INTEK Jurnal Penelitian
Vol. 9, No. 1, pp. 78-81, April 2022

Effect of Heat Treatment Temperature on Tensile Strenght through Welding of Mild Carbon Steel

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***Abstract*—This study aims to explain how much the tensile strength of mild steel welding without heat treatment and with heat treatment and to explain how much influence the variation of heat treatment temperature of mild steel welding results on the tensile strength. The method used is the experimental method, namely by conducting experiments in the laboratory, taking data directly on the object to be observed then recording the required data in the form of the initial length of the specimen, the length of the specimen after breaking, the diameter of the initial specimen, the diameter of the specimen after breaking and maximum load. The results showed that the tensile strength value of the mild steel welding without heat treatment was 27.07 kgf/mm^2, the tensile strength of the specimen welded by heat treatment at a temperature of 500^{0}C was 29.08 kgf/mm^2, at a temperature of 600^{0}C was 35.17 kgf/mm^2 and at 700^{0}C the tensile strength is 40.06 kgf/mm^2.**

Keywords*—heat Treatment; Temperature; Tensile Strength; Mild Carbon Steel

I. Introduction

The results of the field survey at PT. Jasa Marina Indah Semarang shows that in general there are often problems with welded joints in the construction of the ship's hull, this result in cracks or fragments in the welded joints in the hull. Even when the ship is fully loaded or at the dock the ship must be able to maintain its strength [1], [2]. The heat treatment of the welding results is carried out to determine whether the tensile strength of the material is the same if the material is welded without heat treatment. For this reason, in order to utilize the materials and equipment available at the Makassar Shipping Science Polytechnic workshop laboratory and provide additional knowledge about the strength of welded joints, especially the tensile strength properties before and after the heat treatment process, the authors conducted this study.

The purpose of the study was to calculate the tensile strength of the St. 42 steel welding without heat treatment and with heat treatment and to explain how much influence the temperature variation of the ST 42 steel welding result had on the tensile strength.

Mild steel is a type of construction steel commonly used in the manufacture of new shipbuilding [3]. This steel has carbon content (C) below 0.3%, so it is included in low carbon steel. Steel in general has a carbon content of 0.0 to 1.5% [4]. Welding is a metal joining process in which metals become one due to heat with or without the influence of pressure. It can also be defined as a metallurgical bond caused by the attractive forces between atoms. A clean surface will result in a much stronger welded joint; the surface oxide must be removed because it can become trapped in the solidified metal [5], [6].

SMAW is the simplest and most versatile arc welding process. SMAW can be performed in various positions or locations that can be reached with an electrode [4]. Welding results are largely determined by the correct welding techniques. Welding techniques that need to be considered are how the position and direction of the welding will be carried out. The position of the brander on the workpiece being welded greatly affects the welding result. The position of the workpiece to be welded cannot all be placed in a position that is easy to weld [7].

To heat the steel with a uniform temperature throughout the part, careful holding time is needed, with the name "Holding Time", the length of the holding time

DOI : http://dx.doi.org/10.31963/intek. v9i1.3733

is very dependent on the size of the work piece and the rate of diffusion of carbon in the steel. Tensile tests are intended primarily to measure yield strength, tensile strength and modulus of elasticity of materials [8]. Tensile strength is determined by tensile testing. Tensile strength is the maximum load divided by the initial cross-sectional area of the specimen. This strength is useful for the purposes of specification and quality control of materials [9].

II. Research Methodology

This study uses an experimental method conducted in the workshop laboratory. The material used is mild steel (Strength of 42 MPa) with a length of 300 mm and a diameter of 19 mm. This material is cut into two parts each with a length of 150 mm, one end is formed on a lathe with a double v seam using a 600 tilt conical lathe. Connecting the material using a SMAW DC welding connection type E 6013 electrode which will be the tensile test object. Tensile test specimens are formed in the center using a lathe to produce a diameter of 16 mm. The next step is the tensile test object is heat treated in a furnace with temperature variations of 500^0C, 600^0C and 700^0C. The heating process lasts for 1 hour 15 minutes with a holding time of 15 minutes. After receiving heat treatment, it was then cooled for 1 hour before the test object was withdrawn. Tensile tests were also carried out on the specimens without heat treatment to determine the tensile strength after welding. In the tensile test, first measure the initial length of both the upper and lower grips on the tensile testing machine and carry out tensile loading until the test object breaks.

III. Results and Discussion

A. Results

In the results of this study, there are 2 (two) parts of data processing, namely processing specimen data without heat treatment and processing specimen data with heat treatment for temperatures of 500^0C, 600^0C and 700^0C. Initial test data is used to obtain calculation data in determining tensile stress, strain and reduction as follows:

- Initial specimen diameter (d) = 16 mm
- Maximum load (F) = 5440.5 kgf
- Original length (L_o) = 50 mm
- Length after breaking (Lu) = 52 mm
- Smallest diameter (d_0) = 15.4 mm
- The cross-sectional area, A = $\pi/4\ d^2 = 3.14/4 \times 16^2 = 200.96\ mm^2$
- Tensile stress, τ = 27.07 kgf/mm2
- Strain (elongation), $\varepsilon = \frac{Lu-Lo}{Lo} x\ 100\% = \frac{52-50}{50} x\ 100\% = 4\%$
- The smallest cross-sectional area (after breaking), $A_0 = \pi/4\ d_0^2 = 3.14/4 \times 15,4^2 = 187.17\ mm^2$
- Reduction of cross section, $q = \frac{A-A_0}{A_0} x\ 100\% = \frac{200,96-186,17}{200,96} x\ 100\% = 7,36\%$

The complete calculation results can be seen in Tables 1 and 2, and also described in Figure 1.

Table 1. The calculation results

Specimen	Temperature Heat Treatment	Tensile Stress, τ (kgf/mm^2)	Initial length, L_0 (mm)	Final length, Lu (mm)	Strain ε (%)	Initial area (mm^2)	Final area (mm^2)	Red. Cross section, q (%)
1	Non HT	27,07	50	52	4	200,96	186,17	7,36
2	500^0C	29,08	50	52,5	5	200,96	176,63	12,11
3	600^0C	35,17	50	53	6	200,96	165,05	17,87
4	700^0C	40,06	50	54	8	200,96	153,86	23,43

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Table 2. Tensile Test Report

Specimen	Temperature Heat Treatment	Maximum Load (kgf/mm^2)	Break Load (kgf/mm^2)	Tensile Stress, τ (kgf/mm^2)	Strain, ε (%)
1	Non HT	5440,5	5331,69	27,07	4
2	500^{0}C	5845,6	5728,69	29,08	5
3	600^{0}C	7068,4	6927,032	35,17	6
4	700^{0}C	8051,1	7890,	40,06	8

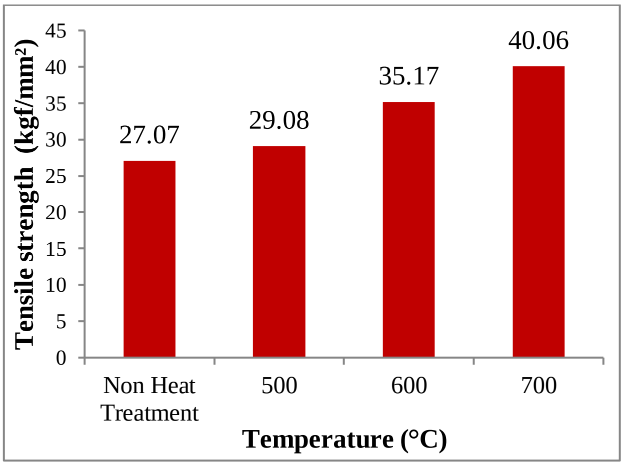

Figure 1. Tensile strength result versus temperature

Figure numbers and labels should be placed one line under the figure:

(a)

(b)

Figure 2. Specimen condition (a) after welding and before tensile test, and (b) tensile test result

B. Discussion

Figure 1 shows the relationship between the tensile strength of the ST 42 Steel specimens which were welded without heat treatment (Non Heat Treatment) and the heat treated specimens starting at temperatures of 500^{0}C, 600^{0}C and 700^{0}C with a holding time of 15 minutes each. In the graph it can be seen that the specimens welded without heat treatment has the smallest tensile strength of 27.07 kgf/mm^2 compared to specimens welded by heat treatment. This can happen because the heat treatment received by an object will change the microstructure of the object where the grain structure of the object will change and affect the tensile strength of the material.

This can be seen in the results of the study in table 1 where the tensile strength of ST 42 steel increased after the steel was welded and then heat treated with temperature variations of 500^{0}C, 600^{0}C and 700^{0}C with the same holding time on each specimen for 15 minutes. The maximum tensile strength of the specimens welded by heat treatment at 500^{0}C is 29.08 (kgf/mm^2). The maximum tensile strength of the specimens welded by heat treatment at 600°C is 35.17 (kgf/mm^2). In Figure 1 it can also be seen that the greatest maximum tensile stress occurs in the welded specimen which is then heat treated at a temperature of 700 °C where the maximum tensile stress is 40.06 (kgf/mm^2).

In Figure 1 it can be seen that as the heat treatment temperature increases, the maximum tensile strength of the welded specimen increases. This is because steel with a carbon content of 0.3% heated at a higher temperature will result in the formation of coarse grains and usually have a higher hardness described in reference [3] that hardness is proportional to tensile strength, which means the harder a material is. the tensile strength will increase. This is also consistent with the previous explanation that one of the purposes of heat

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treatment is to improve the tensile strength of the material.

IV. Conclusion

From the results of data processing, experimentation and discussion, it can be concluded as follows:

1. The tensile strength of the St. 42 steel welding without heat treatment has the smallest tensile strength of 27.07 kgf/mm^2 compared to the specimens welded by heat treatment welded and then given heat treatment with different temperature variations can affect the tensile strength of the material.
2. The specimens welded by heat treatment at 500°C had a tensile strength of 29.08 kgf/mm^2, at 600°C had a tensile strength of 35.17 kgf/mm^2 and the highest tensile strength occurred at 700°C at 40.06 kgf/mm^2.
3. In this study, it was obtained that the higher the heat treatment temperature after welding, the higher the tensile strength of the St. 42 steel specimen but it does not always depend on the heat treatment temperature.

Acknowledgement

This research is an experimental research in the field of Material Technology that utilizes several new equipments in the Makassar Shipping Science Polytechnic Workshop laboratory. Author would like to thank The Makassar Maritime Science Polytechnic Research Center which supports this research, thanks also to colleagues at PIP Makassar who have provided suggestions for the accomplishment of this research.

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