Experimental Comparison of the MIG and Friction Stir Welding Processes for AA 6061(Al Mg Si Cu) Aluminium Alloy

Anjaneya Prasad. B, Prasanna. P

Abstract—Aluminum alloys are welded using both metal inert gas (MIG) and friction stir welding (FSW). Mechanical properties like tensile strength, hardness and impact strength for both welding processes are evaluated for AA6061 aluminum alloy. The results indicate that, the microstructure of the friction stir weld is different from that of MIG welded joint. The weld nugget consists of small grains in FSW than those found in MIG weld. The tensile strength of the weld joints can be increased using FSW instead of MIG welding. The heat affected zone (HAZ) of FSW is narrower than that of MIG welding.

Keywords—Friction stir welding, Metal inert gas welding, Aluminium alloy, Mechanical Properties.

I. INTRODUCTION

ALUMINUM alloys are light-weight, have relatively high strength, retain good ductility at subzero temperatures, have high resistance to corrosion, and are non-toxic. They have a melting range of 482°C to 660°C, depending upon the alloy. Properties of Aluminum alloy AA6061 is given below. Table 1,2 gives the properties of the material used in the present study.

Table I

<table>
<thead>
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<th>Chemical Composition of AA6061-T6</th>
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<td>Mg</td>
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<td>0.8-</td>
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It is impossible in practice to stop the tenacious oxide film formed due to oxidation at exposed surfaces. It can nevertheless be welded because the oxide can be dispersed by the action of a welding arc, although fragments of oxide may become entrapped into the weld. Resistance spot welding of aluminum is difficult (though not impossible) because the oxide film can cause uncontrolled variations in surface resistance. Unlike iron, aluminum has only one allotropic form. Hence there are no phase transformations which can be exploited to control its microstructure. The main methods by which it can be strengthened include deformation, solution-hardening, or by introducing precipitates into the microstructure. The heat introduced by welding can severely disrupt the deformed or precipitation-hardened alloys. In order to avoid these difficulties a new technique i.e Friction stir welding was developed in 1991 at Cambridge, UK. It can weld all aluminum alloys, including those that cannot normally be joined by conventional fusion welding techniques such as aluminum-lithium alloys. Dissimilar aluminum alloys can also be joined, for e.g. 5000 to 6000 series or even 2000 to 7000 series.

Friction stir welding has enjoyed worldwide interest since its inception because of its advantages over traditional joining techniques. Essentially, FSW is a local thermo-mechanical metal working process with additional adiabatic heating from metal deformation that changes the local properties without influencing properties in the remainder of the structure. As mentioned later, the pin and shoulder of the tool can be modified in a number of ways to influence material flow and micro-structural evolution.

A rotating tool with pin and shoulder is inserted in the material to be treated, and traversed along the line of interest (Figure 1). During FSW, the area to be processed and the tool are moved relative to each other such that the tool traverses with overlapping passes until the entire selected area is processed to a fine grain size. The rotating tool provides a continual hot working action, plasticizing metal within a narrow zone while transporting metal from the leading face of the pin to its trailing edge. The processed zone cools without solidification, as there is no liquid and hence a defect-free recrystallized fine grain microstructure is formed.

Table II

<table>
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<th>MECHANICAL PROPERTIES OF AA6061-6</th>
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<td>Temper</td>
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<td>0</td>
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<td>T1</td>
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<td>T4</td>
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FSW tool is generally made with a profile pin which can be implemented with a conventional milling machine. The FSW process is repeatable, can be monitored, and does not major safety hazards, such as fumes or radiation. The FSW process was developed and patented by the welding institute (TWI-UK) for ferrous and non-ferrous materials. The process which was developed and patented by the welding institute (particularly CO2) are now employed. MIG welding is a description, because both inert and reactive gases (usually argon, protecting the base metal from contact with oxygen, nitrogen or hydrogen. Figure 2 show a MIG welding setup.

Fig. 1 Schematic of Friction Stir Welding

Fig. 2 Metal Inert Gas Welding Process

II. LITERATURE SURVEY

Friction stir welding (FSW) is a solid state welding process which was developed and patented by the welding institute (TWI-UK) for ferrous and non-ferrous materials. The process is repeatable, can be monitored, and does not produce major safety hazards, such as fumes or radiation. The FSW process can be implemented with a conventional milling machine. The FSW tool is generally made with a profile pin which is contained in a shoulder with larger diameter than that of the pin as seen in the figure. The tools are manufactured from a wear resistant material with a good static and dynamic properties at elevated temperatures. A properly designed tool permits up to 100m of weld to be produced in 5mm thick aluminium extrusions. The tool is shaped with a large diameter shoulder and a small diameter profiled pin that first makes contact as it is plunged into the joint region. The plates to be welded are fixed rigidly to prevent the joint faces from being forced a part as the probe passes. Through and along the seam. For thick plate welding, usually a pilot hole of smaller diameter than that of the profiled pin is drilled at the start to assist the plunging of the tool. The depth of penetration is controlled by the length of the profiled pin. Below the shoulder of the tool. The initial plunging friction contact heats the adjacent metal around the probe as well as a small region of material underneath the probe, but the friction between shoulder and material interfaces generates significant additional heat to the weld region. In addition to generating heat, the shoulder of the tool also prevents highly plasticized material from being expelled from the welding region. The thermally softened and heat-affected zone takes up a shape corresponding to that of the over-all tool geometry. The heat affected zone is much wider at the top surface and tapers down towards the tip of the tool. The combined friction heat from the profiled pin of the shoulder creates a highly plasticized condition around the immersed probe. This plasticized material provides a hydro-static affect as the rotating tool moves along the joint, which helps the plasticized material to flow around the tool. The thermal effects behind the tool as the latter moves along the weld line. For butt joining, the length of the pin increases to the thickness of the work-piece. If the weld is done from one side. For a double-sided weld the length of the pin is approximately equal to half of the welded plate thickness. The onion-ring the structure of the nugget is typically of I quality stir welding in which no porosity or internal voids are detectable. In macro-sections of good quality welds, the nugget is visible at the center of the weld, as shown schematically in the figure 1. Outside the nugget, there is a thermo-mechanically affected zone, which has been severely, plastically deformed under shows some areas of partial green refinement. The main application of FSW is in the production of long-straight welds in aluminium alloy plates, extruded aluminium profiles, and tailored blank. Lightweight aluminium alloys are used widely in applications such as aerospace and transport (ship-camels, frames of high speed railways and automobile parts). The joints obtained with FSW reduce up to 30% the involved cost compared to mechanical fastening together with a weight reduction of 10%. On the other-hand, traditional welding processes present a series of disadvantages when applied to aluminium alloys.[1-20]

III. EXPERIMENTAL DETAILS

The FSW was carried out on 3-axis CIMTRIX make computer numerical controlled milling machine with FANUC controller and is shown in fig.3. The specification of the machine is given in table2. Computer Numerical Control milling machine is the most common form of CNC. CNC
mills can perform the functions of drilling and often turning. CNC mills are classified according to the number of axes that they posses and these axes are labeled as X and Y for horizontal moment, and Z for vertical movement. CNC milling machines are traditionally programmed using a set of commands known as G codes represent specific CNC functions in Alpha numeric format.

![CNC milling machine with tool and fixture](image)

Although MIG welding is a well-established method for joining aluminum, it has several shortcomings. Weld porosity is more commonly detected in MIG welds in aluminum when compared to those undertaken in steel; this is due to the high solubility of hydrogen in the molten aluminum weld pool, but low solubility in solid aluminium. The higher thermal conductivity and expansion coefficients, and lower modulus of elasticity, result in greater shrinkage and distortion, again when compared to steel. A loss of strength also occurs in the heat affected zone (HAZ), in heat-treated alloys through over-ageing and in strain hardened alloys through annealing, resulting in the material properties differing between the weld metal, HAZ and parent plate. The MIG weld pool solidifies to form a reinforced area around the joint, commonly termed the weld bead. The weld bead leads to stress concentration effects and the failure of MIG welds frequently occurs due to crack initiation and growth along the weld toe. Within the weld bead grain growth on cooling results in columnar grains growing from the fusion zone into the weld bead and within the bead large equiaxed grains. To reduce the stress concentration effect, removal of the weld bead can be undertaken, but the processes is expensive. Similarly, the effect of microstructural changes can be reduced through the application of thermal processes. Residual stresses form due to the contraction of the weld metal on cooling. These are tensile and typically of yield magnitude at, and near to, the weld toe, in both the direction. Another set of aluminium alloy plates were but welded(single-sided one joint) using the MIG process the plates were cleaned before the MIG welding procedure with a scraper and acetone. In the MIG welding process, a MIG-350 type semiautomatic welding machine was used for welding the plates with the parameters of 240(+or-) A (Current) and 24(+or-1) V (voltage). A 4145 filler of 1.2mm diameter with a welding speed of 110mm per min was used to carry out the MIG welds. The hardness test gives an idea of the resistance to indentation of the weld metal. This is important with respect to components which have been built up and have to withstand abrasive wear. Hardness values can give information about the metallurgical changes caused by welding.

IV. RESULTS AND DISCUSSION

Macrographs of MIG and FSW welded joints of AA 6061 alloy are shown in figure4&5. The surface appearance and roughness of the FSW weld is similar to the surface obtained by the milling process. The surface of the MIG welds is similar to the cast structure and has a rough surface. The Micro structure of the FSW is a refined structure, while MIG welds have a cast structure. The stirring effect of the FSW process gives a finer microstructure, while MIG welds gives a columnar crystalline structure is obtained. The stirring effect and refined structure improve the mechanical properties of the FSW joint.

![Microstructure of MIG Grains at weld Nugget zone(x400)](image)

![Microstructure of FSW Grains at weld Nugget zone(x400)](image)

The tensile strength of FSW, MIG and Base metal of AA 6061 alloy were 121, 95 and 145 N/mm², respectively, as seen in the table III. The tensile strength of FSW was 17% lower than base metal. On the other hand, strength decrease was about 34% in MIG welded specimens. The results of the tensile tests show that 22% strength improvement can be obtained with the FSW process when compared with MIG. The tensile strength of the FSW joint is stronger than the MIG weld joint but lowers than the base metal.
The microstructure of the FS weld is different to that resulting from the MIG process. The weld nugget consists of small grains in FSW, typically, 10-100 times smaller than those found in the MIG. The small grain size of the weld nugget would generally be considered beneficial to the mechanical properties of the material, although the reduction in dislocation density that have been reported may result in the effect of the grain size being reduced or diminished.

2. The tensile strength of welded joints can be increased using the FSW process instead of MIG.

3. Hardness change in the weld material is affected from the amount of the heat input during the welding process. Less heat input in the FSW process lowers the area where hardness changes. The heat-affected zone of FSW is narrower than the MIG process. The shoulder diameter of FSW and heat input during the welding process determines the width of the hardness.

4. Higher performance in production rate and quality, as well as decreasing production costs, can be obtained by FSW welding. The required pre-operations before the welding process are very limited in FSW. This feature of the FSW process saves consumable material time cost and improves the quality of welds.

**REFERENCES**


[18] Properties of Aluminum alloy by John Gilbert, Kautman