INFLUENCE OF FRICTION STIR WELDING PARAMETERS ON PROPERTIES OF AL-6061(F) ALLOY

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Abstract— Welding of non-ferrous materials like aluminum, magnesium, copper etc, is difficult with conventional welding process as they are affected by oxidation. Friction stir welding (FSW) appears as a promisingly ecological weld method that enable to reduce material waste and to avoid radiation and harmful gas emissions usually associated with fusion welding processes. The welded joints are mainly affected by the rotational speed and transverse speed of the tool during welding. As the tool rotation speed and feed increases the tensile strength and hardness values are improved at the weld joint. Tensile strength and hardness can also be affected by the tool design. The tool designs like flat shouldered, concave shouldered and convex shouldered with different profiles like concentric circles can affect the welded joints. The material flow rate can be minimized by using concave shouldered tools.

Index Terms— Friction Stir Welding, Aluminum 6061 Alloy, Concave Shouldered Tool.

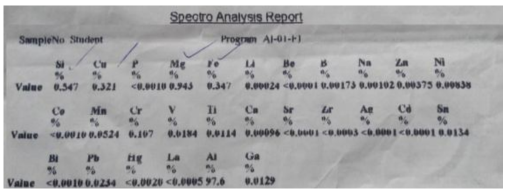
I. INTRODUCTION

Most of the engineering applications today require materials having properties like low weight to strength ratio, low density, low cost and abundantly available. These requirements are nearer to many materials but mostly satisfied by aluminum metal which results the use of aluminum in air crafts, ship vessels, rockets, pressure vessels and many more applications. Generally aluminum alloys are divided as non-weldable because of the poor solidification microstructure and porosity in the fusion zone. Furthermore, the loss in mechanical properties as compared to the base material is very significant. The factors put together the joining of these alloys by conventional welding processes unattractive.

Some aluminum alloys can be resistance welded, however the surface preparation is expensive, with surface oxide being a major problem. To compensate the huge equipment cost of above process we go for an alternate process of joining technique for metals called friction stir welding which is a simple ,compact and effective method of welding high thermal conductive materials like aluminium, copper ,bronze and others .Friction stir welding process can be done on non-ferrous and also ferrous materials. FSW has proven to be an excellent joining technique for a variety of different materials, including polymers and metals.. Metals among low melting temperatures such as copper and aluminium were among the first to be joined this technique using a steel tool.FSW retain much of the base material strength and have many other advantages over joints produced by traditional welding techniques. It is generally thought that such advantages stem from the lower heat input required by FSW. FSW can create welds that are high in superiority, strong, and economical to make with absence of oxidation and porosity

II. LITERATURE REVIEW

The Response Surface Methodology based on a central composite rotatable design with three parameters which was used to develop a mathematical model predicting the tensile properties of friction stir welded AA6061 aluminum alloys.[1] The mechanical properties and failure mechanisms of friction stir welded 6061 aluminum alloy is investigated based on experimental observations. A preferable appearance of the joint can be obtained at higher rotational speed and longer duration time. The insufficient pressure vertical to the tool, and the amount of material extruded upward and the effective weld width increase with the increasing of rotational speed and duration time. The tensile/shear strength increases with the increasing rotational speed at a given duration time. However, under a given rotational speed, differences in tensile/shear strength among three duration times are rather small. The tool rotational speed plays a determinant role in determining the tensile/shear strength. The dependence of tensile/shear strength on tool holding time is less remarkable at lower rotational speed There was a direct correlation between the effective weld width and the strength, the presence of larger effective weld width results in stronger weld [2]. The relationship between tool profiles, spindle speed, travel speed, and other process parameters for friction stir welding (FSW) at high spindle speeds, and correlate the results predicting the properties, tensile strength and hardness.[3-12]


Spectro Analysis Report

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	Si %	Cu %	P %	Mg %	Fe %	Li %	Be %	B %	Na %	Zn %	Ni %
Value	0.547	0.321	<0.0010	0.945	0.347	0.00024	<0.0001	0.00173	0.00102	0.00375	0.00838

	Co %	Mn %	Cr %	V %	Ti %	Ca %	Sr %	Zr %	Ag %	Cd %	Sn %
Value	<0.0010	0.0524	0.107	0.0184	0.0114	0.00096	<0.0001	<0.0003	<0.0001	<0.0001	0.0134

	Bi %	Pb %	Hg %	La %	Al %	Ga %
Value	<0.0010	0.0234	<0.0020	<0.0005	97.6	0.0129

Figure 1: Typical composition of aluminum alloy 6061

Table 1: Mechanical Properties

Property	Magnitude
Ultimate tensile Strength	110-152 (Mpa)
0.2% proof stress	65-110(Mpa)
Brinell Hardness	30-33
Elongation 50mm dia (%)	14-16

III. EXPERIMENT AND RESULT

The base material used in this study was aluminum alloy Al 6061 plates thickness of 5 mm. Aluminum alloys 6061 is one of the most extensively used of the 6xxx series aluminum alloys. It is a heat treatable extruded alloy with medium to high strength capabilities. Aluminum 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 figure-1. Mechanical and physical properties are given in Tables -1 respectively. The Al-6xxx are aluminum/magnesium/silicon alloys (magnesium and silicon additions of around 1.0%) and are found widely throughout the welding fabrication industry ,used predominantly in the form of extrusions and incorporated in many structural components. It is typically used in Architectural applications, ship vessels, aircrafts, extrusions, window doors and shop fittings.

AA-6061 as fabricated posses
(i). Workability – Cold: Good
(ii). Machinability: Acceptable

IV. TOOL DESCRIPTION

Tool geometry is the mainly dominant aspect of process development. The tool geometry plays a critical role in movement of material and in turn provides the traverse rate at which FSW can be conducted. An FSW tool consists of a pin and shoulder. As said earlier, two primary functions of tool are: (a) Localized heating, and (b) Material flow. In the initial stage of tool thrust, the heating results first and foremost from the friction between pin and work piece. An additional heating results from deformation of material. The tool is plunged till the shoulder enters the work piece. The friction between the shoulder and work piece results in the biggest component of heating. From the heating aspect, the relative size of pin and shoulder is important, and the other design features are not critical. The shoulder also provides confinement for the heated volume of material. The second function of the tool is to 'stir' and 'move' the material with increasing experience and some improvement in understanding of material flow; the tool geometry has evolved significantly.

V. CONCAVE SHOULDERED TOOL

Complex features have been added to alter material flow, mixing and reduce process loads. The design features of the concave shoulder of concentric circles tapered pin with three slots is used to (a) reduce welding force, (b) enable easier flow of plasticized material, and (c) increase the interface between the pin and the plasticized material, thereby increasing heat generation. It has been demonstrated that aluminum plates with a thickness of up to 50 mm can be successfully friction stir welded in one pass using this tool. This shoulder profile improves the coupling between the tool shoulder and the work pieces by entrapping plasticized material within special re-entrant features. This tool is designed on Lathe, CNC and CNC milling machine. The tool profile design is shown in fig2. The tool specifications are given below in the table .2.

Table 2: Concave shouldered tool specifications

Specifications	Magnitude
Tool Material	H13
Length Of Tool	100mm
Tool Shoulder Diameter	24mm
Pin diameter with taper section	9mm-6mm
Pin length	4.6mm
Concave angle	8 degrees
Taper angle	18 degrees

Figure 2: Concave shouldered tool profile design

VI. WELDNG PROCESSES

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FSW is a solid state joining process carried out on a vertical milling machine. The plates to be welded are initially cut to the required dimensions, a clamping system must keep the work-pieces rigidly fixed using fixtures onto a backing bar to prevent the abutting joint faces as shown in fig.4.Prior to welding initially a hole is made using a drill bit that is fixed in the tool holder then the drill bit in the tool holder is replaced with the weld tool. Then the shouldered pin is made to rotate at constant speed and plunged into the joint line between the two metal sheets butted together. Once the tool probe has been completely inserted, the shoulder base will be in contact with the base metal surface so that it can take part in heating the metal surface for proper weld to occur. It is moved at constant advancing velocity along the welding line while rotating. There are two tool speeds to be considered in friction stir welding how fast the tool rotates and how quickly it traverse the interface. These two parameters have considerable importance and must be chosen with care to ensure a successful and efficient welding cycle

Due to the rotation and the advancing motion of the pin , the material close to the tool ,in the so called stir-zone ,is softened by the heat generated by the plastic dissipation(stirring effect) and the heat induced by the contact friction between the probe, shoulders and the sheet. As a consequence, the material is stretched and forged around the rotating probe flowing from the advancing side to the retreating side of the weld, where it can rapidly cool down and consolidate, to create a high quality solid-state weld. By using the tool with profile of concave shoulder of concentric circles with tapered pin of three slots giving maximum rotation speed and high feed rate are conducted initially.

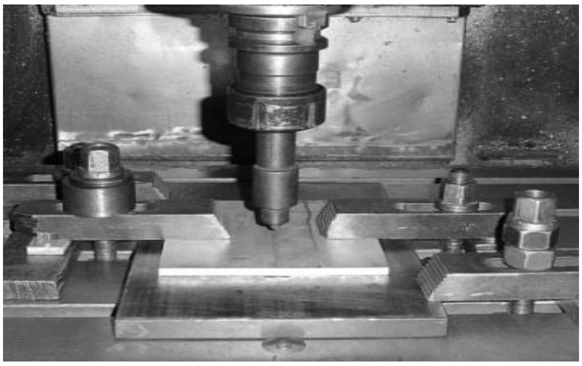

Figure 3: Clamping fixture of FSW

The welding speed and feed combinations are 1400 rpm and 100mm/min. By using this combination maximum strength is obtained and the weld specimen

Figure 4 FSW Rotational speed 1400rev/min and transverse speed 100mm/min

By using the same tool profile and giving high speed and low feed the material is deviated from the normal surface (weld zone) is treated as failure specimen. The welding speed and feed combinations are 710 rpm and 25mm/min. The failure specimen is shown below

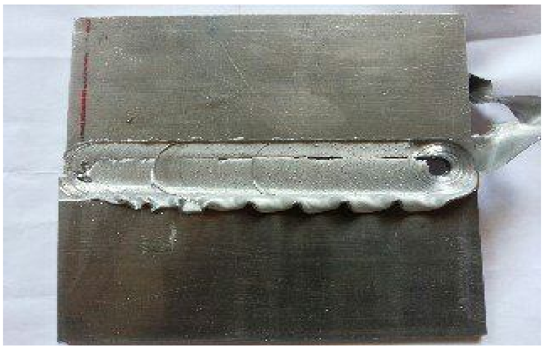

Figure 5 Failure specimen Rotational speed 710rev/min and Transverse speed 25mm/min

Further by using a tool profile with flat shouldered tapered pin by using the combination of welding speed welding speed 710rpm and feed 63mm/min hardness is increased but the strength is decreased. The obtained weld specimen is shown below.

Figure 1 Rotational speed 710 rev/min and Transverse speed 63mm/min

VII. EXPERIMENTAL RESULTS

Testing is carried out on weld specimens, the results obtained from which the optimum values of speed and feed are defined for the specimen having good weld and mechanical properties. The weld obtained is tested for its different mechanical properties as:

1. Hardness test (Rockwell)
2. Tensile strength test

Figure 7: Test specimens before and after tensile test

A. Hardness Test

The hardness results are obtained for concave shouldered tool and flat shouldered tool show differences between their values. The values obtained for concave shouldered tool with high rotational speed and less transverse speed are better when compared with flat shouldered tool. The hardness of the concave shouldered tool are very close to the base metal hardness i.e. (Al-6061) where as the hardness for flat shouldered tool are very less i.e. the values are much deviated from the base metal hardness . The hardness at the weld zone even depends on the weld speeds and feeds.

1. For concave shouldered tool at rotational speed 1400rev/min and transverse speed 25mm/min the maximum hardness value obtained is 37 HRB.
2. At rotational speed 1400rev/min and transverse speed 100mm/min the hardness value obtained is 32 HRB.
3. At rotational speed 710rev/min and transverse speed 63mm/min the hardness value obtained is 30 HRB.
4. For flat shouldered tool at rotational speed 710rev/min and transverse speed 63mm/min the hardness value obtained is 30 HRB

B. Tensile strength

Tensile strength is the main characteristic considered in this work described in the quality of friction stir welding joint From the results obtained it has been analyzed that for the concave tool welds the better weld joint is achieved at 1400 rpm and 100 mm/min. Regardless of welding conditions, the welds analyzed in this work were successfully jointed and showed no porosity and defects in both weld top and root surfaces the aspect of the weld roots and crowns is shown in for welds produced with concave tool and flat tool as it can be seen

Table 3: Table for Hardness and Tensile strength.

Specimen. no	Welding speed (rpm)	Feed (mm/min)	H R B	Tensile strength (M pa)	% of Elongation
1	1400	100	32	188.198	6.4
2	1400	25	37	128.88	5.85
3	710	63	30	179.171	11.16

CONCLUSION

It was concluded that the differences in tool geometry and welding parameters induced significant changes in the material flow path during welding in weld nugget. The different mechanical properties of the weld obtained like hardness and tensile strength is observed to be greatly influenced by two parameters one the rotation of the tool and second the weld speed. It is observed that observed now that by varying these two parameters the strength of the joint can be varied and optimized .It is also seen that the friction stir welding may also depend upon many other factors like the material used for tool and base metal, indentation force, tool geometry, rigidity of the machine and other miscellaneous parameters. After FSW operations carried on and then considering the all above terms, the better values obtained for hardens test, tensile test constituting specific speed and feed are like

1. FSW weld at speed 1400 rpm and feed 100 mm/min has good strength property.
2. FSW weld at speed 710 rpm and feed 63mm/min has good elongation.

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