The effect of the welding methods on the corrosion rate and impact strength of AA5083 material

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Abstract. The 5xx series aluminum alloy is currently widely used in marine construction applications for the fabrication of chemical tankers, offshore and others because it has good corrosion resistance. This study aims to determine the effect of the welding method on the corrosion rate and impact strength of 5083 aluminum. Four specimens of AA 5083 in this observation were preheated until reaching temperature 50°C, 150°C, 250°C and 300°C as the selected variations. Then, welding result were tested by Charpy impact test with different load for determining amount of energy absorbed during the fracture process. After comparing the the impact toughness, the best specimen was conducting the corrosion rate test by using Corrosion Tester 3-Electrode system. The study result show that specimen with 250°C preheat was the highest impact toughness with 0.1593 mmPY corrosion rate result.

Keywords: AA5083, impact test, Corrosion rate

1. Introduction
Welding is a process combining one pieces of metallic materials to another piece together by using heat and pressure. In this recent day, there are several welding methods using nearly 30 types of welding method that using such as gas, electricity and laser beams. Effectiveness of welding processes has emerged as an integrated part of the construction industry [1]. This was also accompanied by the large use of aluminum 5xxx and 6xxx as the experimental object under consideration[2], [3]. The effect of welding method has to be connected with measurement of weld toughness by impact test. Grimsmo et al., [4] performed impact test using a 1444 kg trolley with 2.3-2.5 m.s⁻¹ in terms of velocity for testing fillet welds. Mohanavel et al., [5] also conducted impact test for determining impact strength of the AA6061 following with Taguchi techniques. Focusing on HAZ, Kunigita et al., [6] conducted Charpy impact test for incorporating microstructural parameters.

In the other side, the corrosion rate is a critical evaluation to determine how fast corrosion grows. Using ASTM 262, previous study conducted by Kumar et al., [7] , two specimens were welded and dissolved in solution of CSUO₄ and H₂SO₄. In similar with this study, Ahmad et al., [8] was using 3.5% NaCl solution since popularity and high corrosion propensity.

Before conducting the welding process, there are some references stating that it is necessary to do pre-treatment process. Pre-treatment using seawater has been observed by Montaya et al. [9]
resulting in improvement of corrosion resistance because phases reinforcing. However, that experimental observation was not observing about passive layer. An inevitable increase changes of HAZ as welding heat input increase is observed by [10]. This is affected not only from increased the temperature but also welding time. From several reasons that already mentioned before, it was an urge for analyzing the effect of welding method by exposing by acidic solution and analyzing the impact and corrosion rate effect as will be presented later below.

2. Experimental method
In this study, the true experiment research was selected using the several steps. The initial steps were testing, observing, and direct research to the selected objects. The specimen material was AA5083 which was exposed into a chemical based solution NaCl 3.5 percent. Then, the next step was measuring corrosion rate by using 3-Electrode Potential Corrosion Tester. A complete experimental scheme for this study is illustrated in Figure 1.

![Experimental Scheme](image)

**Figure 1.** Experimental scheme

2.1 **Welding and STT treatment**
The material used in this study was a 3 mm aluminum plate AA 5083, which is an Al-(4-5.5 percent) Mg alloy with a V-seam. Two aluminum plates AA5083 with a length of 300 mm and a width of 300 mm were welded using the inert metal gas (MIG) welding technique, with a welding speed of 10 mm / s, a feed wire speed of 9 mm / s, a current of 100 amperes, a voltage of 20 volts, and an argon shielding gas (Ar). Static Thermal Tension (STT) was a way to reduce distortion by providing a heat source and cooling during the welding process. The scheme of the STT is shown in Figure 2.
The research scheme is depicted in Figure 2a. Initial heating or preheating process was carried out in the welding area. The electrical heater around the weld (red area) was set with a preheating temperature variation of 50°C, 150°C and 250°C. The preheating process was aimed to decrease the temperature difference since it can result internal stresses and risk of cracking.

2.2 Corrosion Rate

The preparation of tensile test specimens was performed under ASTM E8 standards, where the specimens were cut and rounded based on the specimen thickness to be tested. The corrosion rate test used a potential tester for 3-Electrode corrosion. Figure 2b illustrates corrosion test specimens according to ASTM E8.

\[ CR = 3.27 \ corro \left( \frac{E}{d} \right) \]  (1)

2.3 Impact Test

Impact testing is a test used to determine the properties of a material that is subject to dynamic loads, so that it can be seen from this test that the strength properties of a material are either in the form of clay or ductile and brittle. With a record high in tenacity. Where the higher the test material, there is an uneven fracture plane in the material and it appears fibrous. But if the material is brittle, the result of the fracture appears tare and brilliant. Using ASTM E23, brittle oat can be experienced in conidial ductile material with the energy absorbed per unit transversal area of the test specimen as presented in Figure 3.

\[ K = \frac{W}{A_o} \]  (2)

3. Result and analysis

The results of the data collection were carried out in the Gajah Mada University Engineering Materials Laboratory to simulate corrosion tests using the 3-Electrode Potential Corrosion Tester method so that the results were obtained in the form of a corrosion rate graph and impact tests.
using the Charpy method with temperature variations of 50 °C, 150 °C and 250 °C. The experimental data were calculated as follows.

| No | Cos α | Cos β | T (°C) | G (kg) | λ (M) | Ao (mm) | Fracture form |
|----|-------|-------|--------|-------|-------|---------|---------------|
| 1  | 153º  | 140º  | 50 ºC  | 150 kg| 1 M   | 40mm²   | Ductile       |
| 2  | 153º  | 139º  | 150 ºC | 150 kg| 1 M   | 40mm²   | Ductile       |
| 3  | 153º  | 135º  | 250 ºC | 150 kg| 1 M   | 40mm²   | Ductile       |
| 4  | 153º  | 137º  | 300 ºC | 150 kg| 1 M   | 40mm²   | Ductile       |

Table 2 Result of corrosion testing by using 3-Electrode Potential Corrosion

| No | Specimen | T (°C) | Solution | Ecorr (mV)   | Icorr (μA) | Cathodic Beta (mV) | Anodic Beta (mV) |
|----|-----------|--------|----------|--------------|------------|--------------------|------------------|
| 1  | AA 5083   | 250 ºC | NaCl 3.5%| -739.148 mV  | 14.403 μA  | -125.761 mV        | 125.761 mV       |

Table 3 Result of Impact Value Calculation

| No | Temperature | W (kg.m) | A˳ (mm) | K (kg.m.mm⁻²)   |
|----|-------------|----------|---------|-----------------|
| 1  | 250 ºC      | 2700 kg.m| 40 mm² | 67.5 (kg.m.mm⁻²) |
| 2  | 50 ºC       | 1950 kg.m| 40 mm² | 28.75 (kg.m.mm⁻²) |
| 3  | 150 ºC      | 2100 kg.m| 40 mm² | 52.5 (kg.m.mm⁻²)  |
| 4  | 300 ºC      | 2450 kg.m| 40 mm² | 61.25 (kg.m.mm⁻²)  |

3.1 Impact Testing Results Using the Charpy Method

![Effect of W and Cos β on Temperature Changes](image)

**Figure 4.** W Result from temperature changes and Cos β Result
The energy absorption on the test specimen in impact testing was influenced by a mass of hammer (W) and angle of the end of the swing (Cos β) as previously presented in Table 1 and Table 3.

![Impact Value on Temperature Changes](image)

**Figure 5** Impact result from temperature changes

The resulting work impact coefficient is the highest on specimen 3, i.e. 67.5 kg m mm$^{-2}$. With a welding temperature of 250 °C and on specimen 1 which is 28.75 kg m/mm2 with a welding temperature of 50 °C, this is also supported by [6] the value of K is influenced by the result of the angle of the pendulum after the rupture of the test specimen (Cos β) which was calculated in such a way using the formula used by the researcher which yields the value of the effort required by br. The effect of this W factor is the greater the energy absorbed by the specimen (K). This is supported by [11] about the temperature of the specimen is strongly affected the crack propagation.

### 3.2 Corrosion Rate

| No | Specimen | Solution | T (ºC) | Icorr (μA) | Corrosion rate (mmPY) |
|----|----------|----------|--------|------------|-----------------------|
| 1  | AA 5083  | NaCl 3,5%| 250    | 14.403 μA  | 0.1593 mmPY           |

Based on the previous test about impact test, the third specimen with 250oc was selected to be observed about corrosion rate since it has the highest impact value. The results of the 3-electrode potential corrosion tester testing of the MIG welding results at a temperature of 250 °C in a 3.5 percent NaCl solution was shown in Figure 6. This graph will later be used as a reference for the calculation of the corrosion rate (CorrRate). Corrosion current (Icorr) cannot be determined directly, but its value can be determined by extrapolating a curve containing the corrosion potential (Ecorr). It is defined as the potential at which the total velocity of all anodized reactions is equal to the total velocity of all cathodic reactions. The intersection of the extrapolated curve
results in a point that determines the values of $I_{\text{corr}}$ and $E_{\text{corr}}$ so that the corrosion current and the corrosion stress can be detected.

Figure 6 shows a graph formed after corrosion testing using a potentiodynamic polarization method with the help of the Versa Studio software. Referring to the polarization graph in Figure 6, the specimen was showed a corrosion current value of 14.403 μA ($I_{\text{corr}}$) with a corrosion stress ($E_{\text{corr}}$)-739.148 mV so that the corrosion rate results were 0.1593 mmPY in a 3.5 percent NaCl solution as shown in Table when viewed from the resulting current density, the higher the corrosion current density ($I_{\text{corr}}$) generated will increase. The increase in the corrosion rate of the AA5083 welding results for NaCl was influenced by the conductivity of the NaCl solution, which causes a high conductivity, which causes a high corrosion current between the anode and the cathode, thereby increasing the corrosion rate of the AA5083 material and in line with experimental research from Ahmad et al.[8].

4. Conclusion
The results obtained on the corrosion rate from the results of GMAW welding on Aluminum AA5083 at 3.5 percent NaCl at 0.15935 mmPY and also the value of the impact strength on temperature variations from the results of GMAW welding on Aluminum AA5083 have shown that the higher the temperature variation used, the higher the impact value is also large, which is 67.5 kg (m / mm2) with temperature variations. From the obtained result, the value of Cos $\beta$ while conducting impact test, it is highly correlated with W and K.

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