STUDY OF MECHANICAL PROPERTIES FOR ALUMINIUM ALLOY (6061) BY USING DIFFERENT TOOL SHAPES IN FRICTION STIR WELDING

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ABSTRACT

In this experimental work, an extensive investigation had been carried out on Al Alloy (AA6061) grade aluminum alloy plates. This material is taken under investigation due its popularity in aircraft. The material of weld tool used High Carbon Steel. The tool material is used high carbon steel due to its low wear rate. Hence an attempt has been made to study the effect of influence of tool shape on the mechanical properties (tensile strength) of (AA6061) in single and double sided friction stir welds in this project. In this work the speed of tool rotation were taken as 3080 rpm, transverse speed as 30mm/min. and tool tilt angle was taken as 2^0. *In both single and double pass, the highest tensile strength of the joints was obtained by using the square pin profile tool. The square pin profiles tool is best and tensile strength significantly decreases for, cylindrical, triangular and threaded pin profile tool due to defect formation. In double sided weld, the joints fabricated by cylindrical pin profiled tool showing almost matching tensile properties to that of square pin tool profile*

Keywords: *Al-Alloy (6061), High Carbon Steel Tool, Mechanical Property (Tensile)*

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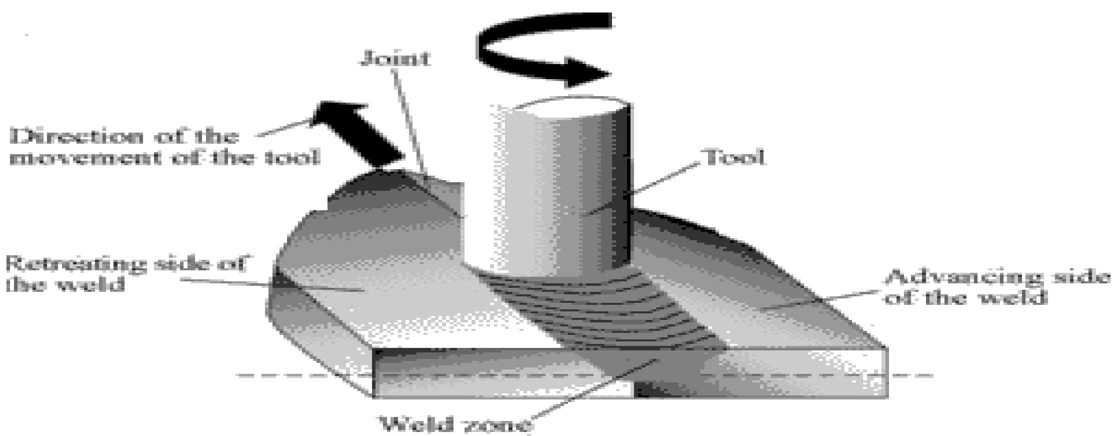
INTRODUCTION

Friction stir welding (FSW), a solid-state welding process was invented and experimentally proven by Wayne Thomas and a team of his colleagues at the Welding Institute UK and patented by the TWI in 1991, emerged as a welding technique to be used in high-strength alloys that are difficult to join with conventional technique . The process was developed initially for aluminum alloys, but since then FSW was found suitable for joining a large number of materials. In aeronautics, for instance, riveting is the preferred manufacturing process for aircraft fuselage structures; nevertheless, In FSW process, a non-consumable rotating tool, consisting of a shoulder and profiled probe or pin, is forced down into the joint line under conditions where the frictional heating is sufficient to raise the temperature of the material to the range where it is plastically deformed as shown in figure. 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



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. In aluminum alloys, the mechanical properties of friction stir welds are usually better than those produced by conventional gas metal arc welding. Most of the work in friction stir welding has been done on aluminum alloys, where the mechanical properties were near those of the base plate. A number of potential advantages of FSW over conventional fusion-welding processes have been identified Good mechanical properties in the as welded condition. Improved safety due to the absence of toxic fumes or the spatter of molten material. No filler materials are required.

COMPOSITION OF AL ALLOY6061

The base material (BM) used in this investigation is aluminium alloy (AA6061). The chemical composition of the material is given in

Chemical composition of aluminium alloy (AA6061)

Material	Mg	Cu	Mn	Si	Fe	Cr	Al
AA6061	0.8-1.2 %	0.15-0.40 %	0-0.15%	0.40-0.80%	0-0.7%	0.04-0.35%	Remainder

TOOL USED FOR SET UP

Diameter of tool head used 17 mm.

Dimensions of welding tools are given below

length of tool – 50 mm, head diameter- 17 mm

For Single sided friction stir welding

1. Straight Cylindrical (SC) – pin diameter-5mm and pin length – 6 mm
2. Square (SQ)- pin dimensions –(5x5)mm , diagonal 7 mm and pin length – 6 mm
3. Cylindrical Threaded (TH) – pin diameter 6mm , pitch of thread- 0.7 mm, pin length- 6 mm
4. Triangular (TR) – diagonal – 5mm , pin length- 6 mm

Similarly four shapes of tools being used for double sided FSW dimensions are given below

1. Straight Cylindrical (SC) – pin diameter-5mm and pin length – 3 mm
2. Square (SQ)- pin dimensions – (5x5)mm , diagonal -7 mm and pin length – 3 mm
3. Cylindrical Threaded (TH) – pin diameter 6mm , pitch of thread- 0.7 mm, pin length-3mm

4. Triangular (TR) – diagonal – 5mm , pin length- 3 mm

All tools were machined on the basis that the maximum shank diameter of tool should be 17 mm.

PROCEDURE FOR FRICTION STIR WELDING

First of all seventeen pieces having size 100x50x6mm of AA6061 material are prepared for friction stir welding purpose. For this firstly AA6061material blank is pressed in a press to make it straight and stress free. After that from this material blank, thirteen plates of size 100x50x6mm are cut on shaper machine as shown in figure. After cutting plates of proper size, then the edges of these plates are made straight by passing cutting tool at angle 90° simultaneously on all the pieces. Then these plates are made burr free by filing so that when two plates are kept in fixture simultaneously for friction welding, then there should not be any gap present between two pieces in order to make better samples for friction welding. In this work the tool rotation speed kept constant at 3080 rpm, transverse speed was 30mm/min. and tool tilt angle was taken 2^0.Tool tilt angle given to provide required pressure in the welding.



TENSILE TESTING

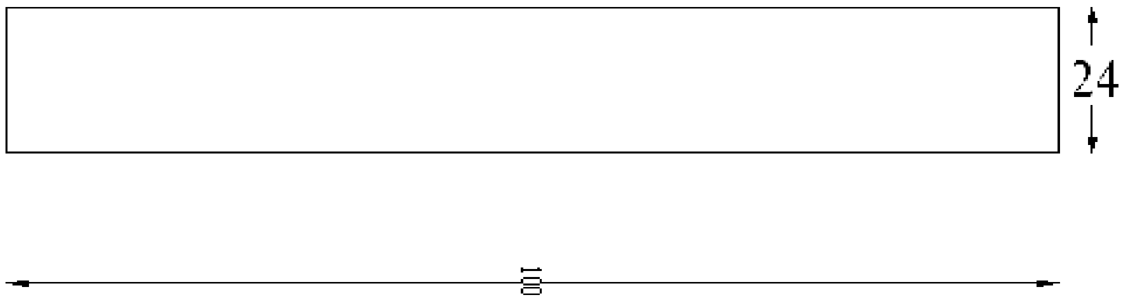
Tensile testing, also known as tension testing, is a fundamental material science test in which a sample is subjected to a controlled tension until failure. The results from the test are commonly used to select a material for an application, for quality control, and to predict how a material will react under other types of forces. Properties that are directly measured via a tensile test are ultimate tensile strength, maximum elongation and reduction in area. A tensile specimen is a standardized sample cross-section. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.

Steps involved before the test were

1. Make gauge marks on the specimen.

2. Measure the initial gauge length.

3. Load scale to deform and fracture the specimen taken is Kgf on UTM.



Specimen's Dimensions

Before testing welded specimen (single and double sided) were assigned number as S1to S4 for single pass specimen and S5 to S8 for double pass specimen.

Sr. No.	Specimen name	Type of weld pass	Tool shape
1	S1	Single	Square
2	S2	Single	Straight cylindrical
3	S3	Single	Cylindrical threaded
4	S4	Single	Triangular
5	S5	Double	Square
6	S6	Double	Straight cylindrical
7	S7	Double	Cylindrical threaded
8	S8	Double	Triangular
9	S9	Base metal	-

Steps followed during the tensile test.

1. Record the maximum load.
2. Conduct the test until fracture.

After the test Measure the final gage length and calculate Elongation. The length has been measured according to the gage marking. Mechanical properties which had been tested are

a. Ultimate tensile strength b. Percentage of elongation c. By finding UTS, joint efficiency of samples

RESULTS AND DISCUSSIONS

The welded specimens were put under tensile testing and the values of ultimate tensile strength, percentage elongation and joint efficiency were noted. The results of tensile loading of the base metal and welded specimens in single and double pass are shown in Table 1, Table 2 and Table 3 respectively. The variation of ultimate tensile strength, percentage elongation and joint efficiency are shown in Graphs 1- 3 respectively.

Formulae used for mechanical testing are given below

Stress :- Load/Area All load values we got from testing are in Kgf.

For conversion of kgf into N/mm^2:-1 kgf :- 9.8 N/mm^2

1. Percentage Elongation :- (Final length – initial length)/100
2. Joint Efficiency :- UTS of welded specimen/UTS of base metal

On the basis of above formulae, we can make the Table for tensile testing of specimen in single and double pass.

TABLE 1 Tensile Test Results of Base Metal

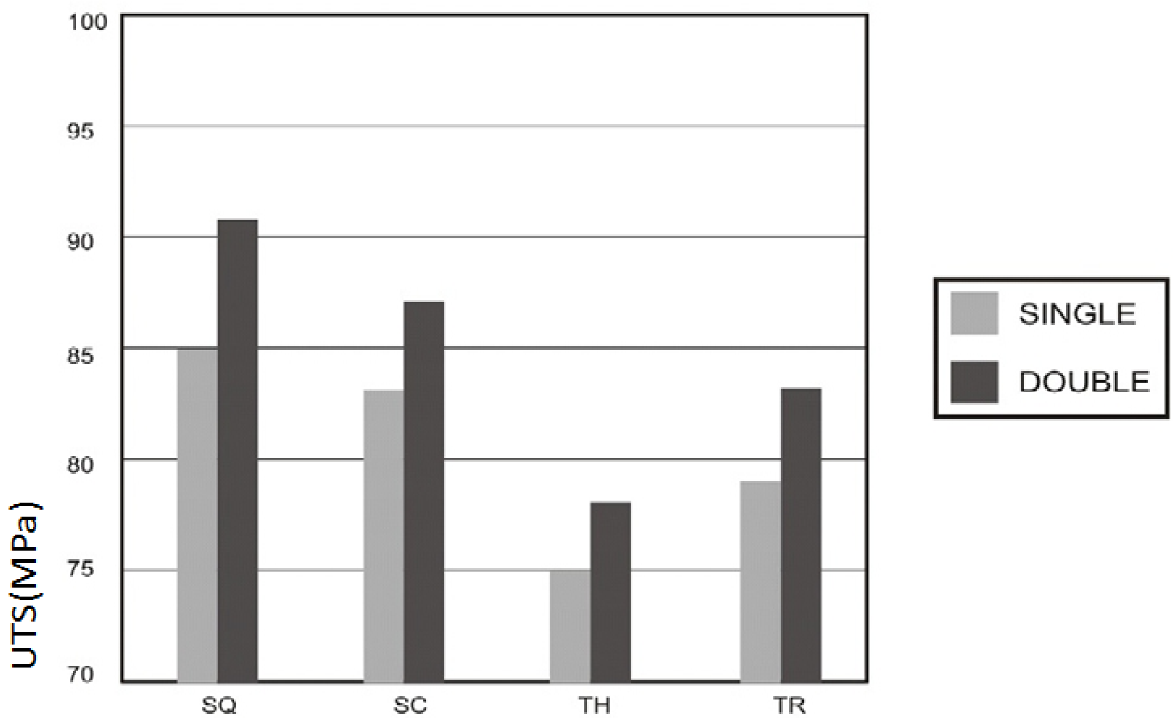
Specimen No.		Ultimate Tensile Strength		Percentage Elongation	
	Area(in mm^2)	Load (kgf)	Stress (N/mm^2)	Elongated Length (mm)	% Elongation
S9	87	1150	130	56.50	11.5

TABLE 2 Tensile testing Results of welded specimen in single pass

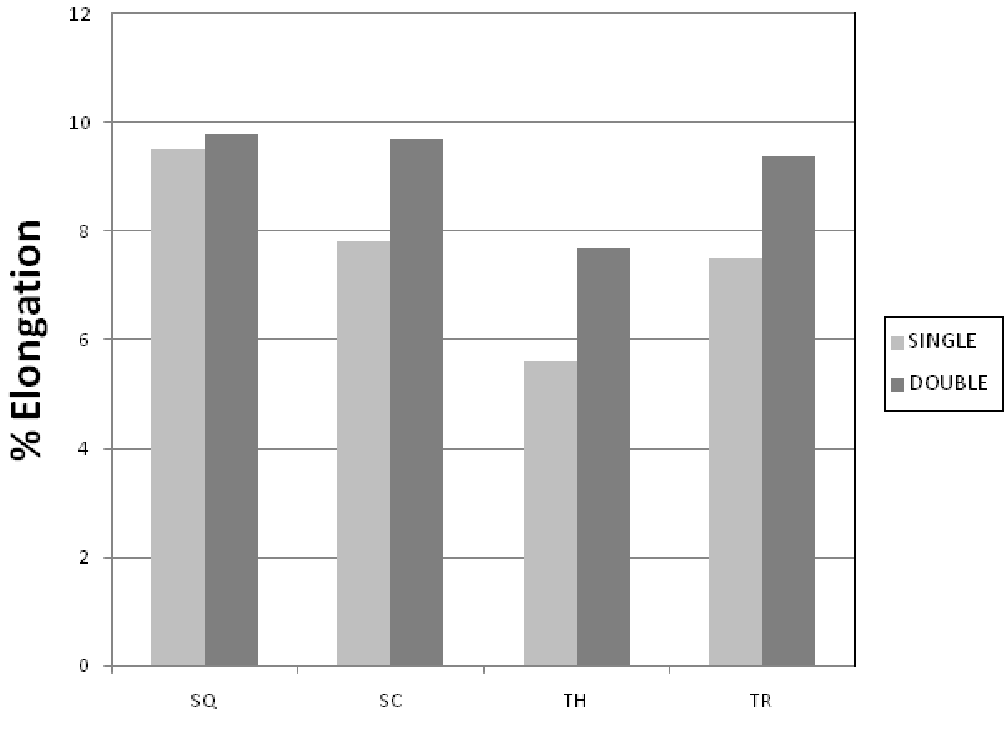
Specimen No.		Ultimate Tensile Strength		Percentage Elongation		Joint Efficiency (%)
	Area(in mm^2	Load (kgf)	Stress (N/mm^2)	Elongated Length (mm)	% Elongation	
S1	144	1248	85	55.30	9.5	65.3
S2	142.8	1208	83	54.25	7.8	63.8
S3	144	1104	75	53	5.6	57.6
S4	142.2	1148	79	54.10	7.5	60.7

TABLE 3 Tensile testing Results of welded specimen in double pass

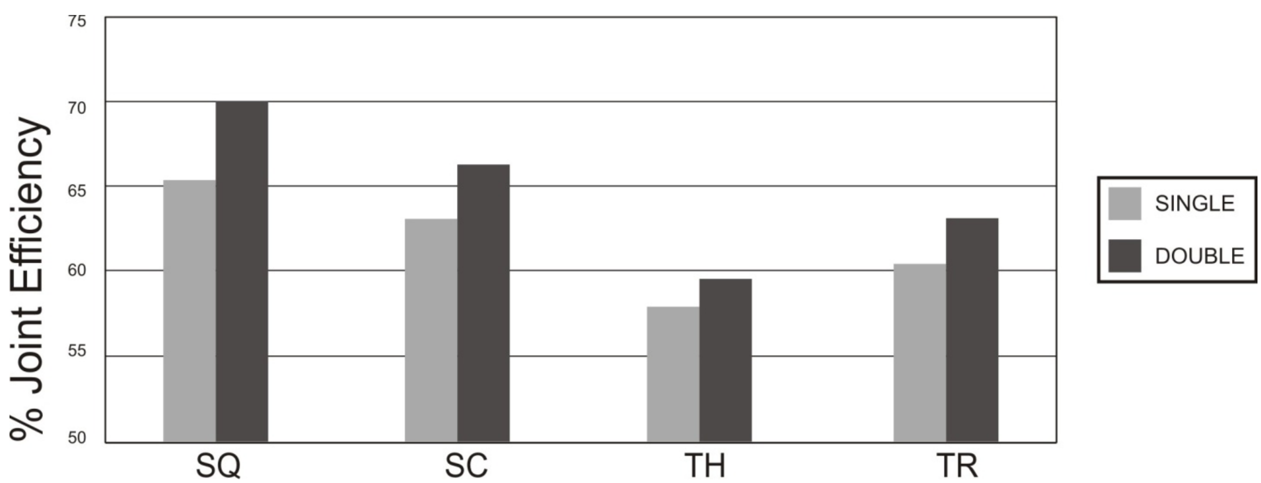
Specimen No.		Ultimate Tensile Strength		Percentage Elongation		Joint Efficiency (%)
	Area(in mm^2	Load (kgf`)	Stress (N/mm^2)	Elongated Length (mm)	% Elongation	
S5	139.2	1292	91	55.45	9.8	70
S6	144	1280	87	55.38	9.7	66.90
S7	144.6	1132	77	54.20	7.7	59.23
S8	143.10	1208	83	55.20	9.4	63.8



Graph 1 Variation of Ultimate Tensile Strength



Graph 2 Variation of Percentage Elongation



Graph 3 Variation of Joint Efficiency

Tensile properties of FSW joints i.e. ultimate tensile strength, percentage elongation and joint efficiency were evaluated. From the graphs, it can be seen that the tool profile and passing of tool in full depth in single pass and half in double pass are having influence on tensile properties of the FSW joints. In both single and double pass, the highest tensile strength of the joints was obtained by using the square pin profile tool. The square pin profiles tool is best and tensile strength significantly decreases for cylindrical, triangular and threaded pin profile tool . Square tool pin profile tool exhibited superior tensile properties compared to other joints,. Similarly, the joints fabricated by triangular pin profiled tool are also showing almost matching tensile properties to that of square tool profile in double sided weld. The joints fabricated by single pass have shown lower tensile strength and lower percentage of elongation compared to the joints fabricated by double pass and this trend is common for all the tool profiles. The joints fabricated by threaded pin profile tool in single sided weld shown inferior joint efficiency.

CONCLUSIONS

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

(i) The joints fabricated by double pass weld have shown higher ultimate tensile strength and also higher percentage of elongation as compared to the joints fabricated by single pass for all the tool profiles.

(ii) Square pin tool having superior joint efficiency among all tool profiles.

(iii) The joints fabricated by threaded pin profile tool in single sided weld shown inferior joint efficiency due to crack formation.

(iv) The joints fabricated by double pass weld have shown higher ductility as compare to the joints fabricated by single pass for all tool shapes.

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