The Effect of Cooling Media on Tensile Strength of Medium Carbon Steel in Post Welding Process Using Electric Welding (SMAW) with E7018 Electrodes

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ABSTRACT

The use of cooling media in post welding process will affect the tensile strength of a material. This study aims to determine how much the influence of using cooling media in post welding and which cooling media is appropriate to use. The process is done by comparing the tensile strength of each cooling media, namely the cooling media of water, air, and coolant. The use of cooling media is carried out after the welding process, until the material that is ready to be welded reaches room temperature. Based on the experiments that have been conducted, the use of post-welding cooling media affects the tensile strength of medium carbon steel with the highest effect on the water cooling media, then the coolant media, and the lowest is the air cooling media. Therefore, the choice of the use of cooling media significantly affects the tensile strength of medium carbon steel in the post-welding process.

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1. INTRODUCTION

Metal is generally used in machine construction [1]. One of the most widely used metals is steel [2]. Steel is widely used in machine construction because it has ductile, strong, and hard properties [3]. AISI 1050 steel is classified into the part of medium carbon steel [4]. In addition, steel with the main elements Fe and C can be combined with other elements such as Cr, Ni, Ti, and so on to obtain the desired mechanical properties [5]. AISI 1050 medium carbon steel is one of the steels that is widely used in the world of machinery such as gear components, chains and shafts [6]. AISI 1050 steel is a medium carbon steel with a carbon content (C) of 0.50% [7]. It also consists of other elements including Silicon (Si), Manganese (Mn) 0, Phosphorus (P), Sulfur (S), Boron (B), and Chromium (Cr) [8]. The carbon content of the steel determines the hardness of the material [9]. Steel is divided into three types based on its carbon content, namely Low Carbon Steel, Medium Carbon Steel, and High Carbon Steel [10]. Steel AISI 1050 or steel with the American Iron and Steel Institute standard is classified into medium carbon steel [11].

One method for forming steel is the SMAW (Shield Metal Arc Welding) method or electric arc welding [12]. SMAW welding is very commonly used in combining iron and its alloys such as low, medium, and high carbon steel, stainless, and cast steels [13]. SMAW welding is a shielded arc welding where heat is generated between the electrode tip and the metal tip to be welded. Welding is an important manufacturing process which can be joined together of similar or dissimilar metals of various shapes and sizes [14]. The difference in the use of the types of electrodes will affect the tensile strength of the welding results and elongation [15]. One of the effects of welding is a change in the tensile strength of a material [16]. In the welding process a heating and cooling process is required, the heating speed depends on the welding process, while the cooling process depends on the cooling media [17]. Variation of cooling media will result in different cooling rates so that the strength and hardness will also be different [18]. As a result of the heat transfer from the steel specimen to the cooling media, a vapor sheath is formed around the steel surface so that it will inhibit the rate of heat transfer from the steel to the cooling media [19]. The ability of a type of media to cool the specimen can vary, and the difference in the ability of the cooling media is caused by temperature, viscosity, solution content and the basic

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material of the cooling media [20]. The purpose of cooling is to obtain a martensite structure, the more carbon elements are, the more martensite structures will be formed [21]. Since martensite is formed from the Austenite phase which is cooled rapidly, so that its hardness increases [22].

The main objective of the tensile testing process is to determine the strength of the material under tensile loads [23]. The influence of different cooling media is to determine the comparison of its tensile strength and suitability for its application so that a decision can be made to use the cooling treatment process on the right media in order to save time and production costs [24]. The physical changes of AISI 1050 steel depend on the way of cooling and welding, so it is necessary to identify the type of cooling media that suits the needs [25]. This research uses Shield Metal Arc Welding (SMAW) method by providing several post-welding coolants, namely water, air, and coolant to determine the effect on the tensile strength of medium carbon steel AISI 1050. So this research will provide information for the welders and the like. for the selection of post-welding cooling media. The next goal is as a guideline or literature, especially in the field of welding, materials or technical materials for further research.

2. METHOD

The research method used in this study was an experimental research method, namely a quantitative research design that was carried out to determine whether a treatment affects the results of the study [26]. The material used in this study was AISI 1050 Medium Carbon Steel with a thickness of 12 mm which was welded using Electric Welding (SMAW) with the electrode code E7018. For the connecting seam, it used seam V. After the materials have been welded, it would be immediately cooled with several variations of cooling media including water, air, and coolant. The research implementation process can be seen in Figure 1.

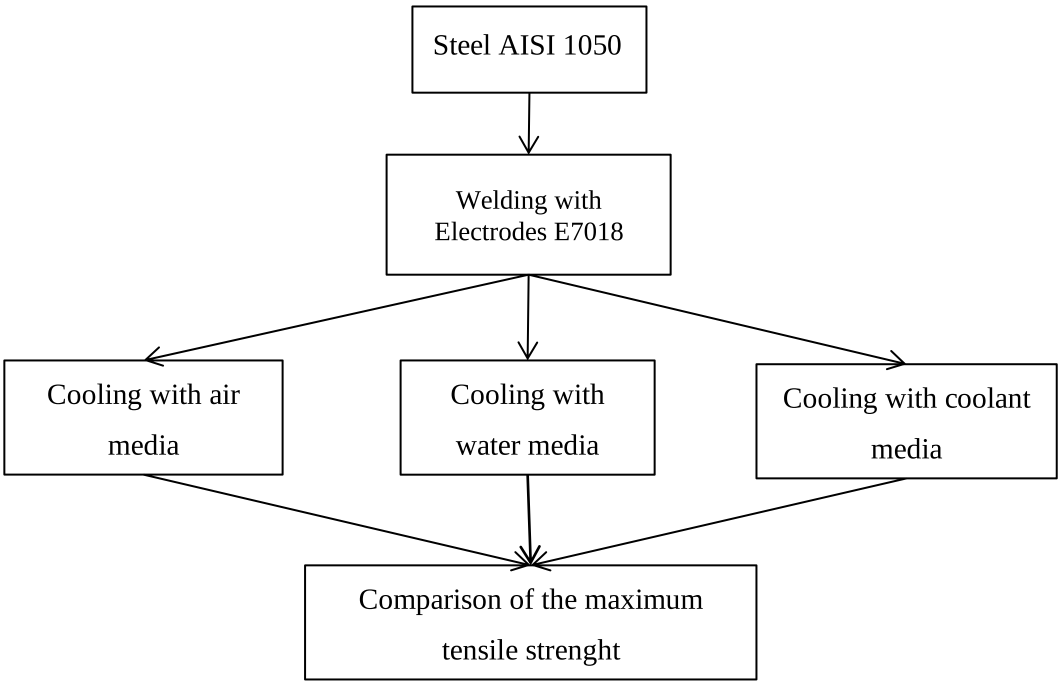

Figure 1 : Research Design

The research process began with the manufacture of seam V. Seam V was used to join metal or plates with a thickness of 6-20 mm with a seam angle between 50º- 70º, plate lip distance 0-2 mm, plate lip height 0-2 mm with seam angle of 30^0 [27].

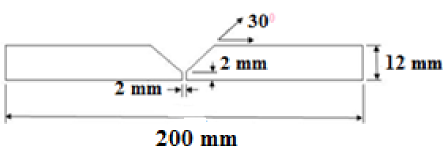

Figure 2 : Seam V

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From Figure 2. then the welding process was carried out in a horizontal welding position. After the welding was complete, the steel material was cooled with 3 cooling media, namely water, air, and coolant. This cooling process was carried out until the steel plate was completely cold. After the cooling process was done, the next step was making a tensile test specimen. There were 13 specimens used in this study, with details of 1 original specimen of AISI 1050 Steel to equalize the results of its tensile strength with Mill Certificate obtained from the market. Then there were 4 specimens for air cooling media, 4 specimens for water cooling media, and 4 specimens for Coolant cooling media. From each specimen that was welded would be cooled with a variety of cooling media, then the tensile testing process was carried out by the Universal Machine Testing and was taken the average value of the tensile test results.

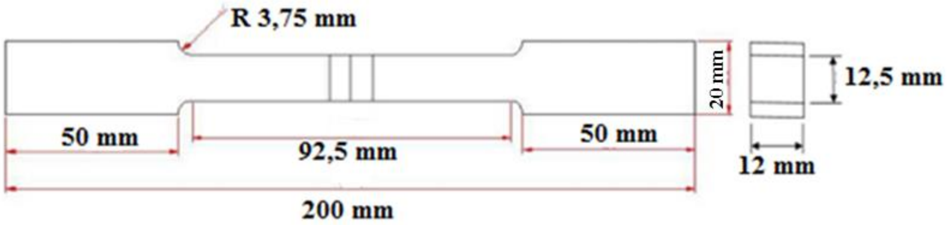

Figure 3 : Dimensions of ASTM E-8 Standard Tensile Test Specimen [28]

In the Tensile Test, the load is given continuously, slowly and constantly, as well as observing the elongation experienced by the specimen and the resulting stress-strain curve. To determine the value of the maximum tensile strength (σ), the value of the maximum tensile force (Fm) is divided by the cross-sectional area (Ao) (equation 1). After the tensile strength is obtained, the next step is to determine the strain value (ε), which is done by subtracting the length of the specimen after testing (Li) with the length of the specimen before testing (Lo) then divided by the length of the specimen before testing (Lo) then multiply by 100% (equation 2). Finally, to determine the modulus of elasticity (E), the maximum tensile strength (σ) is divided by the strain (ε) [29].

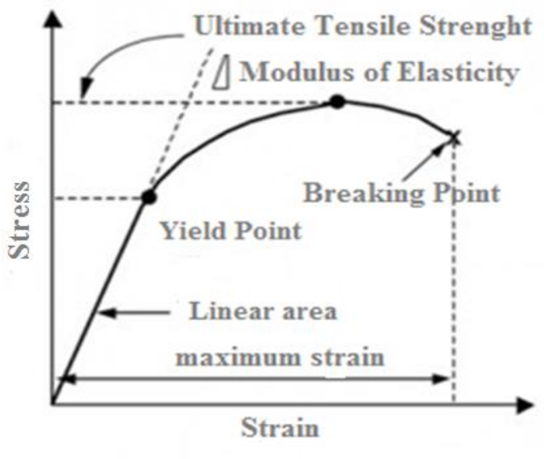

Figure 4 : Stress-strain Curve [22]

$$\sigma = \frac{F_m}{A_o} \qquad (1)$$

$$\varepsilon = \frac{Li - Lo}{Lo} \text{ x } 100\,\% \qquad (2)$$

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

3. RESULTS AND DISCUSSION

Based on the results of research conducted at the Civil Engineering Tensile Testing Laboratory, Faculty of Engineering Padang State University, it can be seen that each specimen has different tensile strength, strain, and modulus of elasticity. From the data obtained, the influence of the use of post-welding cooling media variations affects the tensile strength of AISI 1050 Steel. Here are the data obtained from tests carried out at the Civil Engineering Tensile Testing Laboratory, Faculty of Engineering, Padang State University:

Table 1 : Tabulation of test data

No	Sample Code	specimen	Lo (mm)	F_m (KN)	F_y (KN)	Li (mm)	ε (%)	σ		E	
								Mpa	Kgf/mm^2	Gpa	Kgf/mm^2
1	Steel AISI 1050	1	50	108,66	64,64	9,6	19,2	724,4	73,868	3,772	384,636
2	Air Conditioning Media	1	50	90,26	65,94	6,65	13,3	601,733	61,359	4,524	461,319
		2	50	90,42	64,61	6,55	13,1	602,8	61,468	4,601	469,171
		3	50	90,6	65,44	5,65	11,3	604	61,590	5,345	545,038
		4	50	64,26	55,28	2,3	4,6	428,4	43,684	9,313	949,661
		Average				5,287	10,575	559,233	57,025	5,945	606,221
3	Water Cooling Media	1	50	113,24	67,34	4,9	9,8	754,93	76,981	7,703	785,487
		2	50	97,36	68,02	6,35	12,7	649,06	66,185	5,110	521,074
		3	50	81,6	69,34	3,5	7,0	544	55,472	7,771	792,421
		4	50	87,42	60,18	6	12	582,8	59,429	4,856	495,174
		Average				5,187	10,375	632,697	64,517	6,36	648,539
4	Coolant Cooling Media	1	50	81,44	68,14	3,4	6,8	542,93	55,363	7,984	814,141
		2	50	99,66	68,68	5,1	10,2	664,4	67,749	6,513	664,141
		3	50	98,04	68,94	5	10	653,6	66,648	6,536	666,486
		4	50	96,88	68,28	6,4	12,8	645,86	65,859	5,045	514,446
		Average				4,975	9,95	626,697	63,905	6,519	664,752

From Table 1. It can be seen that each test specimen has a different tensile strength. Based on the results of the analysis that has been carried out, the tensile strength of AISI 1050 steel has a tensile strength of 724.4 Mpa, for the strain it is 19.2%, and the modulus of elasticity is 3.772 Gpa. Then for tensile strength with air cooling media is 559.233 Mpa, for the strain is 10.575%, and the modulus of elasticity is 5.945 Gpa. Next, for the water cooling media, the tensile strength is 632.697 Mpa, the strain is 10.375%, and the modulus of elasticity is 6.36 Gpa. Finally, the Coolant cooling media has a tensile strength of 626.697 MPa, a strain of 9.95%, and a modulus of elasticity of 5.045 Gpa.

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It can be seen in Figure 5. comparison of the tensile strength graph of AISI 1050 steel with several specimens including AISI 1050 Steel, air cooling media specimens, water cooling media specimens and coolant cooling media specimens. In addition, this graph serves as a comparison of the average tensile strength of each sample. So it can be concluded that the use of E7018 electrodes with a variety of cooling media reduces the tensile strength compared to the tensile strength of AISI 1050 Steel.

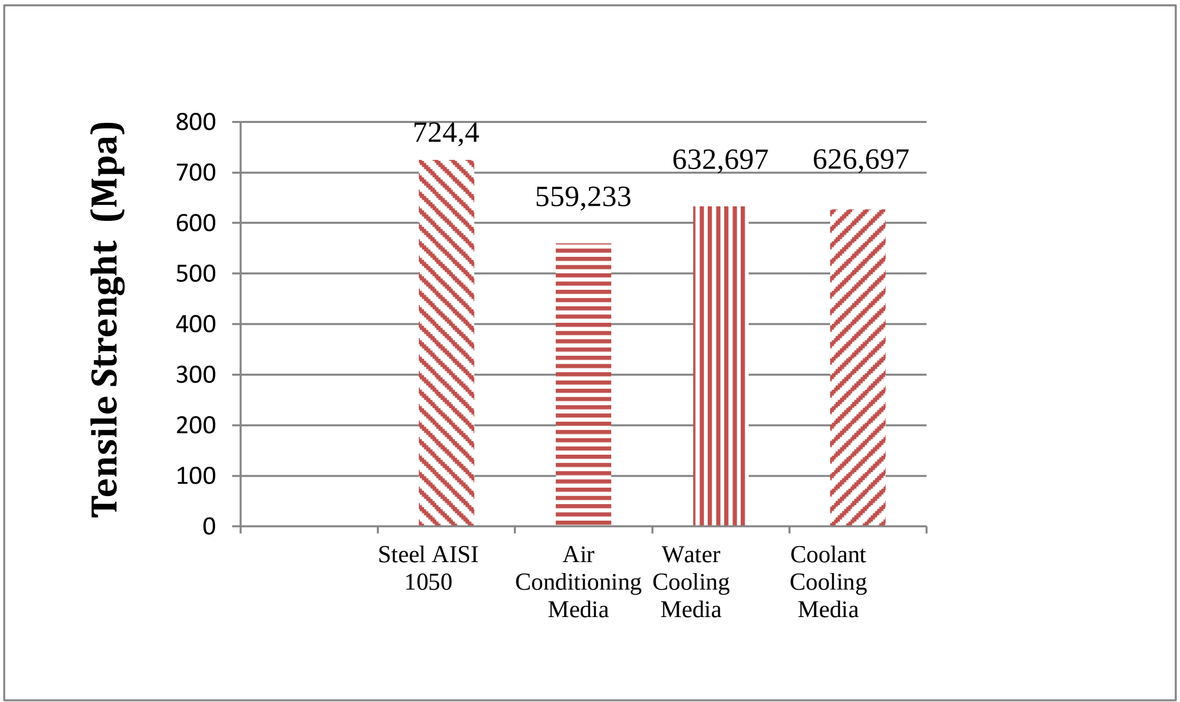

Figure 5 : Comparison of Tensile Strength Graph

3.1 AISI 1050 Steel Specimen

This specimen does not undergo any treatment because it aims to equalize the tensile strength contained in the mill certificate and as a comparison with specimens that received welding and cooling treatment. The tensile strength of AISI 1050 steel from the results of data analysis and testing is 724.4 Mpa. This is in accordance with previous studies which state that the tensile strength of AISI 1050 steel ranges from 600-800 Mpa [30]. The tensile strength value of AISI 1050 Steel is the highest tensile strength value compared to specimens treated with cooling media, this is because there is no effect of structural changes due to welding and cooling processes.

3.2 Tensile Test Specimens with Air Cooling Media

In this specimen, the electric welding process or Shield Metal Arc Welding (SMAW) was carried out using E7018 electrodes with air cooling media, which the number of specimens was 4 specimens. Furthermore, after the welding process using air cooling media, a tensile test specimen will be formed according to the predetermined standards and then a tensile test will be carried out. After carrying out the tensile test for all specimens the break in the weld joint was caused by the low tensile strength of the E7018 electrode compared to AISI 1050 steel. The average tensile strength obtained after data analysis and testing was 559,233 Mpa. This is a specimen with the use of a cooling media that has the lowest tensile strength compared to other cooling media, but the tensile strength of each specimen is not too different, this is because the level of stability of the air cooling media is quite good and the cooling space is also wide.

3.3 Tensile Test Specimens with Water Cooling Media

In this specimen, the electric welding process or Shield Metal Arc Welding (SMAW) was carried out using E7018 electrodes with water cooling media which has 4 specimens. Furthermore, after the welding process using water cooling media, a tensile test specimen will be formed according to the predetermined standards, then a tensile strength test will be carried out. After conducting a tensile test for all specimens and analyzing the data, the value obtained was 632.697 MPa. This is the highest value compared to specimens with other cooling media. This is due to the influence of water media which significantly changes the structure of AISI 1050 Steel. However, the tensile strength value for each specimen has a significant difference; this is due to the weakness of the water cooling media which causes steam so that it can cause a steam trap that produces uneven hardness and unfavorable stress distribution, causing distortion, and soft speckling [31].

3.4 Tensile Test Specimens with Coolant Cooling Media

In this specimen, the electric welding process or Shield Metal Arc Welding (SMAW) was carried out using the E7018 electrode with coolant as a cooling media, which number of specimen is 4 specimens. Furthermore, after the welding process using water cooling media, a tensile test specimen will be formed according to the predetermined standards, then a tensile strength test will be carried out. After conducting a tensile test for all specimens and analyzing the data, the average value obtained was 626.697 Mpa. This is the second highest value after water cooling media. This is because the coolant consists of a mixture of water and coolant so that the strength value is below the water cooling media.

4. CONCLUSION

From the results of the discussion and data analysis that has been carried out, it can be concluded that the use of air, water, and coolant cooling media after welding with electric welding (SMAW) affects the tensile strength of AISI 1050 Medium Carbon Steel. Water cooling media is the media with the highest tensile strength compared to other cooling media which is 632,697 Mpa. Thus, the selection of cooling media is very important because it will have an impact on the tensile strength of AISI 1050 Medium Carbon Steel.

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NOMENCLATURE

The meanings of the symbols used in this equation are as follow :

σ	meaning of maximum tensile strength
Fm	meaning of maximum tensile force
Ao	meaning of cross-sectional area
ε	meaning of strain
Li	meaning of length of the specimen after testing
Lo	meaning of length of the specimen before testing
E	meaning of the modulus of elasticity

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