The Variation Effect of Electric Current Toward Tensile Strength on Low Carbon Steel Welding with Electrode E7018

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Article Info	ABSTRACT
	The strength of the welding result is strongly influenced by several factors, one of which is the selection of high current. This study aims to determine the effect of high current of welding on the strength of low carbon steel welding joints. The process of welding the material uses the open V seam connection type. The variations of the high current used were 80 A, 100 A and 130 A. The specimen used was a carbon steel plate with code of 1.0038 with thickness of 8 mm and the electrode used was the E7018 electrode with diameter of 3.2 mm. The strength of the welding results is influenced by arc voltage, amount of current, welding speed, amount of penetration and electric polarity. Determination of the amount of current in metal joints using arc welding affects the work efficiency and welding materials. Based on the research, it was found that welding using high current of 100 ampere produced the highest tensile strength value of all test specimens that were given welding treatment and good penetration results.

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1. INTRODUCTION

Welding is a metallurgical bond in a metal or metal alloy joint which is carried out in a melting state. Based on this, it can be further explained that welding is a local joint of several metal rods using heat energy [1]. Welding is the process of joining the material which results in the fusion of the material by heating it to the right temperature with or without the use of a filler [2]. Welding is a metal joining process in which the metal becomes one due to welding heat, with or without the influence of pressure and with or without filler metal [3]. Welding has a very important role in the engineering and repair of metals that are used by humans, besides, in today's construction, many welding elements involve, especially in the engineering field [4]. The widespread use of the welding process is due to low cost, relatively fast implementation, lighter weight and more varied forms of construction [5]. From some of the opinions above, it can be concluded that welding work is to join two or more metal parts using heat energy [6]. The welding process involves steel plates made of iron and carbon crystals according to their microstructure with a certain shape and direction, the metal plates are heated until they melt. When the edges of the metal plates are joined together, a joint is formed [7].

Shield Metal Arc Welding (SMAW) is a welding process in which the alloying of metals is generated through heat from an electric arc that arises between the ends of the electrodes wrapped in the metal surface being welded [8]. The factor that affects the welding result is the welding procedure, which is planning for implementation which includes how to make a weld construction according to the plan and specifications by determining all the things needed in the implementation such as welding equipments, welding machines and safety tools [9]. Welding production factors are the manufacturing schedule, the manufacturing process, the tools and materials required, the order of execution, the preparation of welding (including: welding machine selection, the appointment of the welder, the electrode selection, the use of the seam type) [1]. SMAW welding is widely applied in constructions that use iron or steel as a material for manufacture [10]. Examples of SMAW welding applications in the construction sector include building bridges, multi-storey building construction, pipe industry, storage tank industry, pressure vessels, and structural industries such as shipping,

transportation, heavy equipment and so on [4]. The widespread use of this welding technology is due to the fact that the joints are lighter with a simpler process, so that the costs required are cheaper. This advantage causes welding joints to be used as a substitute for rivet and bolt joints in machine structures and designs [11].

Welding involves various variables such as time, temperature, electrodes, power input and welding speed which will affect the final properties of the weld metal [13]. The most likely result of the welding process is the occurrence of weld cracks due to the occurrence of diffusion hydrogen and residual stress [15]. Diffusion hydrogen is caused when the weld metal melts, and it absorbs a large amount of hydrogen which is released by diffusion at low temperatures because at that temperature the solubility of hydrogen decreases [16]. The sources of absorbed hydrogen are water and organic substances contained in the flux and parent metals [15]. In addition, the tensile strength value is influenced by the increasing temperature of the material due to the gauze process, this indicates that the welded joint will be vulnerable to brittleness than the base metal and will also cause residual stress in the material [14]. residual stress is the occurrence of greater voltage surges due to changes in the properties of the material in the connection, especially in the heat affected area or HAZ (Heat Affected Zone), because the area is a metal area adjacent to the weld metal area which during the welding process experiences a thermal cycle of heating and rapid cooling resulting in decreased tensile strength and hardness at the weld joint [1]. In addition, the decrease in tensile strength can be attributed to the presence of voids and other defects that occur as a result of high welding currents which can also cause a decrease in tensile strength [12].

The strength of the welds is influenced by the arc voltage, the amount of current, the welding speed, the penetration magnitude and the electric polarity [17]. Determination of the amount of current in the joining of metals using arc welding affects the efficiency of work and welding materials [18]. In addition to the polarity of the determining factor which is one of the parameters in welding, namely a clean surface will produce a much stronger welded joint, surface oxides must be removed because they can become trapped in frozen metal [19]. So that it is possible to have a weld defect that causes a reduction in the strength of the weld metal, therefore a test is needed so that the resulting data can be valid [10]. Welding joints are a critical component because failures that occur in welding will have fatal consequences, to avoid this the acceptable standard of welding results is increasingly enhanced [20]. This acceptance standard represents the minimum weld quality based on a test specimen welded containing multiple discontinuities [21]. Carbon steel with code 1.0038 is used for this study because it accounts for about 90% of total ordinary carbon steel and is widely applied because of its economic value, excellent weld ability, good mechanical and physical properties which can be accepted by many applications [22]. The purpose of testing is to determine the quality of certain products or specimens, while the purpose of the inspection is to determine certain quality standards. In short, the purpose of testing and inspection is to guarantee the quality and to give confidence in the construction being welded. Therefore, the use of a control system in arc welding can eliminate much of the "guessing work" often used by welders to determine welding parameters for a given task [23]. This study uses the SMAW welding method with variations of electric current 80 Ampere, 100 Ampere, 130 Ampere using a manual arc welding machine (SMAW) DC (direct current) and electrodes measuring 3.2 mm using seam V. The process of this research discusses about how the effect of variations in welding current on the tensile strength of low carbon steel as a result of SMAW welding using E7018 electrodes.

2.   METHOD

The research method used is the experimental research method. The research object to be studied is carbon steel with a code of 1.0038 with thickness of 8 mm as a result of SMAW welding using the E7018 brand electrode with diameter of 3.2 mm. The connection used is an open seam V connection which is welded with three variations of the welding current, namely 80 A, 100 A, 130 A, and each variation of the current has three specimens that are tested using the Universal Testing Machine.

Table 1 : Tensile Testing Machine Specifications

Tipe	WE-1000
Tahun	2000
Buatan	China
Kapasitas	1000 kN
No. Serial	1057

Welded joints that will be used in this study are joints in the form of an open seam with angle of 60˚. The seam joint V is used to join metal or plates with thickness of 6-20 mm with a seam angle of 50˚, the root distance of 0-2 mm and the root height of 0-3 mm [24].
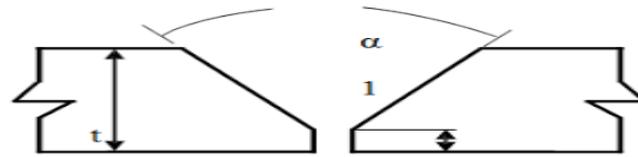

Figure 1 : The seam V [24].

Figure 1 illustrates the shape of the work unit that will undergo the welding process using seam V. The groove weld used in welding is divided into three parts; full penetration weld without retaining plate, full penetration weld with retaining plate, partial penetration weld. Therefore in the welding process the choice of connection type is very important and must be selected based on needs and uses. The form of the test specimen to be used in tensile testing is as follows:
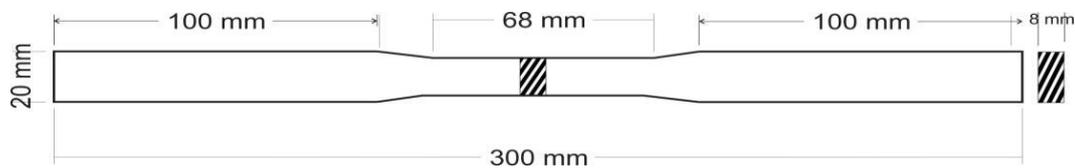

Figure 2 : Dimensions of ASTM E8 Tensile Test Specimen [25]

3. SPECIMEN

The test specimen used is carbon steel with code 1.0038 which is given welding treatment using magnitude of welding current about 80 A, 100 A, and 130 A. The following is a picture of carbon steel with code 1.0038 after being formed into a tensile test specimen:

Figure 3 : 1.0038 Carbon Steel Tensile Test Specimen (Without Welding)

Figure 4 : Specimens of Tensile Testing for Carbon Steel 1.0038 with Welding Current of 80 Ampere

Figure 5 : Specimens of Tensile Testing for Carbon Steel 1.0038 with Welding Current of 100 Ampere
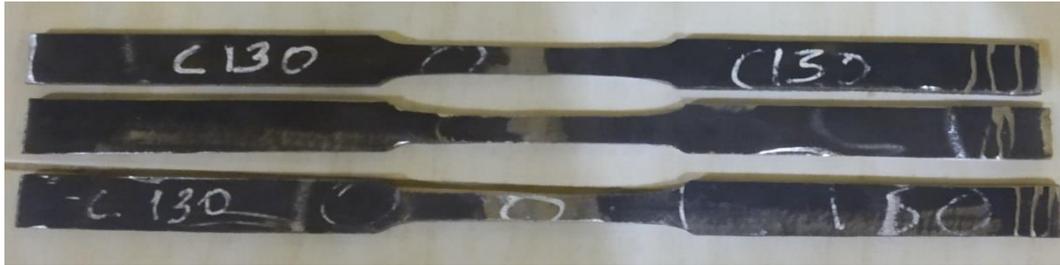

Figure 6 : Specimens of Tensile Testing for Carbon Steel 1.0038 with Welding Current of 130 Ampere

Tensile test is carried out for 3 times of testing for each type of specimen. Each type of specimen has 3 materials tested with the Universal Testing Machine. Tensile testing is a test carried out by giving a load on the material until a failure or break occurs. If an object is given a pull force, the object will experience an extension in length which happens because there is a relationship between the application of the attractive force and the increase in length. If the force per unit area is called stress and the increase in length is called strain, then this relationship is expressed as a stress-strain graph.

In the tensile test, the load is given continuously and slowly and constantly, at the same time observing the elongation experienced by the specimen and a stress-strain curve is generated. To determine the value of the tensile strength of the material (σ) the value of the maximum force (F) is divided by the cross-sectional area (A_0) (Equation 1). After determining the value of the tensile strength then determining the strain value (ε) by means of the final length of the material after testing (L_i) minus the initial material length before the tensile test (L0) divided by the length of the initial material (L_0) then multiplied by 100% (Equation 2) . Last, to determine the value of the modulus of elasticity of the material (E), the amount of tensile strength (σ) is divided by the strain that occurs in the material (ε) (Equation 3) [25].

$$\sigma = \frac{F}{A_0} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$\varepsilon = \frac{L_i - L_0}{L_0} \text{ x } 100 \text{ \%} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$E = \frac{\sigma}{\varepsilon} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots .(3)$$

4.   RESULTS AND DISCUSSION

Tensile test result data is obtained by testing all test specimens so that a graph of the tensile test results is obtained which is attached to the attachment. Tests carried out on carbon steel with code 1,0038 without treatment will be carried out 3 times of the test, carbon steel with code 1,0038 with welding using a current of 80 A for 3 times of the test, carbon steel with code 1,0038 with welding using a current of 100 A as much as 3 times testing and finally for carbon steel with code 1.0038 by welding using a current of 130 A for 3 times and the total of all tests was 12 times. For the results of these tests, the data is written in table 2.

Table 2 : Test Result Data

No	Kode Sampel	Tipe / Merek Sampel	Ukuran T (Mm)	L (Mm)	Ao =T.L (Mm)	Fy (Kn)	Fm (Kn)	L0 (Mm)	Δl (Mm)	Ɛ %	σ (N/Mm²)	E (Kn/Mm²)
												L (above Δl) Ɛ σ E
						Baja 1.0038						
1	Spec 1	Baja 1.0038	8	12,5	100	23,84	41,36	90	20,6	22,9	413,6	1,806
	Spec 2	Baja 1.0038	8	12,5	100	23,53	41,22	90	27,1	30,1	412,2	1,369
	Spec 3	Baja 1.0038	8	12,5	100	23,62	39,44	90	26	28,9	394,4	1,364
		Rata Rata							24,7	27,3	406,7	1,489
						80 A						
2	80 Spec 1	Baja 1.0038	8	12,5	100	23,44	36,48	90	24,4	27,1	364,8	1,346
	80 Spec 2	Baja 1.0038	8	12,5	100	24,74	40,32	90	26,8	29,8	403,2	1,353
	80 Spec 3	Baja 1.0038	8	12,5	100	22,87	38,49	90	25,8	28,6	384,9	1,345
		Rata - Rata							25,7	28,5	384,3	1,348
						100 A						
3	100 Spec 1	Baja 1.0038	8	12,5	100	24,02	39,98	90	25,3	28,1	399,8	1,833
	100 Spec 2	Baja 1.0038	8	12,5	100	23,96	38,82	90	26,6	29,6	388,2	1,311
	100 Spec 3	Baja 1.0038	8	12,5	100	23,24	38,68	90	27,7	30,8	386,8	1,255
		Rata - Rata							26,5	29,5	391,6	1,327
						130 A						
4	130 Spec 1	Baja 1.0038	8	12,5	100	22,84	37,82	90	26	28,9	378,2	1,308
	130 Spec 2	Baja 1.0038	8	12,5	100	21,90	38,66	90	26,5	29,4	386,6	1,314
	130 Spec 3	Baja 1.0038	8	12,5	100	23,06	40,24	90	28,1	31,2	402,4	1,289
		Rata - Rata							26,8	29,7	385,7	1,298

Information :
Ao = Area
Fm = Maximum Force
Ɛ = Strain
Fy = Yield Strength
σ = Tensile Strength

Based on table 2 the following graph of average tensile strength of each test specimen:
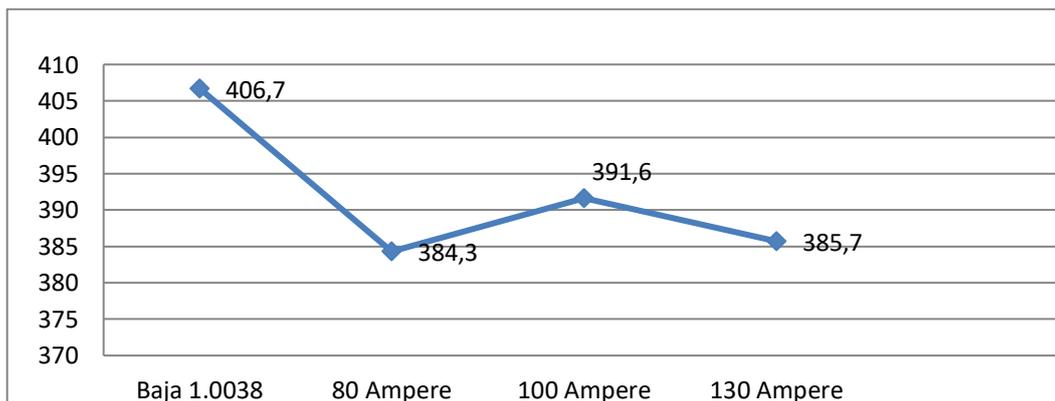

Figure 7 : Comparison Chart of Specimen Tensile Strength

Based on the graph in the figure, it can be seen that each specimen has different tensile stress, strain, and modulus of elasticity. In addition, this graph is the comparison of the average tensile strength of each specimen. Thus it is concluded that the current strength and the tensile stress are inversely proportional, where the higher the welding current used, the lower the tensile stress and vice versa, the lower the welding current used, the higher the tensile strength produced.

Based on the analysis that has been carried out, the tensile strength of the control specimen has a tensile stress value of 406.73 N/mm^2, for the strain it has a value of 27.3% and a modulus of elasticity of 1.489 KN/mm^2 And the results of the tensile strength with a current of 80 A have a tensile strength of 384.3 N/mm^2, then for the strain it has a value of 28.5% and the modulus of elasticity is 1.348 KN/mm^2. The current of 100 A has a tensile strength of 391.6 N/mm^2, then for the strain it has a value of 29.5%, and the modulus of elasticity is 1.327 KN/mm^2. Finally, the tensile strength with a current of 130 A has a tensile strength of 385.7 N/mm^2, and the strain value is 29.7%, and the modulus of elasticity is 1.298 KN/mm^2.

4.1. Steel Specimens 1.0038

This specimen does not go through heat treatment in the welding process, it aims to be a control for specimens that receive welding treatment, for the control specimen has an average tensile strength value of 406.7 N/mm^2. The value of the tensile strength is the highest value of all tensile testing specimens, this can occur because in the control specimen there is no welding treatment is given before the test so that the test specimen does not experience structural changes.

4.2. Tensile Test Specimens with 80 A of Welding Current

In this specimen, the SMAW welding process was carried out with the magnitude of current about 80 A which was carried out on 3 specimens. Furthermore, after welding the specimen will be formed according to the shape of the tensile test specimen and then the tensile test is carried out. After the tensile test is carried out, the first test specimen breaks in the weld joint. This happens because the metal is not melted during the welding process unevenly. Hence, after analyzing the tensile strength of the specimen with a welding current 80A, it is the smallest value of all test results. From the results of the tensile test, the average tensile strength of the test results with a current of 80 A is 384.3 N/mm^2. This is the lowest value among all test specimens that have been welding and this current is not suitable for being used in plate welding with a material thickness of 8mm. This happens because the welding process with 80 A of current is very difficult to control and arcs often die during the welding process, if the welder cannot control the swing during the welding process the electrodes will die in the middle of the specimen welding process. In addition, for the process of charging with the current of 80 A is not very suitable if it is used for 8 mm thick plates.

4.3. Tensile Test Specimens with 100 A of Welding Current

In this specimen, the SMAW welding process was carried out with 100 A of the current which was carried out on 3 specimens. Furthermore, after the welding process, the specimen will be formed according to the shape of the tensile test specimen and then the tensile test is carried out. From the tensile test results, the average tensile strength of the test results with a current of 100 A is 391.6 N/mm^2. This is a quite good value caused by the 100A current which is included in the standard current in the welding process of plates with a thickness of 8 mm using the E7018 electrode. The results of the welding on this specimen are good for filling and are very good for penetration using seam V joints.

4.4. Tensile Test Specimens with 130 A of Welding Current

In this specimen, the SMAW welding process was carried out with the current of 130 A which was carried out on 3 specimens. Furthermore, after welding the specimen will be formed according to the shape of the tensile test specimen and then the tensile test is carried out. From the results of the tensile test, it was found that the average tensile strength of the test results with a current of 130 Ampere was 385.7 N/mm^2. This value is a fairly high tensile strength value because the current strength used is the highest current strength in plate welding standards with a thickness of 8 mm and the tensile strength value is not much different from the results of welding using a 100 A of current. The welding result on this specimen is good enough for filling and penetrating yet the welding result shows a welding defect in the form of an under cut and the formation of a crater at the end of the weld groove.

5. CONCLUSION

Based on the analysis and discussion of the data obtained during testing, it can be concluded that the welding process using current of 80A, 100 A, and 130 A, and electrode E7018 with a diameter of 3.2 mm will affect the tensile strength of low carbon steel welding. The higher the welding current used, the lower the tensile strength of the material. The welding process using 100 A of current produces the highest tensile strength value of all test specimens that are given welding treatment, which is 391.6 N/mm^2, and the welding results are good for the filling and penetrating process. So this indicates that the most suitable welding current for the plate welding process with a material thickness of 8 mm is to use a current of 100 A.

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