



THE EFFECT OF VARIATIONS IN THE SHAPE OF THE SEAM ON MICROSTRUCTURE, HARDNESS AND TENSILE STRENGTH IN THE WELDING PROCESS OF STEEL SS400 WITH THE SMAW METHOD

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KEYWORDS

Shielded Metal Arc Welding (SMAW)
SS400 Steel
Groove Weld
Micro-Structure
Hardness
Tensile Strength

ABSTRACT

The purpose of this research is to investigate the influence of groove weld type on the welding joint to the physical and mechanical characteristic using the Shielded Metal Arc Welding (SMAW) method. The welding process causes the around metal has thermal cycles and then resulting metallurgical changes, deformations and thermal stresses. Because of these structural changes, the mechanical characteristic will change as well. This research used an experimental method that is researcher doing butt joint welding with X, V and $\frac{1}{2}$ V groove weld type by using low carbon steel SS400 with carbon content 0,1% then testing microstructure, hardness and tensile strength. Based on the results of the study, it can be concluded that the results of microstructure test showed improvement of the acicular structure of ferrite and pearlite after welding. In raw material, the grain boundary structure of ferrite is evenly distributed. Hardness values on welding results indicate a different level of violence. The specimen with V type has the highest hardness of 248,6 VHN, then the sample with $\frac{1}{2}$ V form is 233,7 VHN, and the sample with the X type is 228,6 VHN while the raw material has hardness value 200,58 VHN. The amount of tensile strength on the welding results indicates a difference. The specimen with the V type have the highest tensile strength level of 430,97 MPa and strain 18,11% then the $\frac{1}{2}$ V type is 419,93 MPa and strain 15,52% followed by the X type with the average of tensile strength 414,88 MPa and strain 14,92% and on raw material has a tensile strength value 401,94 MPa and strain 13,26%. This study shows that welding using variations of groove weld type changes the microstructure and affects the hardness and tensile strength of SS400 Steel.

INTRODUCTION

Metal connections with welding methods are increasingly being used, both in the construction of buildings and machinery, because of so many advantages. However, it must be admitted that the welded connection also has weaknesses, among others: the emergence of a voltage surge due to changes in microstructure in the area around the weld which causes a decrease in the strength of the material and due to residual stress, and the presence of cracks due to the welding process (Jamarsi, 1999).

Metal has a mechanical property that depends not only on the chemical composition of an alloy, but also depends on the microstructure. A composite with the same chemical composition can have a different microstructure, and its mechanical properties will be different, this depends on the hot-selling process received during the process.

The blunt connection is the most efficient type (Wiriyosumarto and Okumura, 1985). To produce welding results that have good quality, technicians should pay attention to many things related to welding among those that influence welding, namely weld seam. Because the factors that affect welding are welding procedures namely planning for conducting research which includes the method of making weld construction according to the plan and specifications by determining all the necessary things such as the selection of welding machines, appointment of welders, electrode selection, use of the type of seam (Wiriyosumarto, 2000).

According to Sonawan (2003), the selection of welded surfaces must also pay attention to plate thickness, type of plate, desired strength and welding position. A Single Welded V Surfaced can be used to receive high compressive force. It is more resistant to static load conditions, but this seam is not suitable for thick plates below 5mm because this seam is used on plates with a thickness of 5-20mm. So that permeation (penetration) can be achieved 100 percent (Handra, 2011). Double V (X) is preferred for plate thickness above 10mm. The use of fillers will be less when compared to the use of single V seams with the same depth. Distortion will be easier to control because welding is done on both sides (Handra, 2011). Single tapered ($\frac{1}{2}$ V) is used for large compressive loads. The single-layered tapered camp is recommended to be open and used on 6-20mm plate thickness (Nukman, 2009).

The purpose of this study was to determine the effect of variations in the shape of the seam on the microstructure, hardness and tensile strength of SS400 steel with the SMAW welding method.

RESEARCH METHODS

This research method uses the experimental approach. This research carried out in the laboratory with the conditions and equipment completed to obtain data to study the physical and mechanical characteristics of the results of SS400 steel plate welding using variations in the shape of the seam with the SMAW welding method. The filler rod used uses E7016.

Tests carried out include metallographic (microstructure) test, hardness test, and tensile strength test. The tools used in this study are hand grinding machines, calipers, Olympus Metallurgical Microscope machines, Micro Hardness Tester Vickers Machine, and Universal Testing Machine.

Specimens used in this study for testing microstructure and hardness amounted to 3 pieces for welding specimens and one part for samples without welds measuring 50 mm X 30 mm X 12 mm. Specimens for tensile strength testing were ten specimens (1 specimen without welding, 3 X specimens, 3 V specimens, and 3 $\frac{1}{2}$ V specimens) with measurements according to ASTM E8 standards.

The data analysis technique used in this study is an analysis with descriptive methods. Data obtained in this study were data on chemical composition, hardness, and microstructure and from observations then analyzed descriptively.

RESULTS AND DISCUSSION

SS400 steel is classified as low carbon steel because it only contains 0.1% carbon. Welding is carried out on three specimens with variations in the shape of the seam, $\frac{1}{2}$ X, V and $\frac{1}{2}$ V with the SMAW welding method. The purpose of this study was to determine the value of tensile strength, hardness value, and microstructure in each shape of the seam. Microstructure testing in this study aims to assess the microstructure of SS400 low carbon steel after SMAW welding. The microstructure of the material read through microphotographs with 100X and 200X magnification using Metallurgical Microscope with Inverted (Olympus PME)

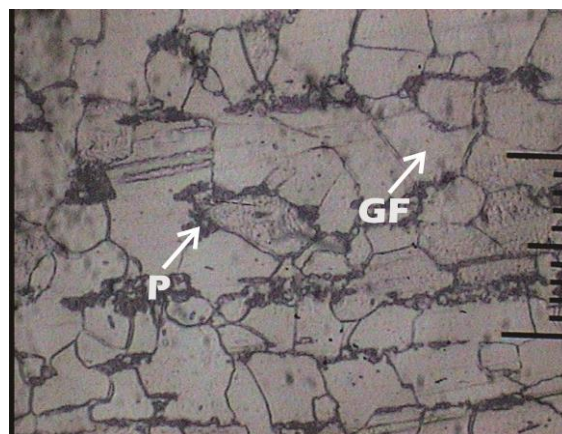


Figure 1. The Microstructure of Specimens Without Welds

Figure 1 shows the results of the microstructure of raw material test (without welding). In raw material ferrite granules, dominate or ferrite very evenly compared to perlite (P), which is not dominant. Ferrite formed in the raw material is a grain boundary ferrite (GF).

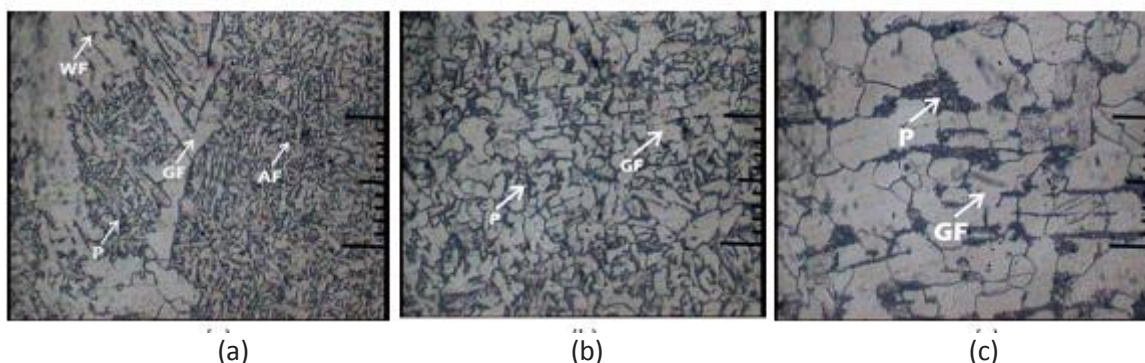


Figure 2. (a) The Microstructure of Weld X Joint, (B) The Microstructure of The HAZ Region of X Joint, (C) The Microstructure of The Parent Region of X Joint

Figure 2 show that the microstructure formed in this welding area is perlite (P), boundary ferrite grain (GF), widmanstatten ferrite (WF) and acicular ferrite (AF). Acicular ferrite (AF) has an amount very dominant compared than other areas. It is show good welding, because this structure is an interlocking structure that can inhibit crack propagation rate (Suharno, 2008).

In the HAZ region (figure 2a) and the parent area (figure 2b), the structure of perlite (P) and grain boundary ferrite (GF) appears. The structure of grain boundary ferrite (GF) is very dominant in the HAZ region, but in the parent area the number of perlites is more dominant and looks very clear compared to the HAZ. Grain boundary ferrite (GF) is formed because the cooling rate is low and the ferrite formation process takes place in carbon diffusion.

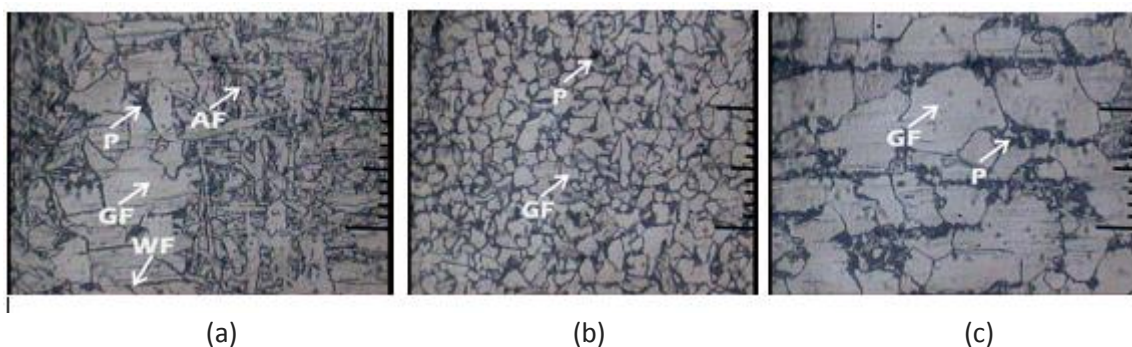


Figure 3. (a) The Microstructure of The Weld V Specimen Area, (B) Micro Structure of The HAZ Area of V-Specimens, (C) The Microstructure of The Parent Region of Specimen V

Figure 3a show microstructure formed in this welding area is perlite (P), boundary ferrite grain (GF), widmanstatten ferrite (WF) and acicular ferrite (AF). Acicular ferrite (AF) has an amount very dominant compared to the others in this welding area. This is because the cooling rate in this welding area is of moderate speed and is also affected by inclusion.

In the process of microstructure formation, especially acicular ferrite is strongly influenced by many factors, including inclusion. Inclusions are fine particles as a result of oxidation or reduction reactions during the welding process and are not soluble in liquid welding metals. While the formation of inclusions is influenced by several things including the composition of the parent metal, welding electrode, gas, air, or flux used (Suharno, 2008). In the HAZ region, Figure 3b of the structure seen perlite (P) and boundary grain ferrite (GF), acicular ferrite (AF) is not visible. Also, in the parent area, figure 3c is seen perlite (P) structure and grain boundary ferrite (GF), but the grain structure boundary ferrite (GF) is very dominant, this is caused by the relatively slower input heat and cooling time.

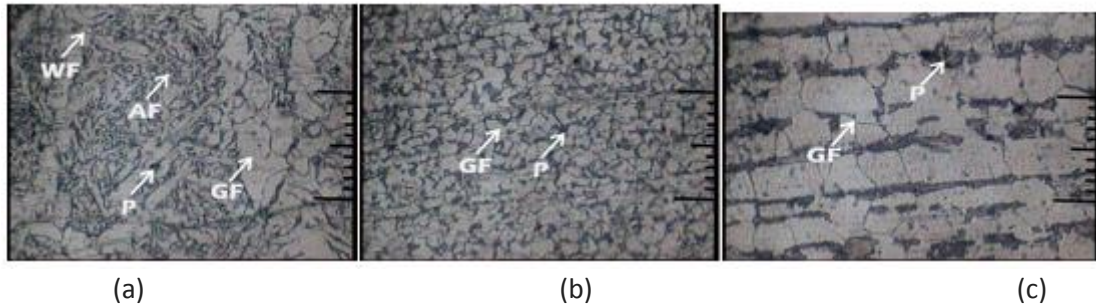


Figure 4. (a) The Microstructure of The 1/2 V Joint, (b) Microstructure HAZ Spesimen 1/2 V Joint Area (c) The Microstructure of The Parent Region of The 1/2 V

In figure 4a it can be seen that the microstructure formed in this welding area is perlite (P), grain boundary ferrite (GF), and acicular ferrite (AF). It sees that acicular ferrite has a very dominant amount compared to the others in the weld area. In the HAZ region (figure 4b), the structures are seen in perlite (P) and increasing boundary ferrite (GF), and acicular ferrite (AF) are not visible. Moreover, in the parent region (figure 4c), the perlite (P) and grain structures are seen boundary ferrite (GF), the amount of grain boundary ferrite (GF) structure is very dominant, this is caused by the relatively slower input heat and cooling time.

From each shape of the welding seam has different microstructure photos, because the weld seam is different, so the input or spread of heat produced in each variation of the shape of the seam is also different. The results of photos of SS400 steel microstructure with variations in the shape of seam X (double V seam), V (sole) and 1/2 V (Half V camp) show separate ferrite regions. It is following Vlack's theory (1985: 386) that steel with a microstructure containing separate ferrite regions is called hypo eutectoid steel (low carbon steel).

Hardness testing is done on specimens without welding and also the results of welding which include the weld area, HAZ (Heat Affection Zone) and on the base material. The diagonal results of the indentor diamond cone are measured with the aid of a magnifying lens (Linen Tester Lope). Based on the results of observations from Vickers hardness testing, the highest hardness value was found in Specimens with V strain having an average value of hardness of 248.6 VHN, then specimens with 1/2 V hump shape which was 233.7 VHN and samples with X-shaped form 228,6 VHN while in raw material has a hardness value of 200.58 VHN.

The weld area in the three specimens tends to be harder when compared to the HAZ and parent. If observed in the microstructure, the weld area tends to have a broad acicular ferrite microstructure, but in the HAZ region and the acicular ferrite parent is not visible, and grain boundary ferrite dominates the area. The smaller value of violence from the center of the weld is also following the Easterling statement (1983) that the value of violence tends to decrease from the melting limit to the base metal depending on grain size (microstructure). It is because the farther away from the center of the weld, the effect of heat will decrease. Tenacity and toughness of weld metal will also increase if the microstructure formed is in the form of acicular ferrite, on the other hand, a decrease in ductility and toughness occurs when the microstructure weld metal is formed in the form of grain boundary ferrite (Suharno, 2008).

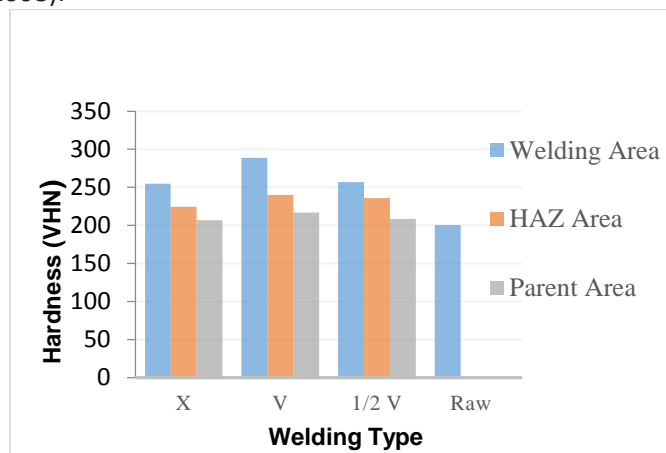


Figure 5. Hardness Vickers Average Analysis

Figure 5 shows us the results of the tensile test data obtained in the form of stress and strain values. From figure 5 the average value of the tensile strength of SS400 steel for X shape (double V seam) is 414.88 MPa, while

the average value of the strain is 14.92%. The average tensile strength of SS400 steel for V shape (single V seam) is 430.97 MPa, while for the average strain value is 18.11%. From table 4.8. The average tensile strength of SS400 for ½ V (half V) is 419.93 MPa, while the average value of strain is 15.52% and in raw material, the tensile strength is 401.94 MPa with strain 13.26%.

The results of tensile strength testing there are differences in stress and strain values between each variation of seam shape. The highest stress and strain values were obtained from variations of V shape with an average tensile strength of 430.97 MPa and strain average value of 18.11%. The lowest tensile and strain strength values were obtained in variations of X (V double) seam shape with an average tensile strength 414.88 MPa, while average strain values is 14.92%.

Figure 6, the results of this tensile test are directly proportional to the hardness test. Hard material affects the amount of tensile strength. It is in accordance with the relationship of violence with tensile strength, where it is known that violence and material strength have a straight line relationship (Zuliardie, 2004). This is due to the influence of experienced welder and current that is used appropriately (Santoso, 2006). In the research carried out (Santoso, 2006) the use of current that has the right effect on the results of fracture tensile strength. This was proven in this study that the fault area did not occur in the HAZ region or the weld area. In addition, tensile strength is also influenced by the type of fault. In this study the fracture that occurred was a resilient fracture, this was influenced by carbon (C) in SS 400 steel and electrodes.

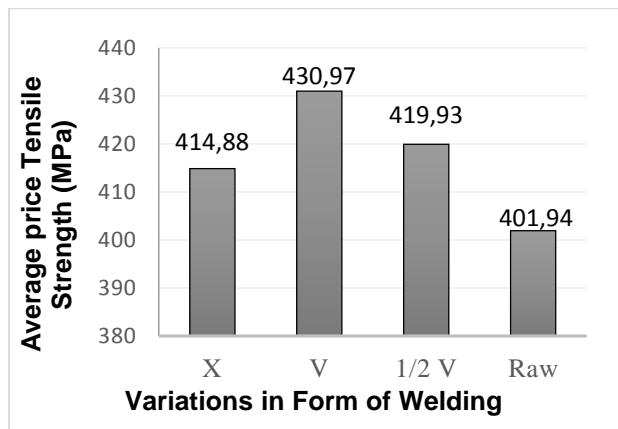


Figure 6. Graph of Average Value of Tensile Strength Test

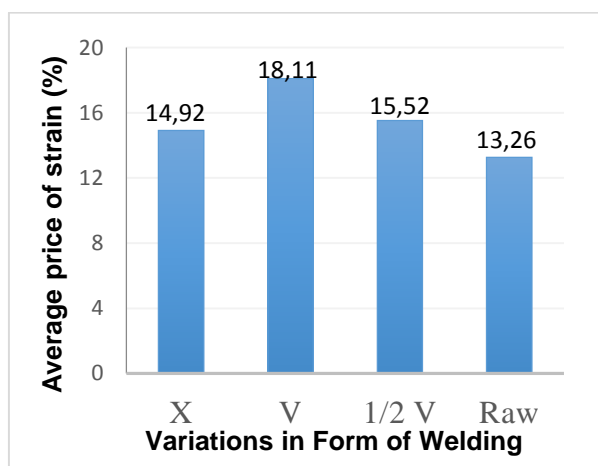


Figure 7. Graph of Average Value of Tensile Strain Test

The voltage is also directly proportional to the strain, high voltage values affect the high voltage (like figure 6 and figure 7). For almost all metals, in the very early stages of the tensile test, the relationship between the load or force applied is directly proportional to the change in length of the material. It is called a linear region or linear zone. In this area, the long-added curve vs. load follows Hooke's rules.

CONCLUSION

Based on the results of the study, conclusions can be drawn that, there are differences in microstructure in each variation in the shape of the seam. In the raw material structure of grain boundary ferrite looks evenly distributed, in weld area X, V and $\frac{1}{2}$ V. The acicular ferrite structure looks smoothly followed by widmanstatten ferrite, grain boundary ferrite, and pearlite. In weld boundary area with HAZ acicular ferrite structure decreases and grain boundary ferrite is slightly increased and in the HAZ area, the limit of HAZ with the parent, the parent of acicular ferrite was not visible, the boundary ferrite grain was very dominant, and there was little pearlite. There is a difference in the value of hardness in each variation of the seam. Specimens with V strain have an average amount of hardness of 248.6 VHN, then samples with $\frac{1}{2}$ V shape are 233.7 VHN and specimens with X-shaped form are 228.6 VHN while those in raw material have a hardness value of 200.58 VHN. There are differences in stress and strain values in each variation of seam shape. Specimens with V shape have the highest tensile strength, namely 430.97 MPa and strain 18.11%, then the $\frac{1}{2}$ V shape is 419.93 MPa, and the strain is 15.52% followed by X shape with average tensile strength 414, 88 MPa and strain 14.92% and in raw material has a tensile strength value of 401.94 MPa and strain 13.26%.

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