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Research Article

Experimental Study of Hardness by Friction Stir Welding of 6061-T6 Aluminium Pieces

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Abstract

Friction stir welding (FSW) is a relatively new joining process that has exhibited many advantages over traditional welding processes, including greatly reducing distortion and eliminating solidification. The present work aims to determine the feasibility to weld of two pieces of aluminum alloy (AA 6061) sheets of thickness 6mm by friction stir welding process and study the effect on hardness of the welding joints with respect to welding speed. special welding fixture fixed on conventional milling machine has been conducted to attempt this welding with three tool rotation speed 1950,3080,4600(r.p.m) with feed rate.20,25,30(mm/sec). Mechanical property (Hardness Number) was investigated using Hardness testing machine. Based on the stir welding experiments conducted in this study results show that aluminum sheet (AA 6061-T6) can be welded by (FSW) processes with maximum welding efficiency in terms of hardness Number, using rotational speed (r.p.m), and Feed rate (mm/sec).

Keywords: *Friction Stir Welding, Hardness, Aluminium Alloy.*

Introduction

[1]FSW is a rapidly maturing solid state joining process that offers significant benefits over conventional joining processes. Invented by the Welding Institute (TWI) in 1991. In FSW heat is not additionally given but generate by application of pressure and movement of tool i.e. rotational speed and transverse feed. Friction welding is a form of solid state welding process, which relies on the formation of molten bridge, deformation and on the flow of metal. Figure 1.shows the principle of operation of the friction stir welding process. The basic principle of friction welding involves the simultaneous application of pressure and relative motion, generally in a rotational mode, between the components to be joined. The frictional heat thus generated raises the interface temperature of the components to their melting points while the applied pressure perpendicular to the plane of motion serves to extrude the heated material including any dirt and oxide films from the interface, bringing the components to be joined into intimate contact.

Principle of friction stir welding

In friction stir welding (FSW) a rotating cylindrical, shouldered tool with a profiled probe penetrates into the material until the tool shoulder contacts with the upper surface of the plates, which are butted together as shown in figure 1. The parts have to be clamped on to a backing bar in a manner that prevents the abutting joint faces from being forced apart. Frictional heat is generated between the wear resistant welding tool and the material of the work pieces. This heat causes the later to soften without reaching the melting point and allows traversing of the tool along the weld line.

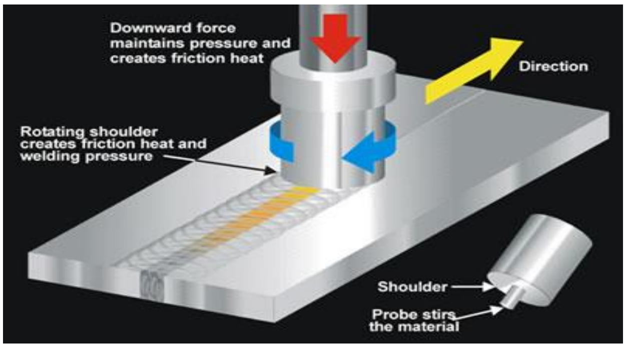

Figure 1 Principle of Friction stir welding

This paper focus on finding the optimal speed (rpm) and feed rate (mm/sec) with respect to mechanical property (hardness number)

Experimental Method

A milling machine was used for joining of aluminum alloys (AA6061) for friction stir welding. Specification of

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milling machine used for friction stir welding is shown as below table1.

Table 1 Specification of the FSW machine

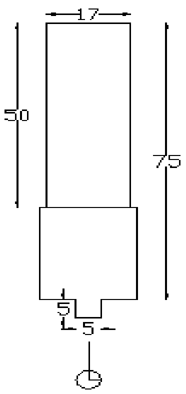
Specifications	Values
Make	PACMILL(Semiautomatic)
Range	100-4650 rpm on 50 Hz,
Type	Vertical
Longitudinal bed range	900mm
Cross bed range	600mm
Traverse feed range	12-900 mm/min.
Motor	3H.P, 1450 rpm
Tool holder diameter	50 mm

The material used in this investigation was Aluminum alloy (AA6061) plates of 6mm thickness and 100mm length. Chemical compositions of AA 6061 alloy are shown as in table.2.

Table 2 Chemical compositions of AA 6061 alloy are shown as follow

Material	Cu	Mn	Si	Fe	Mg	Cr	Zn	Al
AA6061	0.31	0.08	0.66	0.25	0.99	0.16	0.01	Balance

A cylindrical tool shape was used to fabricate joints of single sided of aluminum pieces on friction stir welding as shown in figure.2. The variables were (i) tool speed & (ii) Feed rate. Test specimens were prepared for mechanical and hardness testing, tensile testing done on UTM. Mechanical properties (Ultimate tensile strength, Rockwell hardness number and Brinell hardness number) are noted.



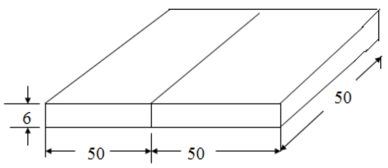


Figure.2 Straight work piece

Figure 3 Dimensions for the cylindrical tool

Shaper machine is used for Cutting aluminum plates in required dimensions of 6mm thickness and 100mm length. Punch presses is used a shaped tools to knock out geometry in sheet metal. Dimensions of the work piece is shown in the above figure.3Cast iron **fixture** is used for this process of friction stir welding as shown in figure .4. Fixture was a backing steel plate to prevent slipping of aluminum plate during welding. Sheet should have the required strength to withstand with operations.

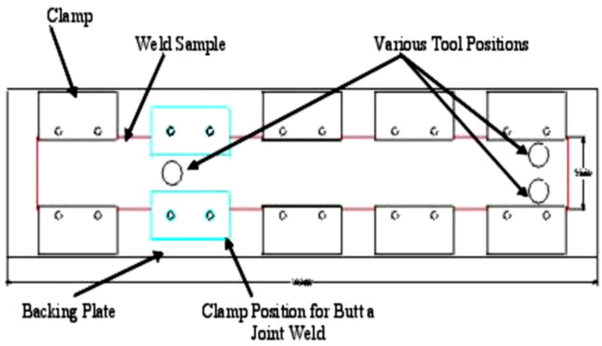


Figure .4 Two Dimensional View of Fixture

There may be many nuts on the fixture according to the requirement to hold the work piece. But in this experiment four nuts are used to hold the job in the fixture.

After preparing eighteen pieces of size 100x50x6mm, we take two plates out of eighteen and put those in fixture together with side edge meet each other. The fixture is fixed on the bed of vertical milling machine (VM) after setting of fixture on VM, a cylindrical tool having length 50mm, Head diameter 17mm, Pin diameter 5mm and Pin length 5.5mm is fixed in tool holder of vertical milling machine. Then by varying the feed rate and tool speed nine sample pieces were prepared from AA6061 material plates.

After that specimens was prepared for mechanical testing (Rockwell hardness testing & Brinell hardness testing) and result was calculated as shown in the table.3.

Experimental Plan

Table 3 Experimental plan

Speed (r.p.m)	Feed (mm/sec)	Specimen name	Type of weld pass	Tool shape
1950	20	S1	Single	Straight cylindrical
	25	S2	Single	Straight cylindrical
	30	S3	Single	Straight cylindrical
3080	20	S4	Single	Straight cylindrical
	25	S5	Single	Straight cylindrical
	30	S6	Single	Straight cylindrical
4600	20	S7	Single	Straight cylindrical
	25	S8	Single	Straight cylindrical
	30	S9	Single	Straight cylindrical

Result and Discussion

Hardness number for the welding cross section evaluated by Knoop hardness tester and Rockwell hardness tester is shown in tables.4 & 5. And calculation shows that maximum brinell hardness number obtained at speed 3080 r.p.m was 135 with feed rate of 30 mm/sec for sample S6.and maximum Rockwell hardness number was 55 at speed 3080 r.p.m with feed rate of 30mm/sec for sample S6.

Hardness tests was completed with higher accuracy and results was calculated as shown in the below table.4.

Calculation of Brinell hardness number

Brinell Number (H)

$$H = \frac{P}{\frac{\pi D}{2}\left(D - \sqrt{D^2 - d^2}\right)}$$

P = kg load D=ball dia. mm
d = impression mm

Table 4 Brinell Hardness Number

Speed	Sample No.	Feed	Indentation mark(mm)	Brinell hardness No.
1950	S1	20	1.1	100
	S2	25	1.1	100
	S3	30	1	122
3080	S4	20	1	122
	S5	25	0.95	135
	S6	30	0.95	135
4600	S7	20	1.1	100
	S8	25	1.1	100
	S9	30	1	122

After calculation of Brinell hardness number, Rockwell hardness number was calculated on B-Scale of hardness machine. And calculated values are shown in the table.5. For samples from S1 to S9 on same speed and tool feed rate on which Brinell hardness number was calculated.

Rockwell hardness number was calculated on B-Scale of hardness machine as shown in the below table:-

Calculation of Rockwell hardness number

Below table shows the variations in the hardness numbers for different values of speed and feed rate. Values of hardness number observed was increasing and decreasing during testing. Brinell hardness and Rockwell hardness tests were conducted for measuring hardness along the weld zone. From results of the hardness testing it is observed that maximum hardness number obtained for Rockwell and Brinell hardness for sample S6 using straight cylindrical tool at speed 3080r.p.mand feed 30mm/sec.

Conclusion

In this investigation an attempt has been made to study the effect of tool pin profile (straight cylindrical) on the formation of friction stir processing zone in a single sided friction stir weld on Al Alloy (AA6061). From this investigation, the following important conclusions are derived:

Table 4 Rockwell Hardness Number

Speed rpm	Sample No.	Feed (mm/sec)	Rockwell hardness No. (B-Scale)
1950	S1	20	20
	S2	25	46
	S3	30	12
3080	S4	20	46
	S5	25	28
	S6	30	55
4600	S7	20	25
	S8	25	11
	S9	30	32

- The joints fabricated by single pass weld have shown higher hardness number for both Brinell and Rockwell hardness is at 3080 r.p.m. at feed rate of 30mm/sec.
- The joints fabricated by straight cylindrical pin profile tool in single sided weld shows increasing and decreasing type hardness number for varying speed and feed rates.

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