# Charpy V-Notch Impact Testing

ENGR45 – Materials Science Laboratory

Chad Philip Johnson

Submitted: May 15th 2013

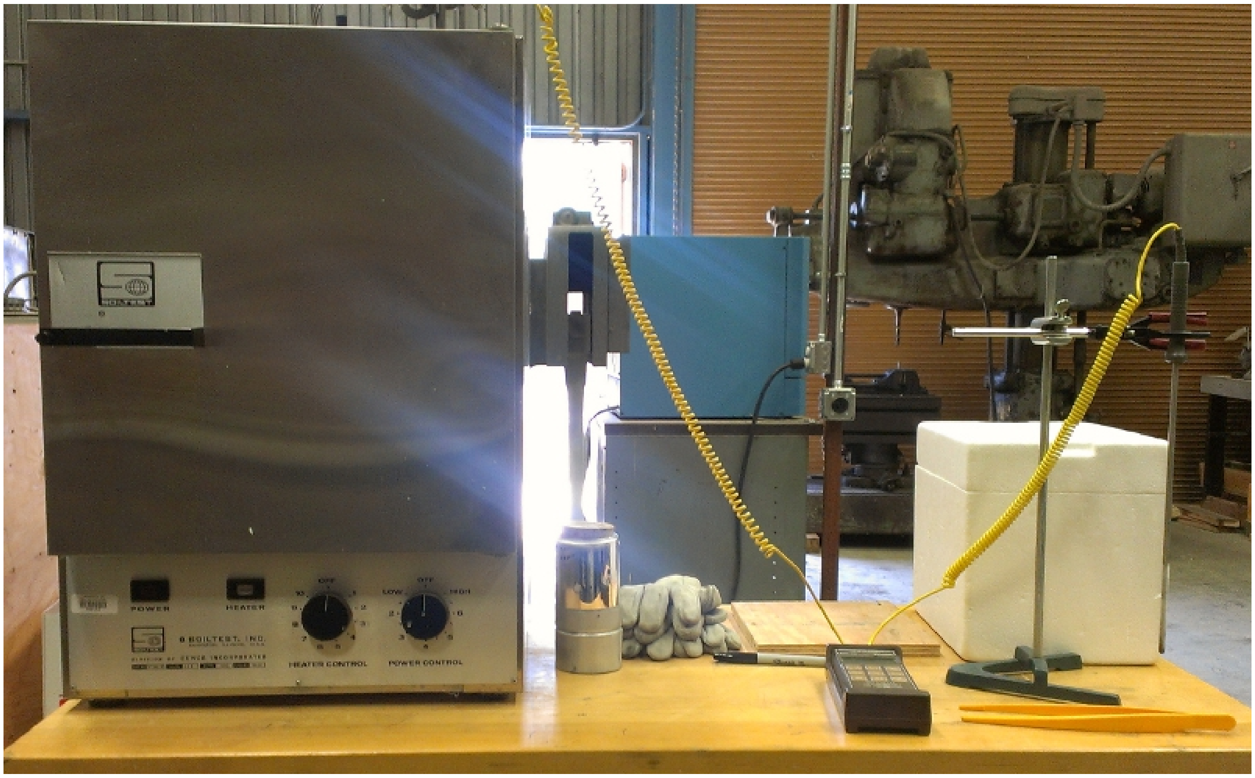
## Abstract

The Charpy V-notch test is an engineering method that is frequently used to measure the toughness of a material, where the toughness represents the amount of energy a material can absorb until it fractures. The measurement and plotting of toughness values assists in understanding its brittle and ductile characteristics at varying temperatures. Although the Charpy V-notch test is not considered to be very precise compared to other toughness tests, it has been widely adopted because it is a simple procedure to perform and also inexpensive. The test involves a bar specimen of a material specially prepared so that a V-notch is machined into it. It is first secured and then struck in the location of this purposed defect by a special pendulum hammer that is released from a fixed height—the resulting amount of energy absorbed by the material is then reported by the machine. In this experiment the CVM energies of two different steel samples were tested: A36 Steel and 1095 Steel.

| Material | Upper Shelf Energy Absorbed | Lower Shelf Energy Absorbed | Upper Temperature | Lower Temperature |
|---|---|---|---|---|
| A36 Steel | 200 ft-lb | 4.3 ft-lb | 60°C | -20°C |
| 1095 Steel | 4.3 ft-lb | 0.0 ft-lb | N/A | N/A |

## Procedure

Many different samples of A36 Steel and 1095 Steel were prepared to specific temperatures through the use of an oven for heating and an acetone bath mixed with dry ice for cooling. A thermal couple was used to monitor the temperatures in both cooling and heating chambers to ensure that the samples achieved the requisite temperature values for each measurement in the experiment. Heat levels in the oven were manipulated by adjusting control knobs on the device while the coldness levels were controlled through addition of dry ice to the acetone bath. The cooling temperatures were more difficult to manage because a specific amount of dry ice had to be added to the liquid to achieve and maintain a desired value; this usually required the addition of many small pieces along with close monitoring of the reported temperature. Many material samples were heated and cooled simultaneously in their respective chambers so that an individual sample could be retrieved at a desired temperature while the remaining samples remained to equilibrate to more extreme temperatures for other Charpy V-notch measurements. The temperature control station used for preparing samples is shown in **Picture 1** below.



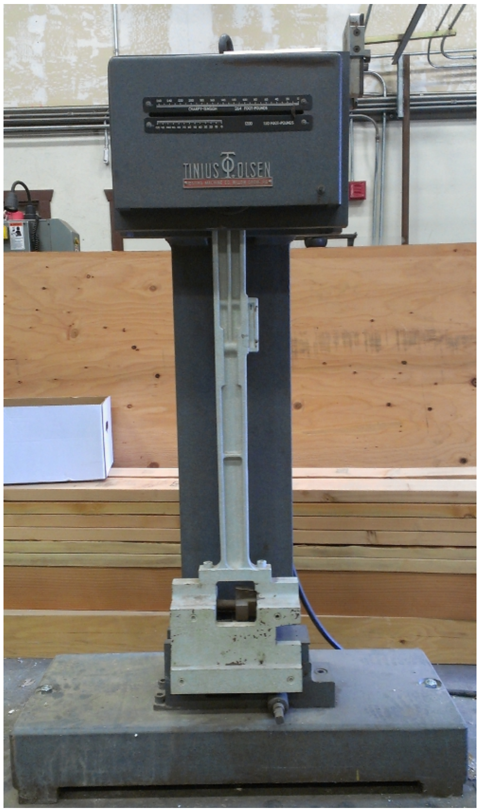
**Picture 1.** Temperature control station for Charpy V-notch samples.

Operation of the Charpy V-notch machine was uncomplicated, although great care was taken in every part of the procedure to ensure that all safety precautions were followed. The pendulum hammer is necessarily massive and swings with a large amount of energy when it is breaking a sample. In order to obtain accurate experimental data, samples had to be inserted into the machine with five seconds of removal from the heating or cooling chamber. The hammer was then immediately released so that a minimal amount of thermal energy was exchanged with the surroundings. Failure to take a nearly immediate impact reading has a negative effect on the accuracy of the associated energy reading. The Charpy V-notch machine used in this experiment is shown in **Picture 2** on the following page.

The machine had not been serviced in many years so a calibration reading was performed by swinging the hammer without a loaded sample. The resulting value given by the machine was then subtracted from all subsequent measurements so that the true measured values could be determined. This data was then used to construct a ductile-to-brittle transition curve within a graph of impact energy versus temperature for each sample using the software *Charpy Regression Test v2* found at the website http://www.novanumeric.com/samples.php?CalcName=Charpy. Information about each material was then obtained from this statistical plotting of data.

## Results

Difficulties existed in completing all of the measurements planned for the experiment. In the case of A36 Steel only four of the expected six measurements were taken. For the initial measurement for a sample at room temperature the hammer was reset to its raised position after the impact but before the value for the impact energy was recorded. This adjustment altered the reading and the measurement could not be repeated due to a lack of available A36 Steel samples. The four measured values—two heated samples and two cooled samples—are shown in **Figure 1** located at the end of this report. Also, a brittle-to-ductile transition curve was produced for this material and is shown in **Figure 2**. Using this statistical curve the following values were found: ~20°C upper temperature, ~200 ft-lb upper shelf energy, ~-60°C lower temperature, and ~4.3 ft-lb lower shelf energy. As is evidenced in these figures, A36 Steel is capable of absorbing a much larger amount of energy at a higher temperature than at a lower temperature. The approximate transition temperature is -20°C, which represents the point at which A36 Steel changes from being a brittle substance to a ductile substance. This is also the temperature at which it is expected that 50% of the fracture will be brittle.



**Picture 2.** Charpy V-notch machine.

For the 1095 steel sample only two measurement could be taken due to time constraints: one at room temperature and another at ~78°C. The third measurement at an extreme cold temperature (approximately -78°C) could not be performed due to difficulties in cooling the sample to this temperature. With only two data points a brittle-to-ductile transition curve could not be produced. A simple plotting of data communicates the likely upper and lower energy shelves—4.3 ft-lb and 0ft-lb, respectively—but the upper and lower temperatures cannot be confirmed nor can the transition temperature. The value for the lower shelf is expected to be accurate because the steel sample is so brittle that it absorbs nearly zero energy from the hammer. However, it is possible that the value for the upper shelf is incorrect.

## Conclusion

Time constraints on the experiment prevented ample readings to be obtained for the 1095 Steel sample so that a brittle-to-ductile transition curve could be produced. Also, an additional reading is required at higher temperatures to confirm that the value obtained for the upper shelf is accurate. For the A36 Steel sample, a reasonable representation of the material's brittle and ductile temperatures was created, although it is desired that more measurements be taken to increase the accuracy of the associated curve. Additional measurements are required to obtain a complete set of data for the 1095 Steel sample so that the toughness properties of each material can be compared and further investigations can be made into each.

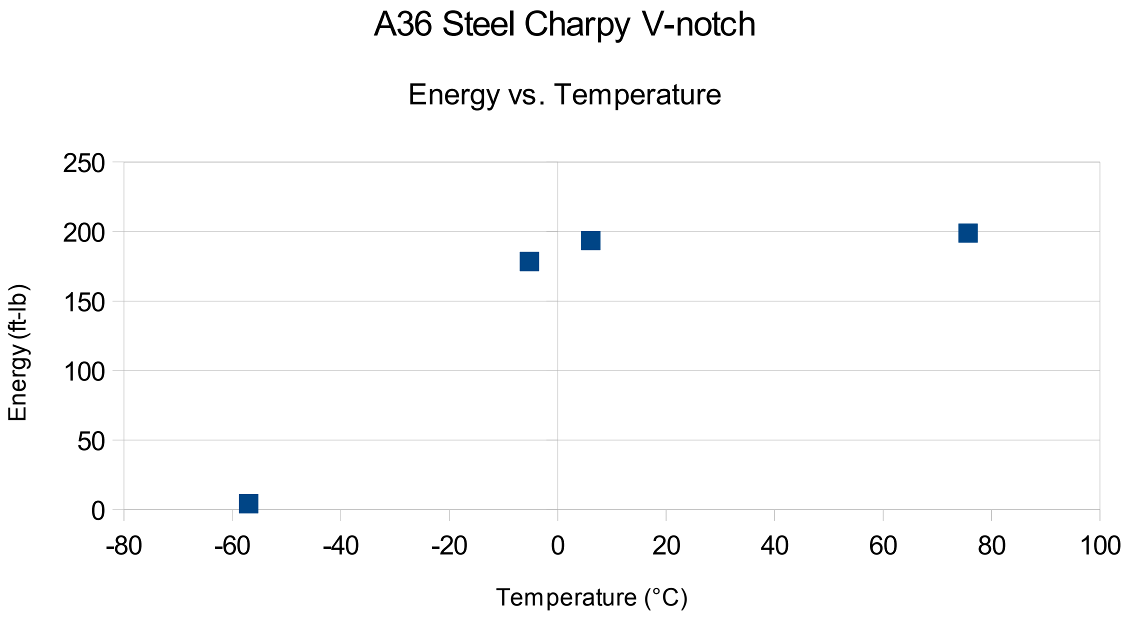


**Figure 1.** A36 Steel Charpy V-notch measured values.

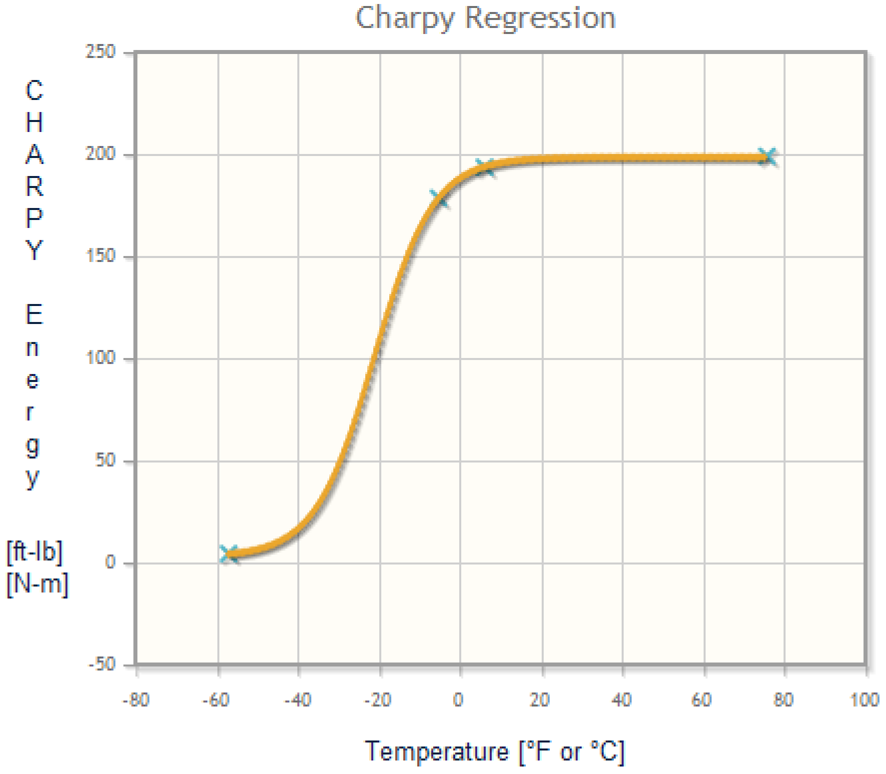


**Figure 2.** Brittle-to-ductile transition curve for A36 Steel.

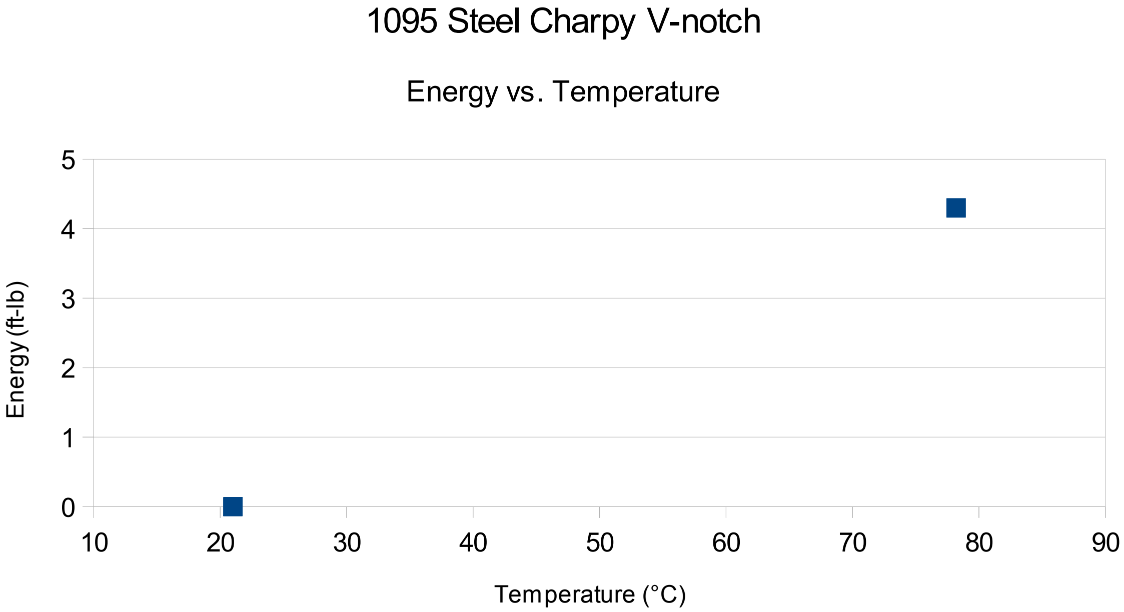


**Figure 3.** 1095 Steel Charpy V-notch measured values.