



EXPERIMENTAL STUDY OF FRICTION STIR WELDING OF AA6061-T6 ALLOY FOR OPTIMIZATION OF WELDING PARAMETERS BY USING LATHE MACHINE

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Abstract - Friction stir welding is a new solid state welding process for joining metallic alloys and it is useful in several industries for joining aluminium, magnesium and copper alloys. The various parameters such as rotational speed, transverse speed and tool tilt angle play important roles in FSW process and quality weld. The aim of this study is to know the relation between the effects of different transverse speed and tool profile on the weld quality of AA6061-T6 aluminium. The geometry of the pin tool along with the process parameters plays an important role in dictating the path that the material takes. The tool geometry was carefully chosen and fabricated to have an nearly flat welded interface in profile. In this work, a number of attempts have been made to analyze the effect of various tool profiles on mechanical properties of aluminium alloy. Various tool profiles have been used to fabricate joints by using varying thickness work piece of Aluminium alloy. Numerical techniques particularly, the finite element method for the simulation of FSW for thermal, mechanical and thermo-mechanical modelling has been investigated. The current studies also aim to understand mechanical properties during the FSW.

Key Words: Friction Stir Welding, Transient Thermal Analysis, Al6061, Process parameter, Tool Profile

1. INTRODUCTION

Friction Stir Welding process is relatively a new joining process that is presently attracting considerable interest. Since the joint can be obtained below the

melting temperature, this method is suitable for joining a number of materials that are extremely difficult to be welded by conventional fusion techniques. The process is solid state in nature and relies on the localized forging of the weld zone to produce the joint. A constantly rotated non-consumable cylindrical tool with a profiled pin is transversely fed at a constant rate into a butt joint between two clamped pieces of butted material. The pin is slightly shorter than the weld depth required, with the tool should be riding at the top of the work surface.

Frictional heat is generated between the wear-resistant welding components and the workpieces. This heat, along with that generated by the mechanical mixing process and the adiabatic heat within the material, causes the stirred material to soften without melting.

FSW is actually performed in different steps as shown in figure 1. The primary function of the pin is to mix the material under the tool shoulder, which can be enhanced by threads. First, the pin is plunged into the joint formed by the two sheets to be welded, until the shoulder gets in contact. As the tool rotates at a high velocity, the sheets are heated up by plastic deformation and friction. As the pin is moved forward, a special profile on its leading face forces plasticized material to the rear where clamping force assists in a forged consolidation of the weld. This process of the tool traversing along the weld line in a plasticized tubular shaft of metal results in severe solid state deformation involving dynamic recrystallization of the base material. Figure 1 shows the process of tool traversing along the weld line. [1], [2]

1.1 Keyof Benefits

In contrast to the traditional friction welding, which is usually performed on small axis symmetric parts that can be rotated and pushed against each other to form a joint, FSW can be applied to various types of joints like butt joints, lap joints, T butt joints and fillet joints.

Table-1: The key benefits of FSW Process

Metalurgical benefits	Environmental Benefits	Energy benefits
Solid phase process	No shielding gas required	Reduction in weight
Good dimensional stability and repeatability	Eliminate grinding waste	Decrease fuel consumption
No loss of Alloy ingredients	Eliminate solvents required for degreasing	
Excellent metallurgical properties in the joint area	Consumable materials saving such as rags, wire or any other gases	

1.2 Comparison of friction stir welding to other welding processes

Comparison of FSW to other welding processes is typically done within the context of justifying the use of the process over other, more conventional techniques. Successful application of FSW depends upon a clear misunderstanding of the characteristics of the process, so favorable technical and economic justification can be developed.

The unique, favorable characteristics of

FSW compared to traditional arc welding methods provides several sources for technical justification for use of the process. [3],[4]

The main points for technical justification of FSW compared to arc welding processes are;

- Improved weldability
- Reduced distortion
- Reduced residual stress

Table-2: Light duty lathe machine specification

Sr no	Features	Values
1	Swing over bed	90mm
2	Swing over carriage	45mm
3	Distance between center	430mm
4	Overall length	820mm
5	Overall width	220mm
6	Overall height	200mm
7	Shipping weight	140kg
8	Hole through spindle	10mm
9	Spindle speed range	575-900rpm

- Improved cosmetic performance
- Elimination of under matched filler metal
- Improved static strength and ductility
- Mechanized process
- High robustness and few process variables

2. DESIGN APPROACH

Generally, Friction stir welding is performed on the Milling or Radial cum drilling machine. But our main objective is to perform operation on Lathe Machine. So for that an attachment is required to hold a welding plate on a lathe machine. [9],[10]

2.1 Basic Requirement of machine:

The performance test on Lathe machine for the FSW Technique is analyzed for the different parameters.

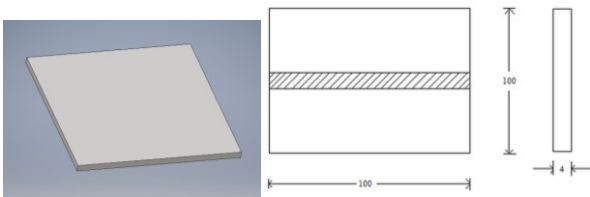


Fig-7: CAD Geometrical Dimension (All dimensions are in mm)

3. SIMULATION BASED APPROACH

Three-dimensional thermomechanical model and the thermomechanical effect of the welded material is developed for the FSW of an Al-alloy, in order to build qualitative framework to understand the thermomechanical process in FSW. In this analysis work below figure shows the total deformation and temperature graph for a cylindrical tool geometry. The prediction and the measurement show that the maximum temperature gradients in longitudinal and lateral directions are located just beyond the shoulder edge. To simulate this kind of welding process, a fully coupled thermo-mechanical solution has been adopted to simulate the FSW process. [11],[13]

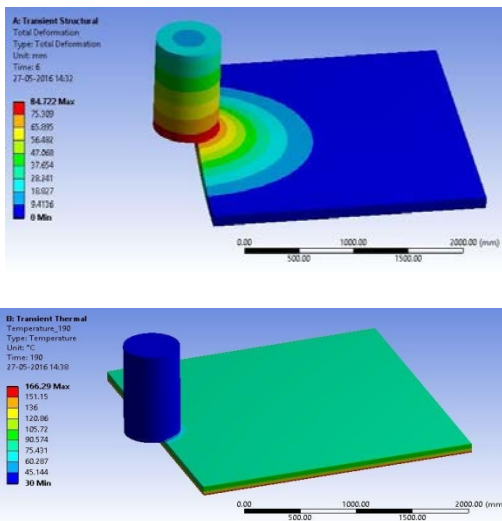


Fig-8: Total deformation and Temperature profile

Figure 8 shows the Total deformation and temperature profiles in the work piece during the welding operation for $N_2=900$ rpm; $T_2=3.16$ mm/min and for a cylindrical tool profile for the size of 4mm thickness plate. [14],[16]

are discussed below which are effecting for the Analysis on FSW. [15]

4.1 Process parameter

4. EXPERIMENTAL WORK

Experimental setup was recognized using a light duty lathe machine. No extra setup is required for friction stir welding except tool and fixture, so as to place piece in proper position during welding. The different process parameters The various process parameters play important roles in FSW process and quality weld.

Table 4: Main FSW process variables

Tool design variables	Machine variables	Other variables
Shoulder and pin material	Welding speed	Anvil material
Shoulder diameter	Spindle speed	Anvil size
Pin diameter	Plunge force or depth	Work piece size
Pin length	Tool tilt angle	Work piece properties
Thread pitch		
Feature geometry		

There are so many parameters are effecting for the analysis on friction stir welding as shown in Table 4. As many parameters are important in the friction stir welding but in this experiment maintain two parameters are selected for analysis by using lathe machine;

- (1) Tool speed
- (2) Transvers speed

The proper choice of tool rotation and transvers speed will produce a good quality weld. The material use for base plate is Al alloy 6061 and the material use for the tool geometry is EN8.

4.2 Process step for friction stir welding on lathe machine

The experimental study includes the butt joining of aluminum plates. The welding

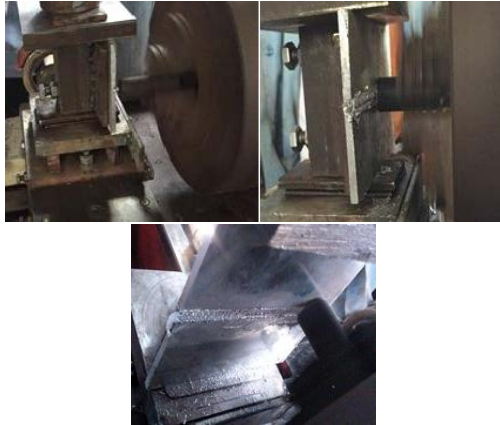


Fig-9: Process steps for FSW Experiment

In the present work, different FSW butt welds were reobtained by varying the process parameters within the range and the optimal values are drawn based on the trend of the values. In this experiment it is observed that the process parameters like tool design, tool rotational speed, welding speed and materials are the main parameters to produce the effective butt joint by friction stir welding. [17]

4.3 Observation table

Table 5: Experiment data

Sr No	Material Aa-6061	RP M (n)	Transverse Speed (mm/min)	Pass	Material size (mm)
1	Plateno: 2	N2=900	T2=3.16 mm/min	P1	S2=100*45*4
2	Plateno: 9	N9=900	T9=3.37 mm/min	P2	S9=100*45*6
3	Plateno: 8	N8=575	T8=7.35 mm/min	P1	S8=100*45*4
4	Plateno: 3	N3=575	T3=8.16 mm/min	P2	S3=92*45*6
5	Plateno: 6	N6=900	T6=4.41 mm/min	P1	S6=100*45*4
6	Plateno: 4	N4=900	T4=6.15 mm/min	P2	S4=100*45*6
7	Plateno: 7	N7=575	T7=4.50 mm/min	P1	S7=100*45*4
8	Plateno: 5	N5=575	T5=4.49 mm/min	P2	S5=100*45*6

Plateno2:(P1N2T2S2C); Cylindrical Tool = C; Tapper Tool = t; RPM = N; Transverse speed = T; Material size = S; Single pass = P1; Double pass = P2

4.4 Tensile Tests:-

Tensile strength, along with elastic modulus and corrosion resistance, is an important parameter of engineering materials used in structures and mechanical devices.

- Tensile test specimen geometry

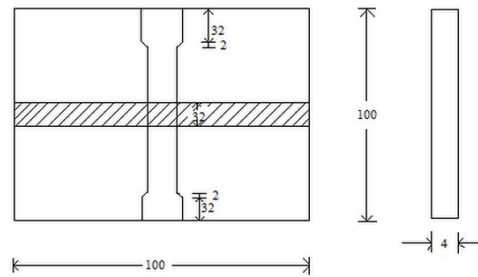
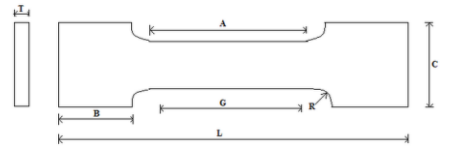


Fig 10: Tensile test specimen (All dimensions are in mm)

- Subsize specimen:

G: Gauge length: 25 + 0.08mm
 W: Width: 6.25 + 0.05mm
 T: Thickness: Thickness of material
 R: Radius of fillet: 6mm
 L: overall length: 100mm
 A: Length of reduced section: 32mm
 B: Length of grip section: 32mm
 C: Width of grip section: 10mm

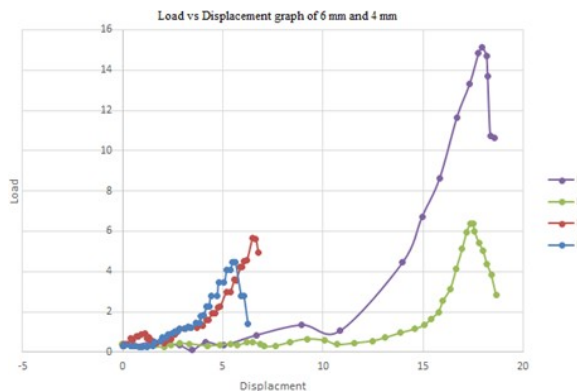
4.5 Tested plate and results

The process parameters selected were mainly tool rotational speed, welding speed and tool geometry etc. Tests are performed as per the ASTM Standards at TCR Advance Engineering at Vadodara. A machined specimen is placed in the testing machine and load is applied to measure the resistance of a Material. The result for tensile strength for sample specimen is shown in Table 6.

Table 6: Tensile strength of samples specimen

Srno	Plateno	Force (KN)	Area (mm ²)	Ultimate tensile strength (N/mm ²)
1	P2	15440	158.35	98
2	P9	7640	163.11	47
3	P10	5679	87.95	65
4	P11	4420	98.57	45

Figure 12 shows the load vs displacement graph for varying thickness of plate on Tensile strength.



5. CONCLUSION

Important process parameters that control the quality of the weld are rotation speed (575 - 900 rpm) and traverse speed (3.16-8.16 mm/min) were performed to obtain defect free welded joints.

The following various conclusions summarize the present paper;

- From this investigation, it has been found that tool profile cylindrical tool, transverse speed 3.37 mm/min and rotational speed is 900 rpm produced good tensile strength.
- Mechanical properties of the joints increase with increase in tool rotational speed and reach maximum at 500 to 575 rpm but again decrease with further increase in tool rotational speed.
- The heat input from the tool shoulder was assumed to be the frictional heat. The coefficient of friction was

continuously adjusted to keep the calculated temperature from exceeding the material melting point.

- Increase in pin length decreases penetration depth on the back side of welded plate. It is also observed that more than 6 mm thickness of workpiece is possible to weld by friction stir welding butt. The condition is to design a different tool for different thickness. While designing tool, the tool tip length should be less than the thickness of the base material, i.e., less than 0.25 to 0.8 times of the base material thickness.

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