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Microstructure and Tensile Properties of SS400 Carbon Steel and SUS430 Stainless Steel Butt Joint by Gas Metal Arc Welding

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Abstract

The application of SS400 carbon steel and AISI430 ferritic stainless steel joint has been increased in industries because of the advantage of both metals was able to increase the service lifetime of the important structures. Therefore, a fusion welding process that could produce a sound weld and good joint properties should be optimized. This research is aimed to weld a butt joint of SS400 carbon steel and AISI430 ferritic stainless steel using Gas Metal Arc Welding (GMAW) welding process and to study the effects of welding parameters on joint properties. The experimental results were concluded as follows. The optimized welding parameter that produced the tensile strength of 448 MPa was the welding current of 110A, the welding speed of 400 mm/min and the mixed gas of 80%Ar + 20%CO_2. Increase of the welding current affected to increase and decrease the tensile strength of the joint, respectively. Lower welding current produced the incomplete bonding of the metals and indicated the low tensile strength. Microstructure investigation of the welded joint showed a columnar grain in the weld metal and a coarse grain in the heat affected zone (HAZ). The unknown hard precipitated phases were also found at the grain boundaries of the weld metal and HAZ. The hardness profile did not show the difference of the hardness on the joint that was welded by various welding currents but the hardness of the weld metal was higher than that of the other location.

Keywords*: carbon steel, stainless steel, tensile strength, microstructure,*

1. INTRODUCTION

Nowadays, the manufacturing process has introduced a dissimilar metals joint for producing the flexible structure that could withstand various forces that affect the structure [1]. An application of the dissimilar metals joint requires a joining process that could produce a strong joint than a base metal. The joining

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processes could be a mechanical joining, an adhesive method, a welding process, *etc* [2]. The welding process is a joining process that is widely applied to weld the dissimilar metals joint in industries and produce a joint strength that is higher than that of base metals. However, the welding of the dissimilar metals joint is difficult because the metals have a difference in a mechanical properties, physical properties and a chemical properties [3]. In Thai agriculture industry such as a sugar production industry has introduced the dissimilar carbon steel/ stainless steel joint in a machine structure for decreasing the processing cost and increasing a flexible design in engineering. This industry has applied the carbon steel part to replace the stainless steel part at locations that do not require the corrosion resistance property such as the supporting column of the sugar transferring unit, *etc*.

The fusion welding that was widely applied in the sugar industry could be a shielded metal arc welding (SMAW) process and a gas metal arc welding (GMAW) process. Recently, these welding processes has been applied to weld the dissimilar metals and showed the experimental results that could be applied effectively in the industries. These consisted of the welding of martensitic stainless steel to austenitic stainless steel [4], the welding of duplex stainless steel to carbon steel [5], the welding of austenitic stainless steel to inconel [6], the welding of austenitic stainless steel to titanium [7]. These studies have been done for optimization of the electrode for welding the dissimilar metals joint consisting of the stainless steel.

However, most of the research works that were reported, applied the SMAW process to weld the dissimilar metals joint. The optimization of the GMAW process parameters for welding the butt joint of dissimilar carbon steel/ stainless steel has still not been reported and prepared for a sugar industry. Therefore, the objective of this work was to weld the butt joint between JIS SS400 and JIS SUS430 and study the effects of welding current on the joint properties. The butt joint that was welded by the specified welding parameter, was investigated for the relation between tensile strength, the hardness and microstructure of the joint.

2. EXPERIMENTAL PROCEDURE

Figure 1. a set up of the butt joint.

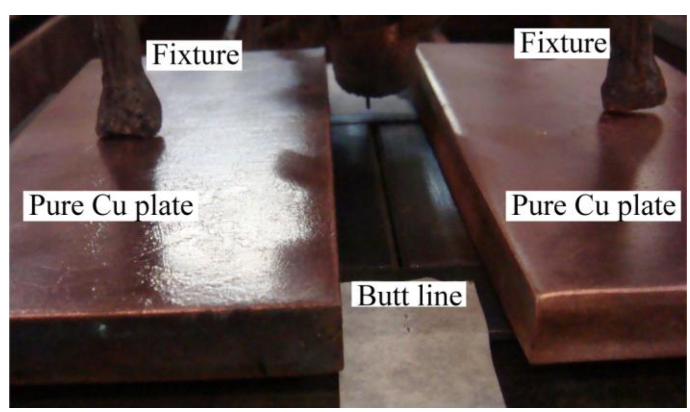

Figure 2. the clamping of the butt joint.

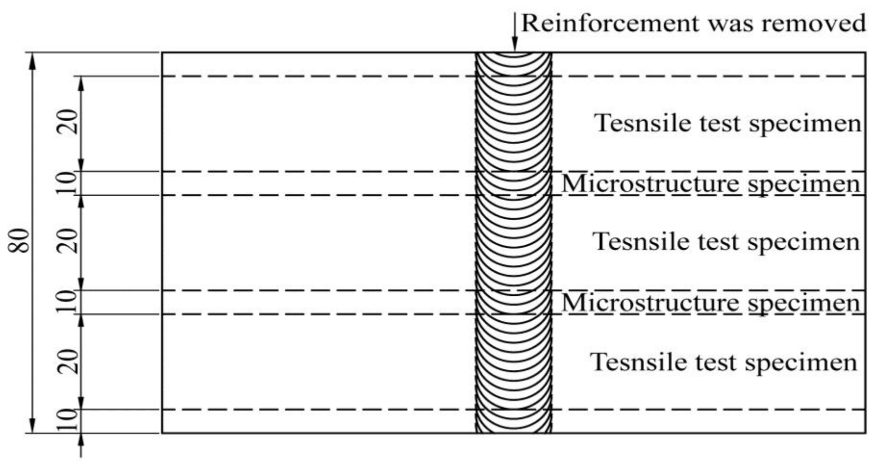

Figure 3. Cutting plan of the butt joint (Unit: mm).

Materials used in this experiment were JIS SS400 carbon steel (Fe-0.08%C, 0.20Si, 0.39%P, 0.01%S, 0.03%Cr, 0.01%Mo, 0.05%Ni, in %wt) and JIS SUS430 stainless steel (Fe-0.119%C, 0.36Si, 0.23%Mn, 0.03%P, 17.57%Cr, 0.12%Ni, in %wt). The materials were prepared into a rectangular shape with a dimension of 65 mm wide, 80 mm long and 3 mm thick. The butt surfaces of the material plates were mechanically prepared to be a V-groove followed AWS D1.1 / D1.1 M: 2600. The SS400 steel plates (a dimension of 200 mm wide, 50 mm long and 3 mm thick) were 4 points tag welded using a gas metal arc welding at the ends of the joint for setting up the butt joint that had a root opening of 1 mm as shown in figure 1. The butt joint was firmly clamped using the fixture via copper plates on the steel table as shown in figure 2.

A welding process applied to weld the butt joint in figure 1 was the gas metal arc welding (GMAW) process. Welding process parameters were a welding current of 90-120 A, a welding speed of 400 mm/min, a shielded gas, which was a mixed gas of 80%Ar+20%CO_2, a gas flow rate of 12 L/min, a backing shielded gas flow rate of 5 L/min. A solid wire electrode with a wire diameter of 1.2 mm that was recommended for the SUS430 stainless steel followed AWS A5.9: ER430 and chosen for welding the joint.

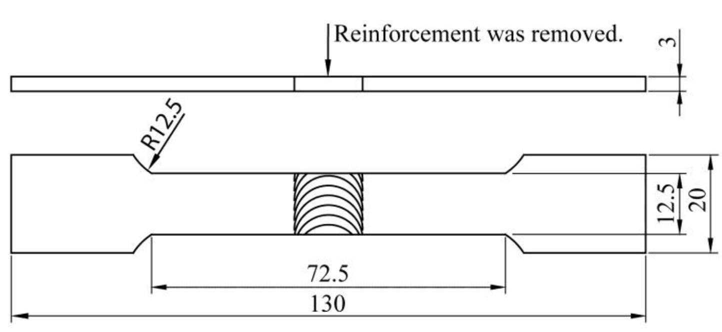

Figure 4. Confrigulation of the tensile strength test specimen (Unit: mm).

After the butt joint was completely welded, the butt joint was mechanically cut according to a cutting plan as shown in figure 3. The tensile strength test specimen that had a welding line at a center of the specimen had a configuration as shown in figure 4 was mechanically prepared. A cross section of the joint that was perpendicular to the welding line was mechanically polished and then investigated by a light optical microscope. The hardness test was conducted at the half of the plate thickness, across the weld metal, and had a distance between 2 test points of 1 mm as shown in figure 5.

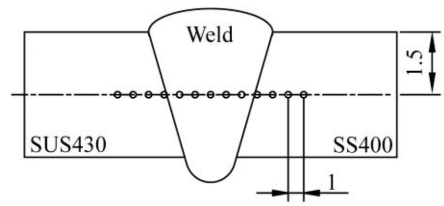

Figure 5. Location of the hardness measurement (Unit: mm).

3. RESULTS AND DISCUSSION

Figure 6 shows the tensile strength test results of the joint specimens that were welded by various welding currents and various welding speeds. The tensile strength of the joint increased when the welding current was increased but when the welding current was higher such as 120 A, the tensile strength slightly decreased. The increase of welding speed decreased the tensile strength of the joint. For the welding speed of 400 mm/min, the failure location of the tensile strength test specimen was occurring at about 10-20 mm from the center line of the butt joint in the SS400 base metal as shown in figure 7. The failure location of tensile strength test specimen changed on the weld metal when the low welding current of 90 A was applied to weld the butt joint at the welding speed of 350-500 mm/min as shown in figure 7.

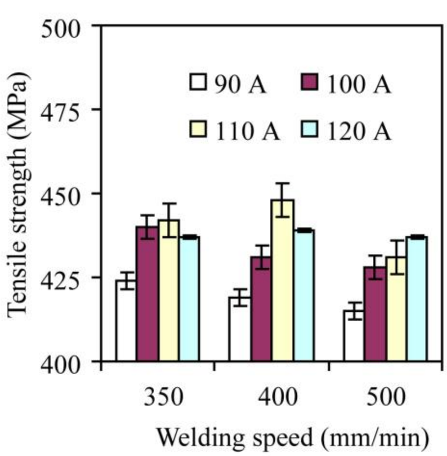

Figure 6. Tensile strength test results.

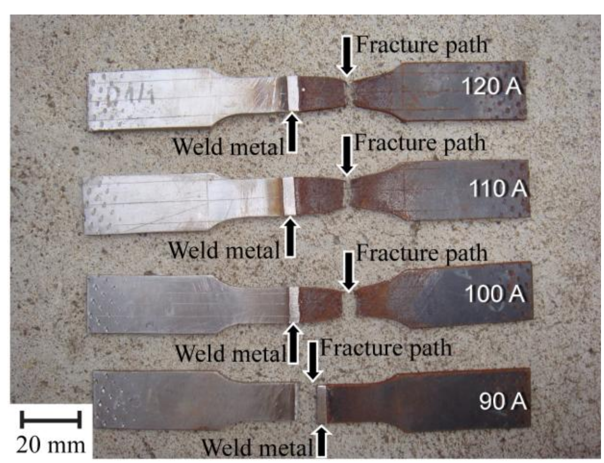

Figure 7. Failure location of the tensile strength test specimens that welded by 400 mm/min.

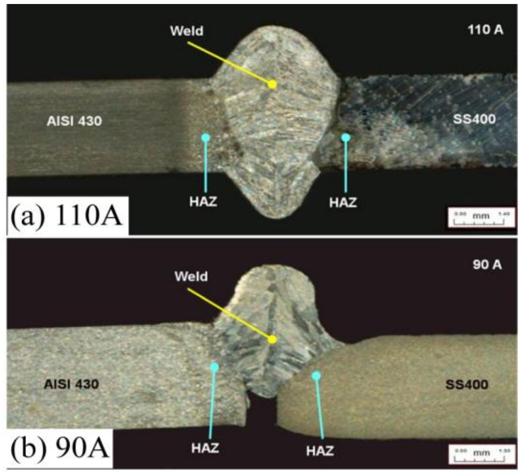

Figure 8. Macrostructure of a joint penetration.

The variation of the failure location of the tensile strength test specimen was because of the completion of the weld metal of the joint as shown in figure 8. Figure 8 shows macrostructures of the cross-section of the butt joints that were perpendicular to the welding line and welded by various welding currents. Various welding currents produced the difference in a weld width, a weld height, a penetration and a completion of the weld metal. When the high welding current of 110 A was applied to weld the butt joint, it was found that the weld metal was sound, the completed combination of the metals in the butt joint was visually observed as shown in figure 8 (a). The boundary of the welding area such as the center of the weld metal, the weld metal, the heat affected zone (HAZ) and the base metals were clearly identified. The comparison of the macrostructure of the 110 A welding current specimen and the low welding current of 90 A, the latter showed the incomplete combination of the metals in the butt joint and the penetration of the weld was about 0.5 times of the plate thickness as shown in figure 8 (b). This incomplete weld metal was the cause to locate the failure location at the weld metal of the tensile strength test specimen as shown in figure 7.

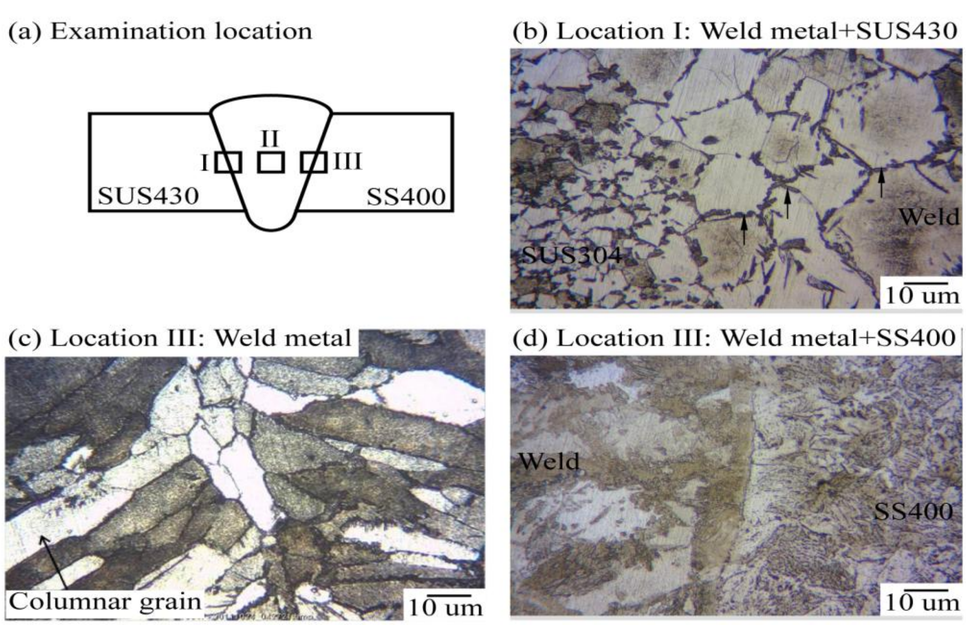

Figure 9. Microstructure of the weld metal produced by a welding current of 110 A.

Figure 9 shows microstructures of the butt joint that indicated the maximum tensile strength in this study and was welded by the welding current of 110A and 400 mm/min. The microstructures of the location I to III in figure 9 (a) were investigated using a light optical microscope. Figure 9 (b) shows the microstructure at the boundary of the weld metal and HAZ of SUS430 side and it was found that the grain size of the weld metal was larger than that of the HAZ grain size of SUS430. The formation of some small and fine precipitate phase was observed at the grain boundary of the weld metal and HAZ grain boundary of the SUS430 side as shown by the arrows in figure 9 (b). In this study, this precipitate phase was not analyzed but seemed to be the chromium carbide that always formed when the stainless steel was fusion welded. However, for clear understanding of the formation, the precipitate phase should be studied and clarified in near future.

Figure 9 (c) shows the microstructure at the center of the weld metal and the formation of the comlumnar grain that had a direction from the centre of weld metal to the base of SUS430 stainless steel. This orientation of the columnar grain seemed to be parallel to the heat transfer during the weld metal and was cooled at the room temperature. The small precipitate phase that was found at the boundary of the grain in the weld metal and HAZ of SUS430 side as shown in figure 9 (b) could not be observed in this location.

Microstructure of the boundary between the weld metal and the HAZ of SS400 side showed the finer columnar grain that occurred during the weld metal solidification is shown in figure 9 (d). No precipitate phase as found in figure 9 (b) could be observed in this boundary location. The microstructure investigation also showed that the grain size and shape of this location was a columnar grain and finer than that of the other location.

Figure 10 shows the cross section hardness profile of the butt joints that were welded by the welding current of 90-120 A and had the measurement as shown in figure 5. The hardness of the cross section of the butt joint decreased when the welding current was decreased. When compared, the hardness of the cross section to the base metals and the HAZ, it was found that the hardness of the weld metal was highest about 321HV. This was because of the formation of the precipitate phase that occurred at the grain boundary of the weld metal and HAZ, as shown in figure 9 (b). However, this hardness seemed to be not affecting the failure location of the tensile strength test specimen because the failure was located at the base SS400 carbon steel.

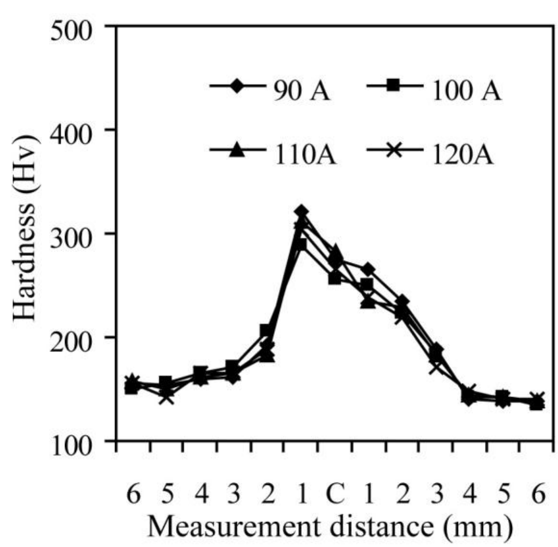

Figure 10. Hardness measurement.

4. CONCLUSION

This research work applied GMAW for welding the butt joint of SS400 carbon steel and SUS430 stainless steel and studying the effects of welding current on the joint properties. The summarized results are as follows.

4.1 The optimized welding parameter that produced the tensile strength of 448 MPa was the welding current of 110A, the welding speed of 400 mm/min and the mixed gas of 80%Ar + 20%CO_2.

4.2 Increase of the welding current affected the increase and decrease in the tensile strength of the joint, respectively. Lower welding current produced the incomplete bonding of the metals and resulted in lower tensile strength.

4.3 Microstructure investigation of the welded joint showed a columnar grain in the weld metal and a coarse grain in the heat affected zone (HAZ). The unknown hard precipitated phases were also found at the grain boundaries of the weld metal and HAZ.

4.4 The hardness profile did not show any difference in the hardness on the joint that was welded by various welding currents, but the hardness of the weld metal was higher than that on the other location.

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