PLASTICS TESTING

I. Question

What are some of the characteristics of plastic that make products useful to us?

II. Background

Different types of plastics with different additives and different shapes made by different forming methods give us a wide range of useful tools. Some of the characteristics are discussed briefly here and ways that we can observe these characteristics are described in the Procedure Section.

Plastics are lighter than other materials like metal, glass or wood. For example, aluminum is three times as heavy as polyethylene and steel is eight times as heavy as polyethylene.

Plastics are easy to process. Chemicals are mixed and the reaction forms a plastic material. The plastic can be made inside a mold to shape it as the chemicals react to form plastic or the plastic material can be softened with heat and pressed into the shape that we want to use.

Plastics can be made into any color we want by mixing dyes and pigments with the plastic. Unlike paints or coatings, the color is present all the way through the plastic material so it does not disappear with wear and need to be repainted.

Reinforcing materials such as glass, carbon or other fibers can be embedded in the plastic to give it extra strength. Fillers like sand or air can be included in the plastic to help it increase in size while maintaining its characteristics of strength and light weight.

Plastics can act as insulation against electric current because unlike metals, plastics have practically no free electrons. Plastics also insulate against heat and cold.

Once formed into a polymer, plastics resist many chemicals but you must be specific for the plastic that resists oil-type chemicals may be dissolved by water and the plastic resistant to water may be dissolved by an oil-based solvent such as gasoline.

Plastics may be permeable, letting certain liquids or gases through while preventing other things from passing through the plastic layer. For example, plastic wrap protects meat from the atmosphere by preventing air from entering the package and darkening the meat and also prevents the moisture in the meat from escaping to the atmosphere and drying out the stored meat. Plastic used in artificial kidneys allows toxic waste products to escape from blood without losing important parts of the blood itself.

Plastics have strength, abrasion resistance, elasticity, flexibility and recovery characteristics that can be chosen or adjusted to fit the user's needs. These are the characteristics we will examine in this exercise.

III. Materials

- Abradants: various types of sandpaper (e.g. fine, medium and coarse) and a gritty, abrasive bathroom cleanser
- Various plastic samples that will resist some scratching (e.g. different types of plastic floor tile samples, plastic fabric samples such as nylon and polyester, and plastic countertop samples)
- Various weights
- Large coffee can or empty paint can
- Wide rubber bands that fit around coffee can
- Meter stick or tape measure
- Darts: various sizes of weighted balls, smooth weights, or bolts with smooth and rounded tops
- Various plastic film samples (e.g. trash bags, food wrap, microwave wrap, grocery bags, dry cleaning bags)

<u>Optional Items</u>
- Stopwatch (optional)
- Balance (+/- 0.001 g)
- Calipers (+/- 0.001 in or cm)

V. Procedures

<u>Abrasion Resistance</u>

Plastic is often the material of choice because it will withstand friction and scratching. A piece of plastic film can be stretched across a paint or coffee can and secured with masking tape or a heavy rubber band. Participants can brush the top of the plastic with various materials and examine the surface for scratching and/or watch for tearing of the plastic. The characteristic could also be demonstrated with a good quality nonstick frying pan.

Many plastic products, such as floor tile, countertops, clothing and carpet, are designed to be abrasion resistant. Abrasion is caused by three main factors: the type of abradant, the surface area, and the force of abrasion. For example, a small child with sandpaper on her shoes will cause less abrasion on a floor than an adult. The child has smaller soles on the shoes of her feet (surface area) and weighs less than the adult (force) does. Likewise, fine sandpaper will cause less abrasion than coarse grit sandpaper (type of abradant).

Activity A
Ask the students to develop an abrasion test that determines the abrasion resistance of three different brands of plastic floor tiles.

Activity B
Using one type of sandpaper (fine, medium or coarse), ask the students to develop a test to determine the effect of varied load weights on the abrasion resistance of one of the plastic samples.

Activity C
Ask the students to develop a test to determine the number of strokes or time span that will result in abrasion damage to one of your plastic samples, keeping the abradant (type of sandpaper or abrasive cleanser) and the load weight constant.

Activity D
Ask the students if they think samples change in mass or thickness after abrasion. Now ask the students to test their hypothesis.

Strength, Elongation and Elasticity

Strength is the resistance to force applied to plastic. The type of plastic, its form and the time over which the force is applied will affect the ability to resist failure. If the force is applied along the axis of the plastic, we are conducting a tensile test. If the force is applied perpendicular to the surface of the plastic, we are conducting a puncture test. The puncture test can be demonstrated by putting a thin sheet of plastic over a paint can or coffee can or something similar, and dropping a flat object such as a bolt from increasing heights until the plastic fails to withstand the impact.

Elongation is the increase in length as a force is applied. Cut dog bone shaped pieces of plastic from garbage bags with some cut along the grain of the extruded or blown film and some cut from across the grain. Have two participants pull on the plastic from opposing ends. Pull until the plastic fails. The response is time-dependent so how fast the plastic is pulled will determine the amount of stretch before failure.

Elasticity is defined as the amount of deformation that the plastic will stand either by stretching or compressing or bending without permanently changing the original form. A tensile test can be performed by taking a strip of plastic, attaching it to the end of a meter stick, measuring the length, hanging a weight on bottom of the plastic strip, measuring the stretched length, releasing the weight, and remeasuring the length. If the weight has not exceeded the elasticity of the plastic, the released plastic will return to the original length.

The characteristic of “creep” can be demonstrated by adding a weight that has been found in a short-term test not to permanently deform the plastic strip and leaving the weight in place for an extended period of time such as overnight or several days.

When instructed to cut out plastic bars, you may use the template available at the end of this document. Make sure to cut out bars with the plastic parallel or transverse to the extrusion direction of the polymer chains. By holding the bag to the light, the direction of extrusion is visible (a more detailed explanation of this is provided in the activities themselves): Using a plastic freezer bag, cut strips approximately 2.5cm by 12cm. Slowly pull the ends apart (stress) and feel the resistance of the material as you pull it (strain). Using the suggestions that follow, have the students develop their own procedure to test tensile strength. Students' results can be either quantitative (producing numeric values as their results) OR qualitative (producing descriptive text as their results).

Activity A

Have the students cut strips from a variety of different plastics. They could use different brands of freezer bags, food wrap, microwave wrap, trash bags, grocery bags, or any other type of similar plastic. The students will be testing the strength needed to break each of these strips of plastic. The students could compare the strength needed to break different brands of trash bags or grocery bags. Have the students clamp down one end of one of their plastic strip samples. Give the students a variety of weights that they can attach to the other end of the plastic strip. Have the students develop a test to determine the weight needed to break each of their plastic strips.

Activity B

Hold a plastic bag up to a light and note the grain of the material. The lines you see indicate the general direction of the polymer chains of the sheet of plastic. The direction in which these chains are lined up is also known as the anisotropic nature of the material, or the direction of extrusion. Have the students develop a procedure, which tests to see if there is a difference in the tensile strength of a material when they pull with the grain and against the grain.

When pulling the sample against the grain very slowly, did you notice how the material thinned? What you are seeing is called "necking". The molecules reorient from across the sample to the direction you are pulling. If you continue to slowly pull, the strain you feel will increase as the molecules are reconfigured.

Activity C

Tensile strength is also affected by how fast the sample is pulled. Have the students develop a simple procedure to test the difference in tensile strength at different pulling speeds. Ask the students to record the grain of each of the materials they compare.

Activity D

Some plastic strips will stretch further before breaking than others. How far they stretch depends on the material itself (i.e. what type of plastic), the direction of the material's grain, the size of the sample, and the speed of the pull.

Have the students develop a procedure to test the maximum elongation of various plastic strips. There are four factors in determining how much a plastic strip stretches. Make sure the students keep three of these four variables constant (e.g. the speed of the pull) when performing this activity.

Impact Resistance and Toughness - Falling Dart and Drop Dart Tests

Two industrial tests that are used to determine a material's impact strength are the falling dart and drop dart tests. To determine the force of impact, multiply the mass of the dart by the height of the fall. Note: notice how the coffee can has a plastic film sample secured over the opening with a strong elastic band.

Impact calculation:
mass x distance = force

Activity A
Ask the students to develop a Falling Dart Test (where the weight of the dart changes while the height remains fixed). Ask them to determine the impact force needed to break a variety of plastic film samples.

Activity B
Ask the students to develop a Drop Dart Test (where the height of the fall changes while the weight of the dart remains fixed). Ask them to determine the impact force needed to break a variety of plastic film samples.

Activity C
Ask the students if they think there is a difference in impact force needed to break a sample if the same spot is impacted every time or if instead a new sample plastic film is tested each time. Ask the students to develop a test to verify their hypothesis.

Flexibility

Obtain some plastic like heavy fishing line and some equal diameter wire. Bend both back and forth and count the number of bends before each one breaks.

Obtain thicker pieces of different types of plastics and equal thickness of metal and wood. Try to bend them. Determine which have the most flexibility.

Thermal Insulation

Obtain a replacement handle for a kitchen pan or pot. The handle is usually metal centered with plastic covering. Hold the handle by the plastic and apply a match to one end of the exposed metal for a few minutes. Use a thermometer to measure the temperature of the outside of the handle and the temperature of the metal center. How good is the plastic insulation? (be careful not to touch the hot metal)

Electrical Insulation

Obtain a flashlight. Show that the flashlight has a complete circuit and the lamp will light. Turn off the flashlight and open it to expose the batteries. Place a piece of plastic between the batteries. Close the flashlight and note that the plastic will not conduct enough energy to light the lamp. Different types and thicknesses of plastic will give no or small amounts of light. (be careful that the plastic does not cause overheating in the flashlight)

VI. Discussion and Evaluation

VII. Continuing the Concept

VIII. References

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American Plastics Council (APC)
1801 K Street NW, Suite 701 L
Washington, DC 20006
www.plastics.org

Society of Plastics Engineers (SPE)
P. O. Box 403
Brookfield, CT 06804-0403
Tel. 203-775-0471
Fax 203-775-8490
www.4spe.org