Mechanical Characteristics of Friction Stir Welding Joints of AA 6063

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ABSTRACT

Friction Stir welding (FSW) is a joining technique which generates high strength and quality weld with less distortion in solid state. A spinning tool bit which is non-consumable is inserted into material. The rotating tool produces friction which heats the material to plastic state which creates heat affected zone around the tool. Enhancement of Temperature and high speed rotation of tool make joint between two plates. The FSW process is applied in various industries like fabrication, automotive, marine, rail and also in aerospace to join different alloys of aluminum, copper and magnesium. The purpose of the study is to examine the effect of different rotating speeds of WPS material tool on the weld quality of Aluminum Alloy 6063. This studies intent to evaluate mechanical properties of weld during FSW process. The mechanical properties of FSW AA6063 will be measured by various mechanical tests.

Keywords/ Index Term— Friction Stir Welding, Welding Purpose Steel.

1. INTRODUCTION

Friction Stir Welding is a new welding technique for aluminum alloys invented by The Welding Institute, Cambridge, U.K. in 1991. This technique uses a non-consumable steel welding tool to generate frictional heating at the point of welding and to induce gross plastic deformation of work piece material while the material is in a solid phase, resulting in complex mixing across the joint. A detailed account of the process has been provided by others. Although Friction Stir Welding can be used to join a number of materials, the primary research and industrial interest has been to join aluminum alloys.

Defect-free weld with good mechanical properties have been made in a wide variety of aluminum alloys, even those previously thought to be "unweldable", in thicknesses from less than 1mm to more than 35mm. In addition, friction stir welds can be accomplished in any position. Clearly, friction stir welding is a valuable new technique for butt and lap joint welding aluminum alloys. The goals of the FSW program were 1st to produce welds with equivalent strength and increase ductility compared to conventional arc welding, then to fabricate and test ballistic weld samples. Work in this program involved using a thermal model to initially predict the FSW tool geometry and welding parameters. The model data were used to develop a statically designed experiment to further refine the welding parameters needed to produce the desired results. Work from this program produced friction stir welds with similar strength to gas metal arc welds (26psi yield strength and 43psi tensile strength), but significantly higher ductility (11% vs. 58% elongation). Using the development process parameters, butt joint weld sample plates were fabricated and successfully passed ballistic weld shock test requirement.

Friction stir welding technology has been demonstrated to produce very good and sound joints especially in the applications for light alloys. Based on friction heating at the faying surfaces of two sheets to be joined, in the FSW process a tool with a specially designed rotating probe travels down the length of contacting metal plates, producing a highly plastically deformed zone through the associated stirring action. The localized thermo-mechanical affected zone is produced by friction between the tool shoulder and the plate top surface, as well as plastic deformation of the material in contact with the tool occurs.

2. PRINCIPLE OF OPERATION

A Schematic diagram of the FSW process:

(A) Two discrete metal work pieces butted together, along with the tool (with a probe).

(B) The progress of the tool through the joint, also showing the weld zone and the region affected by the tool shoulder.

In FSW, a cylindrical-shouldered tool, with a profiled threaded/unthreaded probe (nib or pin) is rotated at a constant speed and fed at a constant traverse rate into the joint line between two pieces of sheet or plate material, which are butted together. The parts have 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 nib is slightly less than the weld depth required and the tool shoulder should be in intimate contact with the work surface. The nib is then moved against the work, or vice versa.

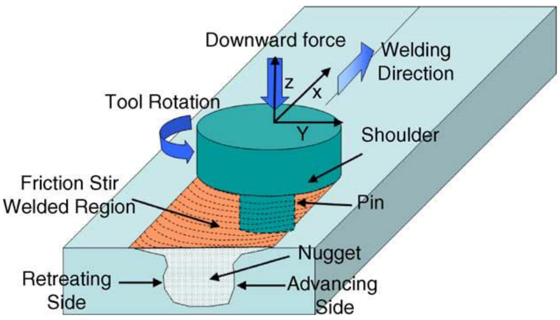

Fig-1: Principle of FSW

Frictional heat is generated between the wear-resistant welding tool shoulder and nib, and the material of the work pieces. This heat, along with the heat generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without reaching the melting point (hence cited a solid-state process), allowing the traversing of the tool along the weld line in a plasticized tubular shaft of metal.

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 while 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.

3. DEVELOPMENT OF TOOL AND FIXTURES

3.1. Development of Tool

A novel pin is design for a friction stir welding (FSW) tool that can penetrate more deeply into work pieces to form a thicker weld joint without overloading the tool. The pin is provided with cylindrical taper, square and triangle on its surface. When the pin is rotated and driven into work pieces under an applied vertical load, the penetration of the pin into the work pieces and shearing of work piece material into particles. The pin diameter is decreased from its proximal end to its distal end, either discretely in steps or linearly in a tapering manner. The reducing profile of the pin further eases penetration of the pin into work pieces, and also reduces the amount of transverse welding load required to traverse the pin along the weld interface. Cylindrical taper type of pin profile tool has been used to perform the experiment.

Material of Tool is Welding Purpose Steel and its details given below:

Hardening Temperature (cold Work)	**= 880°C**
Quenching medium	**= Meta Quench Oil**
Tempering Temperature	**= 150°C**
Brinell hardness	**= 60 HRC**

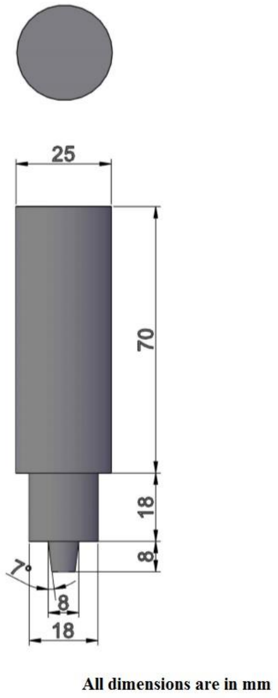

Fig-2: Diagram of Welding Tool

TABLE-I

CHEMICAL COMPOSITION OF WPS

ELEMENT	% PRESENT
SILICON	0.3 TO 0.4%
CARBON	1.8 TO 2.1%
MANGANESE	0.3 TO 0.4%
CHROMIUM	11.8 TO 12.2%
IRON	Balanced

3.2. Development of Jigs and Fixtures

A fixture is a device for locating, holding and supporting a work piece during a manufacturing operation. Fixtures are essential elements of production processes as they are required in most of the automated manufacturing, inspection, and assembly operations. Fixtures must correctly locate a work piece in a given orientation with respect to a cutting tool or measuring device, or with respect to another component, as for instance in assembly or welding. Such location must be invariant in the sense that the devices must clamp and secure the work piece in that location for the particular processing operation.

Fixtures are normally designed for a definite operation to process a specific work piece and are designed and manufactured individually. The following design criteria must be observed during the procedure of fixture design:

1) Design specifications
2) Factory standards
3) Ease of use and safety
4) Economy

From the force calculation design of jigs and fixtures have been carried out and dimensions are found as shown in fig.3 and fig.4.

- **Fixture material- M.S FLAT PLATE**
- **Machining processes- Milling, Drilling**
- **Manufacturing of Fixture**

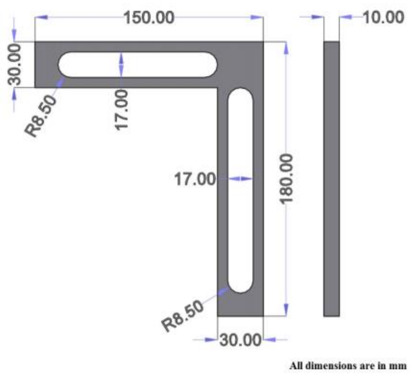

Fig-3: Diagram of Jigs

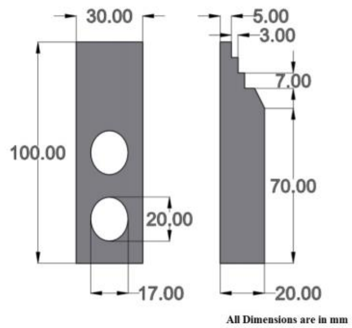

Fig-4: Fixtures

TABLE-II

CHEMICAL COMPOSITION OF MS

ELEMENT	% PRESENT
CARBON	0.16 to 0.18%
SILICON	0.40% Max
MANGANESE	0.70 to 0.90%
SULPHUR	0.040%Max
PHOSPHORUS	0.040%Max

4. COMPONENTS FOR FSW

FSW mainly four components are used:

1. Tool
2. Jigs and Fixtures

3. Plates
4. Milling machine

4.1. Tool

The design parameters of tool are on basis of thickness, properties of plates. The tool shape and size which are compatible for weld, is manufactured on Lathe machine which fulfilled requirement of welding procedure. The upper portion of tool is used for gripping in chuck of milling machine and also can be rotated at required speed. The design of probe is such that it can be easily inserted with high rotation into plate and can make compact weld. FSW tool has been manufactured as shown in fig.5 below.

Fig-5: FSW Tool

4.2. Tool Jigs &Fixtures

The tool will rotate at high speed so there are chances of misplacement of plates and quality reduction. The main purpose of making Jig and Fixtures is to give sufficient grip and support to welding plates and keep plates align. In manufacturing of Jigs and Fixtures different types of machines are used like Drilling Machine, Shaping Machine and Hacksaw machine. The slots in Jigs and Fixtures are for bolts and nuts. As per parameters, jigs and fixtures have been manufactured as shown in fig. 6 and fig.7.

Fig-6: Jig

Fig-7: Fixtures

4.3 Plates

Plates are being welded on milling machine with the help of tool. AA6063 are the plates which are used for FSW process. These plates are having lesser melting temperature than tool. These plates are used door frames, window frames, roofs, pipe and tubing and also in architectural fabrication. It has good weld ability and heat ability. AA6063 plates contain below elements.

TABLE-III

CHEMICAL COMPOSITION OF AA-6063

Element	**% Present**	
	MIN	MAX
Silicon	0.2%	0.6%
Iron	No Minimum	0.35%
Copper	No Minimum	0.10%
Manganese	No Minimum	0.10%
Magnesium	0.45%	0.9%
Chromium	No Minimum	0.10%
Zinc	No Minimum	0.10%

Titanium	No Minimum	0.10%
Other Elements	0.05%	0.15%
Aluminium	Balanced	

Fig-8: AA 6063 Plates

4.4 Milling machine

The essential part in FSW is milling machine. The weld quality is depended on mainly speed and feed rate of milling machine. Plates which are used in FSW may have more thickness so machine should have wide range of speeds. Automatic milling machines give accuracy in alignment during welding rather than manual milling machine gives. Vertical milling machine as shown in fig.9 was used for welding process.

Fig-9: Milling Machine

4.5 Machining Process of AA6063 Plates

The main part of the project is to produce weld with help of WPS Tool on AA6063 plates by Friction. Tool is now hard enough to produce weld by Heat Treatment Process. In this process tool is rotated at high speed on milling machine.

Plates are rigidly attached on the bed of milling machine by Jigs & Fixtures. These Jigs &Fixtures have holes (specified diameter) to clamp on bed. Bolts and nuts are used to clamp clamping devices.

Before starting of welding, tool and plates are aligned with each other perpendicular. The axis of tool and clamped plates must be intersecting before rotation as shown in fig.9.

Fig-10: Arrangements for Friction Stir Welding

After finishing welding of AA6063, Project leads to experimental investigation of Mechanical Properties. For that several tests have been done as follows:

1. Tensile strength test:

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces.

2. Bending strength test:

Bend tests deform the test material at the midpoint causing a concave surface or a bend to form without the occurrence of fracture and are material. Typically this test is performed to determine the ductility or resistance to fracture of that material.

3. Hardness test

Hardness is defined as "Resistance of metal to plastic deformation, usually by indentation. However, the term may also refer to stiffness or temper or to resistance to scratching, abrasion, or cutting. It is the property of a metal, which gives it the ability to resist being permanently, deformed (bent, broken, or have its shape changed), when a load is applied.

The greater the hardness of the metal, the greater resistance it has to deformation.

5. CONCLUSIONS

It can be observed from test that ultimate tensile strength is 107.59 MPa and hardness is 48.7 HBW. Bend test result was not up to mark as minor crack was observed during bend test. But this can be improved by changing tool tip angle.

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BIOGRAPHICAL NOTES

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