Purpose

The purpose of this exercise is to examine the effects temperature on the material fracture toughness using the standard Charpy impact test. The fracture toughness of a material is, in essence, a measure of the material’s ability to absorb energy. In terms of fracture mechanics, this is also the threshold energy required to drive crack propagation leading to failure. It is known experimentally, for example, that the fracture toughness in plain carbon steels decreases markedly as the temperature is lowered, owing to a relatively sudden transition from a ductile to a brittle failure mode. We will examine this transitional behavior in the lab, and from the measurements identify the ductile-brittle transition (DBT) temperature for different materials.

Procedure

The experimental principle for the Charpy impact test is quite simple. A large pendulum device delivers an impact loading to a specimen containing a standard V-notch. After the impact and fracture of the specimen, there will be a loss in the energy of the pendulum as measured by its reduction in maximum height. For this impact testing machine, the fracture energy is measured (in ft-lb) using a calibrated needle and dial combination located on the side of the machine. In the absence of other mechanical losses, the decrease in the pendulum energy is equal to the fracture energy of the specimen.

- The first task is to calibrate the impact machine (pendulum) to account for frictional losses during the swing; in this way, the frictional losses will not be mistakenly included in the fracture energy. To perform the calibration, set the pendulum to swing freely without a test specimen. Release the pendulum and note the reading obtained. Ideally, this reading should be zero; if it is not, you will need to rotate the needle on the dial slightly (CW or CCW) by the offset amount. Reset the pendulum and perform another free swing test. If the reading is still not zero, repeat the calibration procedure until it is. Once you believe you have the machine properly zeroed, make an additional 5 test swings to see if the zero measurement is consistent. It is likely that there will still be some scatter but hopefully the mean should be at zero. From the scatter, estimate the uncertainty (repeatability) of the machine. Use this value for as an experimental uncertainty (error bar) in your fracture energy plots.
Obtain a set of test specimens from the lab TA; depending on the lab section you will receive different materials to investigate. Be sure to record these in your lab notebooks.

For a given material, you will perform impact tests over a range of temperatures between (approximately) +200°F and -200°F. Elevated temperatures will be obtained by heating specimens in an oven. Extremely cold temperatures will be obtained by immersing the specimens in an ice bath or liquid nitrogen. Given the number of specimens you have to work with, decide upon a set of temperatures to use which span the range above. Note that any temperature can be obtained by allowing a hot specimen to cool down or a cold specimen to warm up prior to the testing. For this purpose, a digital thermometer (thermocouple) will be provided to monitor the temperature of the specimen. It is important that you monitor the specimen temperature just prior to the test, along with an estimate of the temperature uncertainty. After each test, record the temperature and fracture energy data. After fracture, collect and label the test specimen piece(s) according to the testing temperature and material. Later, outside of the lab, you will want to examine the fracture surface for clues as to the nature of the fracture (e.g., fibrous, cleavage). A digital camera will be available to photograph the fracture surface.

Repeat the above procedure the remaining material specimens.

**Analysis and Report Guidelines**

**Fracture Energy Diagrams**

- For each material examined, create a plot of the fracture energy (ft-lb) versus temperature. In addition to the individual plots, also create a single cumulative plot containing all of the data.

- From your data, calculate (estimate) the DBT for each material using one of the methods described in lecture. There is no "correct" measure of the DBT, so be sure to identify which method you are using. Compile the DBT values for the different materials and present them in a tabular format or as a bar chart.

**Fracture Surface Analysis**

- In your report, include a montage of digital photographs of the fracture surfaces for each material specimen (see image below, for example) and be sure to label the corresponding notch temperature. Observe the differences in the surface appearance based upon the failure mode. In your Discussion, comment on and discuss the relationship between the fracture surface appearance, the corresponding fracture energy, and the failure mode.

![Notch Temperature = 75°F](image-url)