IMPACT TESTING OF SMAW WELDING CONNECTIONS ON A36 STEEL WITH VARIATION OF WELDING CURRENT

Chris Jeremy Verian Sitorus[1]*, Alamsyah[1], Uswah Pawara[1] Suardi[1] Jusma Wahidah[1] Harlian Kustiwansa[1] Sri Leli Melenia[1] Cindy Lionita Agusty[1]

[1] Department of Naval Architecture, Kalimantan Institute of Technology, Balikpapan, Indonesia
E-mail: chris.sitorus@lecturer.itk.ac.id

ABSTRACT

This study aims to determine the effect of SMAW welding joints on impact strength and to determine the effect of impact loads on the fracture structure of ASTM A36 steel material. This research is based on welding theory, steel and electrode material theory, and impact testing theory. The determining factor of this research is the amount of welding current used. There is an increase in absorbed energy and impact strength for each variation of current, but this increase is not constant. Where at a strong current of 125 A there is an increase in E of 4.35 Joules and HI by 0.054375 J/mm2 compared to a strong current of 100 A. However, at a strong current of 150 A there is only an increase in E of 0.1 Joules, while for an increase in the value of HI by 0.00125 J/mm2 compared to a current of 125 A.

Keyword: SMAW, ASTM A36, Welding Theory, Strong Current

Introduction

As with any industry involving steel and other metals, the production process of a ship cannot be separated from welding. Welding is one of the metal joining techniques by melting some of the additional metal and producing a continuous connection [1]). The heat source at the time of welding comes from a power source so it is called electric welding. Currently, Shielded Metal Arc Welding (SMAW) or shielded electric arc welding is one of the methods of electric welding [2]. Steel is a metal that is often used in everyday life. In shipping, shipbuilding mostly uses this material as the main construction material. The steel is grouped into two, namely carbon steel and alloy. This research uses ASTM A36 low carbon steel which contains less than 0.25% carbon with a structure dominated by ferrite. This low carbon steel is also characterized by high ductility making it easy to machine [3].

On March 4, 2017, the British cruise ship, Caledonian Sky, weighing 4,290 tons, crashed into a coral reef due to being trapped in the low tide waters of Raja Ampat).[4] In other cases of accidents, collisions also often occur between ships and other facilities outside the realm of shipping [4]. One of them is a bridge that stretches along the waters where ships pass. Mahakam Bridge is a bridge that connects Samarinda City and Samarinda Seberang [5]. Where the shipping flow that crosses the bridge is quite crowded and is dominated by tug boats and barges. The barge that hit the pillar of the Mahakam bridge happened on August 30, 2021, at 06.30 WITA. The barge Intan Kelana 13, which was pulled by tug boat JKW, crashed into the four pillars of the Mahakam 2 bridge while carrying 7 people. 630 Metric Tons (MT) of coal (kaltimkece.id). The collision or collusion that occurs on the ship causes the ship to receive a sudden load or can be referred to as an impact load.

Seeing the many cases of collisions that caused damage to both the ship and those that were hit, This research is structured to analyze the strength of SMAW welding results when a collision occurs which results in an impact load or shock load between the hull of the ship and the one being hit.[6] By using variations in welding current strength of 100 amperes, 125 amperes, and 150 amperes, the magnitude of the impact value (HI) will be investigated for each variation of the welding current strength on ASTM A36[7] low carbon steel material, with reference to

the absorbed energy results obtained during the test. From this research, the test results will be obtained in the form of the type of fracture that occurs in the material.

Methodology

The method used in this research is direct or experimental testing. The test was carried out at the Mechanical Engineering Laboratory, Samarinda State Polytechnic using available impact machines. Impact testing can be done by two methods, namely, the charpy method and the izod method as illustrated in Figure 1. Where in this study the charpy test method was chosen, namely the test method with the specimen position being placed horizontally with the notch position back to the direction of impact which in this case is a pendulum. The position of the notch must be parallel to the pendulum. The Izod method is a method in which the specimen is placed in an upright position with the notch facing the pendulum. This izod method is rarely used because the operational costs are more expensive.
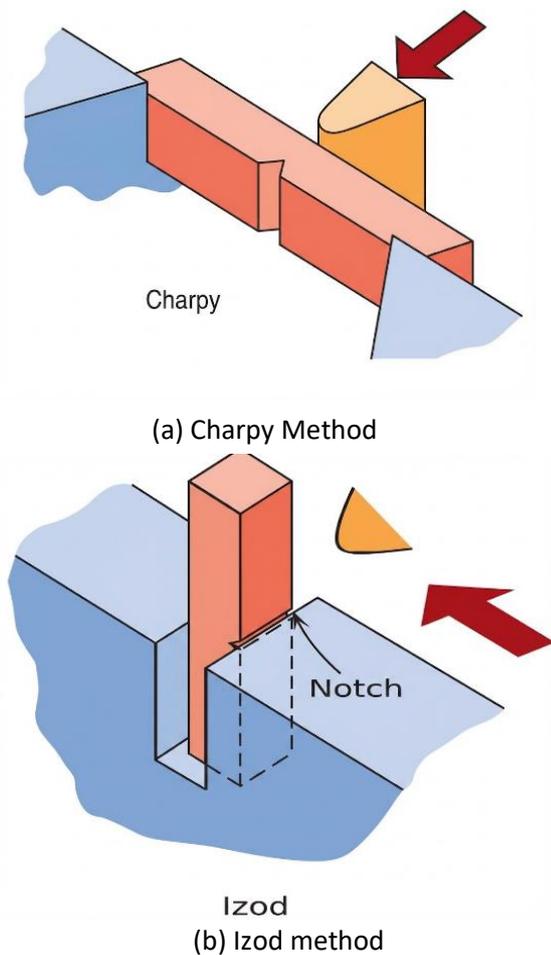

Charpy

(a) Charpy Method

Notch

Izod

(b) Izod method

Figure 1. (a) Charpy Method, (b) Izod method

Figure (a) is a visualization of the impact test of the Charpy method. Where can be seen the placement of the specimen is horizontal and back to the pendulum. As for the Izod method, the specimen is placed in an upright position, and the notch is facing the direction of the pendulum [8].

Tools and Materials

In carrying out impact testing, several tools are needed that are used during the specimen formation process and during testing. In addition to tools, materials and test materials also need to be prepared.

1. ASTM A36. Steel
2. Electrode E6013 3.2 mm
3. NDT kit (Cleaner, developer, penetrant)
4. grinding
5. Gas Cutting
6. SMAW Welding Tool
7. milling machine
8. impact machine

Object of Research

The object of research is the main thing that is used as research material. Steel Composition can be seen in Table 1. Data or physical properties such as metal. This final project research uses ASTM A36[9] low carbon steel which has been welded by the SMAW [10] method and uses a single V seam with a seam angle of 60˚ as the main object of research. As a form of data variation, the welding current strength is given at the numbers 100 Ampere, 125 Ampere, and 150 Ampere.

Table 1. Steel Composition

Composition (%)	Plate thickness(mm)				
	20	20-40	40-65	65-100	> 100
carbon (C), max	0.25	0.25	0.26	0.27	0.29
Manganese (Mn)	…	…	0.18-1.20	0.08-1.20	0.08-1.20
Phosphorus (P), max	0.04	0.04	0.04	0.04	0.04
Sulfur (S), max	0.05	0.05	0.05	0.05	0.05
Silicon (Si)	0.04 max	0.04 max	0.15 – 0.40	0.15 – 0.40	0.15 – 0.40
Copper (Cu), if specified	0.2	0.2	0.2	0.2	0.2

Dimensions of the impact test specimen according to American Standard Testing and Material standards written in the book Standard Test Methods for Notched Bar Impact Testing of Metallic Materials, 2019, are 55 x 10 x 10. The V-Notch type specimen was used for this study as shown in Figure 2, where there is a transverse notch the center of the specimen with a depth of 2 mm and a radius of 0.25 mm [11].
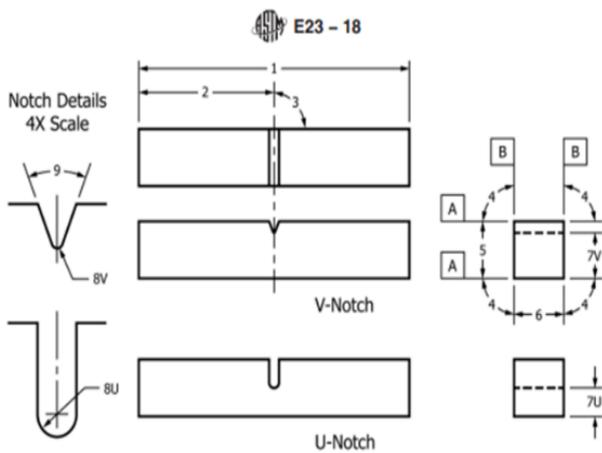
Figure 2. Charpy Test Specimen

Welding Data

In doing welding, it is necessary to make a Welding Procedure Specification (WPS)[12]. WPS is a written parameter that will be a reference for welders. can be seen in Table 2.

Table 2. Welding Parameters and Specifications

Parameter	Specification
Welding Process	Shielded Metal Arc Welding (SMAW)
Base Metal	ASTM A36 Carbon Steel
Plate Thickness	10 mm
Filler Metal (Electrode)	AWS E6013
Electrode Diameter	3.2 mm
Welding Position	1G (Flat / Down hand)
Joint Design	Single V-Groove, 60˚Angle
Root Gap	3 mm
Welding Current (Variations)	100 A, 125 A, and 150 A

Research Stages

This final project research begins with determining the formulation of the problem to be studied. This process is accompanied by looking for references related to the topics raised. The second stage is the process of providing the tools and materials needed as listed. Then proceed with designing the specimen pattern in the AutoCAD graphics application by including the detailed dimensions. After finishing with the pattern making, the ASTM A36 [13] steel material starts to be cut into 18 parts which will later be joined by SMAW welding into 9 parts. Given variations in the strength of the welding current as determined. To ensure that there are no welding defects, the next step is the quality control process of the welding results using the NDT type of penetrant test method. When it is confirmed that there are no welding defects, the

specimen-making process is continued by levelling the welding results using a machine grinder. After that, a pattern is made on the plate that has been welded earlier and refers to the design. Then made a notch as deep as 2 mm and a radius of 0.25 right in the middle of the welding joint. The manufacture of this impact specimen uses a milling machine with a widya carbide eye. When the specimen is ready for testing, the last step is impact testing.

Test

The impact strength test was carried out at the Mechanical Engineering Laboratory of the Samarinda State Polytechnic at 08.00 am accompanied by a laboratory assistant. Impact testing was carried out for 9 samples with 3 samples each for each current variation. Obtained a comparison graph of the absorbed energy and the impact value using the machine value and the value with the approximate formula. The equation can be written as follows:[14]

$$E = mgR(\cos\beta - \cos\alpha) \tag{1}$$

Where:

E = Absorbed energy (J)

g = Scoregravity (m/ s²)

m = Pendulum mass (kg)

R = Long pendulum arm (m)

α = Initial angle of the pendulum before Swinging

β = Final angle of the pendulum after swinging

$$HI = \frac{E}{A} \tag{2}$$

Where:

HI = impact price (J/mm²),

E = absorbed energy (J),

A = cross-sectional area (mm²).

To find the value of A or cross-sectional area, the notch depth value and the specimen height/thickness value are used so that the equation is as follows:

$$A = h \, x \, t \tag{3}$$

Where h is the depth of the notch and t is the thickness of the specimen.

Where h is the depth of the notch and t is the thickness of the specimen.

Impact testing is carried out to obtain the impact strength value of the specimen which has been varied based on the welding currents [15]. The output of the impact value is in the form of absorbed energy and the magnitude of the impact price.

Table 3. Calculation results with approximation formula

Specimen	p	l	t	h	A	corner		cosα	cosβ	E	HI
	mm	*mm*	*mm*	*mm*	*mm2*	*α*	*β*			*Joule*	*J/mm2*
100 A1	55	10	10	8	80	140	121.7	-0.766	-0.525	57.8198	0.722747
100 A2	55	10	10	8	80	140	120	-0.766	-0.5	63.94138	0.799267
100 A3	55	10	10	8	80	140	119.2	-0.766	-0.488	66.82552	0.835319
Average										**62.86223**	**0.785778**
Specimen	p	l	t	h	A	corner		α	β	E	HI
	mm	*mm*	*mm*	*mm*	mm2	*α*	*β*			*Joule*	*J/mm2*
125 A1	55	10	10	8	80	140	119	-0.77	-0.49	67.59463	0.844933
125 A2	55	10	10	8	80	140	119.1	-0.77	-0.49	67.23411	0.840426
125 A3	55	10	10	8	80	140	121.5	-0.77	-0.52	58.53602	0.7317
Average										**64.45492**	**0.805687**
Specimen	p	l	t	h	A	corner		α	β	E	HI
	mm	*mm*	*mm*	*mm*	*mm2*	*α*	*β*			*Joule*	*J/mm2*
150 A1	55	10	10	8	80	140	119.9	-0.766	-0.498	64.30671	0.803834
150 A2	55	10	10	8	80	140	119.3	-0.766	-0.489	66.51308	0.831413
150 A3	55	10	10	8	80	140	120.3	-0.766	-0.505	62.85983	0.785748
Average										**64.55987**	**0.806998**

In this test the value of the absorbed energy of the specimen (E), the angle of incidence of the pendulum (α), the maximum angle of the pendulum after striking the specimen (β), the length of the pendulum arm (R), and the weight of the pendulum (m).

Result and Discussion

Impact Specimen

Figure 3. E23 specimen ready for testing

Made 9 pieces of impact test specimens with the number of specimen samples per each strong current as much as 3 pieces. So, for each strong current will be tested 3 times. Table 3. presents a comprehensive summary of the experimental results obtained from the testing of the E23 specimens, including key mechanical properties and performance indicators that are critical for analyzing the material behaviours under specified test conditions.

Figure 3 illustrates the E23 specimens that have been carefully prepared, labeled, and positioned, demonstrating their readiness for the subsequent series of mechanical tests aimed at evaluating their performance under controlled laboratory conditions.

Impact Test

After the testing process is complete, the data will be obtained which is then used as data in performing calculations. The calculation process is carried out in Ms. Excel to get the absorbed energy value with the formula approach and then compared with the results of the test machine and calculated the value of the impact value of the test specimen.

Where (a) is the result of a calculation with an approximate formula for a current of 100 amperes, (b) is a result of a calculation with an approximate formula for a current of 125 amperes, and (c) is a result of a calculation for a current of 150 amperes with an approximate formula. From these data, a comparison graph can be made between the calculation with the approximate formula and the original value of the test machine. So that we get a graph of the comparison of the absorbed energy value (E) and the comparative value of the impact price (HI).
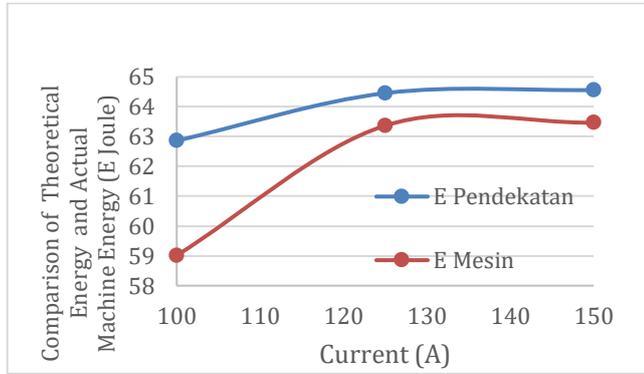
Figure 4. Comparison of Absorbed Energy Values

It is a graph shown ini Figure 4. ratio of absorbed energy (E), the blue curve is for the inauguration value, and the orange curve is the machine value. It can be explained that for the engine E value at 100 A current, the E value is 59.01666667 J, 125 A current is 63.36666667 J, and at 150 A current is 63.46666667 J. While for the energy inauguration absorbed, the value of E at 100 A current is 62.86223475, at 125 A the absorbed energy is 64.45492095, and at 150 A current is 64.5598716 J.
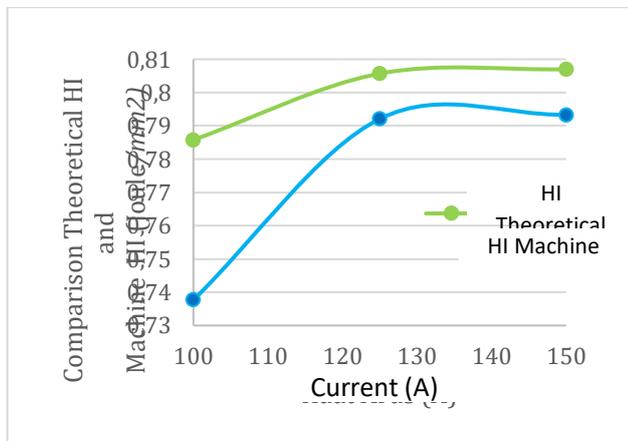
Figure 5. Comparison of Impact Harga Price Values

The Curve in Figure 5 shows the value of the price comparison *impact* (HI), green curve for inauguration value and light blue curve for machine HI. Price*impact* (HI) average for a welding current of 100 A is 0.737708333. While the welding current of 125 A is 0.792083333 and for a strong current of 150 A, the value of HI is 0.793333333. As for HI Inauguration$J/mm^2 J/mm^2 J/mm^2$strong current of 100 A which is equal to $0.785777934 J/mm^2$, the current strength of 125 A is 0.805686512 and the current strength of 150 A is $0.806998395\ J/mm^2$.

Fault Structure Analysis

According to Fajar (2012), in general, impact fractures are classified into 3 types, of which the first type is a fibrous fracture, which is characterized by a fracture that will form a dimple or hollow and absorb light so that the surface will appear blurry. This type of fracture involves a shift in the crystalline plane in a ductile material. Furthermore, crystalline or granular fractures that result in the splitting of grains of material (metal) that are brittle. This fracture surface structure can reflect light in high intensity (shiny). The last type of fault is a mixed fault which is a combination of the two previous types of faults [16].

After testing the 9 test samples, the following fracture results were obtained:

(a) Current Strong 100 A

(b) Current Strong 125 A

(c) Current Strong 150 A

Figure 6. Fault Results after Testing

Based on Figure 6. shows the results of the fracture produced during impact testing on the specimen for each current strength. Among the 3 types of fractures that occurred in the impact test, in this study the fractures that occurred for 9 (nine) test specimens were fibrous fractures. Each variation of the welding current shows the same type of fault.

Conclusion

There is an increase in absorbed energy and impact strength for each variation of current, but this increase is not constant. Where at a current of 125 A there is an increase in E of 4.35 Joules and HI of 0.054375 compared to a strong current of 100 A. However, at a strong current of 150 A there is only an increase in E of 0.1 Joule while for an increase in the value of HI by 0, 00125 compared to 125 A current.

The fracture structure or type of fracture of 9 specimens with variations in welding currents of 100 amperes, 125 amperes, and 150 amperes is a type of fibrous fracture.Characterized by a dimple-shaped fibrous fracture surface that absorbs light and has an opaque appearance. This type of fracture is also known as ductile fracture.

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