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The effect of variations of V-seam root face on Shielded Metal Arc Welding (SMAW) on the mechanical properties of AISI 1045 medium carbon steel

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Abstract: Steel is a metal alloy with the basic ingredients of iron (Fe) as the main element and carbon (C) as the main alloying element. Medium carbon steel is a type of carbon steel that is often used for the vehicle industry. The SMAW welding process is a technology for connecting two or more parts of an object by heating or pressing or a combination of the two in such a way that it unites like a whole object using shrouded electrodes to protect the welding arc against oxidation from the air. The parameter of the size of the root face is important because the size of the root face will affect the amount of filler metal in the seam area and the mechanical properties of shielded metal arc welding (SMAW) results. The purpose of this study was to determine the effect of the root face on the value of the impact price,0.772joules/. Meanwhile, in the tensile test, the result is that the greater the root face value, the less filler metal, which causes the tensile strength value to be greater. Because the value of the tensile strength of AISI 1045 steel is greater than the tensile strength of the E7016 series electrode. And the average value of the greatest tensile strength is at the root face of 3 mm of 559.05 MPa. Based on visual testing, the types of defects encountered in this final project are spatter defects, porosity defects, stop start defects and pin holes mm^2.

Keywords: AISI 1045 steel, SMAW welding, visual weld defect, impact test and tensile test

1. Introduction

Welding is a process of joining two metals, especially steel, to produce a machine construction carried out in a melted or liquid state by utilizing heat energy [1]. Welding in the world of construction technology has an important role in metal repair engineering [2]. Examples of the use of welding in construction include: shipping, bridges, steel frames, pressure vessels, transportation facilities, rails, pipelines and others. Based on the classification of how it works, welding can be divided into three groups, namely liquid welding, press welding and desoldering [3]. The difference between welding and desoldering is that in welding the base metal and the electrode (fill metal) both melt or melt.

Steel is a metal alloy derived from iron, where iron is the basic material and carbon is the mixture. While carbon steel is a combination of steel and carbon whose characteristics are determined by the element carbon. Carbon steel according to the amount of carbon content is classified into three, namely: low carbon steel (low carbon steel) with a carbon content of less than 0.3%C, medium carbon steel (Medium carbon steel) containing carbon of 0.3%C - 0.45% C, and high carbon steel (High Carbon Steel) contains carbon 0.45%C - 1.7%C [4]. AISI 1045 steel is classified as medium carbon steel which has a carbon content of 0.45% and has the characteristics of good machinability, good wear resistance and medium mechanical properties.

Based on previous research, it was found that the type of electrode used affects the results of the tensile strength [5]. In this study, the results of tensile testing on welding SMAw AISI 1045 steel using V seam with 7016 Lb 52 type electrode obtained a maximum stress value of 560 MPa. Meanwhile, the tensile strength of AISI 1045 steel that has undergone a welding process has a value that tends to be lower than the tensile strength of AISI 1045 steel without welding treatment with a value of 720 MPa. Based on other literature, it was found that the tensile strength value of AISI 1045 steel decreased after SMAW welding [6].

The purpose of this study was to determine the effect of the root face on the impact value, the value of tensile strength in SMAW welding of AISI 1045 steel material using tensile testing and impact testing.

2. Materials and Methods

The SMAW welding process for medium carbon steel AISI 1045 with a current of 90 A with a series of electrodes E7016 LB-52U is carried out on a material that has been formed V seam with an angle of 70 ° with root face variations of 1 mm, 2 mm and 3 mm which can be shown in the figure. 1 as follows.

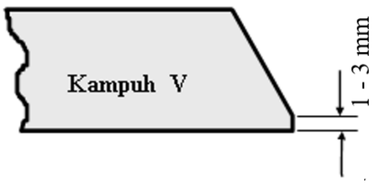

Figure 1. Seam V with Root Face Width 1 mm - 3 mm

The impact test specimens were prepared according to the ASTM E23 standard and their sizes can be shown in Figure 2 and Table 1. As well as the impact testing carried out using the Charpy method of impact testing equipment.

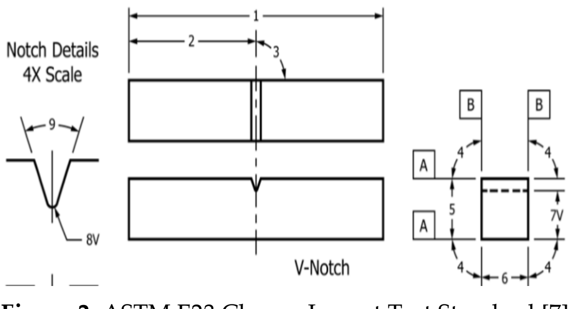

Figure 2. ASTM E23 Charpy Impact Test Standard [7]

Table 1.ASTM Charpy Impact Test Specimen Dimensions E23 [7]

No.	*Description*	*Dimension*	*Tolerance*
1	*Length of specimen*	55 mm	+0/-2.5mm

2	*Centering of notch*	-	±1 mm
3	*Notch length to edge*	90°	±2°
4	*Adjacent sides angle*	90°	±0.17°
5	*Width*	10 mm	±0.075 mm
6	*Thickness*	10 mm	±0.075 mm
7V	*Ligament length, Type V*	8 mm	±0.025mm
8V	*Radius of notch, Type V*	0.25 mm	±0.025mm
9	*Angle of notch*	45°	±1
A	*Surface finish requirements*	2 m (Ra)	◎
B	*Surface finish requirements*	4 m (Ra)	◎

The tensile test specimens were made according to the ASTM E23 standard as shown in Figure 3 and Table 2. And in this tensile test using the MTS Landmark 100KN machine.

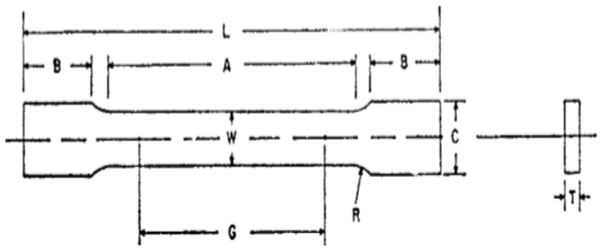

Figure 3.ASTM E8M Tensile Test Standard [8]

Table 2. Dimensions of Standard Size Tensile Test Specimen ASTM E8M [8]

Information	Score
G—Gauge length	25.0 ± 0.1 mm
W—Width	6.0 ± 0.1 mm
T—Thickness	6 mm
R—Radius of fillet	6 mm
L—Overall length	100 mm
A—Length of reduced section	32 mm
B—Length of grip section	30 mm
C—Width of grip section, approximate	10 mm

3. Results

The results obtained in this final project include: visual test welding defects, impact testing results and tensile test results.

3.1. Visual Test Welding Defect

The results of testing for visual defects from SMAW welding results can be shown in table 3 as follows.

Table 3. Welding Results SMAW Steel AISI 1045

1.	Welding Result of Root Face Impact Test Material 1 mm	
	SMAW Welding Results	Intensity
	- Welding results are less stable and less good - Welding spark defects - Porosity Defect - Disabled stop start	- xxxx - Currently - A little - A little
2.	Welding Result of Root Face Impact Test Material 2 mm	
	SMAW Welding Results	Intensity
	- Welding results are less stable - Welding spark defects - Pinhole defect	- xx - Lots - A little
3.	Welding Results of Root Face Impact Test Material 3 mm	
	SMAW Welding Results	Intensity
	- Welding results are less stable - Welding spark defects - Porosity Defect - Disabled stop start	- xx - A little - A little - A little
4.	Welding Results of Root Face Tensile Test Material 1 mm	
	SMAW Welding Results	Intensity
	- Stable weld results - Welding spark defects - Porosity Defect	- x - Lots - A little
5.	Welding Results of Root Face Tensile Test Material 2 mm	

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	SMAW Welding Results	Intensity
	- Stable weld results - Welding Splash - Porosity Defect	- x - Currently - A little
6.	Welding Results of Root Face Tensile Test Material 3 mm	
	SMAW Welding Results	Intensity
	- Stable weld results - Welding Splash - Porosity Defect	- x - Currently - A little

Information:

xxxx= a lot
xx = medium
x = a little

3.2. Figures, Tables and Schemes

Impact testing on AISI 1045 steel material that has been SMAW welding using a 70° seam angle using 3 test variations, namely root face 1 mm, root face 2 mm and root face 3 mm. This welding itself is carried out in the production laboratory of the University of Lampung using welding wire type E7016 Lb52, the current used alone is 90 A. Impact testing on medium carbon steel material AISI 1045 aims to determine the effect of the root face on the maximum load that can be absorbed by the test sample. especially in the weld joint area.
The results of the impact testing of the Charpy method can be shown in table 4 as follows.

Table 4. Impact Test Result Data

root face	Spc.	Area under the notch	Energy absorbed	HI	Average HI	Std. Dev.
1	1	42.43	28.5	0.67	0.77	0.098
	2	40,60	30.0	0.74		
	3	40.39	36.5	0.90		
2	1	38.45	16.0	0.42	0.56	0.101
	2	46,48	30.0	0.65		
	3	40.14	24.5	0.61		
3	1	42.60	22.0	0.52	0.52	0.059
	2	42.44	25.0	0.59		
	3	40.51	18.0	0.44		

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Information:

- ❖ root face = mm
- ❖ Area under the notch $=mm^2$
- ❖ Energy absorbed = joules
- ❖ Impact Price (HI) $=$joules/mm^2
- ❖ Average Impact Price (HI)= joules/mm^2

From the result data seen in table 4, an impact price diagram is obtained to make it easier to find out the results and comparisons of each root face variation on impact testing and the average impact price for each variation is shown in Figure 4 and Figure 5 as follows.

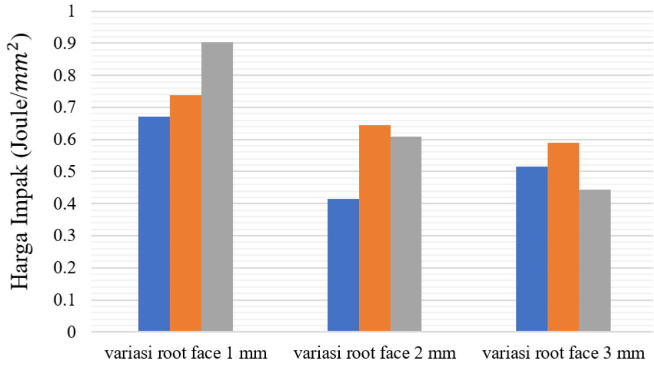

Figure 4. Impact Pricing Chart

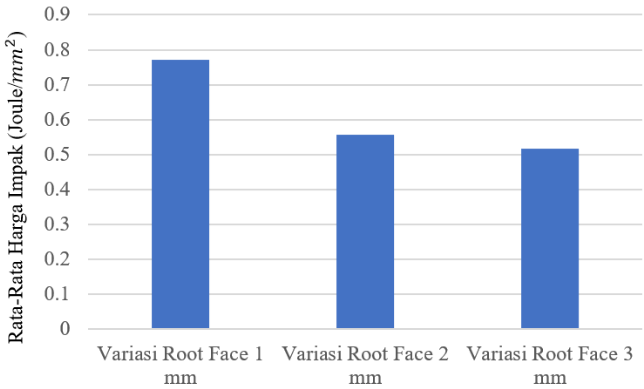

Figure 5. Average Impact Price Chart

3.3. Tensile Test Results

Tensile testing was carried out at the Mechanical Engineering Laboratory, University of Lampung using AISI 1045 steel material which had been SMAW welding previously using a 70° seam angle using 3 variations of the test, namely root face 1 mm, root face 2 mm and root face 3 mm. The welding itself was carried out at the production laboratory of the University of Lampung using welding wire type E7016 Lb52 with a current of 90 A.

The results of the tensile test can be shown in table 5 to table 7 as follows.

Table 5. Tensile Test Yield Stress Results Data

Variation of root face	Spc.	Yield Voltage (MPa)	Average Yield Voltage (MPa)	Standard Deviation

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1 mm	1	383.15	369.71	26.00
	2	392.64		
	3	333.35		
2 mm	1	298.03	368,12	49.68
	2	407.30		
	3	399.04		
3 mm	1	391.04	379.91	7.87
	2	374.19		
	3	374.50		

Table 6. Tensile Test Maximum Stress Result Data

Variation of root face	Spc.	Maximum Voltage (MPa)	Average Maximum Voltage (MPa)	Standard Deviation
1 mm	1	571.80	528.73	74.80
	2	590.87		
	3	423.52		
2 mm	1	351.42	539.99	134.02
	2	617.76		
	3	650.78		
3 mm	1	683.55	559.05	92.66
	2	532.21		
	3	461.39		

Table 7. Tensile Elasticity Modulus Result Data

Variation of root face	Specimen	Modulus of Elasticity (GPa)	Average Modulus of Elasticity (GPa)	Standard Deviation
1 mm	1	205692	200730.7	9601.3
	2	209196		
	3	187304		
2 mm	1	212270	210737.7	1117.4
	2	210306		
	3	209637		
3 mm	1	209637	209852.3	1665.3
	2	211991		
	3	207929		

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4. Discussion

From the results of the impact testing that has been carried out based on Figure 4, the value of the largest dominant impact value in each test is on the root face variation of 1 mm with a value in the first sample of 0.672 joules/mm^2, the second sample of 0.739 joules/mm^2 and the third sample of 0.904 joules/. Furthermore, the root face variation is 2 mm with a value in the first sample of 0.416 joules/, the second sample of 0.645 joules/mm^2 and the third sample of 0.610 joules/mm^2. and the smallest dominant impact value is the root face variation of 3 mm with the first sample value of 0.516 joules/mm^2, the second sample of 0.589 joules/mm^2 and the third sample of 0.444 joules/mm^2.

When compared with other studies [9] the results of impact testing obtained an average value of 2,226 joules/mm^2.Meanwhile, the average result of 1 mm root face variation is 0.772 joules/mm^2, root face variation is 0.557 joules/mm^2 and the 3 mm root face variation is 0.516 joules/mm^2. It can be concluded that the average overall impact price sample from this study has a smaller impact price value. This is due to differences in the use of strong welding currents.

Therefore, it can be concluded that the largest impact value is on the 1 mm root face variation, then the 2 mm root face and the last 3 mm root face. This is because the smaller the size of the root face in the V seam, the more filler metal in the V seam will cause the material to be more ductile than the larger root face.

In the 1 mm root face variation, the diagram always increases in each sample because the energy value (joules) obtained is greater in samples 1 to the third. This is caused by one of the factors of good welding results compared to welding results on variations of the root face of 2 mm and root face of 3 mm so as to obtain an up and down diagram image. Another thing that causes the diagram to go up or down is because during welding there is an area that lacks filler metal so that the seam area is not fully filled. This results in the parent metal and the weld area not having the same size. This lack of filler metal is caused by the current being too large so that the flame from the electrode is more difficult to control.

Based on tables 5 to 7, tensile tests on medium carbon steel AISI 1045 obtained different results. In table 5 regarding yield stress, the data results that have the highest average value are the 3mm root face variation of 375.91 MPa, the second largest is the 1 mm root face variation average of 369.71 MPa and the highest average value is 369.71 MPa. small, namely the root face variation of 2 mm with an average value of 368.12 MPa.

In table 6 regarding the maximum stress of AISI 1045 medium carbon steel, the data results that have the highest average value are the 3 mm root face variation of 559.99 MPa, the second for the 2 mm root face variation is 539.99 MPa and the last is 528.73 MPa at root face variation 1 mm. In table 7 on the modulus of elasticity in AISI 1045 medium carbon steel, the data results that have the highest average value are the 2 mm root face variation with a value of 210737.7 GPa, the second is the 3 mm root face variation 209852.3 GPa and the last is the variation root face 1 mm by 200730.7 GPa.

From the data obtained from table 5 to table 7, it can be concluded that the one with the highest yield stress is the 3 mm root face variation and the lowest is the 2 mm root face variation. For the maximum stress the largest is the root face variation of 3 mm and the smallest is the root face variation of 1 mm. Furthermore, the one that has the greatest modulus of elasticity is the root face variation of 2 mm and the smallest is the 1 mm root face variation.

Based on the data obtained in Tables 5 to 7, a stress-strain graph was made on the tensile test of AISI 1045 medium carbon steel material with variations of root face 1 mm, root face 2 mm, and root face 3 mm as shown in Figure 6 as follows.

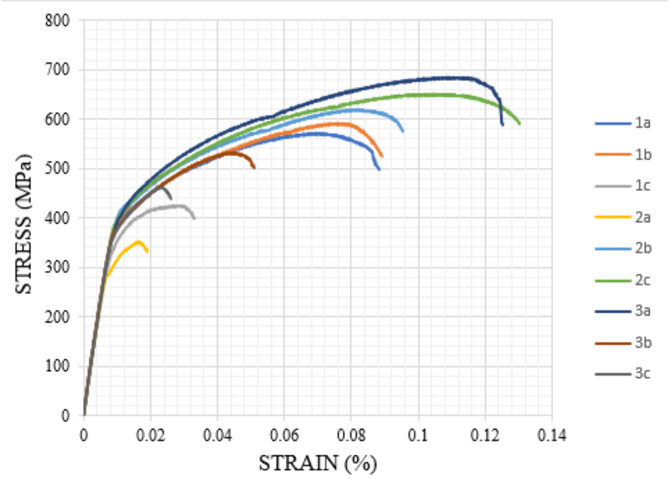

Figure 6. Stress-Stain Graph on AISI 1045 Steel with Variation of Root Face 1 mm, Root Face 2 mm and Root Face 3 mm

Information:

1a = root face variation 1 mm in the first sample

1b = root face variation of 1 mm in the second sample

1c = root face variation of 1 mm in the third sample

2a = root face variation of the first 2 mm sample

2b = 2 mm root face variation of the second sample

2c = variation of root face 2 mm in third sample

3a = root face variation of 3 mm in the first sample

3b = root face variation of 3 mm in the second sample

3c = root face variation 3 mm in the third sample

Based on Figure 6 on the stress-strain graph obtained, at the root face variation of 1 mm the third sample is very much different from the first and second samples which tend to have a maximum stress value that is not much different. Likewise for the 2 mm root face variation in the first sample, as well as the 3 mm root face variation in the second sample and the third sample. This is because at the time of welding, the filler metal is not fully filled in the V seam or at least equal to the medium carbon steel material AISI 1045. Because the greater the root face value, the less filler metal and the greater the tensile strength value. As explained in research [10] that the value of the tensile strength of medium carbon steel AISI 1045 is 585 MPa and other studies [5] that the value of the minimum tensile strength of the E7016 electrode is 483 MPa.

Based on research [5] that the results of tensile testing on SMAW welding of AISI 1045 steel obtained a maximum stress value of 560 MPa. From the comparison of these studies, it can be concluded that in this final test, the overall average value of the maximum tensile test stress is lower.

While the effect of the root face on the value of the maximum tensile strength or stress on the SMAW welding results of AISI 1045 steel, that is, if the value of the root face is greater, the amount of filler metal will be less which causes the value of the tensile strength to be greater. Because the value of the tensile strength of AISI 1045 steel is greater than the tensile strength of the E7016 series electrode.

5. Conclusions

The effect of the root face on the impact price on the SMAW welding results of AISI 1045 steel is that if the size of the root face on the V seam is smaller, the amount of filler metal will increase which causes the material to become more ductile and vice versa. And the average value of the largest impact value is at the root face of 1 mm of 0.772 joules/mm^2. The effect of the root face on the value of the maximum tensile strength or stress on the SMAW welding results of AISI 1045 steel, that is, if the value of the root face is greater, the amount of filler metal will be less which causes the value of the tensile strength to be greater. Because the value of the tensile strength of AISI 1045 steel is greater than the tensile strength of the E7016 series electrode. And the average value of the greatest tensile strength is at the root face of 3 mm of 559.05 MPa.

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