# Material Science – ENGG*2120: Winter 2020

# LAB SUBMISSION COVER SHEET

Lab Performed: Impact Lab

Date Performed: March 3rd, Tuesday

Date Submitted: March 24th, Tuesday.

Group Number: 04

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**GROUP PARTICIPATION EVALUATION FORM**

*****ALL GROUP MEMBERS MUST SIGN TO RECEIVE THEIR MARKS*****

By signing the cover sheet each member is stating that they made a significant contribution to the writing of this lab report and that the distribution of sections completed is accurate.

| **Group Members** | | **Sections Completed** |
|---|---|---|
| **Name (Printed)** | **Signature** | |
| Layal Al-Zaydi | layal | Introduction, Summary & Conclusion |
| Huda Ameer | [illegible] | Results |
| Nasiba Alchach | [illegible] | Discussion questions: 3 & 4 |
| Nishat Tamanna | Nishat | Discussion questions: 5 &6 |
| Rosalee Thomlison | [illegible] | Discussion questions: 1 & 2 |

# University of Guelph

ENGG*2120: Material Science

# Lab 3: Impact Lab

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**Summary**

The aim for conducting this lab is to figure out the consequence when a heavy load is employed rapidly on different materials which make the impact testing differs from the tensile or compression testing, where the force on materials are applied over the time. The reason in the impact testing to apply a large force on the material immediately is to prevent the dislocation of material's molecules. However, in the tensile and compression testing, there is time for the materials to deform and a chance for necking to occur.

In order to determine Ductile-Brittle Transition Temperature (DBTT) and to empathize on the effect of temperature for each metal , the impact test was conducted on two different materials, AISI-1015-Steel, and 6061-T6-Aluminum, Each material was assessed four times at different temperatures, -190°C, 0°C, 75°C, and 120°C and the results were observed and recorded.

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## 1.0 Introduction

The main purpose of the impact test is to determine the ductile to brittle transition temperature (DBTT) of metals, to be able to choose the correct metals for various uses. As the test depends on the conversation of energy law. The impact testing machine hits the samples with a very heavy load rapidly and reads the absorbed energy by the sample.

In the lab, two types of metals, AISI-1015 Steel and 6061-T6 Aluminum, were used to perform an impact test at four different temperatures; 120°C, 75°C, 0°C, and -190°C, using a Charpy impact test machine. At the end of the lab, the differences in the characteristics of steel samples and aluminum samples and how the temperature affected each sample was detected and observed from the plotted graph of the energy absorbed as a function of temperature for each sample.

## 2.0 Experimental Apparatus and Procedures

The experiment apparatus and procedures used for this lab are outlined in the ENGG*2120 Lab Manual [1].

## 3.0 Results

### 3.1 Calculations, Tables and Graphs

***Table 1***. *Results of Impact Testing*

| *Material* | *Temperature (℃)* | *Energy Absorbed (J)* |
|---|---|---|
| *AISI-1015 Steel* | *120* | *19.9* |
| | *75* | *14.5* |
| | *0* | *8.6* |
| | *-190* | *4.1* |
| *6061-T6 Aluminum* | *120* | *70* |
| | *75* | *31.7* |
| | *0* | *85* |
| | *-190* | *114.9* |

***Figure 1.*** *Graph of Energy Absorbed with respect to Temperature for Steel*

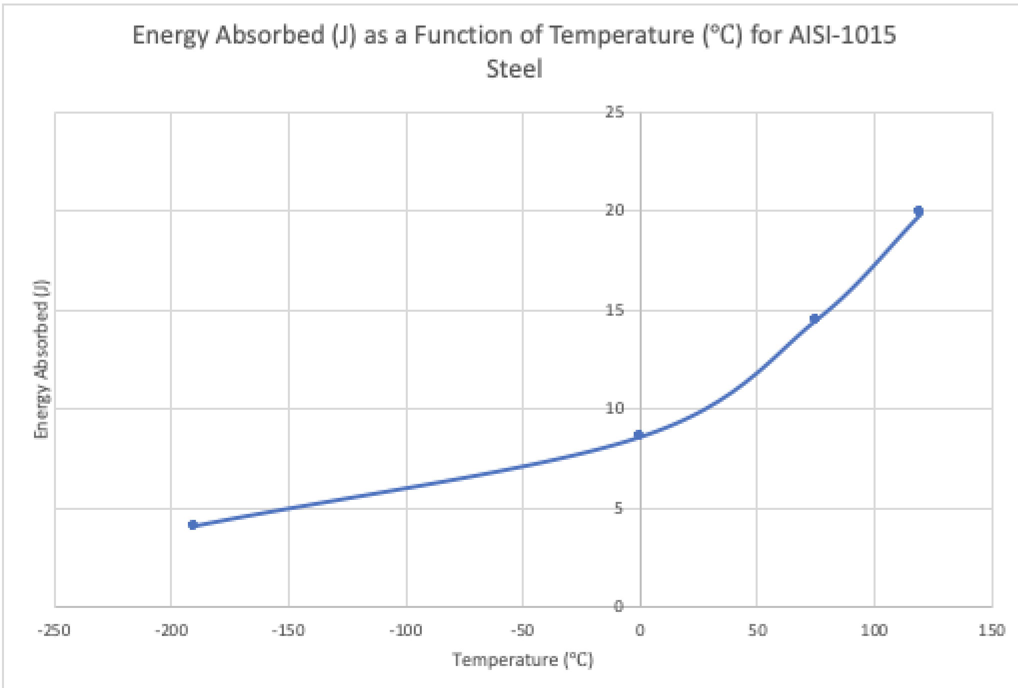



***Figure 2.*** *Graph of Energy Absorbed with respect to Temperature for Aluminum*

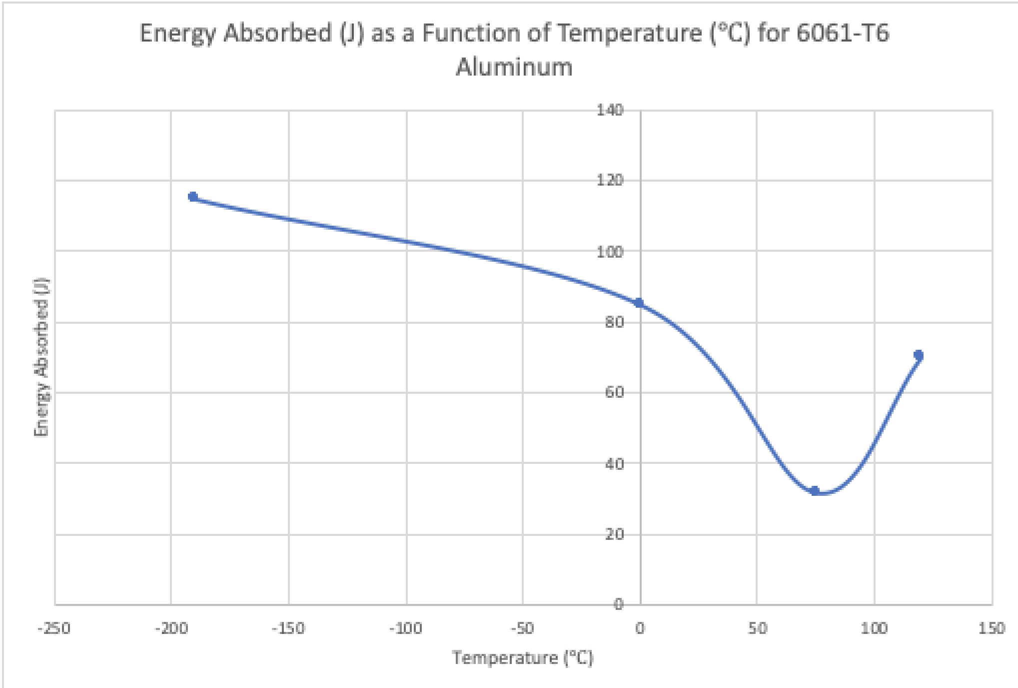



***Figure 3.*** *Sample Fracture Surfaces after Impact Testing for Steel and Aluminum*

***Table 2.*** *Break Characteristics of Steel and Aluminum at Different Temperatures*

| Temp (℃) | AISI-1015 Steel | | 6061-T6 Aluminum | |
|---|---|---|---|---|
| | Break Type | Characteristic | Break Type | Characteristic |
| -190 | Brittle | Broke into two pieces, smooth surface | Ductile | Remained slightly attached, slight necking, rough surface |
| 0 | Brittle | Almost broke off fully, smooth surface, but bumpier | Ductile | Remained attached, slight necking, rough surface |
| 75 | Ductile | Remained slightly attached, bumpier surface, slight necking | Ductile | Remained attached, necking, rough surface |
| 120 | Ductile | Broke into two pieces, rough surface, necking | Ductile | Remained attached, necking, rough surface |

**3.2 Ductile to Brittle Transition Temperature**

The Ductile to Brittle Transition Temperature will be determined in two ways. The first is examining the surfaces of the specimens after fracture, and the second is the Average Energy Criterion. It is generally found that there is a reasonable correlation between the amount of the fracture specimen that has been broken in a ductile fashion and the energy expended in breaking the specimen [1].

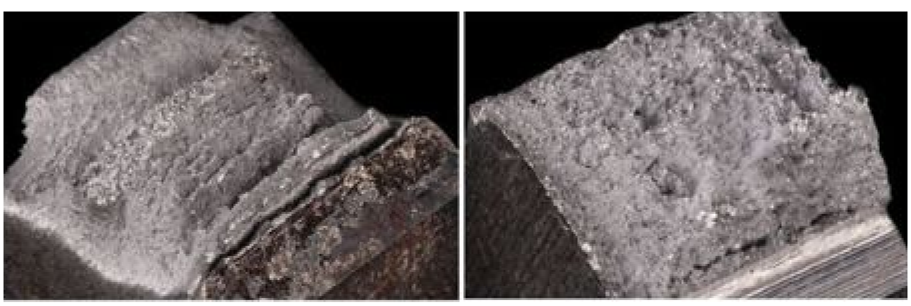
Figure 3 and Table 2 outline the characteristics and appearances of the Steel and Aluminum post-fracture. The Steel sample at -190℃ exhibits a surface which is smooth and flat after being completely broken off. This alludes to the fact that at this temperature, the sample's fracture can be classified as brittle. At 0℃, the sample had almost the same characteristics as the -190℃ sample, but with a bit more bumps. This suggests that the sample is still brittle, but is transitioning into ductile breakage. At 75℃, the fracture surface was bumpier than before, and necking can be seen on the sides. At 120℃, the fracture appeared like the 75℃ sample, but more necking was apparent on the sides, and was rougher, which therefore means it underwent ductile fracture.

The transition from ductile to brittle lies somewhere between 0℃ and 75℃. To make an estimate of the DBTT, we can take the midpoint of 0 and 75, 37.5℃, which is the estimate of the Ductile to Brittle Transition Temperature based on the surface test for AISI-1015 Steel.

Because the fracture surface of Aluminum showed no change at the different temperatures, with them all being rough, it can be concluded that at all the temperatures tested, the fracture experienced is ductile, and therefore a DBTT does not exist for 6061-T6 Aluminum.

The average energy criterion states that the midpoint of the temperature at which a fracture occurs for a completely ductile specimen and the temperature at which a fracture occurs for a completely brittle specimen is the DBTT [1]. Looking at Figure 1, this energy can be found between about 8 J and 15 J, which the average of these two values is 11.5 J. The temperature associated with this energy is found to be about 32℃. Looking at Figure 2, there does not seem to be a steep change of values, which aids the previous conclusion that Aluminum does not have a DBTT.

***Figure 4**. Micrographs of sample fractures of AISI (left) and Aluminum (right)*



Looking at Figure 4, Aluminum's surface is rough, while that of Steel exhibits irregular arrays of small bright facets, which can be seen mostly in the middle. This alludes to the fact that Aluminum undergoes Ductile fracture, while Steel exhibits both ductile and brittle fracture [1].

## 4.0 Discussion

For the aluminium sample, no ductile to brittle transition presented due to the nature of the crystal structure. Aluminum, being of FCC crystal structure and therefore close packed atoms, despite temperature had more plastic deformation [2]. The transition temperature from ductile to brittle for the 1015 steel, observed between fracture surfaces at 0°C and 75°C, was a midpoint of 37.5°C. The "upper" and "lower shelf" energies are known as the maximum and minimum amount of energy found at the ductile and brittle states, respectively. For the upper shelf, found at 75°C, corresponding to an energy of 14.5 Joules. The lower shelf, found at 0°C, is 8.6 Joules. These results closely align with the content presented in class through the discussion of their crystal structures as it pertains to transitions temperatures and brittle to ductile transitions. Steel being of BCC structure and aluminum being of FCC structure, it would predict that the samples would yield these results.

Various metals react differently for several reasons, specifically based on their crystal structure. Different crystal structures yielded different brittle properties, body centered cubic structures in low temperatures are brittle whereas, face centred cubic structures in low temperatures do not become brittle. A body centred cubic (BCC) structure means that there are less slip planes than that of face centred cubic (FCC) and so at lower temperatures the structure of the BCC will deteriorate and FCC will not. Therefore the steel alloy of BCC structure through this temperature change will behave differently and the FCC structured aluminum will not behave differently through change in temperature.

Steels can be made less brittle at low temperatures by manipulating some aspects of the structure of the material. Steels can become ductile at increasing temperatures [3]. Lower transition temperature indicates that the material will be more ductile than the initial sample of steel. In fact, metal heat treatments may be added to prevent overgrowth of grain under tension. This helps develop a less brittle metal at low temperatures [4].

The ductile to brittle transition temperature (DBTT) must be addressed for applications where temperature changes dramatically. The DBTT depends heavily on the decomposition of the metal. Steel is the element most widely used to demonstrate this behaviour [2]. When designing a snow plow blade, it is important that the structure of the steel used is much more regulated and the temperature at which the DBTT takes place is lower [2]. Decreasing carbon content will result in reducing the DBTT which makes the steel stronger at lower temperature and therefore widen the ductile range of steel. Hence, a low carbon steel would be more appropriate than high carbon steel for this application.

Steel embrittlement can be a concern at room temperature. Environmental embrittlement greatly decreases the tensile ductility of intermetallic alloys when measured at room temperature in the ordinary laboratory environment. The extent of the embrittlement depends on two significant kinetic parameters: the moisture or intermetallic kinetic reaction, and the diffusion rate of the hydrogen [5]. External parameters, temperature, the expected service life and the method of use of steel should be taken into consideration when selecting a steel alloy for an application requiring high strength and good toughness. For example, The intensity obtained with alloy steel depends on the elements in which the steel is formed and on the thermal state of the alloy steel. Alloy steels which have been treated or refined would have lower strengths than the same ones heated and easily quenched. This is best to glance at a sheet of details to assess the characteristics of a particular alloy steel material for best application [6].

Within this experiment there are several potential error causes. Possible causes of error for this procedure involve the time required to transfer the samples from the furnace to the effect tester. The sample had cooled in this period and may either have been cooled down to a temperature lower than the temperature it was reported to have been checked, or cooled down to a low degree that should have been calculated. Another possible mistake may be that the samples were not tested at the correct temperature. They may have been overheated or over-cooled. The temperature is deemed right as opposed to the furnaces which have been set at a defined temperature. But the temperature was not measured after the samples were put in liquid nitrogen and stored for an indefinite time frame which might have tampered the precise temperature. Eventually, if the test sample parts had any notched defects, the computer may have produced the wrong impact energy values. That is why it is best to perform the procedure many times on a given specific sample of substance to obtain the most reliable outcomes

## 5.0 Conclusion

By observing the lab results, it can conclude that the steel samples have higher ductile to brittle transition temperature (DBTT) compared to Aluminum. It was found that the steel samples broke into two pieces or almost broken (at 75℃) whereas the aluminum samples remained attached at all temperatures and experienced ductile fracture and hence it is concluded that DBTT does not exist for 6061-T6 Aluminum. The graph of energy absorbed with respect to temperature for 1015 steel shows a continuous slope with speedy rise around 70°C though the graph for aluminum had no reliable trend.

## 6.0 References

**[1]** ENGG*2120 – Materials Science Laboratory Manual, School of Engineering University of Guelph, September, 2012.

**[2]** UNSW - School of Material Science and Engineering. [23 March 2020]. Available from: http://www.materials.unsw.edu.au/tutorials/online-tutorials/2ductile-brittle-transition

**[3]** CAU - Faculty of Engineering University of Kiel. [23 March 2020]. Available from: https://www.tf.uni-kiel.de/matwis/amat/iss/kap_9/illustr/s9_1_1.html

**[4]** University of Illinois at Urbana-Champaign Department of physics. [23 March 2020]. Available from: https://van.physics.illinois.edu/qa/listing.php?id=1683&t=brittleness-of-metals-at-low-temperature

**[5]** "Embrittlement - an overview | ScienceDirect Topics", *Sciencedirect.com*. [Online]. Available: https://www.sciencedirect.com/topics/materials-science/embrittlement

**[6]** "7 Things To Consider When Choosing An Alloy Steel Grade | Metal Supermarkets - Steel, Aluminum, Stainless, Hot-Rolled, Cold-Rolled, Alloy, Carbon, Galvanized, Brass, Bronze, Copper", *Metal Supermarkets - Steel, Aluminum,Stainless, Hot-Rolled, Cold-Rolled, Alloy, Carbon, Galvanized, Brass, Bronze,Copper*. [Online]. Available: https://www.metalsupermarkets.com/7-things-consider-choosing-alloy-steel-grade/