EFFECT OF FSW PROCESS PARAMETERS ON DISSIMILAR METALS WELDING OF Al6061 TO PURE TITANIUM

Tushar M. Thakar[1], Mr. Kapil Banker[2], Mr. Sandip B. Patel[3]
[1]Student, M.E., Production Engineering, MEC Basna, Gujarat, India.
[2,3]Assist. Professor, Mechanical Dept., SVBIT Vasna, Gujarat, India

Abstract: Today, the engineers are increasingly faced with the challenge to join dissimilar materials as they are seeking to create new structures or machine parts. Joining dissimilar materials is often more difficult than joining the same material or alloys with minor differences in composition; however, many dissimilar materials can be joined successfully with the appropriate joining process and specialized procedures in present date. Friction Stir Welding (FSW) is such process being used to join dissimilar materials including metals, alloys and polymers. There has been continuous research on parametric optimization and effects of process parameters on the properties of the welded joint of various processes for joining dissimilar materials. This thesis focuses on the welding of a selected dissimilar metal pair and a few important parameters of FSW. The metal pair and its size would be kept constant and experiments would be done keeping in mind three important parameters of both processes. The welded joint will then be tested for hardness, tensile strength and certain metallographic tests by using Optical Microscopy to compile the conclusions obtained after experimental runs.
Keywords: FSW, Dissimilar Metals, Welding Parameters, Post weld tests.

I. INTRODUCTION

Friction-stir welding (FSW)(1) is a solid-state joining process (the metal is not melted) that uses a third body tool to join two facing metals surfaces. It was invented and experimentally proven at The Welding Institute (TWI) United Kingdom in 1991. In this process, heat is generated between the tool and material which leads to a very soft region near the FSW tool. It then mechanically intermixes the two pieces of metal at the place of the joint, then the softened metal (due to the elevated temperature) can be joined using mechanical pressure (which is applied by the tool), much like joining clay. The FSW tool rotates in the counterclockwise direction and travels into the page (or left to right). In Fig 1. the advancing side is on the right, where having the hard material and the tool rotation direction is the same as the tool travel direction (opposite the direction of metal flow). A constantly rotated non consumable cylindrical-shouldered tool with a profiled probe (Taper) is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The probe is shorter than the weld depth required, with the tool shoulder riding atop the work surface. The basic working principle of FSW is shown in the Fig. 2 below.

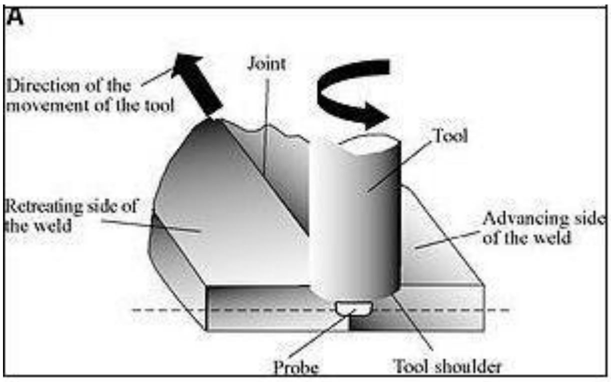

Fig. 1 Two discrete metal pieces are butted together along with the tool

Frictional heat is generated between the welding components and the work pieces. It generated by the mechanical mixing process and the adiabatic heat within the material, cause the stirred materials to soften without melting. The process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in solid state deformation involving dynamic recrystallization of the base material.

The system divides the weld zone into distinct regions, as follows:

• Unaffected material or parent metal: This is material remote from the weld that has not been deformed and that, although it may have experienced a thermal cycle from the weld, is not affected by the heat in terms of micro - structure or mechanical properties.

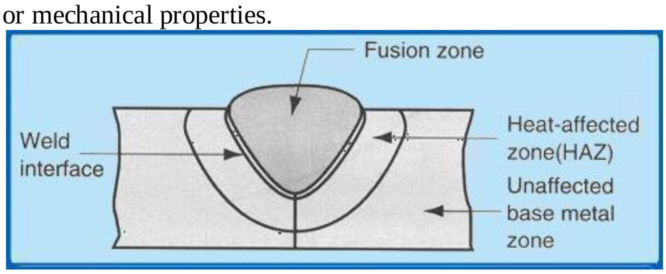

Fig. 2 Different zones of a welded joint
(Source: http://nptel.ac.in/courses/112101005/22)

Heat-affected zone: In this region, which lies closer to the weld-center, the material has experienced a thermal cycle that has modified the microstructure and/or the mechanical properties. However, there is no plastic deformation occurring in this area.

Thermo-mechanically affected zone (TMAZ): In this region, the FSW tool has plastically deformed the material, and the heat from the process will also have exerted some influence on the material. In the case of aluminum, it is possible to

obtain significant plastic strain without recrystallization in this region, and there is generally a distinct boundary be - tween the recrystallized zone (weld nugget) and the deformed zones of the TMAZ.
Weld nugget: The fully recrystallized area, sometimes called the stir zone, refers to the zone previously occupied by the tool pin. The term stir zone is commonly used in friction stir processing, where large volumes of material are processed.

II. TOOL DESIGN AND MATERIAL

De et al .(6) (2011) Investigated here they examined of FSW tools such as tool material selection, size and shape, mechanisms of tool. A friction stir welding (FSW) 1–5 tool is obviously a critical component to the success of the process. The tool typically consists of a rotating round shoulder and a threaded cylindrical pin that heats the workpiece due to friction, and moves around at soft material it to form the joint. In this they investigated such various tools materials for different workpiece materials. According to that for Ti alloys mostly the tool materials are used as PCBN, WC, W-Rh etc. For the hard materials they are used as mostly Tungsten Carbide material having good tool life.
As the review of Literature survey, the selected tool material is WC(89-91%) – CO(9-11%) which having the dimensions as follows:

Table 2 Tool Dimensions:

Shoulder Diameter	18mm
Shoulder Length	25mm
Pin Length	3.8mm
Root Diameter	6.5mm
Tip Diameter	4mm
Pin Shape	Taper Threaded Free

As per the survey of the literature for the titanium alloy joint, its preferable tool materials are PCBN, WC alloy. The geometry of the tool was as follows:

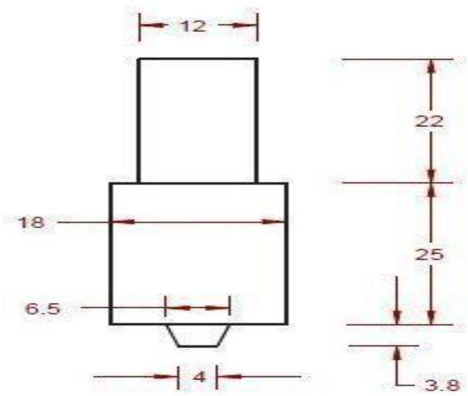

Figure Tool Design with dimensions

III. EXPERIMENTS PROCEDURES

To examine the weldability of joints, Al6061 alloy were joined to pure Ti and by FSW. The joining conditions are shown in Table 2 and a schematic diagram of FSW is shown in Fig. 1, in which the probe insert position was offset on the joint interface.

Table 2 Friction stir welding conditions.

Tool Material	WC-12%Co based alloy
Tool Rotational Speed RPM	1500, 1070, 765
Travel speed, mm/min	20, 31.5 , 50
Tilt angle, degree	1, 2, 3
Tool Offset, mm	2

alloy.This joining method was suggested by some research. In this study, the Ti alloy plate was positioned on the advancing side and the Al alloy plate was positioned on the retreating side. Square butt joints with 50 mm X 100 mm X 4.0 mm rectangular plates were used. Metallurgical investigations on a cross section of the joint were done after polishing and etching. Metallurgical investigations on a cross section of the joint were done after polishing and etching. The distribution of elements on the joint interface was examined using a optical microscopy(OM).

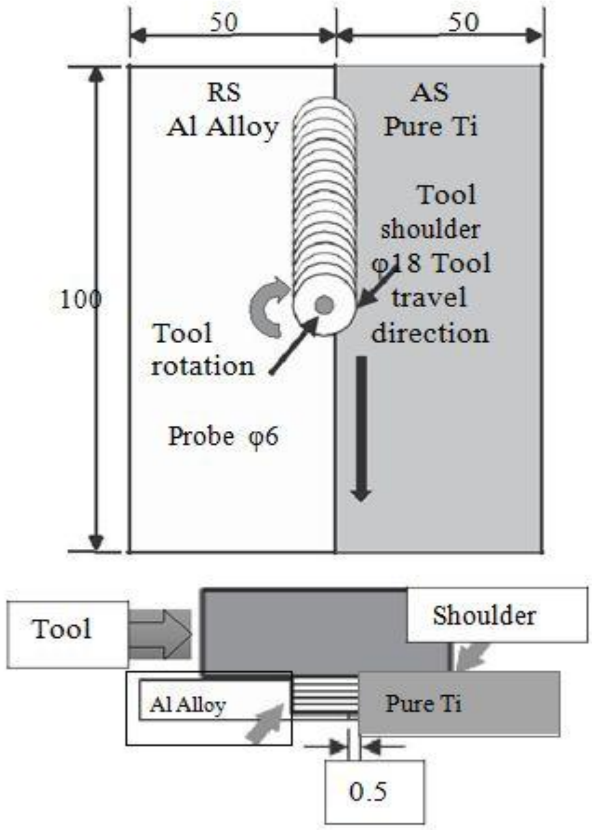

Fig. 3 Schematic diagram of friction stir welding.

were measured in tensile tests. The tensile tests were carried out at a cross-head speed of 0.5 mm/min. The shape of the tensile test specimens was rectangular and the width was 10 mm.

IV. RESULT AND DISCUSSION

Figure 4 shows the macroscopic appearance of a cross section of the joints. In observing the surface appearance of the joints, defects were observed near the groove in the Al6061/pure Ti joint at a travel speed of 20 mm/min. However, a decreasing travel speed tended to increase the width of the stir zone on the Al alloy side. The butt joint interface, which was originally straight and vertical to the plate surface, was deformed from the Ti alloy side to the Al alloy side, especially in the upper half of the plates. The temperature tends to rise near the surface of the plate beneath the rotating shoulder. Thus, the Ti alloy near the interface at the upper half of the plate is plastically deformed more easily. Cross-sectional microstructures of the joint interface of Al alloy and pure Ti joints are shown in Fig. 5. White regions are observed at the joint interface. These regions contained a mixture of pure Ti and Al alloy. The mixed regions did not cover all the joint interfaces. These regions were observed partly at the interface and many of them were observed at the upper half of the plate and at the interface. The width of the plastically deformed region near the interface of pure Ti increased with a decrease in the travel speed. No refined grains of Ti by dynamic recrystallization were observed at the joints in this study. In observing the stir zone in Al alloys by etching adapted to the microstructure of Al alloys, the grains of Al alloy in the stir zone were refined. At the Tilt Angle and Spindle speed of 30 and 1070 rpm respectively, higher tensile strength and exhibited fine grain structure as shown in Fig 6.

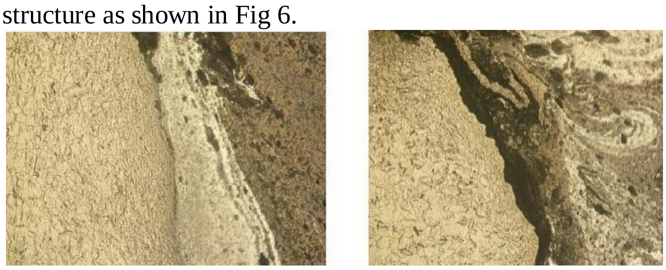

Fig 4 Microstructural Photographs At Spindle speed of 1070 rpm

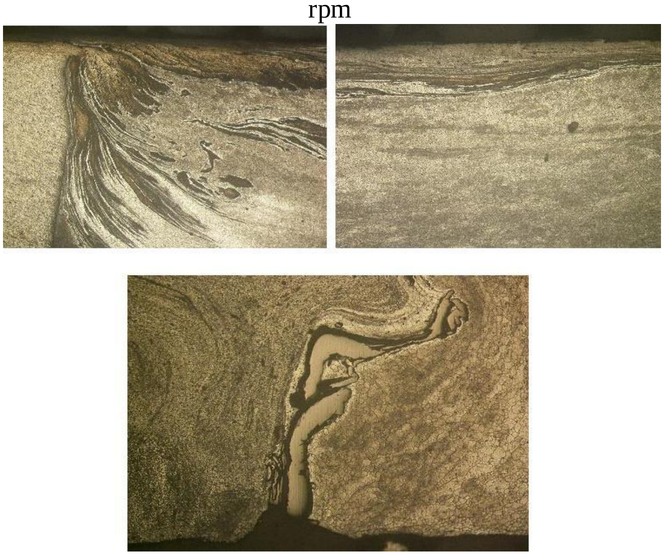

Fig 5 Microstructural Photographs At Tilt angle of 30 and At feed of 20 mm/min.

The effect of the FSW process parameters were influencing the joint efficiency and tensile strength which shown in fellow Fig 6. And Fig 7.

For the Convenience, We had considered joint efficiency and tensile strength at the speed 1070, 765 Rpm.

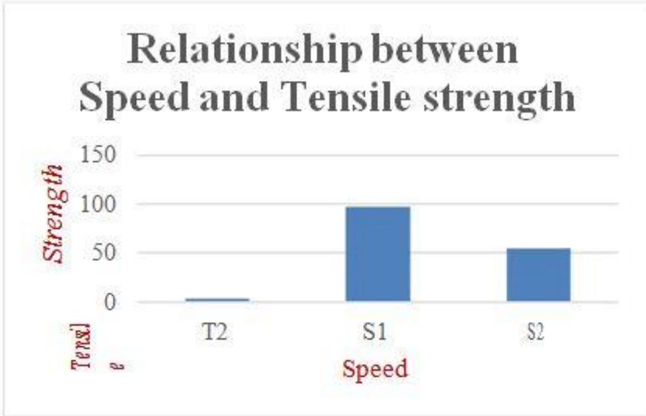

Fig: 6 Effect of Speeds on the Tensile strength

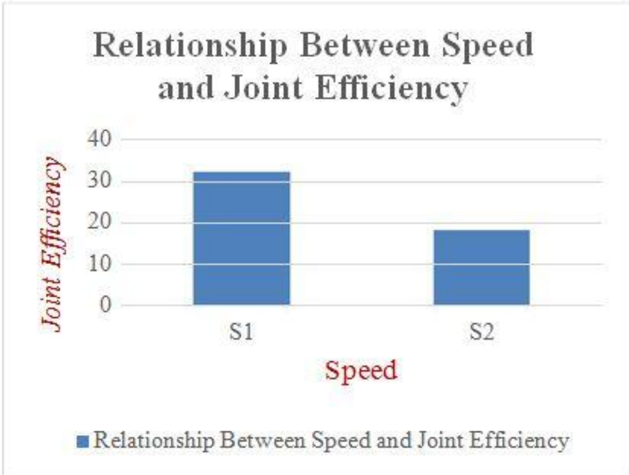

Fig: 6 Effect of Speeds on the Joint Efficiency

It is important to note that the observed trending of increasing joint strength with increasing tool speed suggests that further studies may lead to higher joint strength for the dissimilar FSW of Al6061-to-Pure Ti. However, other process parameters such as the transverse welding speed, and the position of the welded materials with respect to the tool rotation, still needs consideration. Regardless, when compared to the AA6061-Pure Ti base material, the resulting joint strength achieved in this study complies with the Specification for Friction Stir Welding of Aluminum Alloys for Aerospace Applications (AWS D17) from the American Welding Standard (AWS).

V. CONCLUSION

The objective of this work is to examine the effect of various FSW welding process parameters on the joint strength and its efficiency. The present research work investigated the welding of dissimilar metal alloys Aluminium 6061 and Pure Ti by Friction stir welding to produce butt joints for 4mm thickness plates. After the experimentations and the two different tests conducted, following conclusions have been arrived at –

- The tensile strength, % elongation and the joint efficiency vary with various Process parameters varies. As the observed various results, Spindle speed, Feed And Tilt angle were affected the FSW process.
- At the 1070 R.P.M speed, Tensile strength(97.9 MPa) and % Elongation (2.20) were higher compare another to two speeds. Joint Efficiency also was higher at this Speed.
- Effect of Feed at 31.5 mm/min also affect the tensile strength, % elongation and joint efficiency. At the 30 tilt angle having higher tensile strength and elongation.
- The Micro-Examination study reveals the embrittlement of the weld interface, Especially on the Al Side for the FSW process . It shows the Ti particles have been scratched in to Aluminium6061 matrix.
- The overall parametric study for this process for dissimilar materials and constant material size indicates that the FSW welded joint is more preferable than solid state joining process for the industrial applications requiring higher strength.

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