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Analysis of Effect of Temperature Variation Preheat on SMAW Welding of Microstructures, and ST60 and SS400 Steel Hardness

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Abstract

Welding is a metal joining process by melting some base and filler metals. SMAW welding (Shielded Metal Arc Welding) is one of the industry's most widely used welding methods. SMAW welding requires preheating (preheating) to reduce residual stress, distortion, and cold cracking in the weld metal. Preheat also can affect the microstructure and hardness of the weld metal. This study aims to analyze variations preheating on SS400 and ST60 steel against micro tests by SMAW welding, namely electric arc welding with covered electrodes. Temperature variation preheating used in SS400 steel was 140°C, 170°C, 300°C and 400°C in ST 60 steel. The results showed that the higher the temperature preheat, the larger the grain size of the microstructure in the parent metal region, the heat-affected area, and the weld metal area. The higher temperature preheat also led to a decrease in violence in the three areas. ST60 steel has a larger microstructure grain size and lower hardness than SS400 steel at all temperature variations preheat.

Keywords: SMAW;Preheating; SS400 Steel; ST60 Steel

1. Introduction

The use of steel in manufacturing and construction processes, especially in shipping, is very important. Steel is one of the most widely used building materials today because it is flexible, durable and affordable. Almost every project requires the availability of steel, from the construction of houses, roads, and bridges to multi-storey buildings. SS400 and ST 60 steels are low-carbon steel types that are easy to weld.

The welding process plays an important role in construction. Welding is a process of joining metals or non-metals by heating the material until the welding temperature is reached, with or without pressure, only with pressure, or with or without fillers [1]. One type of welding is SMAW (Shielded Metal Arc Welding). SMAW welding involves joining two or more similar metals using an electric heat source and wrapped electrodes as additional material or filler to make a permanent connection [2].

Many aspects must be considered in the welding process, starting from material knowledge to the appropriate method for joining metals for maximum results. Welding processes in steel can cause complex changes in metallurgical properties, deformations, and thermal stress around the weld area, reducing the strength of the welded joint. Three parts distinguish the weld area: the weld metal area, HAZ (Heat Affected and Zone), and the base metal [3].

One way to prevent the occurrence of cracks in the weld is to preheat treatment (preheating) on the weld joint before the welding process is carried out. The heat treatment process is a process that aims to change the properties of metals by changing the microstructure through heating at a certain temperature and adjusting the cooling rate with or without changing the chemical composition of the metal [4]. Preheating is heating the metal to a certain temperature before welding to increase the temperature of the base metal and change the microstructure according to the intended use.

Preheating the metal before the welding process affects the percentage of carbon. Preheat causes a slow cooling rate in the weld metal and HAZ region, which is necessary to prevent cracking due to the emergence of a martensite structure in the area due to the high cooling rate [5].

From the explanation above, the formulation of the problem, which is the subject of this study, is how the influence of process variations preheating on SS400 and ST60 steel against micro tests using SMAW welding. This study aims to determine the differences in microstructure that occur in SS400 and ST 60 steel materials after processing preheating prior to SMAW welding.

2. Materials and Methods

The method in this research is collecting data from journals, reference books, modules, articles, and the internet. The objects studied in this study were SS400 and ST60 steel.

2.1 SS400 Steel

SS400 steel has a low carbon content making it easy to weld, and own tensile *strength* of 400-560 MPa.

Figure 1. SS400 Steel Plate

The composition of the material is very important to know as validation to determine the level of suitability of the type of material used in this study. SS400 / JIS G3101 / ASTM A36 starts with the letters SS, often confused with stainless steel. However, SS here means mild steel.

2.2 ST60 Steel

ST 60 steel is medium carbon steel with a carbon content of 0.3 - 0.7% and tensile strength of 60 kg/mm^2 or 600 N/mm^2.

Figure 2. ST60 Steel Plate [6]

Based on the material certificate received, this material contains main elements such as Manganese (Mn) of 0.67%, which can increase hardness and strength, and Silicon (Si) of 0.240%, which can improve overall performance, wear resistance, heat resistance and rust. This material also contains other elements such as Carbon (C) at 0.500%, Phosphorus (P) at 0.018%, Sulfur (S) at 0.010%, Nickel (Ni) at 0.01%, Chrome (Cr) at 0 04%, Molybdenum (Mo) of 0.008%, and Vanadium (V) of 0.003%.

Table 1. Material Composition [6]

	Element	Content (%)
S	Sulfur	0,010
C	Carbon	0,500
And	Silicon	0,240
Mn	Eat	0,67
P	Phosphorus	0,018
In	Nickel	0,01
Cr	Chromium	0,04
Mo	Molybdenum	0,008
IN	Vanadium	0,003

2.3 SMAW Welding Machine

The SMAW (Shielded Metal Arc Welding) is a metal joining technique that uses an electric heat source and encapsulated electrodes to connect strongly. This method is often used in shipbuilding and repair because of its affordability and ability to adjust the welding position, whether flat, horizontal, vertical, or overhead.

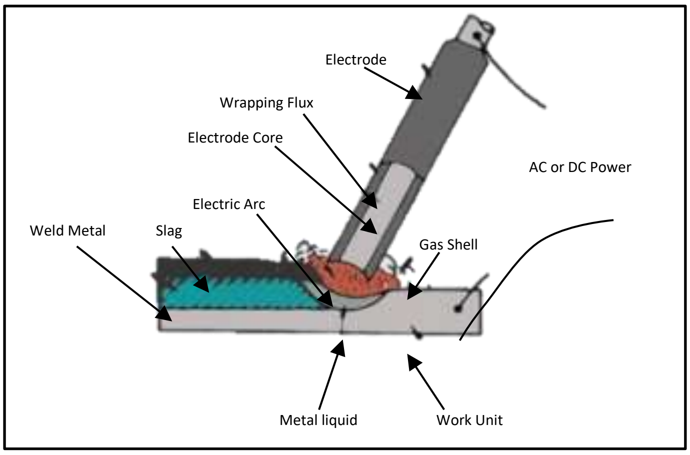

Figure 3. SMAW Welding [6]

The quality of the welded joint greatly determines the strength of the welded joint. Good welds produce quality joints and heat.

2.4 Preheating

Preheating is the process of preheating the base metal around the area to be welded before welding begins to reach and maintain a temperature preheat, which is desired. Tools that can be used for preheating include gas burners, oxy-gas fires, and electric blankets. Ensuring the welding area is heated evenly for good results is important. Uneven or excessive heating can cause problems such as large residual stresses, distortion, or unwanted metallurgical changes in the base metal, leading to increased cracking or decreased corrosion resistance.

2.5 Micrographic Test

Micrography is a technique used to study the microstructure of metals or alloys by taking pictures of the microstructure. In this process, metal or alloy samples are prepared by smoothing and polishing them until their surface is smooth and reflective. Then, the sample is etched with acid or other reagents to clarify the metal grain boundaries. After that, microstructure images of the sample can be taken using a microscope. By looking at the microstructure images, we can find the structure of the metal or alloy being studied, such as grain size, grain shape, and crystal orientation.

This information is very useful in determining the mechanical and physical properties of the metal or alloy.

2.6 The stages of research include:

1. After studying the literature, it is continued by welding and forming specimens using SS400 and ST60 materials.
2. Furthermore, data collection on specimens that have been tested using tools such as callipers and micro-test equipment.
3. After the process, the results and conclusions are drawn at the end of this research activity.

3. Results

Based on the results of the micro testing that has been carried out, this test is grouped into two types of variations, namely Group 1 SMAW welding results with variations preheat 140°C and 170°C on SS400 steel and Group 2 SMAW welding results with variations preheat 300°C and 400°C on ST60 steel.

3.1 Micrographic Test

3.1.1 Micrographic Test Results Effect of SMAW Welding Process Using Preheating 140°C Against Microstructure In SS400 Steel

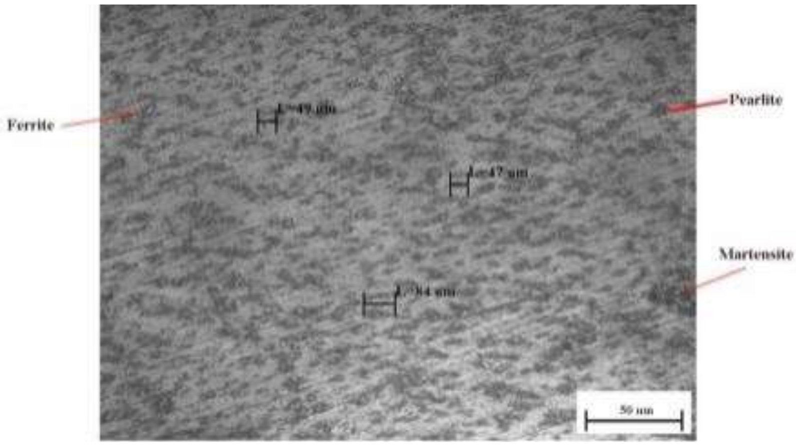

Figure 4. Microstructure test results preheating 140˚C on SS400 steel [7]

For specimen preheat at 140°C, SS400 steel has a fairly dense microstructure, hard properties, and contains a ferrite phase.

3.1.2 Effect of Using SMAW Welding Process Preheating 170°C Against Microstructure In SS400 Steel.

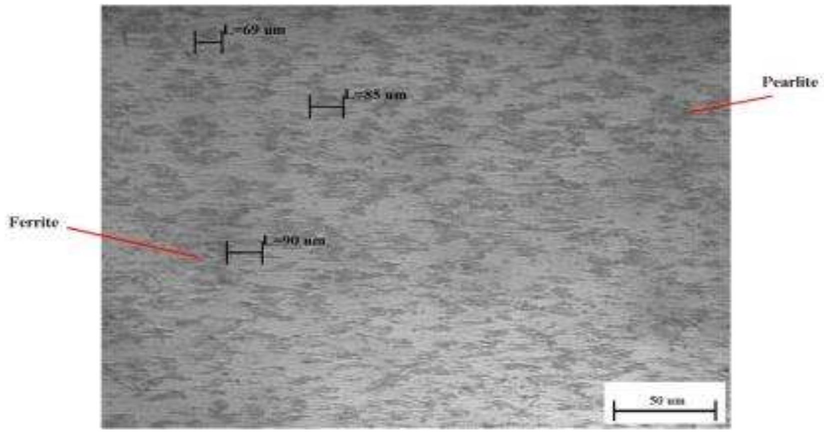

Figure 5. Microstructure test results preheat 170°C on SS400 steel [7]

From the micro test, specimen preheat at 170°C, SS400 steel has a denser microstructure, hardness, and a more dominant ferrite phase.

Micrographic test results, seen in both temperature variations, preheat which produces round grains of ferrite and pearlite at the weld, where ferrite at higher temperatures has more grains, is more spread out and is larger compared to ferrite at lower temperatures, which indicates a decreased hardness.

3.1.3 Effect of Using SMAW Welding Process Preheating 300°C Against The Microstructure Of ST60 Steel

Figure 6. Structure Micro Test results preheating 300˚C on ST60 steel [6]

The specimen preheat temperature of 300°C shows that it has a fairly dense microstructure, hard properties, and more ferrite phase.

3.1.4 Effect of Using SMAW Welding Process Preheating 400°C Against The Microstructure Of ST60 Steel.

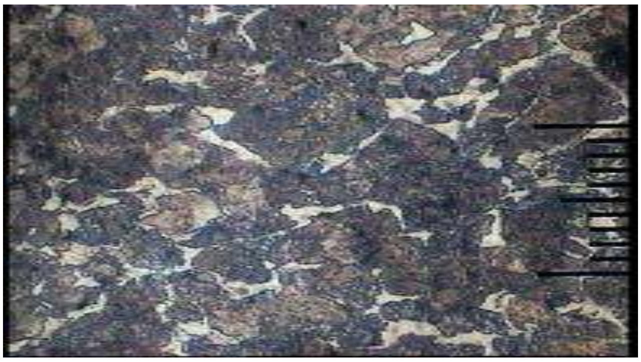

Figure 7. Structure-Micro Test results Preheating 400˚C on ST60 steel [6]

Preheat temperature of 400°C shows a softer structure and more ferrite phases.

Micrographic test results show that each variation preheats ferrite and pearlite phases. The ferrite phase has low strength but good ductility, while the pearlite phase has strong strength and is quite hard. The test results show that variations in preheat temperature of 300OC on SMAW welding on ST 60 steel has higher hardness properties when compared to preheat temperature and 400OC. This result can be seen from the better microstructure density. The denser the microstructure of a specimen, the harder the specimen. However, on variations in preheat temperature, 400OC has a larger structural form to give a better strain value and better and more ductile material properties.

4. Discussion

The results of the micro testing that has been done on SMAW welding with variations preheat on steel SS400 and 60 grouped into two types of variations, namely Group 1 SMAW welding results with variations preheat 140°C and 170°C on SS400 steel and Group 2 SMAW welding results with variations preheat 300°C and 400°C on ST60 steel.

From the micrographic test results, it can be seen that each variation preheat. There are ferrite and pearlite phases. The ferrite phase has low strength but good ductility, while the pearlite phase has strong strength and is quite hard. On SS400 steel, a specimen preheat temperature of 140°C has a fairly dense microstructure, hard properties, and ferrite phase. While the specimen preheat temperature of 170°C has a fairly dense microstructure, hard properties, and a more dominant ferrite phase. The test results show that in both temperature variations, preheat produces round grains of ferrite and pearlite on the weld, where ferrite at higher temperatures has more grains, is more spread out and is larger than ferrite at lower temperatures indicating a decreased hardness.

On ST60 steel, a specimen preheat temperature of 300°C shows a fairly dense microstructure, hard properties, and more ferrite phase. While the specimen preheat temperature of 400°C shows that it has a softer structure and has more ferrite phases. The test results show that variations in preheat temperature of 3000C on SMAW welding on ST60 steel has higher hardness properties when compared to preheat temperature of 4000C. This result can be seen from the better microstructure density. The denser the microstructure of a specimen, the harder the specimen. However, on variations, preheat temperature of 400oC has a larger structural shape, giving a better strain value and having more ductile and good material properties.

Overall, the test results show that preheat variations affect the specimen's microstructure, hardness, and ferrite phase. Preheat Higher temperatures tend to produce more ferrite phase but lower hardness.

5. Conclusions

Based on the results of the micrographic tests carried out, it can be concluded that the micro tests on SMAW welding with variations preheat on steel SS400 and ST60 show that variation preheat affect the microstructure, hardness, and ferrite phase of the specimen. Preheat Higher temperatures tend to produce more ferrite phase but lower hardness. On SS400 steel, preheat temperature of 170°C produces a more dominant ferrite phase compared to preheat temperature of 140°C. On ST60 steel, preheat temperature of 300°C produces higher hardness properties than preheat temperature of 400°C. However, preheat a temperature of 400°C gives a better strain value and has more ductile and good material properties.

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