

FRICION STIR WELDING OF AA6063- EXPERIMENTATION AND TESTING

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ABSTRACT

Generally, for joining process for soft materials such as aluminum alloys and also for hard materials like steels friction stir welding is used as it avoids many of the common problems obtained in fusion welding. Also if we go through joining of aluminum alloys could be usually faced problems in many cases available in various fields like 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. Mainly the problems occurred in the welding processes like porosity formation, solidification cracking, and chemical reaction may arise during fusion welding of dissimilar materials. Even if good welded joints may be obtained in some limited cases with special attentions to the joint design and preparation, process parameters and filler metals. For avoiding the drawbacks of fusion welding friction stir welding (FSW) seems to be a very reliable technique as it permits welding of aluminum alloys. To avoid the majorly obtained health defects observed during traditional welding methods or fusion welding it can be used. The productions of ultraviolet rays and the gases produced in the process which are harmful to human beings are minimized to large extent. The parts produced in FSW of aluminum alloys have been becoming increasingly significant in industrial applications because of their technical and economic benefits. The article contains mainly the selection of tool material and process parameters with experimentation trials of FSW of AA6063. Also this contains the large overview on tool material selection which depends on the operational parameters such as temperature of the operation, wear resistance, geometry and load bearing ability also the tool degradation process. The design of tool is very important because our target is not only the material removing from the metal but also heating and mixing the material by frictional heat. The article contains information about many numbers of tool geometries and importance of tools for friction stir welding of AA6063. And the selection of operational parameters as per the specimen size which are used for the process and the testing of joints after the welding.

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

INTRODUCTION

The process of Friction stir welding (FSW) used for joining metals parts was invented at The Welding Institute (TWI), United Kingdom in 1991 and has found applications in many number of fields like aerospace, automotive, railway and marine. Also it is considered as an alternative welding process to fusion welding. Various number of characteristic of FSW is that the joint is created by a cylindrical rotating tool, mechanically traversed through the materials to be joined. Due to frictional heat generated between the wear-resistant welding tool shoulder and pin, and the material of the work-pieces the joint is take place. Because of the frictional heat and surrounding temperature causes the stirring action material and get softened and mixed to each other [1].

It is to be considered as the most significant development in metal joining as compared to the old conventional welding methods. Actually, the FSW consumes considerably less energy. As no any gas or other flux is used, thereby making the process environmentally. Also the process of 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]

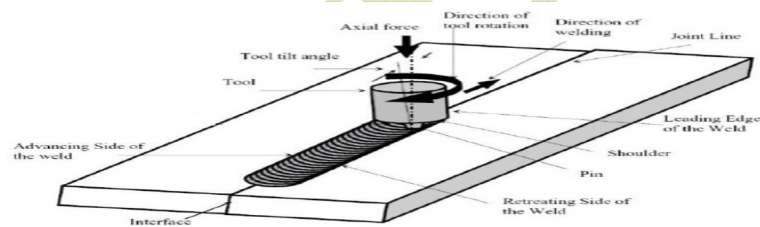


Figure 1: Schematic Diagram of Friction Stir Welding [2]

The actual process of joining involves rotating tool consisting of a shoulder and probe. The tool applies pressure on workpiece continuously through the shoulder of the tool due to which surface which plasticizes material around the probe as shown in figure 1. Due to generation of the heat through the friction and causes the plastic deformation in a relatively thin layer under the bottom surface of shoulder.

LITERATURE REVIEW

In this section the detailed literature review of the friction stir welding was done and experimentation of FSW with parametric study of aluminium and its alloy is carried out. M.K. Sued, D. Pons, J. Lavroff, E.H. Wong propose the design features for bobbin friction stir welding tools; also explains the features for bobbin friction stir welding tool and developed with linking it with physics of the process of FSW production process for obtaining the effects of bobbin friction stir welding tool having different pin structures were tested effectively [1]. R.S. Mishra and Z.Y. Maworks on worked mainly on the aluminium alloys with some process parameters also gave the main points results that, the mechanisms are responsible for the formation of welds and microstructural refinement and also effect of process parameters on the microstructure of the base metals & joints. Also a lot work had been done on the tool design parameters for FSW [2]. Kudzanayi Chiteka, explains tool material selection is an important task which helps to determine the weld quality produced. The tool material selection affects the tool operational parameters like temperature generation, speed of welding, tool wear property etc. The study gives the analysis of tool materials that can be used successfully for the process [3]. R. Rai, A. De, H.K.D.H. Bhadeshia and T. DebRoy had given the information about the feasibility of the FSW for harder alloys such as titanium,

steels etc. Also they explained that the performance of the tools are totally depends on the selection of material and also the design of the process[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. Friction stir processing (FSP), a variant of FSW, has been developed to manufacture composites, locally eliminate casting defects, refine microstructure and/or improve the associated mechanical and physical properties including strength, ductility, fatigue, creep, formability and corrosion resistance[5].

The literature review got some points regarding the FSW and the joining the aluminium alloys. So the FSW is selected for joining of aluminium alloys with studying some of experimental parameters. The parameters are selected for the process and also we will experiment it on conventional milling machine for cost reduction and also successful welding operation can be done. The alloy of aluminium selected for the trials is AA6063 in the form of plates having thickness of 10 mm and conduct the number of trials and get the results.

SELECTION OF MATERIAL & TOOL

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

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 choosing as the tool material is 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 mach inability.

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.

A. 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.

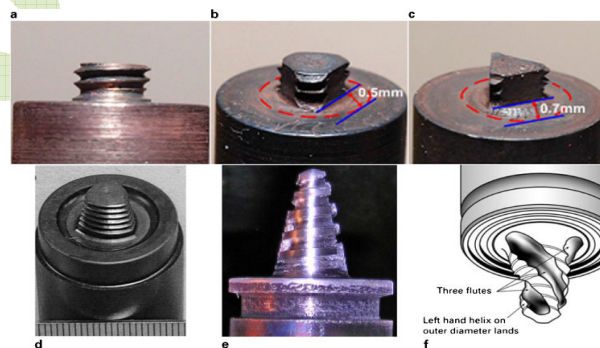


Figure 2: Commonly used tool pin geometries(a. Cylindrical Threaded, b. Three Flat Threaded, c. Traingular, d. Trivex, e. Threaded Conical, f. Triflute)

DESIGN OF TOOL

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.

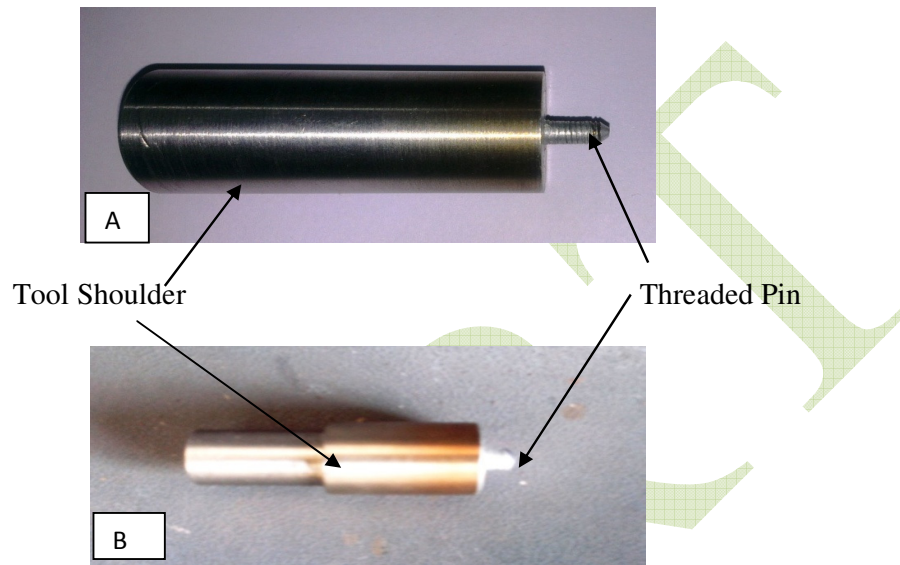


Figure 3: FSW Tools: (A) FSW tool of threading M8x1(B) FSW tool of threading M12x1.75

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

Parameter	Description	
	Tool I	Tool II
Shoulder Diameter (mm)	27	20
Tool Pin Profile	Cylindrical Threaded Pin	Cylindrical Threaded Pin
Threading	M8x1	M12x1.75
Pin Diameter (major) (mm)	7.90	11.90
Pin Diameter (minor) (mm)	6.70	9.95
Pin Length (mm)	7.3	7.4
Tool Shank (Diameter)(mm)	20	20

Shoulder Length	30	30
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From the whole study of materials used generally for FSW, it is revealed that to come up with good quality of weld it is necessary that to have good knowledge of material selection for any process. Also the type of materials to be welded as well as the weld parameters such as transverse speed and rotational speed as well as material characteristics determines the best tool material that should be selected. After this review of the materials, we select the tool steels with MO (3%) which is an alloy of steels as a material for tool. As the we select the aluminium alloys (AA6063) for the study of the FSW experimentation which is belonging to soft materials and tool steel which is sufficient hard material will definitely useful for this process. After the market survey and availability of the steels, the steel rods of 32 mm diameters were brought for the experiment. And as per the design and parameters decided for the tool dimensions, the tools were manufactured.

EXPERIMENTATION OF FSW OF AA6063

In experimentation, mainly two parts are included as; make specimen ready for trials and actual experiment. In the part of making specimen ready to test, we cut the samples from the raw material brought in the form of long strips as per the desired dimensions. The samples or plates of AA6063 are machined again on the same milling machine with surface cutter for doing the plates of equal dimensions and also the sides should rests in jaws of vise with zero deviation along the length i.e. they should fit perpendicularly at the jaws. After the surfacing of the plates the samples are become 51×150 mm for trials T1 & T2 also 80×150 mm for trials T3 & T4 respectively. The trial set up is as:



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 experimentation of the FSW are as per given in table III.

**TABLE III
FSW PROCESS PARAMETERS**

Parameter	Friction Stir Welding Trials			
	T1	T2	T3	T4
Tool Type	Cylindrical Threaded	Cylindrical Threaded	Cylindrical Threaded	Cylindrical Threaded
Threading of the tool	M12×1.75	M12×1.75	M8×1	M8×1
Shoulder Diameter(mm)	20	20	27	27
Shoulder length (mm)	30	30	30	30
Tool Pin Length(mm)	7.4	7.4	7.3	7.3
Tool Rotating Speed(rpm)	720	720	510	510

Welding Speed (mm/min)	0.869	1.65	2.70	8.645
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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 necessary attachment as shown in figure 4.

EXPERIMENTAL OUTCOME

After the conducting the experimentation trials of the friction stir welding of plate's of AA6063 the two plates were joined successfully. This experimentation carried out with some results those are discussed in following sections. The welding joints are obtained as:



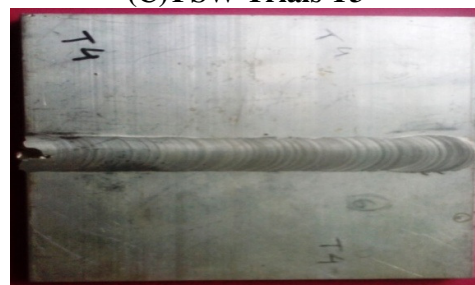
(A) FSW Trials T1



(B) FSW Trials T2



(C) FSW Trials T3



(D) FSW Trials T4

Figure 5: Welding joints of AA6063

TESTING OF FSW JOINT

When the FSW joints are tested under the microscopes we get results in various views like weld penetration, cracks or blow holes if present in the weld, heat affected zone, effect of welding on grain structure of the material. The metallurgical testing of the joints has been done in accredited lab to find out desired results. Also the results of tensile test carried out each of the joints shown in the above figures are tabulated in the following tables.

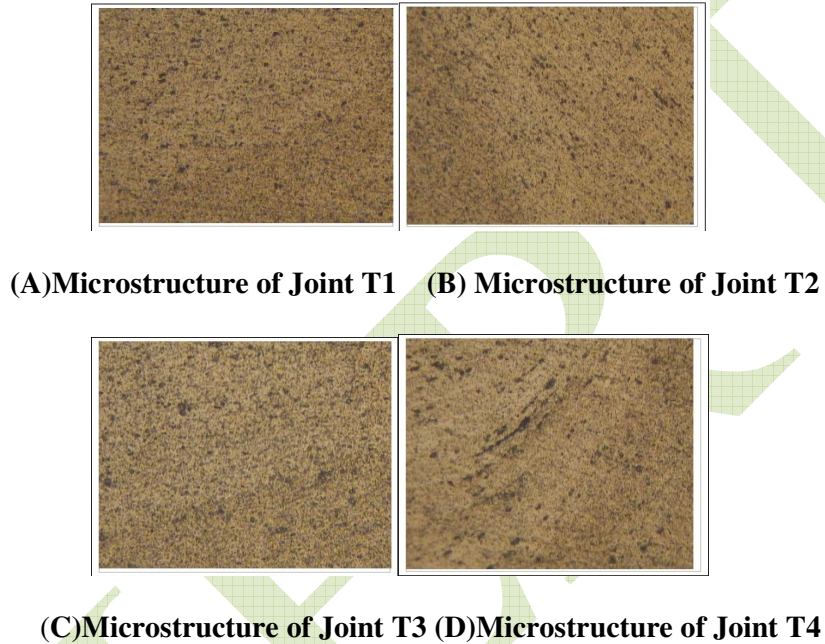


Figure 6: Microstructure of FSW Joints

The results obtained during test conducted on the FSW joints of trials T1, T2, T3 & T4 are summarised in the table IV as:

**TABLE IV
 SUMMARY OF TESTING RESULTS**

Parameters	Samples			
	T1	T2	T3	T4
Total Weld Depth (mm)	8.71	8.56	7.02	7.98
Crack	Not observed	Observed	Not observed	Observed
Blow Holes	Not observed	Not observed	Not observed	Not observed
Heat Affected Zone	Observed	Observed	Observed	Observed
Effect on grain structure	Elongated grains observed	Elongated grains observed	Elongated grains observed	Elongated grains observed
Tensile Strength	32	31	27	25

(KN)			
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RESULTS AND DISCUSSION

After this experimentation, various points are come out from the operation of FSW and testing of welded joints.

- The pin diameter and shoulder diameter are increased with the increase in thickness of the plates or specimen undergoing the process of FSW.
- The speed of the tool is one more important parameter to be selected for the 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 high range the quality of weld increased i.e. quality of weld directly proportional to the temperature created during the process.
- As the tool pin length is more plunge depth of tool in to the workpiece is more. It will take more area of swirling action of material which results in the better mixing of material to each other and weld become stronger. So that when the thickness of the plate increases the tool diameter and length of the tool get increases simultaneously. But it should not exceed the thickness of the plate.
- The clamp and support arrangement acts as a heat sink that dissipates heat. The clamped side may become more hardness value and lower tensile strength.

CONCLUSION

After the study of Experimentation of friction stir welding of aluminium alloys some of the good points were came out. There are also some other points that also taken in to consideration for the extra work to be done. The some of concluded points regarding this study as:

- The process cost gets minimized automatically as the experimentation is done within the available tools and machines.
- The health hazards are decreased to zero whether the fusion welding has many health hazards affected on operator due to ultraviolet rays, also production of harmful gases during the process.
- With the use of conventional milling machine the FSW can carried out successfully for the materials for those fusion welding is not possible.
- Use of backing plate to specimen gives the support and useful to avoid the movement of the plates during the process. Also it helps to form good weld and also it decreases gap on the back side of the welded plate.
- The speed of the tool should be more as possible higher speed can be achieved on the machine. As the higher speed of the tool causes good weld quality and also increase the strength due good mixing of material of both the plates.
- The welding joints test shows us that there is good weld penetration in to all four trials. That means the joints get successfully done with heat affected zone is observed at all the joints. And also within the heat affected zone the grain structure viewed as elongated.

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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