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The Effect of Rootgap Distance and Polarity on Deffects in SMAW Welding Procedure

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Abstract

SMAW (Shielded Metal Arc Welding) welding has wide applications in the industrial world. To master welding technology, it is necessary to carry out further research on the effect of gaps on the microstructure after experiencing welding. Welding is a process of joining metalsby heating process, because of that, the process can change the basic properties of the base material. In this study, the material used was ASTM A36 carbon steel. That material was weldedby many variables that have been determined and the limitations of the problem during the study. The required specimen welding results are 6 pieces. There are three kindsof variables in this research; theywere independent variables, namely the Rootgap distance and polarity on the electrodes of the SMAW welding machine, using two types of polarity, namely (DCEN) and (DCEP). The dependent variables in this study were defects in the translucency of SMAW welding results obtained bySolvent Penetrant Testing method. The control variables in this study were welding current 90A, Voltage 21V, Electrode AWS A5.1 E6013 with SMAW welding process and Butt-joint welding type. The welding joint was a V-groovewith 30º of bevel angle and 2mm of root face. The study results showed that the welding translucency is affected by polarity and rootgap distance, where the DCEN polarity showed better translucent welding results than welding with DCEP polarity, even though it was still not in accordance with the standard.

1. Introduction

Technological developments are increasing rapidly, one of them is welding technology which has a major influence on the advancement of science. Along with the development of technology, various welding methods also develop and contribute to producing quality products. so that knowledge of welding technology is needed to achieve compatibility between the desired results and the welding process that may be carried out in order to obtain optimal results.

Welding is the process of joining two or more metals using a heating process, resulting in a metallurgical bond between the metals being joined. Today's metal joining process is widely used in industry for ship construction, machine building, piping construction and other jobs that require joints. Every process of welding work must meet certain standards governing welding.

Welding is an integral part of the growth of the industrial sector because it plays an important role in the engineering and improvement of metal production. It is almost impossible to build a factory without involving the welding process. The welding industry can be classified into industrial services, where this type of industry has the main activity of meeting the needs of others. Service activities carried out by this industry generally process the supply of raw materials from other industries into finished or semi-finished goods.[1]

Based on the definition of Deutsche IndustrieNormen (DIN), "welding is a process of joining metals together due to heat with or without the influence of pressure. It can be interpreted as a metallurgical bond caused by the attractive force of attraction between atoms"[2]. Welding is a way of correlating solid objects with the process of melting these objects through heating. In simple terms, it can be interpreted that welding is the process of joining two pieces of metal by using heat energy to melt the material being welded and welding wire as the connection[3].

SMAW welding provides high-efficiency joint strength [4]. One type of welding that is widely used to weld carbon steel is SMAW. The advantages of welding with SMAW include being reliable for welding various types of joints, positions and locations that are difficult to work with, relatively low operating costs and being able to be used both indoors and outdoors welding. [5].

This study used the Penetrant Test, which is a fast and reliable Non-Destructive Test (NDT) method to visually see weld defects on exposed surfaces from welding results. [6]. The penetrant test can be used to detect fine discontinuities in surfaces such as cracks, fine leaks and cavities [7]. The working principle of the penetrant test is that the liquid penetrant enters the discontinuity and then exits to the surface with the help of a developer. This developer must have a color that contrasts with the penetrant liquid so that when detecting surface defects can be done easily and correctly, the results of the penetrant test can be rejected if the dimensions do not match the standards set. [8] .

In another study, the effect of the root gap on the mechanical properties and microstructure by testing the hardness in the experiment. It was found that widening the root gap could affect the mechanical properties and microstructure was discussed of the weld. The harder material is, the more brittle it is[9]. There are previous studies that discuss the effect of the root gap distance by using the FCAW type of welding with the tester being carried out, namely the tensile test [10]. There is also research that discusses the effect of distance variations on the mechanical properties of steel welding materials in GMAW welding [11]

This research is important because previous research discussed the effect of the root gap distance on the microstructure of the welding results, while this research aims to determine the effect of the root gap distance and polarity on welding defects in ASTM A36 steel through a penetrant test with the correct standard procedure for SMAW welding defects, which determines the quality of welding based on the correct standard procedure.

2. Research Methods

This research uses a type of descriptive experimental research [12]to obtained data from the results of research through penetrant testing in the laboratory. This study uses a qualitative approach to explain data factually.Researchers apply qualitative methods to understand the problems that are the focus of their research.

2.1 Variable Type

The independent variable is the variable that influences or causes the change oremergence of the dependent (bound) variable. The independent variables in this study are the root gap distance using 3 root gap distances, namely 1, 2 and 3 mm, and the polarity of SMAW welding machine electrodesusing 2 types of polarity, namely Direct Current Negative Electrode (DCEN) and Direct Current Positive Electrode (DCEP).

The dependent variable is the variable that is affected, or is the cause and effect, because of the independent variables. The dependent variable in this study is the defect in the translucent SMAW welding results with the penetrant type NDT test.

Control variables are controlled or kept constant so that the relationship between the independent and dependent variables does not affect external factors that are not examined. while the control variable is a welding machine model FALCON 1619E with the LAKONI brand with a capacity of 20A-160A,a power of 220V (50 HZ), material ASTM A36 size 250 x 50 mm with a plate thickness of 4.5 mm for 6 pairs, welding electrodes E6013 diameter 2.6 x 30 mm brand ENNKA heat/Lot No. 30410004 type Flux high titanium. Welding current 90A, welding voltage 21 V, bevel angle 30°,rootface 2 mm and butt-joint welding technique type.

The analysis of the data used in this study was to determine the existence of inspection results in the form of welding defects based on the American Welding Society Standard D1.1 (AWS D1.1) as the standard acceptance criteria. The method for inspecting results is the non-destructive test (NDT) of the dye penetrant method used in this study. The Liquid Penetrant used when conducting inspections is the solvent-removable method with the Visible penetration type[13]. This method is used to find defects on the open surface of solid components, one of which is ASTM A36 carbon steel, which is the specimen in this study. Through this method, defects in the material will be seen more clearly by looking at the indications on the surface of the test object after being sprayed with developer, which is then sketch in to a work report that will later be translated into acceptance criteria[14].

Tabel 1. Testing Specimens

Specimen	Polarity	Rootgap (mm)
Specimen 1	DCEP	1
Specimen 2	DCEP	2
Specimen 3	DCEP	3
Specimen 4	DCEN	1
Specimen 5	DCEN	2
Specimen 6	DCEN	3

The procedure for carrying out the research was carried out based on the flow chart diagram shown Fig.1, starting with the selection of materials, welding and tests in the form of a penetrant test.

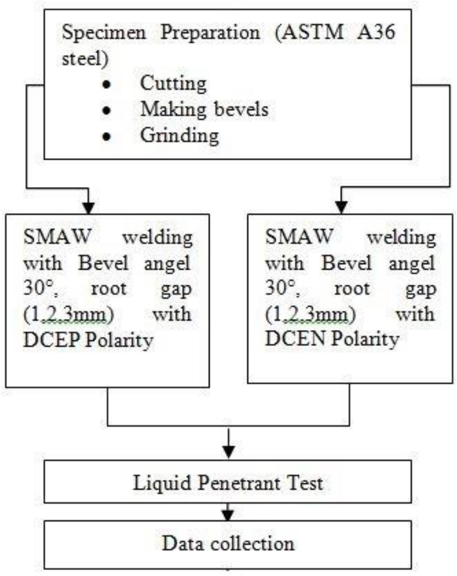

Fig. 1. research flow diagram

3. Results and Discussion

ASTM A36 is the material most commonly used in the manufacture of mild and hot-rolled steel. This material has excellent welding properties and is suitable for grinding, punching, tapping, drilling and machining processes, therefore in this study ASTM A36 was used as the type of plate used as a specimen.

One of the factors that determines the success of the welding process is the amount of heat input. that heat input is one of the essential parameters in welding. Measuring the heat input of a welding process is difficult to do directly, because it is known that the incoming electrical energy is not only converted into heat energy but also into light, sound, and radiation energy. even so that the determination of the amount of heat energy can be done by approximation. Theoretically the calculation of heat input during the welding process is the amount of heat energy per unit length of welding that is provided by the tip of the electrode during the welding process. The amount of heat input that occurs is Eq. 1:

$$HI = \frac{V.I.60}{v.1000}\ (kj/mm) \qquad (1)$$

Where HI is *heat input* (Joule/mm), V is *Voltage* (V), I is *Current* (A), v is *Travel Speed* (mm/minute)

From the test results obtained for travel speed and heat input data from the six specimens.

Table 2. Heat Input

Spec.	Polarity	A	V	Travel Speed	Heat Input (mm)
1	DCEN	90	21	111.3	1.01
2	DCEN	90	21	178.5	0.63
3	DCEN	90	21	69.4	1.63
4	DCEP	90	21	138,8	0,81
5	DCEP	90	21	113,6	0,99
6	DCEP	90	21	68	1,66

From the data generated during the welding process and the Heat Input obtained, it can be concluded that the quality of the welding results is affected by heat energy, which means it is also influenced by welding current, voltage and welding speed. The relationship between the three parameters produces the welding energy, which is known as the heat input.

So when welding, the longer the welder sticks the electrode or touches the heat source on the surface of the weld metal to melt the base metal and electrode, resulting in a greater heat input. This will affect the formation of weld metal, which results in deep penetration. From the results of observations, each root width variation has the same grain shape. From penetrant testing, the quality of the weldcan be known. Weld defects are a variable that can represent quality. In this testing process, the results were obtained from 6 specimens that were tested byLiquid Penetrant Testing with the results of:

Table 3. Specimen 1 Test Results

Rootgap Variation in Specimens (MM)	Type of Defect	Size of Defect (mm)		Result	
		Roun ded	Linier	Acc	Rej.
1	Linier Incomplete joint penetration		205		√

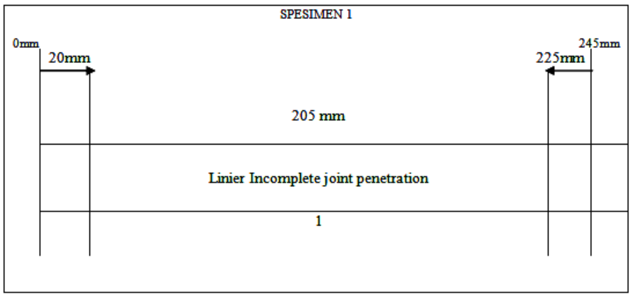

Fig. 1. Results of Specimen 1 Defect Analysis

Based on Table 3 and Fig. 1above, according to the AWS D1.1,based on the available data, the indications for these specimens were not within the limits of the existing standards, so they were declared rejected.

Table 4. Specimen 2 Test Results

Rootgap Variation in Specimens (MM)	Type of Defect	Size of Defect (mm)		Result	
		Roun ded	Linier	Acc	Rej.
2	Linier Inclusion		53		√
	Linier Incomplete joint penetration		7		√
	Linier Inclusion		100		√
	Linier Incomplete joint penetration		4		√
	Linier Inclusion		45		√

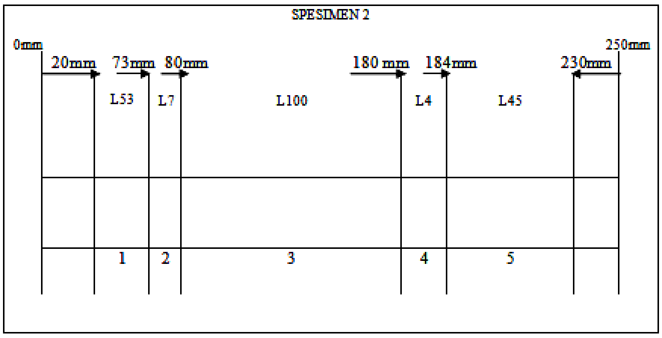

Fig. 2. Results of Specimen 2 Defect Analysis

Based on Table4 and Fig. 2 above, according to the AWS D1.1, the second specimen with a root gap of 2 mm has 5 defects.This indication was not within the limits of the existing standards, so it was declared rejected.

Table 5. Specimen 3 Test Results

Rootgap Variation in Specimens (MM)	Type of Defect	Size of Defect (mm)		Result	
		Rounded	Linier	Acc	Rej.
3	Linier Inclusion		18		√
	Linier Inclusion		24		√
	Overlap Rounded Inclusion, Linier Incomplete joint penetration		44		√
	Rounded Porosity		7		√
	Linier Inclusion		10		√
	Crack		7		√
	Crack		7		√
	Rounded Inclusion		8		√
	Burn-trough, Porosity, Rounded Inclusion		9		√

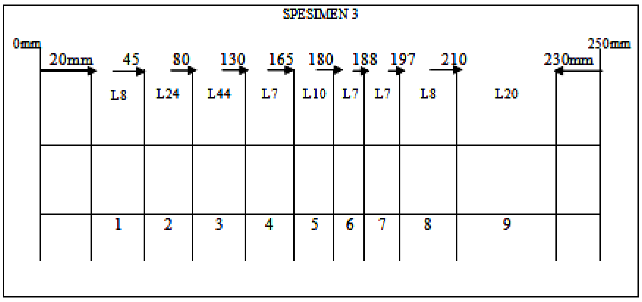

Fig. 3. Results of Specimen 3 Defect Analysis

Based on Table 5 and Fig. 3. above, according to the AWS D1.1, in the third specimen with a root gap of 3 mm has 9 defects, this indication was not within the limits of the existing standards, so it was declared rejected.

Table 6. Specimen 4 Test Results

Rootgap Variation in Specimens (MM)	Type of Defect	Size of Defect (mm)		Result	
		Rounded	Linier	Acc	Rej.
1	Linier Incomplete joint penetration		210		√

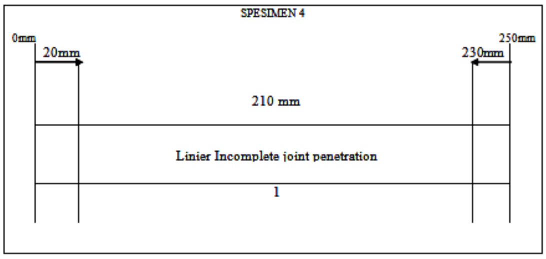

Fig. 4. Results of Specimen 4 Defect Analysis

Based on Table 6 and Fig. 4 above, according to the AWS D1.1 regarding the penetrant test method [15], states that the standard criteria for discontinuity contained in the welding results must be free from linear indications, rounded indications that are greater than 1 mm. Based on the available data, the results for these three specimens can be indicated.In the first specimen with a root gap of 1 mm has one defect, this indication did not fall within the limits of the existing standard, so it was declared rejected.

Table 7. Specimen 5 Test Results

Rootgap Variation in Specimens (MM)	Type of Defect	Size of Defect (mm)		Result	
		Rounded	Linier	Acc	Rej.
2	Linier Inclusion		8		√
	Linier Incomplete joint penetration		15		√
	Linier Inclusion		40		√
	Linier Inclusion		34		√
	Linier Inclusion		57		√
	Linier Incomplete joint penetration		16		√
	Rounded Porosity	1		√	

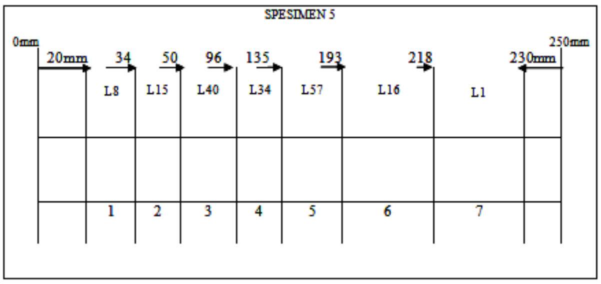

Fig. 5. Results of Specimen 5 Defect Analysis

Based on Table 7 And Fig. 5 above, according to the AWS D1.1 the second specimen with a root gap distance 2 mm has 7 defects based on existing data and indications does not fall within the limits of the standard, so it is declared rejected. but on the 7th defect, it was declared accepted because the defect fell within the limits of the standard, namely rounded porosity with a distance of 1 mm.

Table 8. Specimen 6 Test Results

Rootgap Variation in Specimens (MM)	Type of Defect	Size of Defect (mm)		Result	
		Rounded	Linier	Acc	Rej.
3	Linier Inclusion		46		√
	Excessive Root Penetration	16			√
	Rounded Inclusion	5			√
	Rounded Inclusion, Excessive Root Penetration, Linier Incomplete joint penetration		68		√

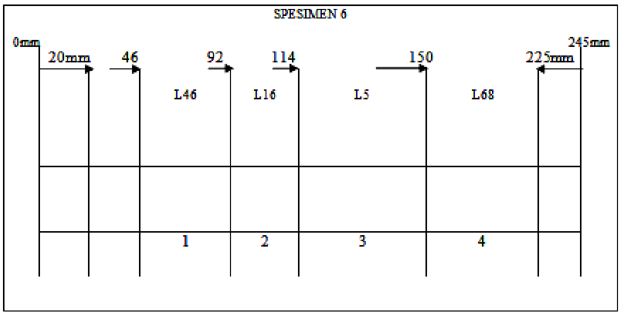

Fig. 6. Results of Specimen 6 Defect Analysis

Based on Table 6 And Fig. 4 above, according to the AWS D1.1 in the third specimen with a root gap of 3 mm has 4 defects, this indication was not within the limits of the existing standards, so it was declared rejected.

The results obtained in this study are presented in tables and the images presented on the DCEN and DCEP polarities produce different defects in each root gap. In the same root gap but with different types of polarity produce different quality defects.

On specimens with a root gap with a distance of 1 mm using DCEN and DCEP polarity, the defect results are known, that is, as long as the welding results are not translucent, it is identified that at a 1 mm root gap using DCEN and DCEP polarity, it still does not produce a weld that is in accordance with the quality of the defect set according to AWS D1.1.

Specimens with a spacing of 2 mm with DCEN and DCEP polarities. In the welding process with a spacing of 2 mm, it is possible to produce a copy. The results of a different translucency are that in the results with DCEN polarity, the number of defects is 5 defects, while in DCEP polarity, the number of defects is 7 defects. It can be seen in this study that the DCEN polarity on a 2 mm rootgap produces fewer defects than DCEP, although it is identified that at a 2 mm rootgap using both DCEN and DCEP polarities in this test, it still does not produce a weld that is in accordance with the quality of the defects set according to AWS D1.1.

Specimens with a spacing of 3 mm with DCEN and DCEP polarities. In the welding process with a spacing of 3 mm, a copy can be produced, different translucency results are obtained between the two polarities, the DCEN polarity has 9 defects, then the DCEP polarity has 4 defects. It can be seen that in this study, the polarity of the DCEP on the 3 mm root gap resulted in fewer defects than the DCEN, even though it was identified that at the 3 mm root gap, using both DCEN and DCEP polarities in this test it still did not produce a weld that corresponded to the quality of the defects set according to AWS D1.1.

4. Conclusion

Based on research conducted on the effect of root gap and polarity in welding ASTM A36 steel materials with a penetrant test for defects in the translucency of SMAW welding results, the results are as follows: The quality of the welding results is affected by heat energy, which means it is also influenced by the welding current, voltage and welding speed. The relationship between the three parameters produces the welding energy which is known as the heat input. Based on the welding translucency in this study, it was found that the polarity and rootgap distance used affected the welding results, where the DCEN polarity at 2 mm rootgap showed better welding translucency results. As for the results of welding with DCEP polarity at 3 mm Rootgap the results of better welding penetration. This states that the use of different polarities and root gaps results in different welding qualities, although in this test it is still not in accordance with the standards specified in this study using the American Welding Society standard D1.1 (AWS D1.1)

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