

Experimental study on friction stir welding of aluminum alloys (aa6063)

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ABSTRACT

Friction stir Welding is used as a solid state joining process for soft materials such as aluminum alloys and also for hard materials like steels because it avoids many of the common problems obtained in fusion welding. In fact, joining of aluminum alloys could be usually faced problems in many cases including automotive, aerospace, ship building industries, electronics etc. where fusion welding is not possible due to large difference in physical and chemical properties of the components to be joined. Problems including porosity formation, solidification cracking, and chemical reaction may arise during fusion welding of dissimilar materials although sound welds may be obtained in some limited cases with special attentions to the joint design and preparation, process parameters and filler metals. In contrast, friction stir welding (FSW) seems to be a very reliable technique as it permits welding of aluminum alloys while avoiding the drawbacks of fusion welding. Also it is very beneficial for minimizing the health defects observed during traditional welding methods or fusion welding. It helps to avoid production of ultraviolet rays which are harmful to human beings. Also the gases produced in the process. Products of aluminum alloys produced in the process have been becoming increasingly significant in industrial applications because of their technical and economic benefits. This paper includes mainly tool material selection and process parameters. The tool material selection depends on the operational parameters such as temperature of the operation, wear resistance, geometry and load bearing ability also the tool degradation process. Tool design is important because our target is not only the material removing from the metal but also the material heating and mixing by frictional heat. Also tool must be meet several important requirements. The paper shows that various types of tool geometries and importance of tools for friction stir welding of AA6063 with this article. It also shows the operational parameter selection as per the specimen size which can be used for the process.

Keywords— Friction Stir welding, Temperature, Tool Material, Tool geometry.

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I. INTRODUCTION

Friction stir welding (FSW) is a solid state joining technique that was invented at The Welding Institute (TWI), United Kingdom in 1991 and has found applications in a wide variety of industries, including aerospace, automotive, railway and marine. It is an alternative welding technology process to fusion welding. A defining characteristic of FSW

is that the joint is created by a cylindrical rotating tool, mechanically traversed through the materials. Frictional heat is generated between the wear-resistant welding tool shoulder and pin, and the material of the work-pieces. The frictional heat and surrounding temperature causes the stirred materials to be softened and mixed [1].

FSW is considered to be the most significant development in metal joining. As compared to the conventional welding methods, FSW consumes considerably less energy. No gas or flux is used, thereby making the process environmentally. The joining does not involve any use of filler metal and therefore any aluminium alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding. When desirable, dissimilar aluminium alloys and composites can be joined [2].

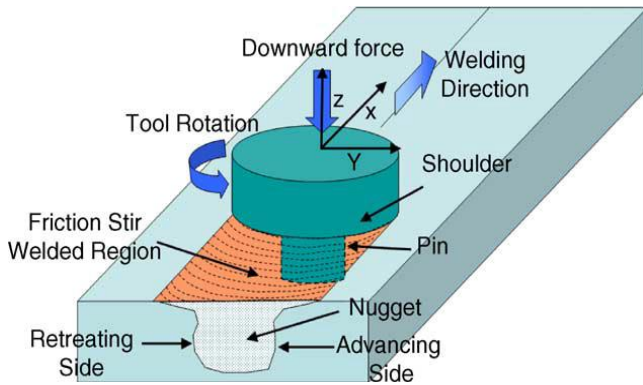


Figure 1: Schematic Diagram of Friction Stir Welding [2]

This joining process involves rotating tool consisting of a shoulder and probe. The shoulder of the tool applies a downward pressure on the workpiece surface which plastics material around the probe as shown in figure 1. And generates the heat through the friction and causes the plastic deformation in a relatively thin layer under the bottom surface of shoulder.

II. LITERATURE REVIEW

This section presents the detailed literature review of the friction stir welding; process, experimental parameter study of aluminium and its alloys. M.K. Sued, D. Pons, J. Lavroff, E.H. Wong gives the design features for bobbin friction stir welding tools; Development of a conceptual model linking the underlying physics to the production process. The effects of different pin features and dimensions of scrolled shoulder bobbin friction stir welding were tested for welding marine grade aluminium, Al6082-T6[1]. R.S. Mishra and Z.Y. Maworks on Friction stir welding and processing with all sense, mainly on the process parameters of FSW. The article includes:(a) Mechanisms responsible for the formation of welds and microstructural refinement, and (b) effects of FSW/FSP parameters on resultant microstructure and final mechanical properties. While the bulk of the information is related to processing on the aluminium alloys[2]. KudzanayiChiteka, explains the process of Friction Stir Welding/Processing Tool Materials and Selection and also selection of friction stir welding/processing(FSW/P) tool material has become an important task which determines the quality of the weld produced[3]. R. Rai, A. De, H.K.D.H. Bhadeshia and T. DebRoy done the Review on Friction Stir Welding Tools, Science and Technology of Welding and joining which gives the information about the feasibility of the FSW process for harder alloys such as steels and titanium alloys awaits the development of cost effective and durable tools which lead to structurally sound welds consistently[4].

Y. N. Zhang, X. Cao, S. Larose and P. Wanjara, done the Review of tools for friction stir welding and processing, in this review the FSW/P tools are briefly summarised in terms of the tool types, shapes, dimensions, materials and wear behaviours[5].

From this literature review, the FSW of aluminium alloys are selected for the study of experimental parameters. And also the parameters are selected for the process and we will experiment it on conventional milling machine with keep in mind that cost reduction and also successful welding operation can be done. The selected aluminium alloy (AA6063) is taken in the form of plates having thickness of 10 mm and conduct the number of trials and get the results.

III. EXPERIMENTATION

In the part of experimentation various types of steps or parts are included as:

A. Selection of material

In the process of friction stir welding the material selection is basic part. From the literature review, there are large number of materials were used for this process. From the various alloys of aluminium the AA6063 is selected. It is available in the round bars and sheets also. As per the availability of the material in the market, we select the desired aluminium alloy i.e. AA6063 with 10mm thickness. The long strips of AA6063 were bought and cut it as per the various sizes of various dimensions as per the setup requirement.

Also in part of material selection one more selection is important for the process is the tool material selection. It is very important parameter for the process. While selection of the tool material we have to consider the effects observed on the tool during the process. Mainly we have to consider the effect of heat generation and dissipation on the tool material. To produce good quality of weld, it is required that the tool material is to be select properly. There are various characteristics of the material which can be choose as the tool material are as:

- Resistance to wear.
- No harmful reactions with the weld material.
- Good strength, dimensional stability & creep resistance.
- Good thermal fatigue strength to resist repeated thermal cycles.
- Low coefficient of thermal expansion.
- Good machinability.

There are various suitable tool materials used for this process are as:

TABLE I

TOOL MATERIALS AND SUITABLE WELD METALS[3]

Sr. No.	Tool Material	Suitable Weld Material
1	Tool steels	Al alloys, copper alloys
2	WC -Co	Aluminum alloys, mild steel
3	Ni-Alloys	Copper alloys

4	WC composite	Aluminum alloys, low alloy steel and magnesium alloys, Ti-alloys
5	W-alloys	Titanium alloys, stainless steel and copper alloys
6	PCBN	Copper alloys, stainless steels and nickel alloys

With considering various parameters and properties discussed above the Tool steel is selected as a tool material. And experiment is carried out.

B. Selection of the Tool

The tool used in the process consists of a pin or probe and a shoulder. The pin of the tool is in contact with workpiece creates frictional and deformational heating and softens the work piece material. The shoulder of the tool contacts to the workpiece increases heats the workpiece, expands the zone of softened material, and constrains the deformed material.

The probe of the tool can produce deformational and frictional heating. The deformation depth and tool travel speed are mainly governed by the probe. Fig. 2 summarizes the probe shapes and their main features. The end shape of the probe is either flat or domed. The flat bottom probe design and manufacture is currently the most commonly used form. The main disadvantage of the flat probe is the high force during plunging. In contrast, a round or domed end shape can reduce the forge force and tool wear upon plunging, increase tool life by eliminating local stress concentration and improve the quality of the weld root directly at the bottom of the probe.

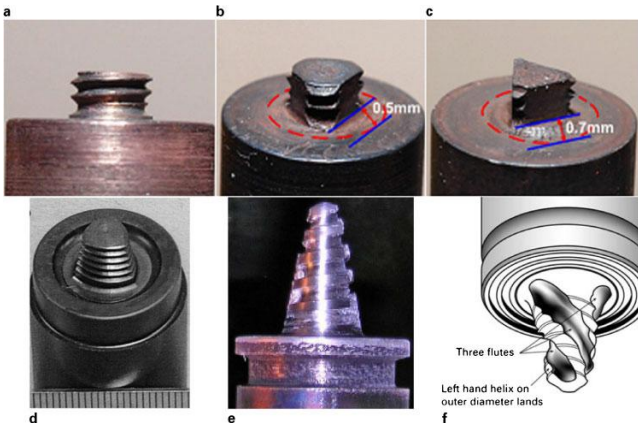


Figure 2: Commonly used tool pin geometries(a. Cylindrical Threaded, b. Three Flat Threaded, c. Traingular, d. Trivex, e. Threaded Conical, f. Triflute)

From the review of the various tool shapes and structures given in the fig. 2 we have to select the proper geometry of the tool with respect to the material of workpiece and operational parameters. We select the cylindrical threaded tool for FSW as shown in figure 3.



Threaded pin

Figure 3: FSW Tool

The cylindrical threaded tool is selected for the process and its dimensions are selected as shown in table II. The parameters of the tool dimensions and the process are selected with the help of some literature and trial and error method.

TABLE II

FSW TOOL DETAILS

Tool Material	HSS
Shoulder Diameter (mm)	20mm
Tool Pin Profile	Threaded Cylindrical Pin
Threading of the pin	M 12×1.75
Pin Diameter (major) (mm)	11.90 mm
Pin Diameter (minor) (mm)	9.95 mm
Pin Length (mm)	7.4 mm

IV. TESTING

For the testing of desired material i.e. AA6063 and selected tool; the test setup is constructed. The two plates of AA6063 are selected and sample pieces are created as per the desired dimensions. (we take 50×150 mm plate of having 10 mm thickness.) The test set up is as:



Tool Shoulder

Figure 4: Experimental Setup for Friction Stir Welding

In a testing part of the tool and operation of FSW, we select some operational parameters for the testing. For example given in the Table III. In this trial we take the two parameters of welding speed i.e. slow (0.869mm/min) and fast (1.65mm/min). With these two different speeds we get the welded joints as shown in figure 5.

TABLE III

FSW PROCESS PARAMETERS

Parameter Name	Value
Tool Rotational Speed (rpm)	720
Welding Speed (mm/min)	0.869, 1.65
Quill speed (mm/rev)	1

We select the parameter for the process as shown in table III for experimentation to check out the welding between the two plates of aluminium alloy (AA6063). The welding joint carried out on the conventional milling machine by doing some necessary attachment as shown in figure 4.

V. EXPERIMENTAL OUTCOME

After the conducting the experimentation of the friction stir welding of plates of AA6063 the two plates were joined successfully. This experimentation carried out with some results those are discussed in following sections. The welding joint is obtained as per shown in figure 5.



Figure 5: Welding joint of AA6063

VI. RESULT AND DISCUSSION

The pin diameter and shoulder diameter increased with the increment in thickness of the plates for good result of the welding process.

And the speed of the tool is one more important parameter to be selected for this process. It is selected as per the thickness of the plates and diameter of the tool. Also suitable higher speed helps to generate higher temperature which is important requirement for the FSW process.

Also for the effective welding process the suitable higher temperature should be created during the process, so that weld quality is to be increased. The higher speed of the tool give more better quality of the weld aesthetically. As the temperature reaches to its higher range the quality of weld is increased i.e. quality of welding is directly proportional to the temperature created during the process.

VII. LIMITATIONS

Heat affected zone is more for this process.

The tool cost of this process is increases because of one or two time use of the tool for single weld is possible and the tool must be changed for the next weld.

The energy cost for the FSW of aluminum alloys is significantly lower than that for the fusion welding processes, the process is not cost effective for the FSW of hard alloys.

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