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Influence of Tool Pin Profile and Tool Rotating Speed on Mechanical Properties of Al6082 Alloy

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Abstract: ***Friction stir welding is a solid state welding which uses non consumable welding tool. It is an automatic process which generally performs on the vertical milling machine. In this type of welding, the relative motion between the tools and work piece creates heat which uses the region of work piece to be welded get softened and to joint the two work pieces. Friction stir welding process is more reliable for the materials which are generally non heat treatable. In this present investigation it will observe that how the rotational speeds of the tool and different shapes of the tool pins effects the mechanical properties of the aluminium alloy 6082. For this purpose three tools with different profiles, i.e triangular, cylindrical and square was designed and fabricated. At three different rotational speeds of 560 rpm, 900 rpm, 1800 rpm work pieces are joined using vertical milling machine. Specimens are prepared and tested for mechanical properties, tensile, impact, and hardness tests are performed and to detect the defects and voids x-ray test performed on the weld joints. And it was observed that highest tensile strength was presented when the square pin tool used at 560 rpm. The rotational speed increased mechanical properties are reducing significantly.***

Keywords: ***Frictions stir welding, Al6082, Rotational speed, welding tools, pin profiles***

I. INTRODUCTION

Friction stir welding is an solid state welding process which is invented by the welding institute in the year of 1991 [1]. Friction stir welding is simple and efficient welding method it is an energy saving and environment friendly welding method. Friction stir welding method doesn't contains any liquid welding pool during the process complete will be done in solid state below the melting point of the materials to be joined. In friction stir welding it contains a non consumable welding tool which will have different shapes of profiles. FSW tool mainly contains the pin and shoulder. Generally the pin will be plunged in to the work pieces during the process. Before the process starts the pin of the tool rotates at the one place till it reaches the lower surface of the work pieces to be joined this is called the dwelling period [2]. Frictions stir welding tool plays vital role in the entire welding process so many literatures concluding the effect of tool geometry on the properties and formation of the defects and voids[3]. pin diameter and shoulder diameter decide the quantinum of heat generated during friction stir welding.

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Shoulder diameter considered to be the primary heat generation source. the shoulder diameter (D) is generally kept as 3 times the plate thickness of the material to be welded.[4] The square pin profile gives better mechanical properties of fsw joints. Strength of pieces welded by square tool is more than that of the pieces welded by round pin tool. The dissimilar friction stir welded joints have very low tensile strength if they are fabricated using the round pin tool. The square pin tool produces the pulsating effect and is having better plastic flow of material [5]. The welding parameter such as tool rotational speed, welding speed, axial force and tool pin profile play a major role in deciding the joint properties [6]. When the rotational speed of the tool increases than the properties of the joints will be reduced significantly because of the formation of voids at high speeds[7].

In this present investigation the effect of the different tool geometry will observe on the mechanical properties of Al6082. And how will be the properties affected by the tool rotational speed.

II. EXPERIMENTAL PROCEDURE

A. Materials

In this investigation aluminum alloy 6082 was used as a base material and high speed steel used to fabricate the tools. Tool material choice depends on the tool material operational characteristics like operational temperature, wear resistance and fracture roughness. H13Tool steel could be a versatile chromium-molybdenum hot work steel that's wide utilized in hot tooling applications. the recent strength of H13 resists thermal fatigue cracking that happens as a results of cyclic heating and cooling cycles in hot work tooling applications. as a result of its wonderful combination of high toughness and resistance to thermal fatigue cracking and additionally referred to as heat checking.H13 is employed for a lot of work tooling applications than the other steel.H-13 alloy steel that is characterised by high harden ability and wonderful toughness. The metal and atomic number 23 act as strengthening agents. The atomic number 24 content assists H- thirteen to resist softening once used at high temperatures. H- thirteen provide a wonderful combination of shock and abrasion resistance. H-13 has sensible machinability, sensible weld ability, and sensible malleability. The composition of the H-13 is as stated in the Table no 1

Table no: 1 composition of H-13 tool steel

Serial no	Element	% of content
1	Carbon	0.32-0.45
2	Chromium	4.75-5.5

3	manganese	0.2-0.5
4	Molybdenum	1.1-1.75
5	Phosphorus	0.3 max
6	Silicon	0.8-1.2
7	Sulphur	0.3 max
8	vanadium	0.8-1.2

Aluminium alloy 6082 may be a medium strength alloy with excellent corrosion resistance. it's the best strength of the 6000 series alloys. Alloy 6082 is thought as a structural alloy. In plate kind, 6082 is that the alloy most commonly used for machining. As a comparatively new alloy, the upper strength of 6082 has seen it replace 6061 in several applications. The addition of a large amount of metallic element controls the grain structure that successively leads to a stronger alloy. It is tough to provide skinny walled, difficult extrusion shapes in alloy 6082. The extruded surface finish isn't as swish as alternative similar strength alloys in the 6000 series. The composition of aluminium 6082 is stated in Table no:2

Table no: 2 Composition of Al 6082 alloy

Serial no	Element	% of content
1	Silicon	0.7-1.3
2	Magnesium	0.40-1.00
3	Manganese	0.60-1.20
4	Iron	0.0-1.5
5	Chromium	0.0-0.25
6	Zinc	0.0-0.25
7	Titanium	0.0-0.10
8	Copper	0.0-0.1
9	Aluminum	balance

B. Tool Design

Three types (triangular, cylindrical, and square) tool pin profiles are designed using CATIA V5 software and fabricated. The dimensions of the tools are collected from the literature and fallowed the ratios as exactly. Considered parameters in the design of the pin is

1. Diameter of the pin (d)
2. Length of the pin (L)

Length of the pin always depends on the thickness of the work piece to be welded

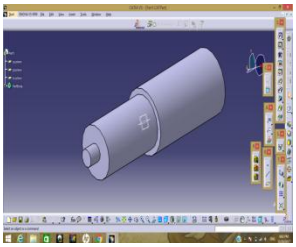
Diameter of the pin always depends on the diameter of the shoulder.

D/d=3

One of the most important parameter of the shoulder is the diameter (D) because it has significant effect to the amount of frictional heat. According to the literature the diameter of the shoulder should be three times greater than the thickness (T) of the work piece to be welded.

D/T=3

Greater shoulder diameter increases the pressure force and the weld shape changes which decreases the mechanical properties of welds. So the choice of shoulder diameter requires consideration**.**



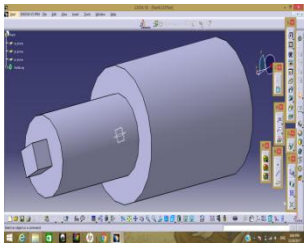


Fig no 1 cylindrical pin tool
Fig no 2 square pin tool

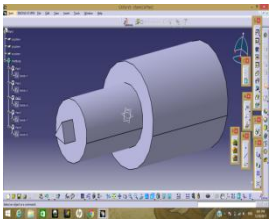


Fig no 3 Triangular pin tool
Fig no 4 fabricated tools

C. Specimen Preparation

The specimens of the size of 100mmx150mmx4mm were machined from AA6082aluminum alloy plates. The two plates of AA6082aluminum alloy were Friction stir welded using three different tool profiles like cylindrical, triangle, and square made of high speed steel. And the specimens were prepared according to the ASTM E8M-04 standards.

Fig no 5 work pieces after welding

III. RESULTS AND DISCUSSIONS

A. Tensile Test

The results obtained from the tensile tests are presented in the figure 6.

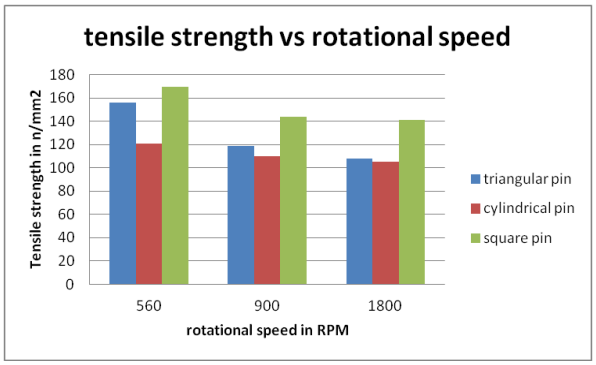


Fig 6 tensile strength vs. rotational speed at feed rate of 14mm/min

The results obtained from tensile test it can be said that the tool geometry and rotational speeds are significantly influencing the mechanical properties of the aluminum alloy 6082. From the fig no 6 it can be observed that highest tensile strength was obtained at 560 RPM when square pin tool was used and the lowest results are observed at 1800RPM of speed and straight cylindrical pin was used. From the results it was known that square pin obtained the highest results when compared with triangular and cylindrical pin tools irrespective of rotational speed. And increasing with speed tensile strength reduced significantly. Highest strength was observed at lowest rotational speed. The best results were obtained at 560RPM for three types of tools. The % of elongation also influenced by the tool geometry and tool rotational speed. The results obtained from the % of elongation and rotational speed is stated in figure no 7. Highest % of elongation was obtained when square pin tool was used and at the rotational speed of 560RPM.

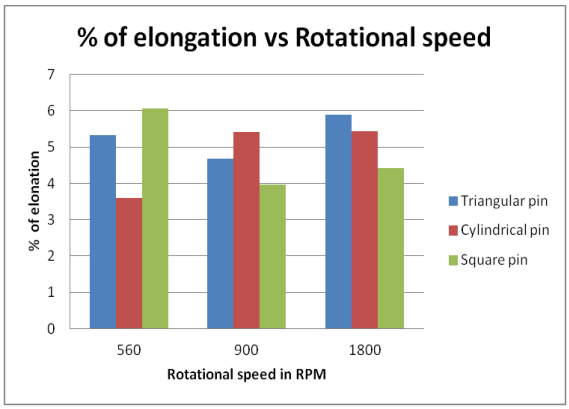


Fig no 7 %of elongation vs. rotational speed

B. Impact Test

Impact test was performed on the specimens to find the impact energy. Specimens were prepared according to the ASTM standards and impact test was performed on the charpy impact test machine. From the figure no 7 highest impact strength was observed at lowest rotational speed of 560 RPM irrespective of the tool pin type and also observed that rotational speed significantly influencing the impact strength when rotational speed increases impact strength gradually decreasing for triangular and square pin tools and for cylindrical pin tool impact strength was decreased at 900 rpm speed and again increased at 1800 rpm speed.

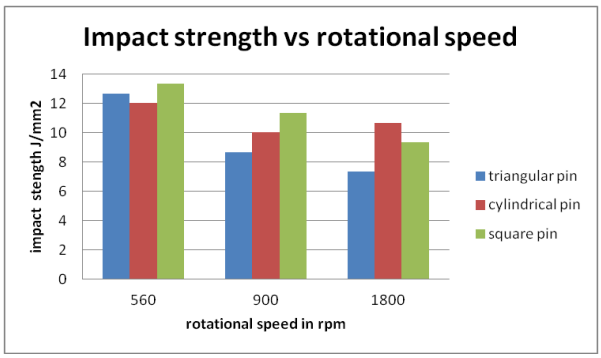


Fig no 8 impact strength vs. rotational speed

C. Hardness Test

Hardness is the value which is material offers to alter in shape. Hardness test was performed on the specimens after friction stir welding was done. And hardness values are found out at the different places from the weld zone for the 9 work piece the Vickers hardness values are tabulated in the below table no 3. Highest values of hardness are obtained at the weld zone. It was observed that hardness was increased with increasing in rotational speed. This is because when rotational speed increases more heat was produced due to which at recrystallization temperature fine grains were formed which resulted in increased hardness. There was difference in hardness profiles formed at different tool rotational speeds and tool pin profiles.

Table no 3 Vickers hardness values

Distance from weld centre (mm)	VICKERS HARDNESS VALUES (VHN)								
	PLATE1 (1800rpm) Triangular pin	PLATE 2 (1800rpm) Cylindrical pin	PLATE 3 (1800rpm) Square pin	PLATE4 (900rpm) Triangular pin	PLATE 5 (900rpm) Cylindrical pin	PLATE 6 (900rpm) Square pin	PLATE 7 (560rpm) Triangular pin	PLATE8 (560rpm) Cylindrical pin	PLATE9(560rpm) Square pin
-10	85	85	90	80	105	78	86	80	80
-08	76	75	85	80	90	80	70	80	75
-06	75	75	80	70	75	70	75	70	85
-04	68	65	70	75	80	80	67	75	70
-02	65	65	68	70	85	85	64	70	75
00	98	104	110	95	120	105	115	100	125
02	77	75	74	70	86	77	75	70	75
04	60	70	80	80	88	80	70	80	85
06	55	67	75	70	76	60	68	70	75
08	70	72	65	65	60	75	70	65	60
10	80	78	70	70	65	70	78	70	77

D. X-RAY RADIOGRAPHY TEST

Radiographic Testing (RT or X-ray or Gamma ray) could be a non-destructive testing (NDT) technique that examines the amount of a specimen. Radiography (X-ray) uses X-rays and gamma-rays to produce a ski gram of a specimen, showing any changes in thickness, defects (internal and external), and assembly details to make sure optimum quality in operation. X-ray test was performed on the specimens after the friction stir welding of the work pieces. From the results the fallowing observations are drawn. Some defects are formed in the specimens as tabulated in table no 4.

Table no 4 X-ray observations of defects

Serial no	Specimen type	observations
1	Triangular pin tool used at 1800 rpm	Surface defect
2	Cylindrical pin tool used at 1800 rpm	Poor/Lack of penetration
3	Square pin tool used at 1800 rpm	lack of fusion
4	Triangular pin tool used at 900 rpm	Surface defect/lack of fusion
5	Cylindrical pin tool used at 900rpm	lack of fusion
6	Square pin tool used at 900rpm	lack of fusion
7	Triangular pin tool used at 560 rpm	Surface defect
8	Cylindrical pin tool used at 560 rpm	lack of fusion
9	Square pin tool used at 560 rpm	Crack

From the observations it was found that more surface defects are observed when triangular pin used irrespective of the rotational speed. Lack of fusion was observed in remain two types of tools used.

IV. CONCLUSION

From this investigations fallowing conclusion may drawn

- Tool geometry and rotational speed of tool have significant effect on the mechanical properties of the base material
- Ultimate tensile properties are observed when square pin tool was used and at 560RPM of tool rotational speed. When rotational speed increases tensile properties are decreased significantly and lowest tensile properties are observed at 1800RPM and cylindrical tool pin used. % of elongation also affected by the speed and type of pin used.
- Impact properties are also affected by the rotational speed and type of tool pin profile used. Highest impact strength observed when square pin used and at lowest rotational speed used.
- Highest hardness was observed at the weld zone. Hardness was increased with the increasing in rotational speed because at high speeds more heat generated which helped in which at recrystallization temperature fine grains were formed which resulted in increased hardness.
- More defects are formed at low rotational speeds more surface defects are formed when the triangular pin tool was used. And cracks were observed when square pin used at 560RPM.
- For the aluminum alloy 6082 square pin tool was most reliable to gain more mechanical properties after welding.

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