Massachusetts Institute of Technology
Department of Mechanical Engineering
Cambridge, MA 02139
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Mechanics and Materials II
Laboratory Project (Monday Section)

Professor Suh /Dr. Saka /Mr. Hayward /Ms. Yuan /Mr. Akiskalos

Suggested Laboratory Projects (Choose one and inform the instructors of your choice)

1. All sliding surfaces encounter resistance to sliding due to friction. Friction force may be defined as the rate of energy dissipation per unit distance slid or the rate of the work done by an external agent per unit distance slid. Therefore, to reduce the frictional force, we need to understand the energy dissipating mechanisms that exist at the sliding interface. Your task is to investigate the effect of surface topography on the frictional force. (Lecture notes on friction will be handed out in the laboratory.)

   Friction tests can be done using a variety of different tests. A common test is the "pin-on-disk" test, which consists of a pin under load sliding on a flat surface. Many other geometric arrangements have been used to determine the friction coefficient such as a cylinder-on-cylinder test. The coefficient of friction, which is defined as the tangential frictional force divided by the normal load, depends on the test geometry, but to a first approximation, we may assume that all tests give similar results, if the contact area (sometimes called the apparent area of contact) is much larger than the actual individual asperity contact area, which is the case in most engineering applications.

   You will be provided with two different kinds of copper specimens: one with a flat smooth surface and the other with an undulated surface. You should obtain the coefficient of friction of these surfaces sliding against a copper pin using a pin-on-disk tester, using the instrument available in the Tribology Laboratory in Building 35, First floor.

   Your lab report should answer the following questions:

   a. What is the primary mechanism for the observed friction?
   b. Is there any difference in the frictional behavior between the flat and the undulated surfaces? If there is a difference, how would you explain the difference?
   c. Is friction a material property?
   d. Describe a means of reducing the friction further without using any lubricant.

2.   Many plastic parts are injection molded. In injection molding, molten thermoplastic resin is injected into a cold mold under high injection pressure. The mold is maintained at a lower temperature than the melting point (or the glass transition temperature) of the resin by circulating cold water through cooling channels machined in the mold. The plastic injected into the mold replicates the shape of the mold cavity as it cools in the mold. Because the mold does not allow the plastic to shrink and the volume of the plastic decreases with cooling, injection-molded parts develop residual stresses. As a result, the shape of the plastic part distorts (i.e., warps) when the cooled part is ejected from the mold. "Warping" increases as a function of time until the residual stress is sufficiently relieved.

You will be given two injection-molded parts, one a solid plastic part and the other a microcellular plastic part made of the same thermoplastic. These two parts appear to be identical in their geometric shape. Although they are made of the same plastic and appear to be the same in shape, the microcellular plastic part has a large number of tiny bubbles (closed cells of 10 to 30 microns)[1].

The bubbles are created by means of phase separation. First, we dissolve a large amount of gas in the molten plastic under pressure at an elevated temperature, forming a "super-saturated" polymer/gas solution. When we suddenly reduce the pressure, the solubility of gas in the polymer decreases and the excess gas molecules diffuse out of the polymer/gas solution. This sudden change in the thermodynamic state nucleates a large number of bubbles, creating a microcellular plastic. The details of the process will be provided in the laboratory.

Your task is to measure the geometric distortion of these two parts by heating them in an oven. Measure the shape of the as-received molded parts. Then repeat the measurement after heating them to (T_{melt} − 10 C) for 20 minutes. Conduct a similar measurement after heating them to (T_{melt} + 10 C) for 20 minutes. Based on your measurements, answer the following questions:

a. How much did the parts distort? Is there a difference in distortion between these two parts?
b. Estimate the maximum residual stress in these two molded parts.
c. Explain the difference in distortion between these plastics parts by "analyzing" the molding process.
d. Why does the plastic part distort?

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[1] Microcellular plastics were invented at MIT and further developed by an industrial firm. Now there are many licensees throughout the world, making a variety of products (e.g., printer chassis, automotive components, etc.).

3.   In manufacturing an internal combustion engine, the cylinder head of the engine (which houses the valves, overhead cams, spark plugs, etc.) is bolted to the engine block. To provide a tight seal, a gasket is placed between the cylinder head and the engine block. Then several bolts are used to fasten them together and contain the high pressure generated in the combustion chamber (i.e., cylinders). Determine the bolt size and the maximum torque you must apply to assure a tight seal throughout the life of the engine. Conduct a test to verify your estimate.

Try to answer the following questions:

a. Given two different size AISI 4130 steel bolts (say 8 mm and 12 mm) bolts, which one is a better bolt to use? Why?
b. How much torque should we apply? Why?
c. How does the cyclic heating and cooling affect your answers?