Effect of current and speed on porosity in autogenous Tungsten Inert Gas (TIG) welding of aluminum alloys A1100 butt joint

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Abstract. Autogenous Tungsten Inert Gas (TIG) welding has been conducted on aluminum alloy A1100. The purpose of this research is to determine the proper current and speed of autogenous TIG welding with butt joint pattern. Variations on welding current are 150 A, 155 A, and 160 A with the variations on welding speed are 1 mm/seconds, 1.1 mm/seconds, 1.2 mm/seconds. The welded results were tested using non-destructive test (NDT) method using X-Ray radiography. After the test, it is found that the appropriate current for the best result without porosity can be achieved using the welding parameter of welding current of 160 A and the welding speed of 1.1 mm seconds.

1. Introduction
Aluminum alloy is widely used in the automotive and aircraft industry [1-3]. This is because the strength of the structure is good, lightweight and resistant to corrosion [4]. Tungsten inert gas welding (TIG) is one of the methods used in aluminum welding. This welding can use filler or without filler (autogenous) [5]. However there are many constraints on welding due to the difficulty of connecting 2 parts of aluminum which will cause welding defects such as porosity and heat crack. Porosity is a type of welding defect caused by contaminated welded gas-shaped metal welding so that in the weld metal there is a cavity. Porosity is generally spherical with the name of spherical porosity and rounded elongated called wormholes. If a welded joint has a lot of welding defects, then its structural strength decreases [6-8]. Many factors can cause the welding defects, such as lack of current and welding speed. To determine the welding defects in this aluminum alloy joint, the test phase must be conducted. Testing to determine the results of welding is done by non-destructive test method (NDT) with X-ray computer radiography system. This testing method is chosen because it is no longer use the film with a long processing, but only using the imaging plate so it does not waste a lot of time and cost. Tests using this method are also very effective and suitable for detecting porosity. Many TIG welding test were performed by previous experiment, but there is limited literature that mentions the specific welding of aluminum alloy A1100 with butt joints in autogenous welding. Then this experiment needs to be performed, by considering butt joint method in welding because this joint type is widely used in the industrial field.

2. Materials and methods
In this experiment, the material used aluminum alloy A1100 with a thickness of 3 mm. Aluminium plates with the size of 1200 x 2400 mm were cut using a specified tool into a 50x120 mm. Before the welding process, the material was treated at the surface using sandpaper with 400 grit number and...
cleaned chemically using acetone to remove the oil that may be attached. The cleaning treatment of the material was intended for the welding results to be good in the absence of impurities. The aluminium material joint used in this welding process is butt joint. The chemical properties of the aluminum alloy A1100 are shown in Table 1.

**Table 1. Chemical composition of sheet materials (wt%)** [9]

|       | Al       | Cu       | Fe | Mn  | Si | Zn  | Res |
|-------|----------|----------|----|-----|----|-----|-----|
| Aluminium Alloy 1100 | 99.0-99.95 | 0.05-0.20 | ≤ 0.95 | ≤ 0.05 | ≤ 0.95 | ≤ 0.1 | ≤ 0.15 |

The welding process were conducted by autogenous method or welding without filler metal. The experimental setup is shown in Figure 1.

![Figure 1. Experimental setup [10].](image)

At the beginning of welding process, the aluminum was placed on a moving table and spot welded on the 2-sided edges. This spot welding was intended to prevent the material from shifting its position due to the heat flowing during the welding process. After holding the arc for 15 seconds, the heat in aluminum could spread well. Current variations used in this experiment were 150 A, 155 A, and 160 A, while the speed variations were 1 mm/second, 1.1 mm/second, and 1.2 mm/second. The welding machine was GeKaMac Power TIG 2200 AC / DC Pulse with specifications as shown in Table 2.

**Table 2. Specification of TIG welding machine**

| Model | TIG | MMA |
|-------|-----|-----|
| Input Voltage | 1 Phase, 230 V, 50-60 Hz | 16 A |
| Fuse (delay action) | 6.3 kVA | 5.4 kVA |
| Installed Power | 5-220 A | 100 V |
| Open Circuit Voltage | 5-180 A | 100 V |
| Current Range | 5-220 A | 100 V |
| Duty Cycle at | %30 200 A | %60 130 A |
| Standards | %100 110 A | %100 110 A |
| Protection Class | EN 60974-1 IEC 60974-10 | IP23S |
| Insulation Class | F | |
| Dimensions (mm) | 465 x 185 x 390 | |
| Weight | 15.5 kg | |
After the welding process, then material was tested using X-Ray computer radiography. The X-Ray machine was Rigaku RF-300EGM2 with the specifications as shown in Table 3.

### Table 3. Specifications of X-Ray machine

| Specification         | Details                                                                 |
|-----------------------|-------------------------------------------------------------------------|
| Tube voltage          | 130 kV ~ 300 kV in steps of 2 kV                                        |
| Tube current          | STD mode 5 mA (at 160 kV or more)                                       |
|                       | LOW mode ~4 mA (at 160 kV or more)                                      |
| Duty cycle            | Intermittent continuous (1:1 Max. 6 min at 25°C)                        |
| X-ray tube            | Ceramic X-ray tube                                                      |
| Inherent filter       | Focal spot size (nominal) 2.5 mm x 2.5 mm                                |
| Dimensions            | Aluminum 2 mm + Beryllium 1 mm                                          |
| Dimensions Generator  | 320 (W) x 320 (D) x 687 (H) mm                                         |
| Dimensions Controller | 360 (W) x 340 (D) x 208 (H) mm                                         |
| Weight Generator      | 36.5 kg                                                                 |
| Weight Controller     | 17.2 kg                                                                 |
| Power supply Generator| Single phase AC 190 V - 240 V 50/60Hz                                   |
| Power consumption STD | 4.1 kVA                                                                 |
| Power consumption LOW | 3.0 kVA                                                                 |
| Generator insulation  | SF6 insulation gas                                                      |
| Generator cooling     | Anode earth, forced air cooling by radiator                             |

### 3. Results and discussions

#### 3.1. Visual test on upper weld surface

Figure 2 shows the result of upper weld surface in different welding current and welding speed.

![Figure 2. Upper weld bead width.](image)

In Figure 2 (a), (b), and (c), the welding was conducted with a current of 150 A and variations of speeds of 1 mm/sec, 1.1 mm/sec, and 1.2 mm/sec. At the speed of 1.2 mm/sec, there is a hole in the center indicating porosity. In Figure 2 (d), (e), and (f) with a 155 A welding current, there was also a porosity at 1.2 mm/sec welding speed. In Figure 2 (g), (h), and (i), there was no visible porosity due to the large welding current of 160 A. The weld bead width of each weld was also measured and the results is shown in Figure 3.
Figure 3. Upper weld bead width.

Figure 3 shows the dimension of upper weld bead width with the variation of welding current and welding current. At the welding current of 160 A and welding speed of 1 mm/sec, it is shown that the result of upper weld bead width is almost constant.

3.2. Visual test on back weld surface

Figure 4 shows the back weld bead produced from the experimental work.

Figure 4. Back weld bead width.

In Figure 4 (a), (b), and (c), the result of back weld bead width with a welding current of 150 A and speed of 1.2 mm/sec was found unstable. In Figure 4 (d), (e), and (f), the result of back weld bead width with a 155 A welding current and speed of 1.2 mm/sec also found unstable. While in Figure 4
(g), (h) and (i), the back weld bead width is relatively constant due to large welding current of 160 A. A summary of the width of the back weld bead can be shown in Figure 5.

![Figure 5](image)

**Figure 5.** Back weld bead width.

In Figure 5, it can be shown that the good welding result can be determined at current of 160 A. However, at the current of 150 A, the welding results seems not in the uniform result.

### 3.3. X-Ray computer Radiography test

X-Ray Radiography tests were performed after visual tests. This process was conducted to determine the welding defect in the form of porosity. The overall results of radiographic testing can be shown in Figure 6.

![Figure 6](image)

**Figure 6.** Results of radiographic testing.
In Figure 6 (a), (b) and (c), there are large and small black circles indicating porosity. Most porosity are found in Figure 6 (c) with a current of 150 A and welding speed of 1.2 mm/sec. In Figure 6 (d), (e) and (f) the welding result with a 155 A welding current also produce a lot of porosity at a speed of 1.2 mm/ sec. In Figure 6 (g), (h) and (i), the welding result with a welding current of 160 A, it is shown that there is no porosity occurred. The best results is shown in Figure 6 (h) with a welding speed of 1.1 mm/ sec and a current of 160 A. This welding result is good because the welded metal almost join the base metal. This result also shows the minimum heat input should be given to perform an autogenous TIG welding with butt joint type in A1100 plate.

4. Conclusions
After autogenous TIG welding of Aluminum alloy A1100 butt joint, visual testing and X-ray radiography, the following conclusions are obtained:

- Good welding can be performed by producing a constant weld bead width.
- Good welding results can be achieved from the result of the upper and back weld bead width at the welding current of 160 A and welding speed of 1 mm/sec, 1.1 mm/sec, and 1.2 mm/sec.
- The best welding result seen from its porosity is a specimen with a current of 160 A and a speed of 1.1 mm/sec.

Further research will be focused on the mechanical properties and microstructure of the welding results.

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