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Analysis of the Effect of Variations in Welding Current of the Combination of SMAW & FCAW Using Double V Groove on Tensile Strength, Impact and Microstructure in ASTM A36 Steel Weld Metal Area

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Abstract

This research uses shielded metal arc welding (SMAW) welding method combined with flux core art welding (FCAW) welding method using ASTM A36 10 mm steel material and using double V seam. Then the electrode used in this study is for SMAW E7018 welding, while for FCAW E71T1 welding. The current variations used are SMAW 60A, 75A, 90A and FCAW 190A, 205A, 220A. The purpose of this research is to determine the optimal current that produces the highest tensile and impact strength and differences in microstructure in the weld metal area. From the results of this study, the highest tensile and impact strengths were at 90A SMAW and 220A FCAW with a tensile strength of 526.96 N/mm and an impact strength of 1.2044 J/mm2. Then the microstructure formed is Grain Boundry Ferrite (GBF), Pearlite (P), Arcicular Ferrite (AF), Ferrite (F). Where the percentage of SMAW weld metal is 72.1% Ferrite and 27.9% Pearlite, while in FCAW weld metal it is 75.63% Ferrite and 24.37% Pearlite.

Keywords: Combination Welding, Current Variation, Weld Metal

Abstrak

Penelitian ini menggunakan metode pengelasan shielded metal arc welding (SMAW) yang dikombinasikan dengan metode pengelasan flux core art welding (FCAW) dengan menggunakan material baja ASTM A36 10 mm dan menggunakan kampuh double V. Kemudian elektroda yang digunakan dalam penelitian ini yaitu untuk pengelasan SMAW E7018, sedangkan untuk pengelasan FCAW E71T1. Besar variasi arus yang digunakan yaitu SMAW 60A, 75A, 90A dan FCAW 190A, 205A, 220A. Tujuan dilakukannya penelitian ini yaitu untuk mengetahui arus optimal yang menghasilkan kekuatan tarik dan impact tertinggi serta perbedaan struktur mikro pada daerah weld metal. Dari hasil penelitian ini didapatkan kekuatan tarik dan impact tertinggi pada arus 90A SMAW dan 220A FCAW yaitu dengan kekuatan tarik sebesar 526,96 N/mm dan kekuatan impact sebesar 1,2044 J/mm^2. Kemudian Struktur mikro yang terbentuk berupa Grain Boundry Ferrite (GBF), Pearlite (P), Arcicular

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Ferrite (AF), Ferrite (F). Dimana didapatkan persentase fasa daerah weld metal SMAW 72,1% Ferrite dan 27,9% Pearlite, sedangkan pada daerah weld metal FCAW yaitu 75,63% Ferrite dan 24,37% Pearlite.

Kata Kunci: Pengelasan Kombinasi, Variasi Arus, Weld Metal

1. Introduction

Updates, improvements and refinements of previous technologies encourage people to continue to seek the latest innovations. One of the manufacturing processes that is often used is the welding process. The use of welding technology in the construction sector is due to the result of the connection between two metals or components being of higher quality and the process is simpler so that it can save costs (Wiryosumarto, 2004). One part that requires a welding connection process is in the process of making storage tanks and also the process of making ship hulls.

Welding is a process of joining two or more metals using heat energy. With this heat process, the area around the weld undergoes a rapid thermal cycle resulting in deformation, complicated metallurgical changes, and thermal stress. According to Azwinur et al, 2020 The welding commonly used in the oil and gas industry is SMAW (Shield Metal Arc welding) welding because SMAW (Shield Metal Arc welding) welding has a more economical and flexible production cost. Then to improve the quality of the welds, combination welding with gas welding can be done to improve the mechanical properties of the welds. One of the welding methods using gas is the FCAW (Flux Core Art Welding) welding method.

Based on the description above, it is necessary to conduct research on the analysis of the effect of variations in welding current strength of SMAW and FCAW combination welding on ASTM A36 steel material to obtain tensile strength and impact strength values which aim to determine the most optimal welding current on the resulting mechanical properties.

2. Methods

Sample preparation includes the making of double V groove with 70o angle and 5 mm groove depth. The dimension of the ASTM A36 plate is 200mm x 200 mm x 10 mm (Figure 1), with its chemical composition available at Table 1. The electrode used are E7018 for SMAW method and E71T-1 for FCAW method, respectively. There are three types of samples being produced with its detail available in Table 2 and the illustration of this method is available in Figure 2.

Table 1: Chemical composition of ASTM A36 plate

Material	Element Content (%)					
	Fe	**C**	**Si**	**Mn**	**P**	**S**
ASTM A36	98,42	0,26	0,4	0,6	0,04	0,05

Table 2: Specimens of this project

No	Spesiment	Thick Plate	Corner	Welding Current		Polarity
				SMAW	**FCAW**	
1	A	10 mm	70°	60 A	190 A	DCEP
2	B	10 mm	70°	75 A	205 A	DCEP
3	C	10 mm	70°	90 A	220 A	DCEP

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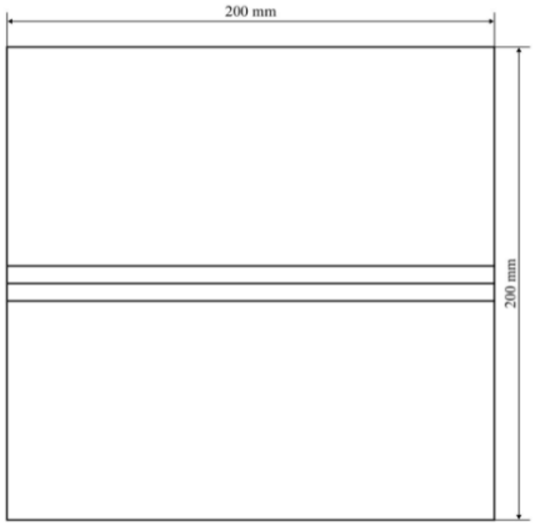
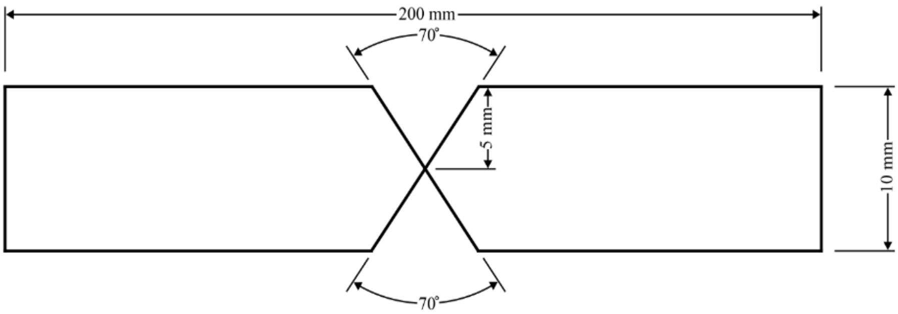
After the welding process, the sample was made into a tensile test sample according to the ASTM E8-9 standard (Figure 3), and made into an impact test sample according to the ASTM E23 standard (Figure 4). Then samples were made for metallographic testing based on ASTM E3-01 Standard Guide Preparation of Metallographic Specimens and with ASM Volume 09 (Figure 5) to observe the microstructure.



(a)



(b)

Figure 1: (a) Top View of The Specimen, (b) Side View of The Specimen

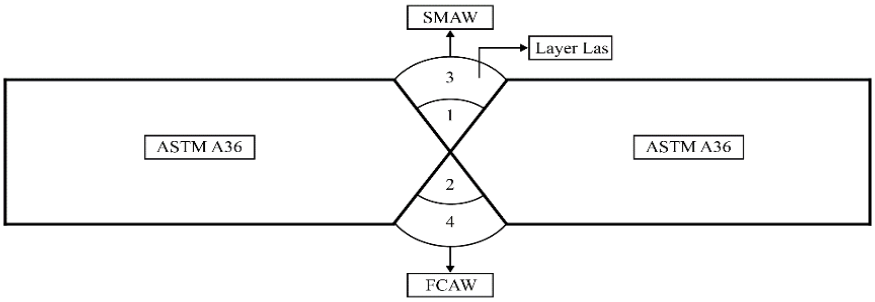


Figure 2: Illustration of welding process

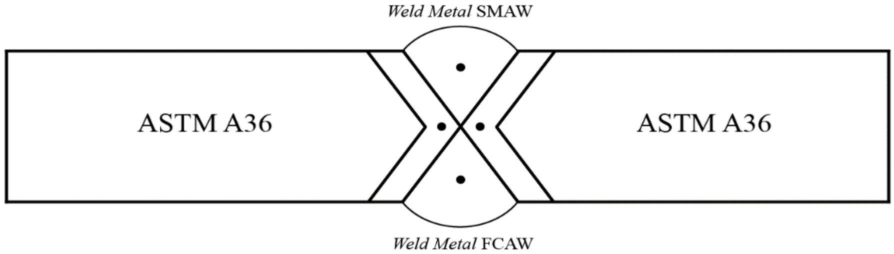


Figure 3: Metallography observation locations

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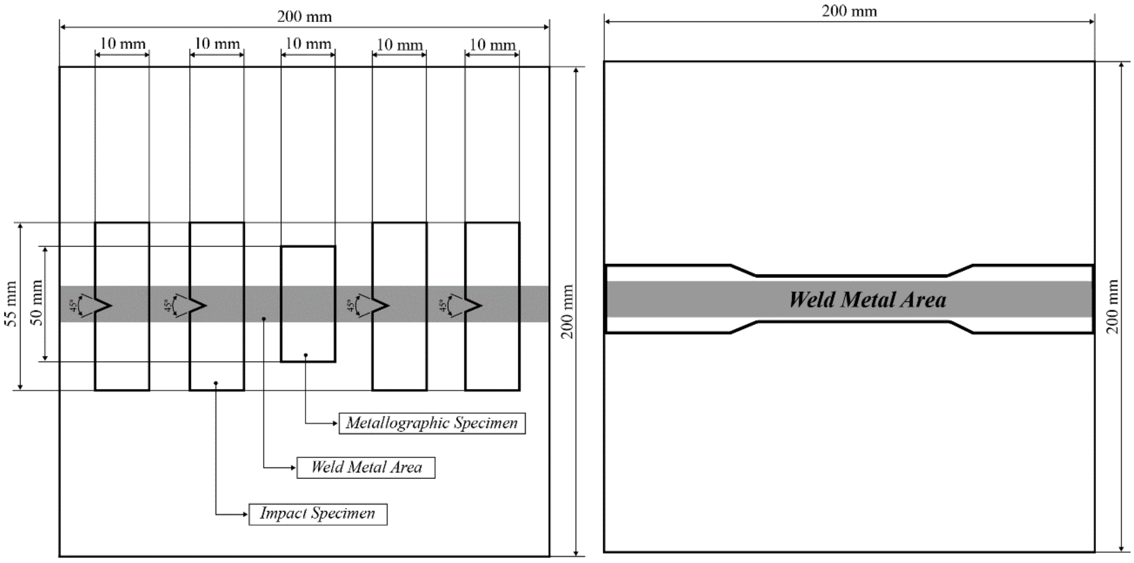


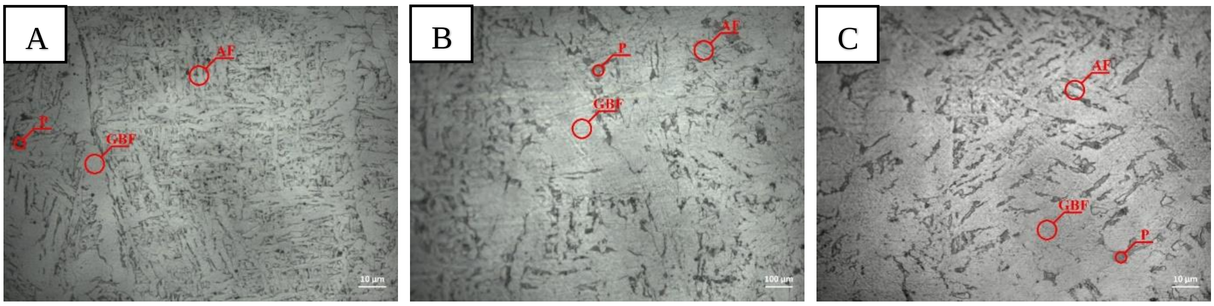
(a) (b)

Figure 4: (a)Impact test sample Dimension (b)Tensile Test Sample Dimension

3. Result and discussion

Figure 5 and 6 show that in the SMAW and FCAW weld metal areas, black or dark perlite (P) phases are obtained, Arcicular Ferrite (AF) and Grain Boundry Ferrite (GBF) are white or bright. According to Setiawan (2006), heat input is very influential on the microstructure formed in the weld metal area. The higher the heat input, the more Arcicular Ferrite (AF) phase will be formed. It can be seen in the weld metal area that the most formed phases are Arcicular Ferrite (AF) and Grain Boundry Ferrite (GBF) which are caused by slow cooling. According to Downling (1986) Arcicular Ferrite (AF) phase is a very desirable structure in a welding. This structure can be regarded as a structure that can inhibit the rate of crack propagation (interlocking structure). Materials that have a dominant ferrite phase will have better ductile properties. In contrast to materials that have more pearlite phase, they will have good strength but tend to be brittle.

It can be seen in Figure 5 and Figure 6 are the microstructures obtained in the HAZ (Heat Affected Zone) SMAW and HAZ FCAW regions with the formed phases, namely Pearlite (P) phase which is black or dark in color, Arcicular Ferrite (AF) and Grain Boundry Ferrite. (GBF) which is white or bright. It can be seen that the ferrite phase formed in the HAZ region is very much compared to the pearlite phase which causes this region to be ductile. According to Suryana (2019) that in the HAZ region the grain size will be larger or coarser. The HAZ area will experience rapid heating and cooling, the higher the heat input, the larger the HAZ area will be. And the grain size in the HAZ area will be coarser (Sarippudin, 2013).



SMAW A SMAW B SMAW C

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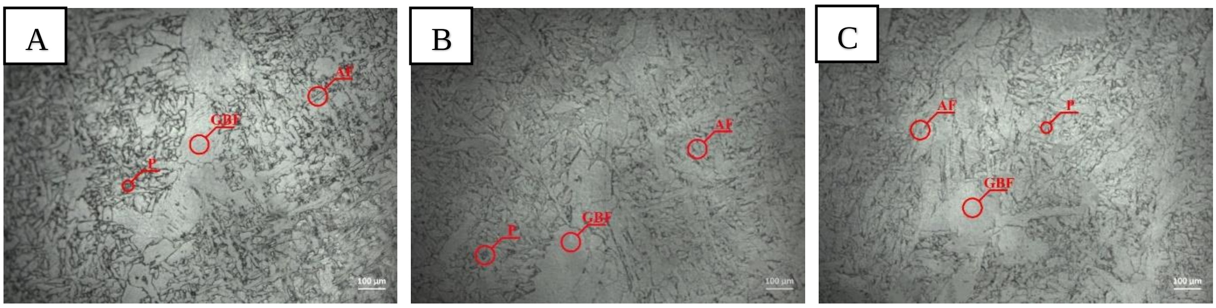
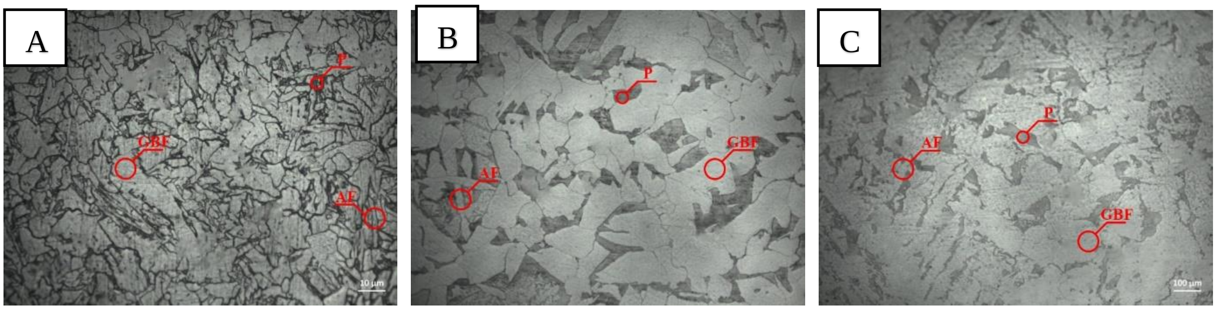
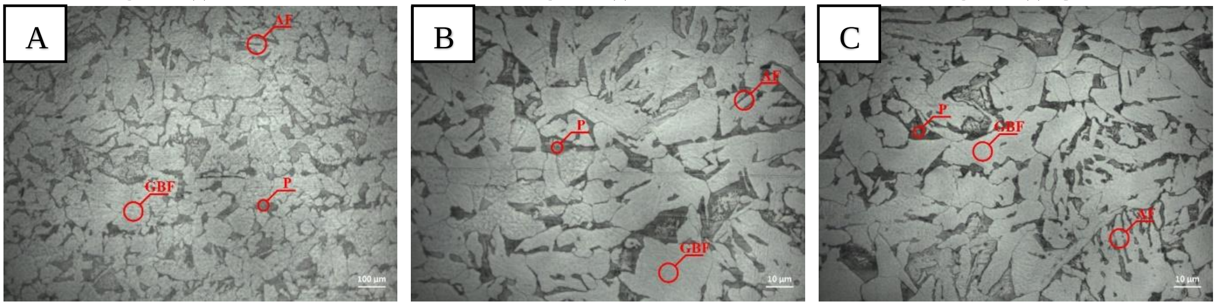


FCAW A FCAW B FCAW C

Figure 5: Microstructure of SMAW with Variation of Welding Current A (60A), B (75A), and C (90A) and FCAW Weld Metal Welding Area with Variation of Welding Current A (190A), B (205A), and C (220A) AF : Arcicular Ferrite, GBF : Grain Boundry Ferrite and P : Pearlite



SMAW A SMAW B SMAW C



FCAW A FCAW B FCAW C

Figure 6: Microstructure of SMAW with Variation of Welding Current A (60A), B (75A), and C (90A) and FCAW Welding HAZ Region with Variation of Welding Current A (190A), B (205A), and C (220A). AF : Arcicular Ferrite, GBF : Grain Boundry Ferrite and P : Pearlite

Table 3: Percentage of ferrite and pearlite phases in weld metal area

Area	***Current (Ampere)***	**Phase Percentage (%)**	
		Ferrite	***Pearlite***
Weld Metal SMAW	60A	70,99	29,01
	75A	71,28	28,72
	90A	72,1	27,9
Weld Metal FCAW	190A	73,18	26,82
	205A	74,13	25,87
	220A	75,63	24,37

Table 4: Results of Calculation of Grain Size for HAZ SMAW and FCAW

Area	***Current (Ampere)***	**Nilai G**	**Average Diameter(µm)**
Weld Metal SMAW	60A	5,82	47,96
	75A	4,16	85,24

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	90A	3,15	120,54
Weld Metal FCAW	190A	5,22	59,06
	205A	4,67	69,9
	220A	4,51	75,26

Table 5: Percentage of ferrite and pearlite phases in heat affected zone area

Area	*Current (Ampere)*	Phase Percentage (%)	
		Ferrite	*Pearlite*
HAZ SMAW	60A	72,62	27,38
	75A	73,24	26,76
	90A	73,77	26,29
HAZ FCAW	190A	72,7	27,30
	205A	73,12	26,88
	220A	74,62	25,38

Table 6: Calculation Results of SMAW and FCAW Weld Metal Grain Size

Area	Current *(Ampere)*	Nilai G	Average Diameter(μm)
HAZ SMAW	60A	3,65	101,36
	75A	3,37	112,06
	90A	2,85	120,06
HAZ FCAW	190A	4,58	73,58
	205A	4,09	87,24
	220A	3,51	106,46

It can be seen in table 5 that the highest number of phases is produced in the weld metal area with a variation of 90A SMAW current and 220A FCAW current. Where at 90A SMAW the ferrite phase is 72.1% and the pearlite phase is 27.9%. At 220A FCAW current obtained 75.63% ferrite phase and 24.37% pearlite phase. In accordance with research conducted by Nasir (2017), low carbon steel pearlite phase will continue to decrease along with increasing heat input.

It can be seen in table 6 that the highest number of phases is produced in the HAZ area with a variation of 90A SMAW current and 220A FCAW current. Where at 90A SMAW the ferrite phase is 73.77% and the pearlite phase is 26.29%. At 220A FCAW, the ferrite phase is 74.62% and the pearlite phase is 25.38%.

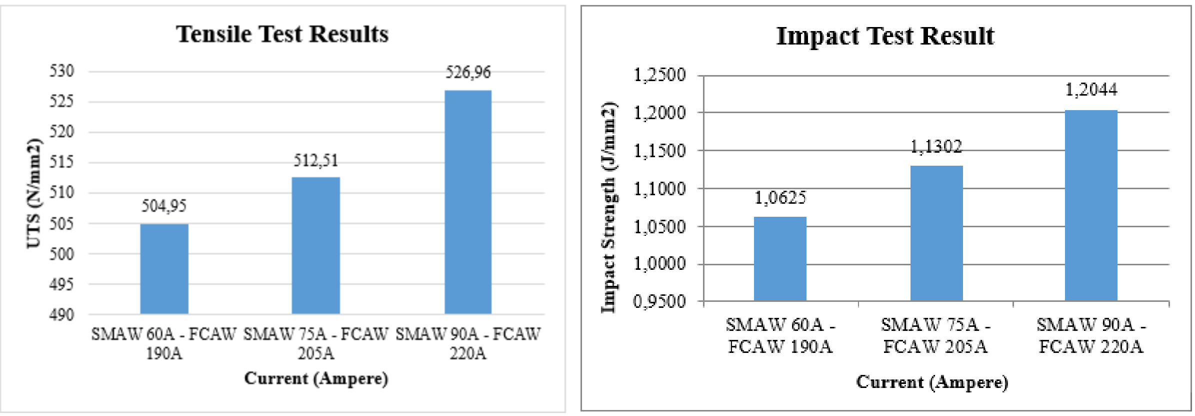

Figure 7: Tensile & Impact Test Results Diagram

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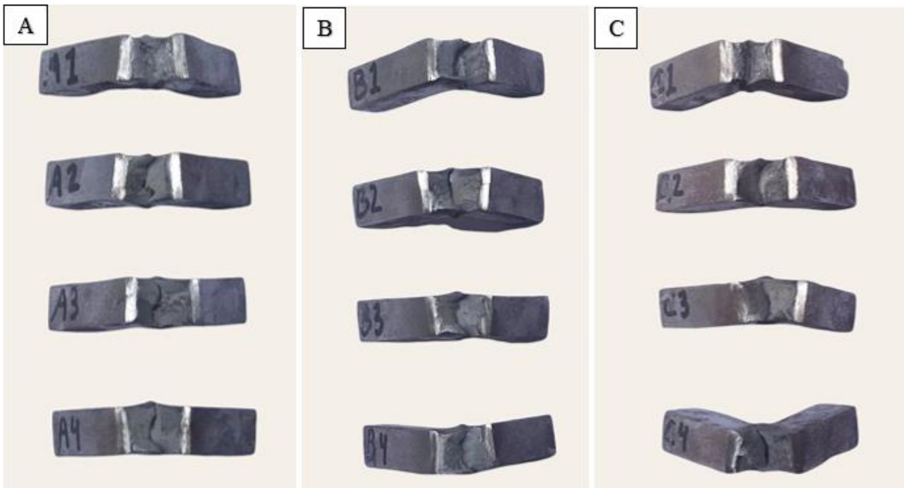

Figure 8: Impact Test Results Specimens

In Figure 7 it can be seen that from the results of impact testing that has been carried out on each current variation with SMAW and FCAW combination welding, the type of fracture is obtained in the form of a fibrous fracture or commonly referred to as a ductile fracture. According to Pramono (2016), this ductile fracture can be characterized by the fracture surface with uneven fibers that can absorb light and have an opaque appearance that will occur in ductile materials as shown on Figure 8.

The results of the impact testing for the three samples can be seen in Table 4. It can be seen from the table that the value of the Impact strength will increase along with the increase in the variation of the current used, the higher the current used, the more heat input will be generated and the resulting Impact strength value will increase. the higher it is. Based on previous research by Hadi in 2009, when comparing the mechanical properties of the specimens welded using the SMAW and FCAW methods, FCAW welding has a better toughness value because the heat input produced is more stable. This is because the higher the variation of the FCAW current used, the greater and more stable heat input will be, so that it affects the results of SMAW welding. FCAW welding has a higher toughness value because in FCAW welding the heat input produced is more stable. So that after a combination of welding with the FCAW welding method causes the impact strength value to increase. According to BKI (2021) the minimum impact value of the ASTM A36 steel weld metal area that can be accepted on the hull is 47 Joules. Where it can be seen that in this study using a combination of SMAW and FCAW welding, the impact value was obtained that met the requirements for the ship's hull.

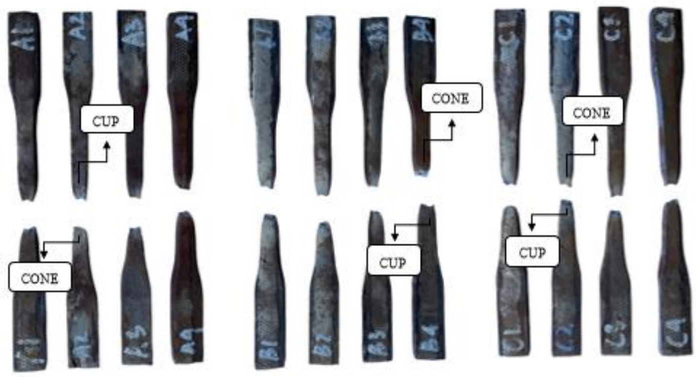

Figure 9: Tensile Test Results Specimens

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Figure 10: Fault Pattern Tensile Test Results

Based on the American Society of Mechanical Engineers (ASME) IX in 2010 concerning acceptance criteria – tension test, it is stated that if the specimen breaks in the weld metal area, the test is accepted but its strength must be above or equal to the tensile strength of the base metal or the weld metal must have a tensile strength of not less than the minimum tensile strength of the base metal. In this study the material used is ASTM A36 steel, where this material has a minimum tensile strength of 400 Mpa. Based on the results of the tensile strength obtained in this study, the test is acceptable, because all the tensile strength values of the weld metal obtained in this study are based on the value of the tensile strength of the base metal. From the tensile tests that have been carried out, the results obtained that the tensile strength value of the SMAW and FCAW combination welding on ASTM A36 material using a double V seam is increasing as the welding current increases. The highest tensile strength value was obtained at the welding current of SMAW 90A and FCAW 220A, the average tensile strength value was 526.96 N/mm². From the results obtained, there is an increase in the value of the tensile strength as the welding current increases, this is because the increasing current causes the heat input received to be greater which causes the number of ferrite phases to increase as the heat input increases). The ferrite phase will tend to give ductile properties to the material so that it will affect the tensile strength value which will be higher (Wryosumarto, 2000). According to Figure 9, the shape of the fractured samples perceptibly showed the pattern of a ductile material on Figure 10, the surface of the fracture pattern showed a shear lip fracture as strongly presented as ductile fracture.

Tabel 7: SMAW and FCAW Welding Heat Input

Welding	***Current (Ampere)***	***Volts* (V)**	***Travel Speed* (mm/detik)**	***Heat Input* (KJ/mm)**
SMAW	60A	24	0,66	2,181
	75A	24	0,74	2,432
	90A	24	0,83	2,602
FCAW	190A	26,5	1,45	3,472
	205A	26,5	1,55	3,504
	220A	26,5	1,66	3,521

Table 8 is the result of heat input calculations that have been carried out on a combination of SMAW and FCAW welding with variations in current for each welding used. The highest heat input is generated by SMAW welding with a current variation of 90A, a heat input of 2,062 KJ/mm is obtained and in FCAW welding with a current variation of 220A, a heat input of 3,521 KJ/mm is obtained. It can be seen that the increasing variation of the current used, the higher the heat input generated.

4. Conclusion

In welding with SMAW 90A and 220A FCAW current is the most optimum current for the welding process, because the highest impact strength value in the weld metal area is 1.2044 J/mm2 compared to the current in other welding combinations. And at this current, the highest tensile strength value is also obtained, which is 526.96 N/mm². And it has also been observed that the higher the current used, the

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higher the heat input, so that the ferrite phase increases and the grain size increases and the more Arcicular Ferrite (AF) phase.

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