TO ANALYSIS THE EFFECT OF PARAMETERS ON ALUMINIUM ALLOY 6063-T6 IN TIG WELDING

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Abstract— Aluminium and its alloys play a critical role in engineering material field; Due to its light weight and resistance to corrosion. Aluminum has become one of the leading materials used by industry where steel or other high strength materials are under question. The welding of aluminium alloys is challengeable by conventional arc welding processes and generally welded by Tungsten Inert Gas (TIG) welding. This TIG welding is limit due to low welding strength of 35-50 percent of the base metal. An attempt has been made to achieve better mechanical properties of welded joint that are closer to the properties of base metal. The performance is measured in terms of ultimate tensile strength with varying parameters like welding current, shielding gas flow rate and preheating. Microstructural characterization of welded joint was carried out to understand the structural property correlation with process parameters. The results show that with increase in welding current and gas flow rate, the tensile strength of welding joint is increases.

Keywords— TIG Welding, welding current, tensile strength, HAZ.

I. INTRODUCTION

Aluminium and its alloys play a critical role in engineering material field. Aluminium is a strongly electro-negative metal and possesses a strong affinity for oxygen; this is apparent from the high heat of formation of its oxide. For this reason, it is isolated until well into the nineteenth century although it is among the six most widely distributed metals on the surface of the earth Sheasby and pinner (2001). In the domain of joining processes of aluminum and its alloys, the tungsten inert gas (TIG) welding process continues its apex position due to its versatility and flexibility in adaptation. Chennaiah (2015).

Tungsten Inert Gas (TIG) or Gas Tungsten Arc welding (GTAW) is the arc welding process in which arc is generated between non-consumable tungsten electrode and work piece. The shielding gas protects the tungsten electrode and the molten metal weld pool from the atmospheric contamination. According to Singh (2006) the shielding gases generally used are argon, helium or their mixtures. A constant current AC power source with a continuous high frequency is used with air water or air-cooled TIG torch. The electric arc can produce temperatures of up to 19,400°C and this heat can be much focused as local heat

II. REVIEW OF LITERATURE

1. Zhang et.al (2016) investigated the comparison of microstructure and mechanical properties of TIG and laser welding joints of a new Al–Zn–Mg–Cu alloy with the thickness of 2mm was selected as the base metal (BM). For the TIG welding, an Al–Mg alloy with the diameter of 1.6 mm was used as filler wire; for the laser welding, none filler metal was used. After welding, the defects in the joint were investigated using X-ray radiography and macrograph of the cross-section of joints was observed using a stereoscopic microscope. Results shows the ultimate tensile strength of TIG and laser joints is about 436.2Mpa and 471.1Mpa, and the elongation of them is about 7.5% and 5.1% respectively.

2. Thakur et al. (2016) presented a review on influence of TIG welding parameters and stated the important parameters for strength of TIG welding of Aluminium structures. Kumar et.al (2015) studied the mechanical and micro structural properties of aluminium alloy AA6061 welded by
TIG welding size 200 mm x 150 mm x 6 mm welding using the filler wire as AA-4047. The aluminum alloy plates were joined by TIG welding technique to examine micro hardness, microstructure of weld and surface roughness of welded specimen. Results showed that optimum weld current out of the three weld currents used (140A, 150A and 160A) was 160A. The micro-hardness of the welded part welded at 160 ampere was increased by 6% and 16% as compared to the welding carried out at 140 ampere and 150 ampere and the surface roughness value was less at the welding current as 160 ampere.

3. Zhu et.al (2014) studied AA2219 aluminum alloy was successfully welded by variable polarity tungsten inert gas (TIG) welding, and the effect of post weld heat treatment (PWHT) process on the microstructure, mechanical properties, and corrosion behavior of the welded joints was investigated. The results showed that, by implementing PWHT, the microstructure of the joint was more homogeneous than the welded joint. Meanwhile, the tensile strength was increased by 44% and the joint efficiency reached 76%. Moreover, the corrosion resistance of the PWHT joint was superior to that of the welded joint.

4. Narayanan et.al (2013) found out the Influence of Gas Tungsten Arc Welding Parameters in Aluminium 5083 Alloy welding with different flow rate of gas and different welding current 200 and 250A. After welding, tensile testing, Micro hardness testing and Macrostructure and Microstructure study tests was done on specimen. From this study it was shown that maximum ultimate strength is 281MPa, hardness of weld metal is 73.5 HVN at welding current 200A and gas flow rate 15 LPM.

Jabbari (2013) studied the Effect of the Preheating Temperature on Process Time in Friction Stir Welding of Al 6063-T6. In this study an analytical model was developed to simulate the contact Temperature in the friction stir welding (FSW).This second order equation which contains thermal characteristics and welding parameters was compared and validated by experimental data in the literature.

### III. EXPERIMENTAL WORK

The material under investigation is 6.00 mm thick Aluminium alloy 6063-T6. A non-consumable tungsten electrode of 3.15 mm shielded by argon gas is used to strike the arc with base metal. Filler rods (2.6 mm) of Aluminium alloy 4047 are recommend for welding of this alloy for getting maximum strength. The chemical composition of base metal and filler rod are tabulated in Table 1-4. Sample plates of size 110 x 40 x 6mm were prepared by milling machine. TIG 250 AC welding set is used in experiments as it will be provide required welding current, voltage, required flow rate of argon gas which concentrates required heat input in the welding area. In order to remove oil, moisture and oxide layer from base metal, they were thoroughly wire brushed, cleaned with acetone and preheated at 150ºC in the muffle furnace to preheat the samples before welding. The preparation of specimen for welding and parameters are discussed in following subsections.

| Table 1: Composition of the base material Al 6063-T6 |
|---------------------------------------------------|
| Aluminum (Al)                                      | 97.5 to 99.4 %             |
| Magnesium (Mg)                              | 0.45 to 0.9 %               |
| Silicon (Si)                                      | 0.2 to 0.6 %                |
| Iron (Fe)                                         | 0 to 0.35 %                 |
| Residuals                                         | 0 to 0.15 %                 |
| Chromium (Cr)                                    | 0 to 0.1 %                  |
| Copper (Cu)                                       | 0 to 0.1 %                  |
| Manganese (Mn)                                   | 0 to 0.1 %                  |
| Titanium (Ti)                                    | 0 to 0.1 %                  |
| Zinc (Zn)                                         | 0 to 0.1 %                  |

| Table 2: Properties of base metal Al 6063-T6 |
|---------------------------------------------|
| Proof Stress                               | 160 MPa                      |
| Tensile Strength                            | 195 MPa                      |
| Elongation                                  | 14 %                         |
Table 3: Composition of filler wire 4046

| Weight % | Al  | Si  | Fe  | Cu  | Zn  | Mn  | Mg  | Ti  | Other |
|----------|-----|-----|-----|-----|-----|-----|-----|-----|-------|
| Alloy 4046 Bal | 9.0-11.0 | 0.50 max | 0.03 max | 0.10 max | 0.40 max | 0.2-0.5 | 0.15 max | .05 max each |

Table 4: Welding process parameter for experimentation

| SR.NO | PARAMETER             | RANGE            |
|-------|-----------------------|------------------|
| 1     | Welding current       | 80,100,120 Amp   |
| 2     | Voltage               | 20V              |
| 3     | Gas flow rate         | 8, 10, 12 LPM    |
| 4     | Preheating temperature| 50,100 ºC        |
| 5     | Electrode material    | 98% W+ 2% Zr    |
| 6     | Electrode diameter    | 3.15mm           |
| 7     | Filler rod            | Al 4047          |
| 8     | Filler rod diameter   | 2.6 mm           |

Specimens preparation

In this experiment the work pieces of aluminium alloy 6063-T6 are prepared according to American Society of Mechanical Engineers (ASME). Total 36 rectangular shape plate pieces are cut into a dimension of 110 x 40 x 6mm by hydraulic press machine. After cutting the pieces, the edge preparation is done by grinding machine, to make V shape groove of 60º for the proper penetration of weld metal. Pictorial view of specimen shown in Figure 1.

Welding procedure

First of all the specimen are cleaned of dirt, grease and other foreign materials by using cleansing agents, dirt removers or other re-agents. After cleaning of work pieces, welding set-up is prepared and tested. Further, the parameters are adjusted according to required level and made ready for welding. Then two pieces are taken which are set up in such a way so as to maintain a 2 mm root gap. Then 18 numbers of welded samples are made by carrying out welding with different levels of current, gas flow rate and preheating of samples. A photographic view of welded specimen for testing are shown in Figure 2 shows the samples for tensile test.

Tensile test results

Tensile test is performed on AIMIL universal testing machine, to examine the regions from where failure/fracture has occurred and to find tensile test of the welded samples. The tensile test results indicate that for most of the samples, tensile strength is satisfactory. The different parameters have an different effect on the tensile strength of the welded joint. Each specimen is tested for a
particular parametric range and each parameter participates in the tensile strength of the specimen. Table 5 shows the percentage effect of different parameters on tensile strength of the joint.

| Source               | Sum of Squares | DF | Mean Square | F Value | Percentage effect (%) |
|----------------------|----------------|----|-------------|---------|-----------------------|
| Model                | 1533.056       | 3  | 511.018     | 80.23542| -                     |
| A- WeldingCurrent    | 693.12         | 1  | 693.12      | 108.8273| 45.02                 |
| B- Gas Flow Rate     | 692.3602       | 1  | 692.3602    | 108.708 | 44.98                 |
| C- Preheating        | 147.5762       | 1  | 147.5762    | 23.17104| 9.59                  |
| Residual             | 89.1659        | 14 | 6.368993    | -       | 0.41                  |
| Total                | 1622.22        | 17 | -           | -       | 100                   |

The percentage effect of each parameter on tensile strength is shown in Figure 2. It can be clearly seen that tensile strength is mostly influenced by the welding current. In pie chart, 45.02% of the region is covered by the welding current. Gas flow rate is the second parameter which contributes almost same (44.98%) as welding current on the tensile strength. Preheating has very less effect (9.59%) on the tensile strength. Rest of the region in Figure 3 shows the effect of errors found less than 1%.

**Effect of welding current and gas flow rate on tensile strength**

The effect of welding current and gas flow rate on tensile strength of the welding joint varies directly with welding current as shown in the Figure 3. A change in welding current and gas flow rate show a relative change in tensile strength. However the increase in gas flow rate showed increase in tensile strength. When the current is reduced even for higher levels of gas flow rate it is found that a marginal decrease in tensile strength is observed. Hence an optimal range of gas flow rate is found in the range of 10-12 LPM for economical welding strength. But for high current, the effect of gas flow rate cannot be rejected. It protected the weld surface to come in direct contact of air, which can contaminate the welding region and cause poor weld joint.

Figure 4 shows the effect of shielding gas flow rate of 8 LPM, 10 LPM and 12 LPM on tensile strength of weld joint for different current levels of 80 A, 100 A and 120 A. It seen from the figure 4 that tensile strength of welded joint is increases by the change in shielding gas flow rate in increasing order till the maximum value of 12 LPM reached that shows the maximum tensile strength of 202.69MPa, 198.13Mpa and 185.86Mpa for weld joint at 100°C preheat. This graph revealed that with the increase in both gas flow rate and welding current, tensile strength of welded joint is increases up to optimum level. Maximum value of tensile strength is achieved at 12 LPM when optimal range of welding current was used.

**Effect of preheating and gas flow rate & Effect of welding current and preheat on tensile strength**

The effect of preheating and gas flow rate on tensile strength of the welding joint varies as shown in Figure 5.
Figure 5: Effect of preheating and gas flow rate on tensile strength

Figure 6: Effect of welding current and preheat on tensile strength

Figure 5 shows the effect of shielding gas flow rate on tensile strength of weld joint at constant current for both preheated temperatures i.e. 50 °C, 100 °C. It shows that tensile strength of welded joint is increases by the change in shielding gas flow rate in increasing order till the maximum value of 12 LPM reached. It shows the maximum tensile strength of 194.5MPa for weld joint at 50°C Welding current is the main parameter which contributes most to the tensile strength of a welded joint. An increase in welding current has a huge impact on tensile strength compared to preheating temperature. The effect of preheating of samples is less but cannot be ignored as it is an important parameter to make a good welded joint. The effect of preheating on tensile strength is shown in figure 6.

Figure 6 shows the effect of welding current on tensile strength of weld joint for both 50°C and 100°C temperature preheated samples. As welding current increases for a constant value gas flow rate of 12 LPM, the tensile strength increases till a maximum value of 194.5Mpa for current value of 120A, with 50°C preheating temperature, on the other hand for 100°C preheating temperature its maximum value is found to be 202.69Mpa.

Microstructure Analysis

Microstructural characterization study is conducted on metallographically polished and chemically etched samples to investigate morphological characteristics of grains and secondary phases. Micrographs of welded pieces are taken with the help of Leica microstructure tester at IIT ROPAR. Etchant used for etching is a mixture of 25 ml methanol, 25 ml hydrochloric acid, 25ml nitric acid and 1 drop of hydrofluoric acid is used for 10-20 seconds on tests samples. After 10-20 sec the samples are washed with water and dried with air dryer. These samples have been studied under Leica microscope and microstructures of base metal, heat affected zone (HAZ) and weld metal are studied to check the difference in microstructure after welding and photographs are taken. The microstructure of base metal is shown in figure 9 and different welded samples it is shown in figures 10-13.
The micrograph as shown in figure 7 is for sample number 18 with the maximum tensile strength of 202.69Mpa at 120A welding current and at 12 LPM gas flow rate. From this micrograph it is clearly revealed that with the increase in input current and gas flow rate and with preheating of samples the grain structures is refined with closely packed grains, due to which tensile strength of welded joint at high current is higher than welded joints at lower welding current and gas flow rate. Unlike that of the base metal weld zone and HAZ, has fine and equiaxed grains and the grain size is much smaller than that of the BM. This structure is produced by the recrystallization and static grain growth after welding.

IV. CONCLUSION

In the present work, butt welding of aluminum alloy 6063-T6 is carried out by tungsten inert gas (TIG) welding, at various levels of welding current, gas flow rate and preheat of samples. The responses considered are the ultimate tensile strength and Microstructure of joints. Based on the experimental results the following conclusions are drawn.

• Optimum parameter setting for tensile strength is obtained at welding current of 120A, gas flow rate of 12LPM and preheating temperature of 100ºC with a maximum tensile strength 202.69Mpa.
• For tensile strength the percentage contribution of gas flow rate is 44.98% and welding current is 45.02%.
• Different welding input parameters have changed the microstructure of welded joint.
• The microstructures with elongated and fine grains have higher tensile strength than others

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