ME 354 MECHANICS OF MATERIALS LABORATORY

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MECHANICAL PROPERTIES AND PERFORMANCE OF MATERIALS: Part a) Charpy V-Notch Impact

February 2004 PEL

PURPOSE

The purpose of this exercise is to obtain a number of experimental results important for the characterization of the mechanical behavior of materials. The Charpy V-notch impact is a mechanical test for determining qualitative results for material properties and performance which are useful in engineering design, analysis of structures, and materials development.

EQUIPMENT

- Charpy V-notch test specimens of 6061-T6 aluminum and 1018 (hot rolled) or A36 steel
- Charpy testing machine with 800-mm long pendulum arm and 22.6-kg impact head
- Type K thermocouple and digital readout unit
- Beakers of room-temperature water, warm water and boiling water
- Beakers of plain iced water
- Cryo-beakers of salted iced water and super cold liquids

PROCEDURE

CAUTION: When using the Charpy testing machine, stand well clear of the swinging area of the pendulum both when the arm is cocked and for some time after the arm is released for a test while it is still swinging. Serious injury will result from a swinging pendulum arm.

For each material repeat the following steps

- Designate a person as the "operator" of the Charpy test machine: all other persons must stand clear during testing
- Designate a person as the "monitor and recorder" of temperatures and impact energies
- Designate a person as the "test specimen loader" who will remove test specimens from the liquid bath, quickly placing them on the test fixture of the Charpy testing machine
- Designate a person as the "test specimen retriever" who will retrieve the broken halves of the test specimens, will bind the halves together and will mark the test temperature on each pair of specimen halves for later examination and inspection. Use the following procedure to conduct tests in the order shown after exposure to the preconditions to give the approximate test temperatures indicated:

Room temperature water (20 to 25°C)
Warm water (50-60 °C)
Boiling water (95-100°C)
Ice water (0 to 4°C)
Salted ice water (-15 to -18°C)
Acetone with some dry ice (-50 to -57°C)
Acetone with much dry ice (-80 to -85°C)

- Place the thermocouple probe in the appropriate liquid being sure to allow both the test specimens and the thermocouple to equilibrate for at least five minutes prior to testing.
- Record the indicated temperature

• "Cock" the pendulum by activating the "raise" mechanism and stand clear while the pendulum is held in the "cocked" position.
• Using the tongs, quickly remove the test specimen from the bath and place it on the test fixture with the notch opening facing away from the direction of the cocked pendulum
• Stand clear
• Release the pendulum
• Secure the pendulum in its rest position (i.e., hanging vertically) and retrieve the fractured specimen halves.
• Record the impact energy (read directly from the dial on the Charpy testing machine)
• Repeat these steps for the each temperature and each material.

BACKGROUND AND ANALYSIS

Static or quasi-static properties and performance of materials are very much a function of the processing of the material (heat treatments, cold working, etc.) in addition to design and service factors such as stress raisers and cracks. The behaviour of materials is also dependent on the rate at which the force is applied. For example, a polycarbonate tensile specimen which might show a relatively low yield point but up to 200% elongation at a low loading rate may show a much greater yield point but at only 5% elongation at an order of magnitude faster loading rate. Low carbon steels, such as 1018, may show considerable increases in yield strength and work hardening at high strain rates.

In quasi-static tests, the amount of energy required to deform a material is determined from the area under the tensile stress-strain curve and is know as the modulus of toughness. Under dynamic loading, stress-strain response is typically not recorded. Instead, the transfer of energy from a device such as a drop weight or a swinging specimen to the deforming or breaking specimen is equated to the "impact energy." The Charpy impact test uses a standard Charpy impact machine to evaluate this impact energy. The machine consists of a rigid specimen holder and a swinging pendulum hammer for striking the impact blow to a v-notched specimen as shown in Figs. 1 and 2. Unfortunately, while the test, including machine and specimen geometry, has been standardized, the test results do not provide definitive information about material properties and thus are not directly applicable to design (as for example might be a yield strength); however, the test is useful for comparing variations in the metallurgical structure of materials and in determining environmental effects, such as temperature on the dynamic response of the material. One of the most dramatic results of Charpy impact tests is in the form of plots of impact energy versus temperature in which sigmoidally-shaped curves (see Fig. 3) show substantial decreases in some materials' abilities to absorb energy below a certain transition temperature. This ductile to brittle transition is most apparent in materials with BCC and HCP crystalline structures as for example in steels and titanium. A classic and dramatic example of this ductile to brittle behaviour is the low carbon steel Victory ships of WWII cracking in half under even the mild conditions of sitting at anchor in a harbor. Materials with FCC structures (e.g., aluminum and copper) have many slip systems and are more resistant to brittle fracture at low temperatures.

In this laboratory exercise the primary outcome will be plots of impact energy versus temperature for two materials (FCC-606-T6 aluminum and BCC-1018 steel). Note the effects of temperature and material type on the levels and shapes of the curves. Examine the fracture surfaces of specimens and compare the type and degree of deformation to the impact energy and the corresponding temperature. Consider not only the type of material, but also the effect of notches and temperature in making design decisions.

REFERENCE:

Annual Book or ASTM Standards, American Society for Testing and Materials, Vol. 3.01
E23 Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

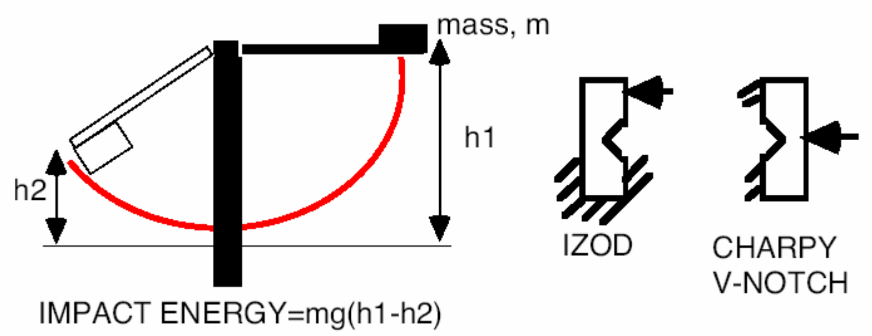


Figure 1. Schematic of Charpy Impact Testing and Izod and Charpy V-notch specimens

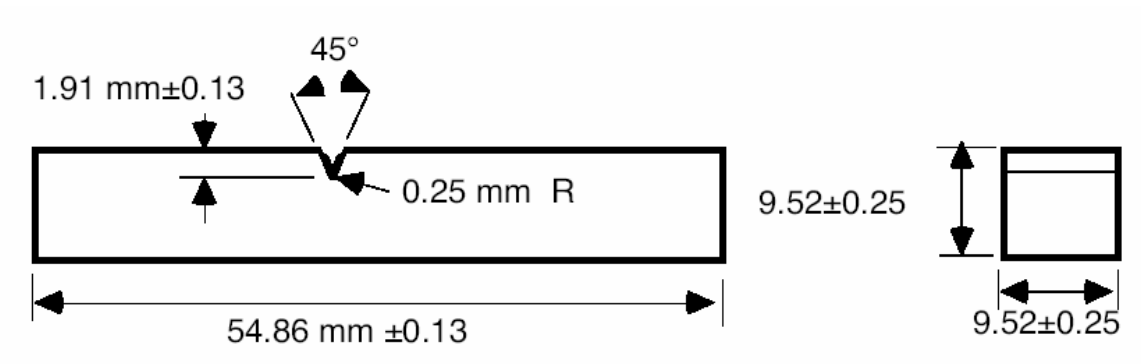


Figure 2 Charpy V-notch specimen used in this laboratory showing dimensions

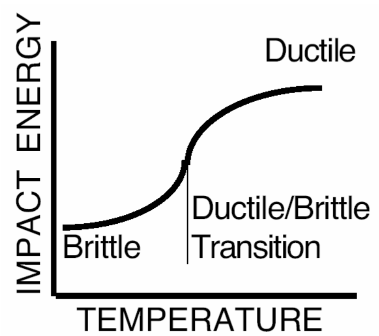


Figure 3. Schematic of plot of impact energy versus temperature showing sigmoidal curve

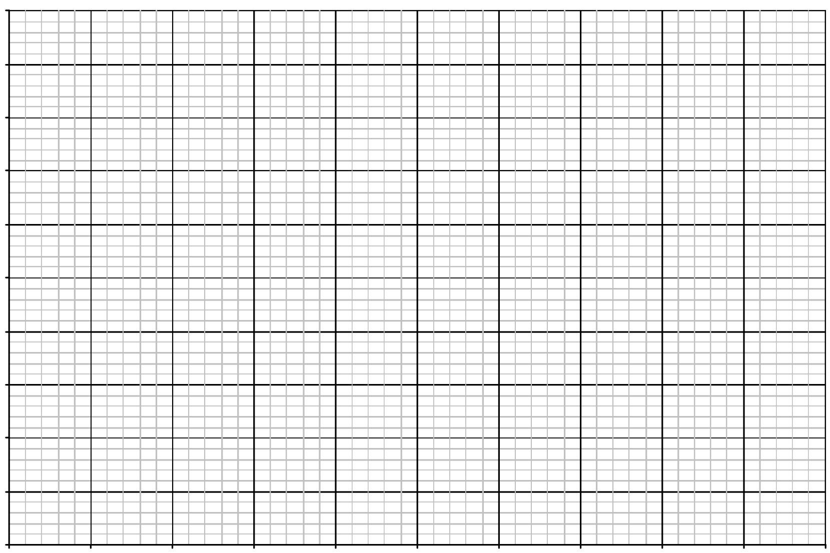
DATA

Fill in the following table:

	Impact Energy (J)	
	6061 T6 Aluminum	1018 (HR) or A26 steel
Boiling hot temperature (^{o}C)		
Warm temperature (^{o}C)		
Room temperature (^{o}C)		
Freezing temperature (^{o}C)		
Cold temperature (^{o}C)		
Very cold temperature (^{o}C)		

RESULTS AND DISCUSSION

Plot the impact energy versus temperature for each material on the same graph.



Compare these impact results for each metal to tabulated values from a source such as the ASM Metals Handbook. Comment on differences and similarities.

Examine the type and degree of deformation of each fracture surface. Correlate this information with the corresponding impact energies. Comment on the correlations.