452 | 0.1459 | 0.1467 | 0.1459 | 0.0008 |
| Oven 1 | 70 | 0.2686 | 0.2470 | 0.2320 | 0.2492 | 0.0184 |
| Oven 2 | 90 | 0.3830 | 0.4061 | 0.3542 | 0.3811 | 0.0260 |

Table2. Data for Tensile Test

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Nylon 6 | PP | PMMA | Poly C | PVC | HIPS |
| Length L (mm) | 114.87 | 114.21 | 113.62 | 114.28 | 114.22 | 114.25 |
| Length S (mm) | 35.68 | 35.4 | 35.75 | 35.38 | 35.79 | 35.51 |
| Width (mm) | 6.42 | 6.4 | 6.29 | 6.3 | 6.3 | 6.41 |
| Thickness (mm) | 3.29 | 3.19 | 2.89 | 2.85 | 2.95 | 3.12 |
| Cross-Section Area (mm^2) | 21.12 | 20.42 | 18.18 | 17.96 | 18.59 | 20.00 |
| Length S (inch) | 1.40 | 1.39 | 1.41 | 1.39 | 1.41 | 1.40 |
| Cross-Section Area (inch^2) | 0.0327 | 0.0317 | 0.0282 | 0.0278 | 0.0288 | 0.0310 |
|  |  |  |  |  |  |  |
| New Length L (mm) | 213.38 | 421.95 | 113.9 | 153.1 | 116.19 | 118.5 |
| New Length S (mm) | 137.65 | 348.9 | 42.1 | 81.4 | 44.79 | 46.89 |
| New Width (mm) | 3.75 | 2.91 | 6.29 | 4.7 | 6.29 | 6.39 |
| New Thickness (mm) | 1.79 | 1.35 | 2.81 | 2.02 | 2.89 | 3.09 |
| Cross-Section Area (mm^2) | 6.71 | 3.93 | 17.67 | 9.49 | 18.18 | 19.75 |

Table3. Mechanical Properties of Each Specimen

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Polymers | Nylon | PP | PVC | Polycarbonate | PMMA | HIPS |
| Elastic Modulus (psi) | 15649 | 46899 | 139286 | 92835 | 134425 | 112920 |
| Tensile Strength (psi) | 9225 | 5149.6 | 11144 | 9798 | 11674 | 2272 |
| Yield strength (psi) | 7531.2 | 5149.6 | 11144 | 9798 | 11674 | 2236 |
| Ductility | 1.547 | 3.385 | 0.688 | 1.030 | 0.704 | 0.726 |

Equation for engineering stress:

Equation for engineering strain: