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A REVIEW OF FRICTION STIR WELDING OF AA6061 ALUMINIUM ALLOY

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ABSTRACT

This paper discuss about the friction stir welding of joining heat treatable aluminium alloys for aerospace and automobile industries. These welded joints have higher tensile strength to weight ratio and finer micro structure. FSW of aluminium alloys have the potential to hold good mechanical and metallurgical properties. The aim of this study was to investigate the effect of process parameters on the tensile strength of the welded joints.

Keywords: friction stir welding, aluminium alloy, rotational speed, welding speed, tensile properties, microstructure.

1. INTRODUCTION

Friction stir welding (FSW), a solid state joining technique invented in 1991 by The Welding Institute (TWI) and is one of the most significant developments in joining technology over the last half century. FSW involves the joining of metals without fusion or filler materials and is derived from conventional friction welding. Nowadays, AA6061 is one of the primary choices for light plane skin, which needs moderately high yield strength and hardness. Among aluminium alloys, aluminium-magnesium-silicon (Al-Mg-Si) heat treatable alloys, although of only medium strength, appears to have weld ability advantage over high strength aluminium alloys. For this reason Al-Mg-Si alloys are widely used for structural components in welded assemblies. FSW may produce high tensile stresses elsewhere in the components, FSW results in a much lower distortion and residual stresses owing to the low heat input characteristics of the process. This technique utilizes a non consumable rotating welding tool with a shoulder ending with a variable shaped pin, which moves along the butting surfaces of two rigidly clamped plates shown in Figure-1. Heat generated by friction at the shoulder and to a lesser extent at the pin surfaces softens the material being welded. Severe plastic deformation and flow of the plasticized metal occurs as the tool is moving along the welding direction.

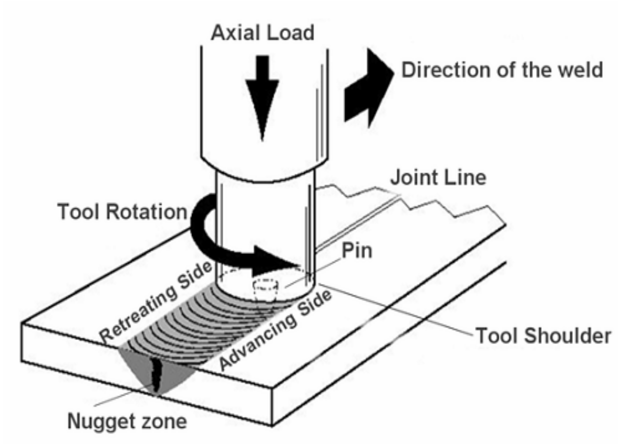

Figure-1. Schematic of Friction Stir Welding.

1.1 Aluminium alloys

Aluminium alloys are designated based on international standards. These alloys are distinguished by a four digit number which is followed by a temper designation code. The first digit corresponds to the principal alloying constituent. The second digit corresponds to variations of the initial alloy. The third and forth digits correspond to individual alloy variations. Finally the temper designation code corresponds to different strengthening techniques. The chemical composition is given in Table-1. Mechanical and physical properties are given in Tables 2 and 3, respectively.

Table 1. Chemical composition of AA 6061.

Mg	Si	Fe	Cu	Cr	Mn	Zn	Ti	Al
0.9	0.62	0.33	0.28	0.17	0.06	0.02	0.02	Bal

Table 2. Mechanical properties of AA 6061.

Yield strength (MPa)	**Ultimate strength** (MPa)	**Elongation** (%)	**Reduction in cross sectional area** (%)	**Hardness** (VHN)
302	334	18	12.24	105

Table 3. Physical properties of AA 6061.

Physical property	**Density** (g/cm^3)	**Melting point** (^{o}C)	**Modulus of Elasticity** (GPa)	**Poison ratio**
AA6061	2.7	580	70-80	0.33

2. METHODOLOGY OF FSW PROCESS

In this process, a cylindrical-shouldered tool with a profiled threaded/unthreaded pin is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of plate material, which are butted together. The parts to be clamped rigidly onto a backing bar in a manner that prevents the abutting joint faces from being forced apart. The length of the pin is slightly less than the weld depth required and the tool shoulder should be in intimate contact with the work piece surface. The pin is then moved against the work piece or vice-versa. Frictional heat is generated between the wear resistant welding tool shoulder and pin, and the material of the work pieces. This heat along with the heat generated by the mechanical mixing process and the adiabatic heat with in the material, cause the stirred materials to soften without reaching the melting point. As the pin is moved in the direction of welding the leading face of the pin, assisted by a special pin profile, forces plasticized material to the back of the pin whilst applying a substantial forging force to consolidate the weld metal. The welding of the material is facilitated by severe plastic deformation in the solid state involving dynamic recrystallization of the base material. The welded joints will be sliced using power hacksaw and then machined to required dimensions, American Society for Testing of Materials (ASTM E8M-04) guidelines should be followed for preparing the test specimens.

3. PROCESS PARAMETERS

The friction stir welding process is dominated by the effect associated with material flow and large mechanical deformation, which in turn is affected by process parameters such as rotational speed, welding speed and axial force. A.K Lakshminarayanan *et al.* (2009) described friction stir welding by optimum process parameter of 1200 rpm rotational speed, 75 mm/min welding speed and 7 KN axial force, this process exhibited yield strength of 224MPa, and tensile strength of 248MPa, which are 34% more than other welding joints and the microstructure contains very fine, equiaxed grains and thus may be due to the dynamic crystallization that occurred during FSW process. Based on the experimental study done by Mustafa Kemal Kulekci *et al.*, (2010) FSW process carried out at a constant tool rotation of 1600 rpm and welding speed of 200mm/min and observed that the average tensile strength of the base metal is 290MPa and for FSW is 270MPa, it seen 7% lower than base metal and stirring effect of the FSW process gives a finer microstructure to the weld. N. T. Kumbhar *et al.*, (2008) explained friction stir welding by employing tool rotational speeds of 710, 1120 and 1400 rpm and welding speeds of 63, 80, and 100 mm/min. It is seen that the weld nugget consists of fine equiaxed grains of an order less in magnitude to that of the parent material ranging between 15-20 µm. This small grain in the weld nugget zone is due to stirring action of the tool. M. Iordachescu *et al.*, (2007) explained friction stir process with rotational speed of 1120 rpm, welding speed of 320mm/min and axial force or friction pressure of 25 KN. They observed refined grains in a discrete series of bands and some precipitates mainly distributed at the grain boundaries as well as coarsened grains in heat affected zone regions. Anand C. Somasekharan *et al.*, (2004) have taken optimum tool rotational speed of 800rpm and welding speed of 90 mm/min to perform the welds of AA6061 aluminium alloy. The base material revealed grains of unequal sizes and was seen distributed in the matrix with the grains tending to be rather elongated. The frictional heat provided by the rubbing of the tool shoulder and the mechanical stirring of the material by the tool nib, the adiabatic heat arising from the deformation induced dynamic recrystallization. And result shows the transitioning of aluminium from the base material to the FSW zone with a clean decrease in grain size.

3. CONCLUSIONS

Based on the results of different researchers, the tensile strength of AA 6061 Aluminium alloy is discussed for optimum process parameters of rotational speed, welding speed and axial force. Superior tensile properties of FSW joints were observed, this is due to the formation of fine equiaxed grains and uniformly distributed very fine strengthening precipitates in the weld region. With a recent research developments in use of heat treatable aluminium alloys, it has been suggested that higher tensile strength of these alloys, a manufacturer allow to use in the area of aerospace and automobile industries, where the high strength to weight ratio is important.

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