Analysis of The Effect of Electric Current Strength in Shield Metal Arc Welding on The Hardness, Impact and Microstructure of Stainless Steel 304

Haitham Melood Abozaian [1*], **Dwi Rahmalina** [1]
[1]*Magister Teknik Mesin, Universitas Pancasila, DKI Jakarta, 12630, Indonesia*
[*]*Email Corresponding Author: miloodh@yahoo.com*

ABSTRAK

Shielded Metal Arc Welding (SMAW) adalah proses pengelasan yang banyak digunakan karena kesederhanaan, keserbagunaan, dan efektivitas biayanya. Akan tetapi pada prosesnya, terdapat banyak energi yang terbuang sehingga mengurangi kemanfaatan dari sumber energi yang ada yaitu tenaga listrik. Pencemaran lingkungan yang semakin meningkat menyebabkan nilai emisi karbon semakin tinggi. Penelitian ini melakukan pengujian terhadap hasil pengelasan SMAW terhadap material Stainless Steel 304 dengan memvariasikan kedalam dua faktor dan tiga level. Material Stainless Steel 304 digunakan karena mudah didapatkan dan sering diaplikasikan dalam dunia industri. Jenis pengujian yaitu Metalografi Visual dan *Destructive Test* (DT). Hasil pengamatan metalografi visual memperlihatkan struktur mikro mengalami perubahan di daerah pengelasan. Sedangkan DT yang digunakan yaitu uji kekerasan, dan uji impact. Hasil uji DT mengalami kenaikan nilai yaitu uji kekerasan dan uji impact. Sedangkan uji tensile mengalami penurunan nilai. Faktor yang paling memengaruhi terhadap Metalografi Visual dan DT yaitu Arus Listrik yang digunakan.

Kata kunci: SMAW; Emisi Karbon; Arus Listrik; Pengelasan; Stainless Steel 304

ABSTRACT

Shielded Metal Arc Welding (SMAW) is a welding process that is widely used because of its simplicity, versatility, and cost-effectiveness. However, in the process, there is a lot of wasted energy, reducing the benefits of the existing energy source, namely electricity. Increasing environmental pollution causes carbon emissions to increase. This study tested the results of SMAW welding against Stainless Steel 304 material by varying it into two factors and three levels. Stainless Steel 304 material is used because it is easy to obtain and is often applied in the industrial world. The types of testing are Visual Metalography and Destructive Test (DT). Observation results visual metalography show that the microstructure has changed in the welding area. While the DT used is the hardness test, and impact test. The DT test results experienced an increase in value, namely the hardness test and impact test. While the tensile test experienced a decrease in value. The factor that most effects visual metalography and DT is the Electric Current used.

Keywords: SMAW; Carbon Emissions; Electrical Current; Welding; Stainless Steel 304

INTRODUCTION

Shielded Metal Arc Welding (SMAW) is a widely used welding process due to its simplicity, versatility, and cost-effectiveness. Stainless steel alloys, known for their corrosion resistance and strength, are frequently used in critical applications across various industries, including construction, automotive, and aerospace.

The optimization of SMAW parameters is essential to enhance the mechanical properties of welded joints, such as tensile strength, hardness, and ductility, while also considering the environmental impacts of the welding process. As sustainability becomes a growing concern, there is a pressing need to develop welding techniques that not only produce high-quality welds but also minimize energy consumption and reduce carbon emissions.

The manufacturing industry is under increasing pressure to adopt sustainable practices to mitigate environmental impacts and comply with stricter regulations. Welding processes, particularly SMAW, play a crucial role in the fabrication of stainless steel structures, but they are also associated with high energy.

This research aims to address this gap by optimizing SMAW parameters to enhance mechanical properties. The urgency of this research is underscored by the growing demand for stainless steel in various industries and the need for more sustainable manufacturing processes.

Welding using GTAW and SMAW with electrode, no defects occurred in the bending test. whereas in testing the corrosion rate of the welding results for both was still below 0.2 mm/year, this is very slow and normal [1]. Heat treatment (normalising) can reduce the strength of hardness and stress. while the impact force increases [2]. Different material will behave differently depending to their chemical composition and thermal properties. In order to improve welded joint of the mechanical performance, a smaller/finer grain size is desired. Therefore, this finding proved that the mechanical properties and microstructure [3].

The results show variety of the welding parameters mostly effected mechanical properties of different steel welded joints. Mainly, the current caused the higher hardness values require further heat treatment to prevent brittle failure. Also, higher current values resulted in lower tensile strength values due to defects formation [4].

Varying into two types of experimental variations the factors that effect SMAW welding, namely three magnitudes of electric current and one type of electrode. In this experiment, observations were also carried out through a microscope to determine the microstructure before and after welding. Carried out in three observation areas, namely Base metal, HAZ, and welding area.

This research focuses on optimizing the SMAW parameters for stainless steel alloy, aiming to improve both the mechanical properties of the welds and the sustainability of the welding process. Which parameters can increase the efficiency of electricity use with maximum results and reduce the occurrence of defects.

The specific purpose of the research that is how is the effect of current variations of 80A, 100A, and 120A SMAW on the mechanical properties of stainless steel materials. How is the effect of electrode type of E308-16 SMAW on the mechanical properties of stainless steel materials. How does the formulation which appropriate to produce good efficiency from parameter effected of Welding SMAW.

RESEARCH METHODS

The first step in conducting this research is to start by determining the problem to be researched to the stage of results and conclusions from the research that has been carried out. The research stages are as seen in Figure 1.

Analysis of the effect of SMAW is looking for a problem to be researched, namely related to the effect of several parameters on SMAW welding. Prepare Materials is preparing experimental material according to the type of material to be tested, namely stainless steel alloys. Making Specimen is forming material into specimens so that they can be used as research material.

Welding Process into three factors and two levels is carried out welding 90 times divided into variations of three factors and three levels. Cold Treatment by oil is After welding is complete, cold treatment is carried out with oil. Welding Result check using visual method or Metalography checking by microscope.

DT using Hardness Test, and Impact Testing. Hardness testing is a widely used method to determine a material's resistance to penetration, deformation, or scratching. It provides a quick and non-destructive way to assess a material's hardness, which is a critical mechanical property in various applications, including selection material, control quality, and determining wear resistance. There are different types of hardness testing methods, each suitable for applications and specific materials [5].

Micro-hardness test is performed in accordance to ASTM E92 to determine the hardness gradient and along a cross section of welded specimen [6]. It is similar to the Brinell method, in that the hardness number is calculated as:

$$DPH = \frac{2L \sin\left(\frac{\theta}{2}\right)}{d^2}$$

Where

d the diagonal of the impression

ɵ the angle between opposite faces of the diamond = 136˚. [7]

Impact testing is a crucial method for evaluating a material's ability to absorb energy under sudden shock or impact loading conditions. It is particularly important in applications where materials are subjected to dynamic or high-speed loading, such as in the aerospace, automotive, and construction industries.

The test involves striking a notched or unnotched specimen with a pendulum or hammer, generating a high-velocity impact. The amount of energy absorbed by the material before fracture or failure is measured, providing insights into its toughness and resistance to sudden loading [5].

Check result is if it does not meet expectations, retesting is carried out by making a new specimen. If it is as expected, then data analysis is carried out. The system randomly assigns each attempt to reflect the entire model. In addition, Minitab Statistical Software program was used in the studies [8].

Data Analysis (factor effected welding process) is analyzing test result data using Minitab software with method Anova. the data analyzed includes factors that effect SMAW welding.

The material used are metal stainless steel 304 with shape round bar. The mechanical properties yield strength 205 MPa and the composition of the alloy content is 0.03 C, 10 Si, 20 Mn, 0.035 P, 13 Ni dan 20 Cr.

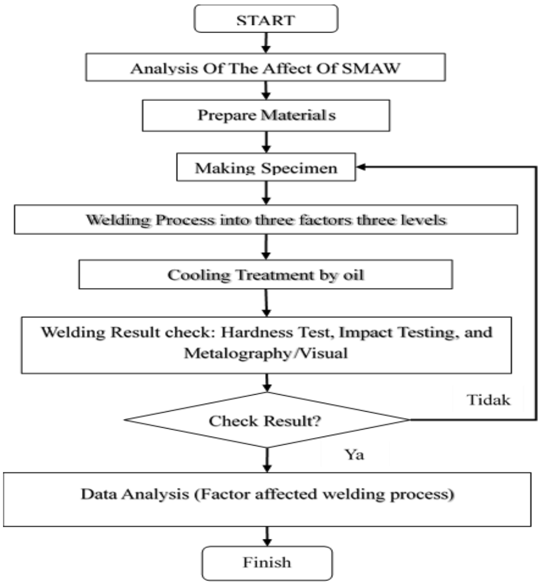


Figure 1 Flow Chart Research

RESULT AND DISCUSSION

The medium used for cold treatment is used 4-wheeled car engine oil because Besides being easy to obtain, economical, oil can improve the mechanical properties of metals such as hardness and tensile strength [9].

Used oil can absorb heat more slowly than other coolants, oil provides slow cooling, this oil is often used in industry to lubricant the machine production. Oil has the highest viscosity or thickness compared to other cooling media and low density so that the cooling rate is slow.

The test results were obtained by varying three factors with two levels. So that it produces two test results, namely Hardness Test and Impact Test. Furthermore, the data was processed using Minitab with the Anova method on each test result. The test results can be seen in Table 1.

Table 1 SMAW Welding Test Result Data

No	Current (A)	Hardness Test (HV)	Impact Test ($J.mm^2$)
1	80	313.61	0.54
2	100	338.31	1.44
3	120	303.11	0.93

Discussion Hardness Test

The data of the hardness test results before welding on three test specimen samples were averaged at 238.73 HV. While the results of the hardness test after welding by taking the average value of the three test specimen samples are shown in Table 1. The hardness test data for the Base Metal area, welding, and HAZ itself are shown in Table 2.

Table 2 Hardness Data on Base Metal Area, Welding, and HAZ

No	Current	Hardness Area		
		HAZ	Base Metal	Weld
1	80	325.40	328.73	286.70
2	100	342.23	297.97	374.73
3	120	344.87	276.93	287.53

Data is taken from the average hardness values taken in the HAZ, Base Metal, and Welding areas. Then the data obtained was processed using Minitab 16 with the Anova method. Can be seen in Table 3.

Table 3 Results of Hardness Test Analysis Using the Anova Method

Analysis of Variance for Hardness HV, using Adjusted SS for Tests						
Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**
Current	1	33.6	33.6	33.6	0.07	0.803
Electrode	1	1948.5	1948.5	1948.5	3.93	0.095
Error	6	2974.1	2974.1	495.7		
Total	8	4956.2				

Table 3 explaination that is the parameter or factor that most effects the hardness of the two factors is none of them have an effect. This is because the P value of both factors is greater than α (α = 0.05) so it is concluded that there is no relationship or effect between the two factors and the hardness value.

The hardness value after the welding process on hardness HAZ area increases in each variation of electric current and one type electrode so that it can be said that there is a relationship between the two factors with the hardness value.

This is because each factor and level can effect the hardness strength itself. When viewed from the irregular graphic shape based on the hardness value obtained from the test, it shows that there is no relationship between electric current and electrode type. Higher welding currents do not always result in higher hardness values. The lowest

Hardness value occurs at an electric current of 80 A in welding area. The highest Hardness value occurs at an electric current of 100 A in welding area. Shown in Figure 2.

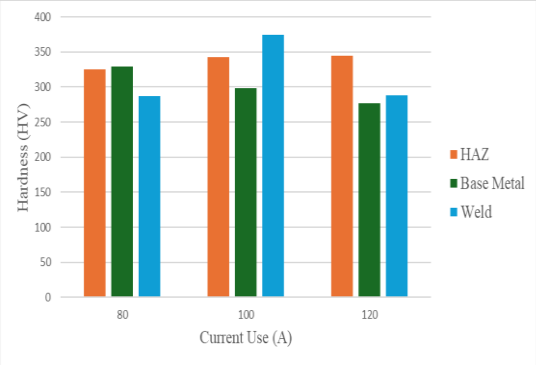


Figure 2 Effect Current on Hardness Area

The hardness value after the welding process on welding area increases in each variation of electric current and one type electrode so that it can be said that there is a relationship between the two factors with the hardness value. This is because each factor and level can effect the hardness strength itself. When viewed from the irregular graphic shape based on the hardness value obtained from the test, it shows that there is no relationship between electric current and electrode type. Higher welding currents do not always result in higher hardness values. The hardness value increases due to the influence of the carbon content in the electrode.

Discussion Impact Test

The Impact test results data before welding on three test specimen samples were averaged at 0.400 J.mm^2. While the tensile test results after welding by taking the average value of three test specimen samples can be seen in Table 4.1. Furthermore, the data obtained were processed using Minitab 16 with the Anova method. Can be seen in Table 4.

Table 4 Results of Impact Test Analysis Using the Anova Method

Analysis of Variance for Impact, using Adjusted SS for Tests						
Source	DF	Seq SS	Adj SS	Adj MS	F	P
Current	1	0.0005	0.0005	0.0005	0	0.953
Electrode	1	0.0248	0.0248	0.0248	0.2	0.67
Error	6	0.7404	0.7404	0.1234		
Total	8	0.7656				

The parameter or factor that most effects the Impact Test of both factors is none of them have an effect. This is because the P value of both factors is greater than α (α = 0.05) so it is concluded that there is no relationship or effect between the two factors and the Impact Test value. The Impact value after the welding process increases in each variation of electric current and one type electrode so that it can be said that there is a relationship between the two factors with the Impact value. This is because each factor and level can effect the impact strength itself. When viewed from the irregular graphic shape based on the impact value obtained from the test, it shows that there is no relationship between electric current and electrode type. The impact value increases due to the influence of the carbon content in the electrode. Shown in Figure 3.

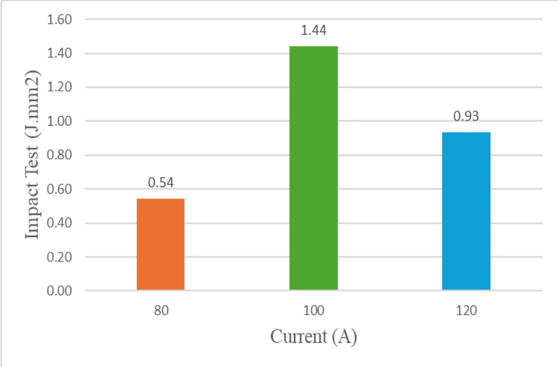


Figure 3 Effect Current on Impact Value

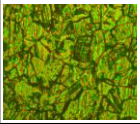
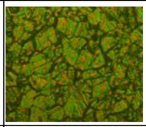
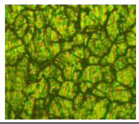
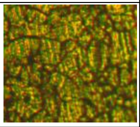
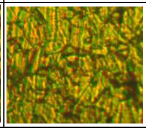
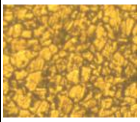
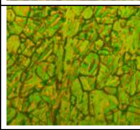
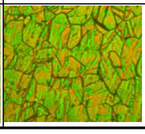
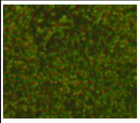
Discussion of Microstructure

Metallography showed the formation of martensite typical of medium-carbon steels subjected to thermal hardening and scanning electron microscopy identified the precipitation of carbides at the grain boundary, as well as the presence of gaps and other metallic and non-metallic inclusions in the microstructure [10].

Microstructure observations were carried out on the Base Metal material, welding, and HAZ areas. Images were taken at 200x magnification. The results of the observations are shown in Table 5. The results of the observations show significant changes in the microstructure between the three areas observed.

The initial microstructure of the Base Metal material has clear grain boundaries, when it starts to enter the HAZ area the microstructure starts to change slightly darker due to the process of uniting the Base Metal metal with the electrode metal. While in the welding area there is a more unified microstructure between the Base Metal metal and the electrode filler metal.

Table 5 Microstructure Observation Results

No	Current	Area		
		HAZ	Base Metal	Welding
1	80			
2	100			
3	120			

The resulting observations can be concluded that in the HAZ and base metal areas there is no significant difference between the microstructure with variations in electric current and one type electrode used.

Furthermore, when viewed in the welding results area there is a significant difference, namely where the microstructure looks unified and increasingly dense between the filler metal and the base metal. Microstructure observations were carried out in the base metal, HAZ, and welding areas, and the grain size comparison could be seen.

The grain size in the base metal area is larger than the grain size in the HAZ area. Meanwhile, in the welding area, the size of the microstructure looks finer/smaller because there is a fusion between the base metal and filler metal. If look at the microscope, it shows a variety of images. So it is necessary to see from the test results the mechanical properties for better results.

CONCLUSION

Based on the results of testing and analysis of hardness and impact use on three parameters that effect it with three level at the current, one level at the electrode used and one level at cooling tratment, it can be concluded into the following notes. That is electric current cannot effect impact strength, but can effect to hardness values. Each variation of electric current has an increase in hardness value from before welding, which is 238.73 HV. Current 80 A has a value of 313.61 HV, current 100 A has a value of 338.31 HV, and current 120 A has a value of 303.11 HV. Based on the results of observations using a microscope, the material melting process greatly effects the microstructure of the material. The closer to the filler metal, the grain boundaries are increasingly invisible due to the process of uniting the Base Metal with the filler metal.

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