Welding current effect of welded joints of base metal st37 on characteristics: corrosion rate and hardness

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Abstract. This study aims to determine the effect of welding current on corrosion rate and hardness on weld metal, Heat Affected Zone (HAZ) and base metal of steel grade st37. Welding is the process of metal attachment by dilution through heating. Due to the heat of the metal around the weld will undergo thermal cycles that cause metallurgical changes in microstructure, which will affect corrosion rate and the mechanical properties such as hardness. Weld joints are one of the critical parts of a structure. The weld joints that get excessive friction will be worn fast and corrosion rate higher than the base metal. The steel grade st37 strips are treated with welding current variations of 75, 85, and 95 Amperes. The method used for corrosion rate testing is ASTM G31-72 standard where this test is based on weight loss test and corrosion solution used NaCl solution with 3% concentration. The results showed that the highest average corrosion rate of 0.10516 mm/py occurred in the strip welded to the current of 95 Ampere, followed by 85 Ampere at 0.06772 mm/py, and the current of 75 Ampere was 0.06152 mm/py. Testing of material hardness at current 75, 85, and 95 Amperes shows that the highest hardness value occurs in weld metal area with 75 Ampere with average hardness at 74.00 HRC. Current selection during welding process has shown a significant effect on corrosion rate and hardness on the welded joint (weld metal).

1. Introduction

Steel grade st37 has been used extensively and acceptable for construction or any metal product due to viability and low cost, in many countries. A welding process is a very common manufacturing stage to utilize the steel into a functional and useful product with an additional coating. During the operation, some st37 base product gets a lot of friction as well as corrosion. Weld metal area is the most critical part to get degradation as wear and weight reduction become dominant as failure causes.

Welding is a process of grafting metal by means of disbursement through warming. Due to heat, the metal around welds will experience cycle thermal that cause change of structure micro. The change of structure micro will affect mechanical properties of like strength and resistance to corrosion from the welded part [1]. In addition, corrosion arises due to the oxidation reaction between metal and oxygen Welding Shielded Metal Arc Welding (SMAW) is a process of grafting metal by the use the source of heat electricity and metal filler of wrapped electrodes. The source of heat this is what used to melt the end of electrodes with a disbursement fill by a metal liquid derived from electrodes and base metal. So crater liquid and frozen and it produces metal welds and slag [2].

Steel grade st37 is a mixed metal consisting of iron and carbon that is prone to corrosion. In a compound of iron and carbon, iron is more dominant than carbon. Any carbon content ranges from
0.2-2.1% of weight steel. The st37 is steel power maximum pull at 37 per kilogram/mm. Chemical composition steel st37 is: C 0.12%, Si 0.10%, Mn 0.50%, P 0.04%, Al 0.02% and Cu 0.10%. Corrosion is damaged material or declines in the quality of because the impact of the reaction of the above chemicals with the environment. The process of corrosion unavoidable by a material, it is just the rate of growth can be slowed [3]. The rate of corrosion is a process for decomposition that occurs in the material. The rate of corrosion is the parameter that used to measure resistance to corrosion in the material [4].

Gist of importance of the subject mainly related to a higher corrosion and wear rates often occur in welded joints compared to the st37 base metal. Thus, welded joints require special attention, taking into account the selection of welding process parameters. One of the welding parameters is current that is generally selected within a certain range of values. The chosen welding current is chosen generally does not consider the corrosion rate and wear rate during product usage. Salient previous research works on the welded joint with the st37 base material were more focused on tensile strength and other mechanical properties [5, 6]. Some base metal other than st37, also get attention in relation to corrosion rates and hardness [7-9].

The state of the art of this study is basically on the mild steel st37 as a base metal. The kind of metal has utilized extensively in many construction works due to low-cost mild steel. Higher corrosion rate and less hardness problem led to a frequent replacement that increases maintenance cost in any project. So, a method to lower corrosion rate and to increase the hardness of welded joint will save overall cost material in a manufacturing industry, especially which involve welding process. However, this base metal has earned less attention due to low-end industry utilization in a most developed country.

A General objective of this study is: to find out whether the parameter a current of welding would affect differences in the rate corrosion and hardness on a weld metal of base metal st37 and to investigate the differences of hardness on an area of weld joint, HAZ, base metal. Two specific objectives were formulated; firstly to create samples of base metal st37 and welding by a certified welder to keep the entire standard were implemented during the welding process and to introduce a standardized corrosion rate testing.

2. Material and Welding Specification
The investigation as follows: welding was done in the laboratory welding technology and fabrication of metals under certificated welding engineer supervision, testing corrosion conducted to follow ASTM standard and testing hardness using the Rockwell standard.

Samples were prepared using a set of a tool as well as procedures. Tools were needed to do this research as follows: a SMAW weld machine, grinding hand, a measuring instrument, automatic cutting torch, occupational safety equipment of welding, hacksaw machine, the balance digital, a hammer, and wire brush. The base material used is a strip of steel st37 (Figure 1).

Samples were prepared in dimensions: length 300 mm, 20 mm wide and thick 8 mm. A Single groove is 70° V, so it is 35° bevel for every piece. Preserving root face is 2-3 mm use grinding. The process of welding conducted by using SMAW with polarity DCEP, and electrodes were used E7018 with diameter 3.2 mm. Next, welding was carried out for the three test objects, with variations of currents of 75, 85, and 95 Ampere. Ampere meters are arranged according to the variation of the welding current to be used. Turn on the engines of welder, and then electrodes clipped to the holder and a negative polarity of welder machine to clip to at the table of the works. Set up the root gap between 2 strips that will weld with sized 3 mm (figure 2). Welding process was started from the root pass welding, fill pass, and cover pass.
To make corrosion test sample, after the welding process is completed, the next step is cutting the st37 steel strip that has been welded with dimensions of 50 mm length, 25 mm wide, and 8 mm thick using a hacksaw machine. Preparation of the corrosion test sample is shown in Figure 3 and 4.

3. Corrosion Rate Testing and Hardness Test
Corrosion Rate Testing is done by the Immersion Test method or immersion into a corrosive solution, namely NaCl solution with a concentration of 3%. Testing is carried out for seven days (168 hours) (figure 5). Calculation of Corrosion Rate using the immersion test method is based on weight losses using the ASTM G31-72 (Standard Practice for Laboratory Immersion Corrosion Testing of Metal standard). After immersion, the next step is to clean the corrosion test sample using water to remove impurities attached to the surface of the test sample and weigh. The rate of corrosion can be calculated in uses the method loses a bit of their weight or Weight Gain Loss (WGL)\[10\]. In the method of measurement WGL, the size of the corrosion expressed as the magnitude of the lost weight metal coupons in the unity the surface area of unity time that formulated mathematically in Equation 1:

$$CR = \frac{W \times K}{DAT}$$

where: $CR$ = the rate corrosion (mmpy), $W$ = weight lost during experiments (grams), $K$ = constant factor $(8.76 \times 10^4)$, $D$ = the density of material $(7.86 \text{ gr/cm}^3)$, $A$ = the surface area $(\text{cm}^2)$, and $T$ = time (hours).

Sample weight of welding results which have been cut with reference to the ASTM G 31-72 standard using a digital balance with an accuracy rate of 0.01 gram (Figure 6). The final weight to determine the weight difference lost in the test sample.
In Hardness test, Samples that have been immersed with a concentration of 3% NaCl then carried out a hardness test using the Rockwell C (HRC) method to determine the hardness values in the weld metal, base metal and HAZ region.

4. Results and Discussion

Experiment result using a systematic and standardized testing has shown significant effect of welding current to the corrosion rate and hardness at the weld metal.

Corrosion rate shown a gradual increase along with welding current increased. The average corrosion rate value for welding samples with 75 Ampere is 0.06152 mmpy. The average corrosion rate value for welding samples with 85 Ampere is 0.06772 mmpy; it indicates an increase in corrosion rate of 0.00622 mmpy from welding samples with a current of 75 Ampere. The average corrosion rate for welding samples with 95 Ampere is 0.10516 mmpy; this indicates an increase in corrosion rate of 0.03744 mmpy from welding samples with 85 Ampere current and an increase in corrosion rate of 0.04364 mmpy from welding samples, with a current of 75 Ampere (figure 7).

The hardness test result indicate the welding current affect the hardness significantly. The hardness value of Rockwell C (HRC) for welding currents of 75 Ampere, 85 Ampere, and 95 Ampere. At 75 Ampere welding current, the average hardness value in the weld metal test area is 74.00 HRC. At the welding current 85 Ampere the average hardness value in the weld metal testing area is 72.40 HRC, this indicates a decrease in hardness of 1.6 HRC from weld metal welding current 75 Ampere. Furthermore, in the welding current 95 Ampere the average hardness value in the weld metal testing area is 65.70 HRC, this indicates a decrease in hardness value of 6.7 HRC from weld metal 85 ampere welding current and a back down of 8.3 HRC from weld metal welding current 75 Ampere (figure 8).
At 75 Amperes welding current, the average hardness value in the base metal test area is 72.00 HRC. At the welding current 85 Amperes, the average hardness value in the base metal test area is 68.00 HRC; this indicates a decrease in hardness of 4 HRC from the base metal welding current of 75 Ampere. Furthermore, in the welding current 95 Amperes, the average hardness value in the base metal testing area is 66.85 HRC, this indicates a decrease in hardness value of 1.15 HRC from the base metal welding current 85 Ampere and a decrease of 5.15 HRC from the base metal welding current 75 Ampere. At 75 Ampere welding current, the average hardness value in the HAZ test area is 70.50 HRC. At the welding current 85 Ampere, the average hardness value in the HAZ test area is 69.65 HRC, this indicates a decrease in hardness of 0.85 HRC from the HAZ welding current of 75 Ampere. Furthermore, in the welding current 95 Ampere, the average hardness value in the HAZ test area is 66.75 HRC, this indicates a decrease in hardness value of 2.9 HRC from the HAZ welding current of 85 Amperes and a decrease of 3.75 HRC from the HAZ welding current of 75 Ampere.

There is averagely a consistent drop of the hardness from weld metal, HAZ and base material area for every single welding current testing. This might be caused by structure micro change due to the heat treatment effect of maximum temperature during welding by a selected welding current. As the weld metal get the highest temperature, the cooling gradient over time is fastest in the area. Welding current at 95 amperes showed the same trend as the 85 amperes. There is a significant drop of hardness value between sample at the weld metal area between 95 amperes and 85 amperes in comparison at the HAZ and base metal. This might be caused by a lesser current at the 85 amperes could not achieve the material phase change as same as at the 95 amperes. A gradual increase of corrosion rate among different welding current from 75, 85 to 95 amperes might introduce a significant effect on cooling time gradient of microstructure changing. In Hardness and corrosion rate testing on the sample has shown a noticeable effect of welding current during the welding process of base material st37.

5. Conclusion

From the study of tests that have been carried out on test samples using different variations of welding currents: The lowest corrosion rate occurs in the welding process using a 75 Ampere current, the average corrosion rate is 0.06152 mmpy. The lowest hardness occurred in the welded sample using 95 Ampere current and the average hardness value in the weld metal area was 65.70 HRC, base metal was 66.85 HRC, and HAZ was 66.75 HRC. The highest hardness occurred in the welded sample using 75 Ampere, the average hardness value in the weld metal area was 74.00 HRC, the base metal was 72.00 HRC, and the HAZ was 70.50 HRC. The Corrosion rate is inversely proportional to the value of hardness; the higher the corrosion rate in a material, the hardness value in the weld metal, base metal and HAZ regions also decreases. The type of corrosion that occurs in corrosion test samples is a type of uniform corrosion.

For the real application, a manufacturing industry that uses the welding process in making products with st37 base metal, requires information on the effect of the welding current on the rate of corrosion and hardness in the welded joints part of the a product. This information is mainly needed for the products that will be used in a corrosive environment, such as being operated on the coast and offshore areas, such as ships, oil platforms or other steel construction. The rest, more specific use, transportation equipment and waste processing implicate a very high corrosion rate. For this garbage transportation equipment, the wear rate caused by friction during transportation is also influenced by the hardness of the welding joints. Therefore, the proper selection of welding current will maintain the weld joint with the same or less corrosion rate and wear than the base metal.

For a suggestion, the further testing is done by using the three electrode cell method to determine the rate of corrosion and hardness in the weld joint and appropriate welding current in a predetermined range to prevent high corrosion rate.
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