Experiment 5 : Impact Toughness using Charpy Test

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1 Objective

The aim of this experiment is

- To study the impact resistance of metals using Impact testing machine of the Charpy type
- Find out the energy loss due to friction in joules
- To determine the variation of impact strength of a material with change in temperature

2 Theory

Some materials like cast iron, glass and some plastics which offer considerable resistance to static load, often shatter easily when a sudden load (impact) is applied. The impact strength is defined as the resistance of the materials to shock dynamic load. The impact testing is to find out the energy absorbed by a specimen when brought to fracture by hammer blow and gives a quality of the material, particularly its brittleness. Highly brittle materials have low impact strength.. Temperature also influences impact strength of the materials. The area under the stress strain curve in a static tensile test is measure of the energy absorbed per unit volume of the material, called the modules of toughness. This is also a measure of the impact strength of the material. Impact test can also be used to determine the transition temperature for ductile to brittle behavior.
The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. Absorbed energy is a measure of the material's notch toughness. It is widely used in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative.

3 Experimental Methods

The instruments used in the experiment are:

- Impact Testing Machine :
  This machine comprises of a pendulum, a scale, supports to latch the pendulum and also clamp the specimen, and a digital output screen. The swinging pendulum would provide the impact required for testing.
- Vernier Calipers :
  It is a length measuring device. We use it to measure the width, length and height of the specimen before the test.
- Furnace Liquid Nitrogen :
  To test the impact resistance of the specimen at different temperatures, we will require a furnace to heat up the specimen and liquid nitrogen to super cool the specimen.
- Thermocouple :
  A Thermocouple is a sensor used to measure temperature. When the junction experiences a change in temperature, a voltage is created. We use the calibration chart to find the temperature corresponding to that voltage.

We begin the experiment by doing the calibration test, where we latch the pendulum and release it without mounting any specimen. The machine gives us the impact energy which should lie within the range specified. If it does not, we need to calibrate the machine. Next, we do the friction loss test which is programmed for 11 half cycles. We latch the pendulum and release it without mounting any specimen. The machine gives us the friction loss automatically.

We get,
The total friction loss = 23.072 J
The average friction loss per half cycle = 2.0975 J

Now we start with the actual test. We start by latching the pendulum and then mounting the specimen. The notch of the specimen should be away from the pendulum. On releasing the pendulum, the striking edge hits the specimen and the output screen gives us the energy absorbed by the specimen.

We also need to find the impact energy of the specimen at different temperatures, so we heat or cool the specimen and repeat the same procedure. We use a thermocouple to find the temperature of the specimen.

4 Results

The dimensions of the specimen is : 55 mm × 10 mm × 10 mm with a notch of depth 2 mm. So, the working area = 10 mm × 8 mm = $0.8 \times 10^{-4}\ m^2$ Also,

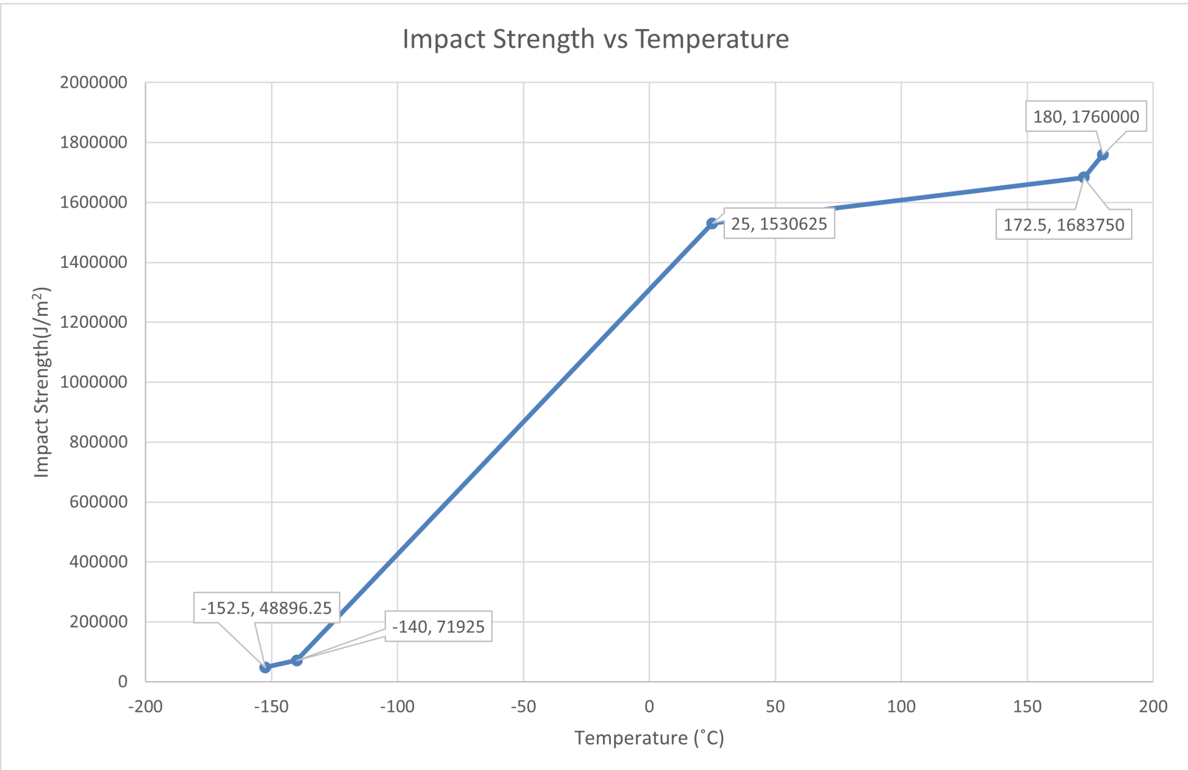
$$Impact\ Strength = \frac{Impact\ Energy}{Area}$$

Impact strength observations for Mild Steel and Aluminum at room temperature ($24°C$)

Material	**Energy Absorbed(J)**
Aluminium	53.04
Mild Steel	204.09

Here is the table of the experimental data for mild steel:
Note that the impact energy that we get already has the frictional loss subtracted from it.

S. No.	Condition of sample	Voltage (mV)	Temperature ($°C$)	Impact Energy (J)	Impact Strength (J/m^2)
1	At room temperature	-	25	122.45	1530625
2	Heat-treated in furnace	6.9	172.5	134.7	1683750
3	Heat-treated in furnace	7.2	180	140.8	1760000
4	Cooled using nitrogen	-5.6	-140	5.754	71925
5	Cooled using nitrogen	-6.1	-152.5	3.9117	48896.25



- Rupture energy of Mild Steel at Room Temperature = 204.09 J
- Rupture energy of Aluminium at Room Temperature = 53.04 J

5 Observations

- The friction loss test for 11 half cycles gives us a total loss of 23.072 J. So the average friction loss per half cycle would be 2.0975 J. This energy is accounted for when we get the impact energy from the machine. So, in reality, the loss of energy of the pendulum due to impact = Impact energy + friction loss per half cycle (2.0975 J).
- The super cooled specimen break into two while the specimen at room temperature and higher temperatures undergo fracture, but do not break.
- The grain structure at the fracture can tell us about the nature of the fracture. We notice that the super cooled specimen show a fine fracture surface, indicating brittle fracture. On the other hand, the specimen at room temperature and higher temperatures have a course surface indicating a plastic ductile fracture.
- We notice that the super cooled specimen after breaking travels away from the motion of the pendulum. This could be because of the reaction forces from the anvil after the rapid fracture forcing the two pieces on the opposite direction.
- We notice that the specimen at room temperature and higher temperatures after fracture travel along the motion of the pendulum. Since the specimen does not break, the pendulum pushes the specimen along it's motion.
- The impact strength for a specimen should increase with the increase in temperature due to increased ductility, but the data suggests a dip in impact energy for temperatures above room temperature. This behaviour could be explained by thermal softening. Finer separation at both end of temp scale would have given the ideal curve, seen in books.

6 References

1. Lab Manual
2. Wikipedia