Journal of Social Research
P-ISSN: 2827-9832
E-ISSN: 2828-335x
http://ijsr.internationaljournallabs.com/index.php/ijsr

IMPACT TEST ANALYSIS ON STEEL METAL MATERIALS AND ALUMINUM

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ABSTRACT

Impact *testing* is carried out to determine the strength of the material against shock *resistance*, such as brittleness caused by heat treatment or the brittleness of the *casting* product and the effect of the shape of the product. This test is carried out on a testing machine designed by having a pendulum with a certain weight that swings from a height to provide shock loads, in this test there are two kinds of testing methods, namely the "Izod" method and the "Charpy" method which differ according to the direction of loading on the test material and the position of the test material. This study aims to determine the ductility of ST 37 steel and aluminum from smelting beverage cans combined with oil. The research method used in this research is a direct review in the field then conducting data collection and literature studies including taking report sources from various books, both in campus libraries and libraries outside the campus. The results showed that 1) The impact price on aluminum material was obtained 0.057 Joules / mm2 with the energy given at 4,588 Joules. 2) The *impact* price on ST37 steel material is 0.192 Joules/mm2 with Energy given at 15.34 Joules.

Keywords: *Impact test analysis, steel and aluminum, metal materials*

INTRODUCTION

In the development of the industrial world, especially those related to material research and its use, in the production process many things must be fulfilled so that these materials can be used in the industrial world (Wang et al., 2022). For use as a material, the distinctive properties of metal materials must be known because the metal will be used for various purposes and conditions (Naseem & Durrani, 2021). The properties of the metal include mechanical properties, thermal properties, chemical properties, hardenability, dimensional accuracy, and so on.

As for this experiment, what will be tested is the mechanical properties of the metal, especially its toughness properties (Jiang et al., 2014). By knowing the level of toughness of metal, of course, we can estimate its ability to receive impact energy given suddenly to be able to break a material. For this purpose, impact testing is carried out on a material or material that will be used in various needs. This test is very important in determining the resistance of a material to fracture, based on the energy exerted by sudden collisions/loads on a material.

Steel is one of the fundamental needs for construction. With various kinds of needs, the mechanical properties required by a material are different. These mechanical properties mainly include hardness, ductility, toughness, toughness, weldability and good machinability (Zhong et al., 2017). With the properties of each material different, there are many methods to test what properties are owned by a material.

Low-carbon steel (St 37) has a carbon content of less than 0.3%. This steel is often used also for the construction of machines that rub against each other such as gears, shafts, etc. because it is very ductile. However, the surface hardness of the steel is relatively low so that before it is used for construction, it needs to be modified or improved the hardness properties on the surface. This low carbon steel cannot be hardened conventionally but through the addition of carbon by a carburizing process (Reddy et al., 2022). The type of carbon steel St 37 for the manufacture of machine components standardized according to tensile strength has a tensile strength of 37-45 Kg/mm2.

Aluminum is a material that has advantages such as lighter loads than steel, not difficult to form, has no taste, has no odor, is toxin-free, able to overcome gas leaks, has good heat conductivity and can be recycled (Basa &; Halawa, 2015). Aluminum is very easy to find such as household furniture, car components, train components, aircraft components, and beverage cans.

Aluminum materials that have been wasted, such as beverage cans, can be reused by recycling to get new materials. Another way to recycle is to re-smelt/cast used aluminum to become raw materials. In addition, aluminum has undoubted mechanical properties, aluminum material is also usually used in the engineering world in addition to steel. So is the capable nature of the machine, as well as its ability to be recycled. This ability can overcome the increase in aluminum waste due to excessive use in everyday life.

Steel and aluminum are two metal materials that are widely used in various industries. Steel, with its high strength and toughness, is often used in building construction, automotive, and other manufacturing industries. On the other hand, aluminum has a lower density and good strength against corrosion, so it is often used in the aircraft industry, automotive, construction, and various other applications.

Impact test is one of the methods used to determine the strength, hardness, and ductility of materials. Therefore, impact tests are widely used in the field of testing the mechanical properties possessed by a material. In tests that have been carried out on two different test equipment, the fractures that occur in aluminum and steel are ductile, but for steel the impact price is higher because steel has toughness. As for the impact price test specimen is different because there are several factors that cause differences in the size of the test specimen, the weight of the pendulum, the length of the pendulum arm, and the difference from the initial angle of the pendulum.

Chaerul Umam Wardani et al in 2009, analyzed the impact testing of the Izod and Charpy methods using ST37 aluminum and steel test specimens. In the Charpy test, a sample of material is laid horizontally, then pounded by a free-falling hammer from a certain height. Meanwhile, the Izod test uses a hammer that is rotated at a 180-degree angle before pounding a vertically placed sample.

Toughness Evaluation: Impact tests provide information about a metal material's ability to absorb kinetic energy during sudden impacts or loads. The results of these tests illustrate the toughness of the material, that is, its ability to overcome shock and prevent cracks or serious structural failures.

Carbon Steel

Carbon steel is one type of alloy steel consisting of iron (Fe) and carbon (C) where iron as the basic element and carbon as the main alloying element with a content of less than 2%. Carbon steel is divided into 3 categories based on the presentation of carbon content, namely: low carbon steel (C = 0.03-0.35 %), medium carbon steel (C = 0.35-0.55 %), and high carbon steel (C = 0.55-1.70 %). Low-carbon steel is less sensitive to heat treatment, so to increase its strength, it is necessary to carry out cold working. In contrast to low carbon steel, the strength of medium-carbon steel can be increased by means of treatment. The last category, namely high carbon steel, has hard but less ductile properties.

Low Carbon Steel

In the trade it is made in steel plate, steel strip and steel bar or profile. This steel is called mild steel or tool steel. This steel can be used as nuts, bolts, screws, weapon tools, precision device tools, tensile rods, cylindrical tools, and almost the same use. This steel can also be completed by cold working by soaking or dipping the steel into an acidic solution that is useful for removing the oxygen layer.

An example of low-carbon steel is ST 37 steel which has a carbon content of less than 0.3%. This steel is often used also for the construction of machines that rub against each other such as gears, shafts, etc. because it is very ductile. However, the surface hardness of the steel is relatively low so it has not been used for construction.

1. Medium Carbon Steel

This steel is widely used for the purposes of tools, tools, machine parts. Based on the amount of carbon contained in steel, this carbon steel can be used for various purposes such as for industrial purposes vehicles, gears, springs and so on.

2. High Carbon Steel

This steel has the highest strength and is widely used for material tools. One application of this steel is in the manufacture of steel wire and steel cable. Based on the amount of carbon contained in steel, carbon steel is widely used in the manufacture of springs, tool tools such as: hammers, saws or cutting chisels. In addition, this type of steel is widely used for other industrial purposes such as making misers, razors, saw blades and so on. Medium carbon steel and high carbon steel contain a lot of carbon and other elements that can harden the steel.

Aluminum

Aluminum comes from the Latin "Alumen" Alum. In 1761 De Morveau proposed the name Alumine for the bases Alum and Lavosier; in 1787, he thought that this was an undiscovered metal oxide. Aluminum (Al) is the most abundant element on earth and the most widely used metal after steel. The metal was discovered in 1825 by Hans Christian Oersted and industrially developed in 1886 by Paul Heroult in France and C.M. Hall in America. Separately they have both succeeded in obtaining aluminum metal from aluminia by electrolysis.

The method to take aluminum metal is by electrolyzing alumina dissolved in Cryolite. This method was invented by Hall in the USA in 1886 and at the same time by Heroult in France. Cryolite, a naturally occurring ore found in Greenland, is no longer used to produce aluminum commercially (Avango et al., 2014). Its replacement is an artificial liquid that is a mixture of sodium, aluminum and calcium fluoride. Compounds that have great uses are aluminum oxide, sulfate, and sulfate solution in potassium. An oxide of aluminum, alumina occurs naturally as Ruby, Sapphire, Corundum and Emery and is used in glassmaking. Pure aluminum, a silvery-white metal has desirable characteristics in metals. It is lightweight, non-magnetic and non-splashable, is the second easiest metal in terms of formation, and sixth in terms of ductility.

Generally, aluminum is mixed with other metals to form aluminum alloys. This material is used not only for household appliances, but also used for industrial purposes, construction, and so on. Until now, the Heroult Hall process is still used to produce aluminum. The use of aluminum as a metal every year is second only to iron and steel, the highest among non-ferrous metals. Annual aluminum production in the world reached 15 million tons per year in 1981. By combining other elements, the pure properties of aluminum can be improved. The addition of other metal elements will result in reduced corrosion-resistant properties and reduced ductility of the aluminum. With the addition of a little manganese, iron, lead and copper greatly affect its corrosion-resistant properties.

Aluminum is widely used as kitchen utensils, building construction materials and thousands of other applications (Surdia & Saito, 1992). Important properties possessed by aluminum so that it is widely used as an engineering material:

1. Specific gravity is light (only 2.7 gr/cm^3, while iron ± 8.1 gr/cm^3)
2. Corrosion resistant
3. Good conductor of electricity and heat
4. Easy to fabricate/shape
5. The strength is low but the alloying strength can be increased

The corrosion-resistant properties of aluminum are obtained due to the formation of a layer of aluminum oxide (Al2O3) on the surface of aluminum. This coating makes Al corrosion-resistant but at the same time difficult to weld, due to differences in melting points. Aluminum generally melts at ± 600°C and aluminum oxide melts at 2000oC. The strength and hardness of aluminum is not so high with blending and heat treatment can be increased in strength and hardness. Commercial aluminum always contains impurities of ± 0.8% usually in the form of iron, silicon, copper and magnesium. Another advantageous property of aluminum is that it is very easy to fabricate, can be cast (cast) by any pouring method.

Table 1. Characteristics of various metals

Jenis logam	Sel satuan	Titik cair (°C)
Timah Hitam, Pb	Fcc	327
Seng, Zn	Hcp	419
Magnesium, Mg	Hcp	650
Aluminium, Al	Fcc	660
Tembaga, Cu	Fcc	1.083
Nikel, Ni	Fcc	1.453
Titanium, Ti	Hcp > 900 °C Bcc < 900 °C Bcc < 910 °C	1668
Besi, Fe	Fcc, 910 < Tc <1.350 Bcc > 1.350 °C	1.535

Impact *Testing*

Material testing is a method used to test the strength of a material/material by applying an axial force load. *Impact* testing according to Malau & Widyaparaga (2008), aims to determine the ability of the specimen to absorb the energy given. *Impact* testing is one of the processes of measuring the fragility of materials. The toughness of a material that cannot be detected by other tests, if two materials will have the same similar properties but if tested with an *impact* test it will be different. *Impact testing* is carried out to determine the strength of the material against shock *resistance*, such as brittleness caused by heat treatment or the fragility of casting products and the influence of the shape of the product.

Impact *testing* is a response to shock loads or sudden loads. This test is carried out on a testing machine designed by having a pendulum with a certain weight that swings from a height to provide shock loads, in this test there are two kinds of testing methods, namely the "Izod" method and the "Charpy" method which differ according to the direction of loading on the test material and the position of the test material (Sudjana, 2008). In the Charpy and Izod standard tests, it is designed and used to measure impact energy known as notch toughness (Saba et al., 2019). Charpy specimens are rod-shaped with a cross-section of square latitude with V notches by machining processes.

The loading in the *impact* test process is given by the swing of the pendulum with weight G and the distance to the rotating axis R moving from height h1 at an initial angle of α.

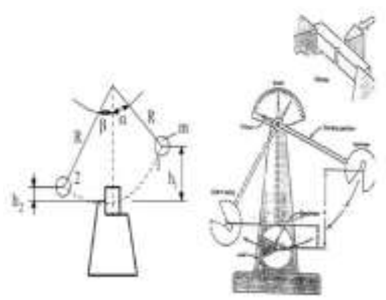

Figure 1: Schematic illustration of Charpy Impact Testing

In *impact tests*, the energy absorbed to break the specimen must be measured. After the pendulum is removed, the test specimen will break, after which the pendulum will swing back, the greater the energy absorbed, the lower the swing back from the pendulum. The absorbed energy can usually be read directly on the calibrated pointing scale found on the testing machine (Haines et al., 1998). Absorbed energy can also be written in the form of a formula:

E = m. g (h1-h2) = force x distance (Wibowo, 2013)
where:
E = absorbed energy = power to break the specimen (Joules)
m = mass of pendulum (kg)
g = gravitational acceleration (m/s2) = 10 m/s2
h1 = sledgehammer falling height (m) = R+R sin (α - 90)
h2 = sledgehammer swing height (m) = R+R sin (β - 90)
R = distance of turning point to weight point of sledgehammer (m)
α = angle of fall (°)
β = swing angle (°)

So that:

$$Impact\ Pricing = \frac{Absorbed\ Energy\ (Joules)}{Cross - sectional\ area\ of\ the\ test\ specimen\ fracture\ (mm^2)}$$

Impact *Test Methods*

In general, impact test specimens are grouped into two standard sample groups: Charpy test rods widely used in the United States and Izzod test rods commonly used in the UK and Europe.

1. Charpy Method

The Charpy specimen has a cross-sectional area of square latitude (10 x 10 mm) with a length of 55 mm2 and has a V-shaped notch with an angle of 45 o, with a base radius of 0.25 mm and a depth of 2 mm. In material brittleness testing by means of impact charpy, the pendulum is directed at the back of the notch of the test rod.

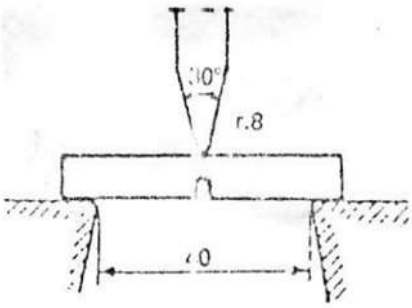

Figure 2: Charpy method specimen laying

The advantages and disadvantages of the charpy method are:

Excess:

1. More accurate test results
2. The work is easier to understand and do
3. Generates uniform stress along the cross-section
4. Cheaper tool price
5. Shorter testing time

Deficiency:

1. Can only be installed in a horizontal position.
2. The specimen can shift from its pedestal because it is not gripped by it.
3. Testing can only be performed on small specimens.
4. Test results cannot be or are appropriately utilized in design because the voltage level given is uneven.

2. Izod method

Izzod test objects are commonly used in the UK, but are now rarely used. The izzod specimen has a cross-section of a square or circle and a v-notch near the clamped end. In the izzod method impact test, the pendulum stroke is directed at a distance of 22 mm from the clamp and the notch is facing the pendulum.

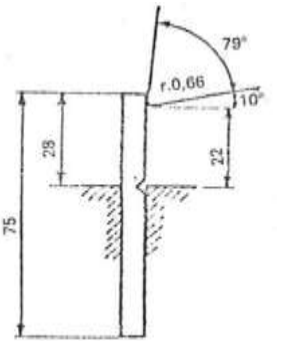

Figure 3: Laying of the izzod method specimen

Advantages and Disadvantages of the Izod Method

Excess

1. The impact is precise on the notch because the workpiece is gripped and the specimen does not shift easily because it is gripped at one end.
2. Can use specimens of larger size.

Deficiency:

1. More expensive testing costs.
2. The loading is carried out only at one end, so the results obtained are not good.
3. The testing process is more difficult.
4. The result of the fracture is not good.

Types of Impact Test Faults

As for the various impact fractures are as follows:

1. Brittle fault: A fault that occurs on brittle material.

Characteristics: Flat and shiny surface, the cut can be reassembled, cracks are not accompanied by deformation, and the notch punch value is low for example: cast iron

2. Clay faults :P that occur in soft materials.

Characteristics: Uneven surface, opaque and fibrous, pair of pieces can not be attached again, there is deformation in cracks, high notch punch value. For example: soft steel, copper etc.

3. Mixed faults :P faults that occur in materials that are strong enough, but ductile.

Characteristics: Combined brittle fracture and clay fracture, slightly dull surface and slightly fibrous pieces can still be attached, there is deformation in cracks most occurring. for example: on tempered steel (Ismail, 2012)

METHOD

Research Sites

The research was conducted at the Mechanical Engineering Production Laboratory of Tama Jagakarsa University. Meanwhile, the research was carried out in the period from January 2021 to March 2021

Research Flowchart

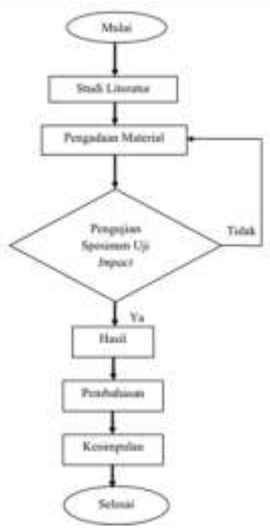

Figure 4: Research flowchart

Materials and Tools

The materials used for *impact* tests are:

1. ST 37 Carbon Steel: The ST37 carbon steel used for the impact test has a diameter of 53 mm and a length of 280 mm.

Figure 5: ST37 Carbon Steel

2. Aluminum: The aluminum used in this test is aluminum from the fusion of beverage cans combined with oil.

Figure 6: Canned aluminum material

3. Motor scrap oil: Used for fuel
4. The tools used for *impact* tests are: Melting furnace aluminum smelting fuel oil.

Figure 7: Smelting furnace

5. Smelted aluminum mold.

Figure 8: Aluminum mold

6. Impack test equipment- Impact test equipment   serves to test specimens.

Figure 9: Impact test equipment

7. Sitting Grinding Machine: The sitting grinding machine is used for cutting carbon steel.

Figure 10: Seated grinding machine

8. Caliper (Sigmat): The caliper is used to measure, both measuring the outer diameter and inner diameter as well as measuring the length of carbon steel.

Figure 11: Caliper (sigmat)

9. Fabric gloves: Fabric Gloves Cloth gloves are used to protect hands when grinding carbon steel.

Figure 12: Cloth gloves

Tensile Hit Testing System

1. Charphy Test

The specimen is placed horizontally and held on the left and right sides. Then the object is hit on the back of the notch, located exactly in the middle. Notch with back to pululan The specimen is clamped at one end in an upright position. Then this specimen is hit from the front side on the other end side.

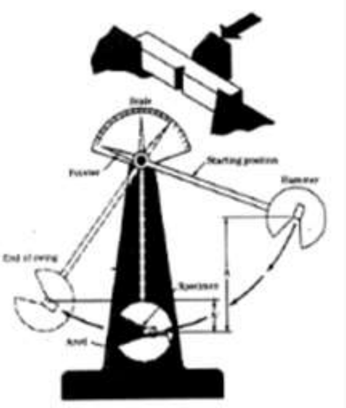

Figure 13: Schematic illustration of impact testing

Testing Process

Impact *testing* aims to measure the price of toughness of a steel and aluminum test material. The implementation of impact testing can *be obtained impact toughness graphs, from this graph can be seen the types of fractures on test specimens, as for the steps for* impact testing *as follows:*

1. Preparing the equipment and setting the tool after which the specimen is clamped to the impact test field, previously known cross-section, initial length and thickness to be used for data collection.
2. Conditioning the testing machine under standard conditions is by calibrating according to standard sizes.
3. Preparing impact test specimens of smelted steel and aluminum
4. After the test specimen is clamped, then pull the pendulum on the testing machine and then remove it. Released by pulling the arm lock, then the pendulum will swing breaking the test specimen.
5. Note the size that is on the scale of the testing machine then recorded.

Perform until all specimens have been tested with the provision of 2 steel specimens with a thickness of 3 mm, and 2 specimens of smelted aluminum. In this test, ST37 carbon steel material measuring 53 mm in diameter and 280 mm in length was used.

RESULTS AND DISCUSSION

Charpy Method Impact Testing

Charpy impact testing (also known as the Charpy v-notch test) is a high strain rate testing standard that determines the amount of energy absorbed by a material during a fault (Kim et al., 2015). Absorbed energy is a measure of the toughness of a particular material and acts as a tool for learning depending on brittle-ductile transition temperatures (Bledzki et al., 2010). This method is widely used in industries with critical safety because it is easy to prepare and perform. Then the test results can be obtained quickly and cheaply.

The purpose of the impact Charpy test is to determine the brittleness or ductility of a material (specimen) to be tested by sudden loading of the object to be tested statically. Where the specimen is notched first in accordance with ASTM E23 05 standard and the test results on the specimen will change shape such as bends or fractures in accordance with the ductility or brittleness of the specimen.

Impact Charpy test experiments are carried out by sudden loading of the specimen to be tested statically, where the specimen is made in advance according to the ASTM E23 05 standard size. The equipment used in impact testing is charpy-type impact test equipment and test specimens. The impact test equipment used in this study is an impact test equipment in accordance with standardization with a pendulum (W) weight of 26.3 kg and a radius of 0.647 m.

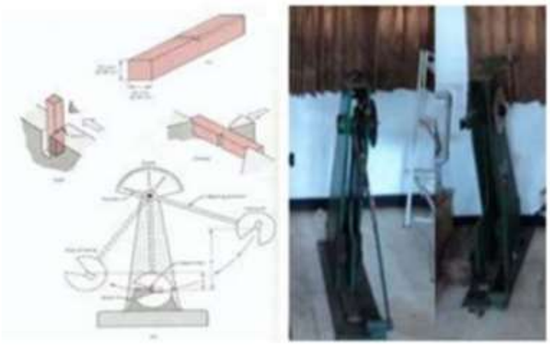

Figure 14 Impact Test Equipment According to Standardization

According to ASTM A370, the standard specimen sizes for Charpy impact testing are 10 mm × 10 mm × 55mm. The specimen shown in the Charpy system test is shown in the figure below. The size of the "V" notch of 450 – 2mm is halfway between the lengths of 55 mm.

Preparation

Manufacture of test specimens based on ASTM A 370:

The manufacture of test specimen notches with allowable tolerances is:

- The angle formed between the center of the notch (drawn vertical line) and the plane of the flat side is 900 ± 10 min
- Correction for transverse size ± 0.025 mm
- Correction for specimen length ± 0.-2.5 mm
- Correction for notch angle ± 10
- Correction of the distance from notch to bottom 8 ± 0.025 mm
- The allowable roughness of notch surfaces is 1.6 µm max and for other surfaces is 3.2 µm

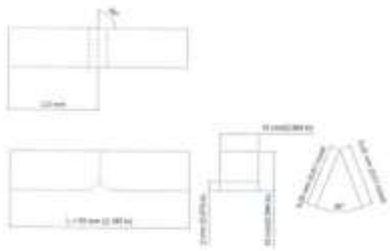

Figure 15: Specimen size and *notch*

Test temperature

Hot temperature using room temperature 300 C

Implementation

1. Based on ASTM, A 370, 25.1.1. Specimens that have been in PWHT are put into the temperature conditioning media and held for ≥ 5 minutes because the temperature conditioning media is liquid
2. Based on ASTM, A 370, 25.2.2. The allowable time to lift the specimen from the specified condition until the pendulum hits the specimen is a maximum of 5 seconds, if the time is more than 5 seconds it must be conditioned again according to the specified temperature

Test Results

1. Use of Impact Testing Equipment and Impact Price on Aluminum Materials

The use of impact test equipment according to standardization using W (pendulum weight of 26.32 kg and radius of 0.647 m, the *impact* price for aluminum material is 0.057 joules / mm2 with the energy given is 4,588 joules.

2. Use of Impact Test Equipment and Impact Price on ST 37 Steel Material

The use of impact test equipment on the impact price on ST 37 found that for the use *of impact test equipment* according to standardization using W (pendulum weight of 26.32 kg and radius of 0.647 m, the *impact* price *for ST 37 steel material was 0.190 joules / mm2 with energy given of 15.34 Joules.*

DISCUSSION

Tests that apply the principle by the specimen are impact tests. In the impact test, a load with a certain speed is collided on a test object until it breaks. The energy absorbed until it breaks indicates the toughness of a material. The greater the energy that can be absorbed by a material to become broken, the more resilient the material is.

The use of impact test equipment according to standardization using W (pendulum weight of 26.32 kg and radius of 0.647 m, the *impact* price for smelted aluminum material is 0.057 joules / mm2 with the given energy of 4,588 joules. The use of impact test equipment *on* the impact price on ST 37 found that for the use of impact test equipment according to standardization using W (pendulum weight of 26.32 kg and radius of 0.647 m, the *impact* price *for ST 37* steel material was 0.190 joules / mm2 with an energy given of 15.34 Joules. The chart of the relationship between impact price and given energy is as follows.

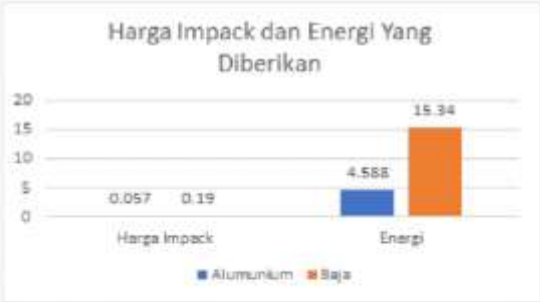

Figure 16: Impact Price and Energy provided

CONCLUSION

The impact price of Aluminum material is obtained 0.057 Joules / mm2 with Energy given at 4.588 Joules. The *impact* price on ST37 steel material is 0.192 Joules/mm2 with Energy provided at 15.34 Joules.

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