Effect of Tool Shape on Mechanical Properties in Single Sided Friction Stir Welding using Aluminum Alloy (AA6061)

Ashampreet Singh
Assistant Professor Department of Mechanical Engineering
Chandigarh Group of Colleges, Jhanjeri
Mohali, Punjab, India

Sanjeev verma
Assistant Professor Department of Mechanical Engineering
Punjab college of engineering & technology lalru
Punjab,india

Abstract - In this experimental work, an extensive investigation had been carried out on Al Alloy (AA6061) grade aluminum alloy plates. Material of weld tool used is high carbon steel Diameter of tool head used 20 mm and length 50mm. Four different tool pin profiles (Straight cylindrical, Square, Threaded and Triangular) be used to fabricate joints in a single sided. In this investigation, tool rotation and traverse speeds are also varied i.e. 1045 rpm ,1776 rpm and 20 mm/min, 25 mm/min respectively. Tensile test specimens are prepared for Mechanical Testing of Materials on UTM. Ultimate tensile strength, and hardness are noted. Various mechanical properties of the joints are evaluated. The present work aims at carrying out the process of welding by friction stir welding method. The variables are (i) shape of the tool (ii) tool rotation and (iii) tool traverse speed.

Several previous studies reported the effects of the tool threads and probe profile on different Al alloys. In spite of these achievements, the effect of tool shape on mechanical properties in single sided friction stir welds of al alloy (AA6061) has not yet been systematically classified. Additionally, in order to design effective tools of high carbon steel to precede FSW on Al alloys, new concept is necessary. The tool requires the following characteristics:

1. As simple a shape as possible to reduce cost
2. Sufficient stirring effect to produce sound welds.

Hence an attempt has been made to study the effect of influence of tool shape on the mechanical properties (tensile strength, hardness) of (AA6061) in single sided friction stir welds in this project. In single pass, the highest tensile strength and hardness of the joints was obtained by using the square pin profile tool. The square pin profiles tool is best and tensile strength and hardness significantly decreases for, threaded, triangular and cylindrical pin profile tool due to defect formation.

Keywords -FSW, Straight Cylindrical (SC), Square (SQ), Cylindrical Threaded (TH) ,Triangular (TR)

I. Introduction

Friction Welding

Friction welding is a solid state joining process which can be used to join a number of different metals. Friction welding achieves 100 per cent metal-to-metal joints, giving parent metal properties. It is the only joining process to do this. No addition material or fillers are required and there are no emissions from the process. The process involves making welds in which one component is moved relative to, and in pressure contact, with the mating component to produce heat at the faying surfaces. Softened material begins to extrude in response to the applied pressure, creating an annular upset. Heat is conducted away from the interfacial area for forging to take place. The weld is completed by the application of a forge force during or after the cessation of relative motion. The joint undergoes hot working to form a homogenous, full surface, high-integrity weld **[38].**

This technique is attractive for joining high strength aluminum alloys since there is far lower heat input during the process compared with conventional welding methods such as TIG or MIG. This solid state process leads to minimal micro-structural changes and better mechanical properties than conventional welding. The process was developed initially for aluminum alloys, but since then, FSW was found suitable for joining a large number of materials. Conventional fusion welding of aluminum alloys often produces a weld which suffers from defects, such as porosity developed as a consequence of entrapped gas not being able to escape from the weld pool during solidification. In contrast, with FSW, the interaction of a non-consumable tool rotating and traversing along the joint line creates a welded joint through viscoplastic deformation and consequent heat dissipation resulting in temperatures below the melting temperature of the materials being joined. Other interesting benefits of FSW compared to fusion processes are low distortion, excellent mechanical properties in the weld zone, execution without a shielding gas, and suitability to weld all aluminum alloys **[20]**

1.1 Types of Friction Welding

Welding is a widespread and versatile technique for joining two pieces of the same kind of metal. A number of different types of welding are used, one of which is friction welding. Types of friction welding are given below.

1.2 Rotary Friction Welding

Rotary friction welding is the most common form of friction welding and has become the industry standard for a number of processes including welding API drill pipes and drill rods, joining of axle cases and spindles and welding of piston rods. Rotary friction welding involves holding one component still while spinning the other component and brining the two together **[38].**

The rotary friction welding process is inherently flexible, robust and tolerant to different qualities of materials. The parameters involved are the rotational speed, time and force applied. There are optimum parameters for each particular weld that Thompson Friction Welding have calculated through years of experience. However, as the process is inherently robust and flexible, deviations on these parameters can still give a good weld **[38].**

II. LITERATURE REVIEW

In recent years, FSW has been widely developed for mostly aluminum and magnesium alloys. Most of the work on FSW has been dedicated to the study of the flow of material, the effect of tool rotation and tool travel speed on the mechanical properties and fatigue property, very less study has been done to study the effect of tool pin shape on friction stir welding. **Mangla Lokesh, et al (2014)** research objective is to quantify the relationship between spindle speed, travel speed, and tool tilt angle parameters for friction stir welding (FSW) at high spindle speeds (1200rpm-4600rpm) to optimize the rockwell hardness testing of Al6061 and AA5083 alloy.**S Venugopal, et al (2014)** had made an effort to analyze the microstructure of aluminium AA 7075-T6 alloy. Three different tool profiles (Taper Threaded, cylindrical and square) have been used to construct the joints in particular rotational speed.

III. RESEARCH METHODOLOGY

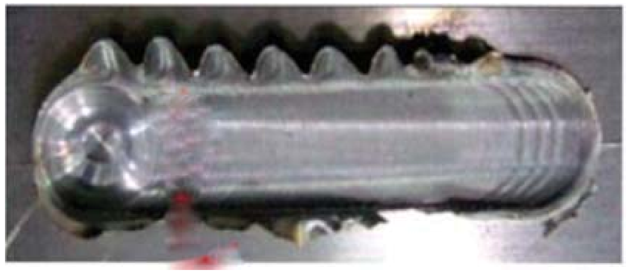
The present work aims at carrying out the process of welding by friction stir welding method. Basically heat is generated as a result of friction due to the stir contact of two similar materials plates i.e. aluminum alloy (AA6061) plates. There is not any systematic study comparing the effect of tool pin profile on mechanical properties of Al weld using Taguchi DOE technique.**[**Four different tool shapes have been used to fabricate single sided joint. The Design of experiment is done and experimental data is analyzed with the help of minitab software and L8 orthogonal Array is used. A correlation was established between input parameters and mechanical properties. The ANOVA was employed to investigate the influence of input parameters like, tool shape, tool rotation and tool travel speed on mechanical properties.

IV. WELDING DEFECTS

The defects that occur in friction stir welds are kissing bond, tunnel-type defect, groove-like defect, flash defect, pull out or run off defect etc. (Kyokai, 2010).

Flash- type defect

When the plunge depth was deeper than optimized value, big weld flash was formed on the retreating side due to the excessive extrusion of the plastic material near the pin.



Kissing bond defect

The cause of kissing bond defects the extremely small stirring done by probe tip. This defect is difficult to detect by standard non-destructive inspection of incomplete welds in which the bonding force is extremely small.

Tunnel-type defect

When the plastic flow of the material is incomplete because of inadequate input heat, when the tool rotates at low speed and the welding speed becomes high tunnel type defect occurs.

.

Groove-like defect

Groove like defect occurred due to in adequate heat input comparatively more than tunnel type defect.

Important welding parameters

The important welding parameters for FSW are mainly:

1. Tool rotation and traverse speeds
2. Tool tilt and Plunge depth
3. Tool design
4. Welding forces
5. Generation and flow of heat

Tool design

The tool of FSW is composed of two parts: a tool body and a probe. The tool technology is the heart of friction stir welding process. The tool shape determines the heating, plastic flow and forging pattern of the plastic weld metal.

The tool shape determines the weld size, welding speed and tool strength. The tool material determines the rate of friction heating, tool strength and working temperature The radius of the tool body's shoulder is almost three times of that of the probe. If the radius of the shoulder is too small, the friction heat is not enough to plasticize the materials beneath the shoulder. On the other hand, the friction heat may too large to make the temperature of the materials beneath the shoulder reach or excess the melt point, consequently reduce the weld strength and raise the irregularity of the weld surface shown in figure1.9

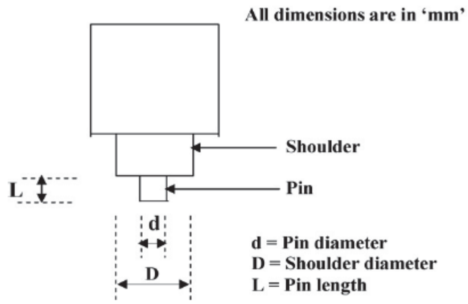
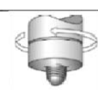
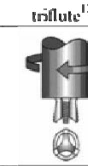
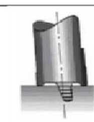
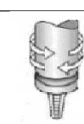


Figure 1.9 FSW Tool Dimensions

The design of the tool is a critical factor as a good tool can improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough and hard wearing, at the welding temperature. Further it should have a good oxidation resistance and a low thermal conductivity to minimize heat loss and thermal damage to the machinery further up the drive train.

Improvements in tool design have been shown to cause substantial improvements in productivity and quality. TWI has developed tools specifically designed to increase the depth of penetration and so increase the plate thickness that can be successfully welded. An example is the 'Whirl' design that uses a tapered pin with re-entrant features or a variable pitch thread in order to improve the downwards flow of material. Additional designs include the Triflute and Trivex series. The Triflute design has a complex system of three tapering, threaded re-entrant flutes that appear to increase material movement around the tool. The Trivex tools use a simpler, non-cylindrical, pin and have been found to reduce the forces acting on the tool during welding.

Table 1.3: - Various tool designs and their application

Tool	Cylindrical	Whorl™	MX triflute™	Flared triflute™	A-skew™	Re-stir™
Schematics						
Tool pin shape	Cylindrical with threads	Tapered with threads	Threaded, tapered with three flutes	Tri-flute with flute ends flared out	Inclined cylindrical with threads	Tapered with threads
Ratio of pin volume to cylindrical pin volume	1	0.4	0.3	0.3	1	0.4
Swept volume to pin volume ratio	1.1	1.3	2.6	2.6	depends on pin angle	1.8
Rotary reversal	No	No	No	No	No	Yes
Application	Butt welding; fails in lap welding	Butt welding with lower welding torque	Butt welding with further lower welding torque	Lap welding with lower thinning of upper plate	Lap welding with lower thinning of upper plate	When minimum asymmetry in weld property is desired

Benefits of FSW over conventional welding:-

1. No filler materials are required.

2. Easily automated on simple milling machines - lower setup costs and less training.
3. Can operate in all positions (horizontal, vertical, etc), as there is no weld pool.
4. Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
5. Weld monitoring can insure 100% weld quality.
6. Friction welding produces a 100% cross sectional weld area.
7. Far Superior weld integrity Compared to MIG welding
8. Limited operator training requires.
9. The weld cycle is fully controlled by the machine.
10. Friction welding is a solid state process and does not suffer from inclusion and gas porosity.
11. Friction welding required no consumable therefore becomes more cost effective overtime.
12. No post machining is needed for friction welded components in many cases.
    Dissimilar materials can be joined with no alloying of the material

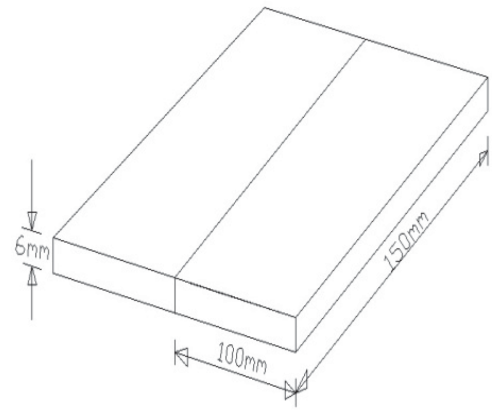
V. DISCUSSION OF RESULTS

Material and its composition

The base material (BM) used in this investigation is aluminum alloy (AA6061). The chemical composition of the material is given in Table 1.4

Table 1.4 Chemical composition of aluminum alloy (AA6061)

Material	**Al**	**Si**	**Cu**	**Mg**	**Cr**
AA6061	97.9%	0.60%	0.28%	1%	0.20%



DIMENSIONS FOR THE WORK PIECE

VI. CONCLUSION

The following inferences have been drawn-

- The tensile strength is mostly affected by tool shape & tool rotational speed.
- Confirmation experiment shows that error (%) associate with tensile strength is 3.00 .
- The hardness is mostly affected by tool shape & tool rotation speed.
- Confirmation experiment shows that error (%) associate with hardness is 1.9.

REFERENCES

[1] A.Pradeep, Muthukumaran S., International Journal of Engineering, Science and Technology, "An analysis to optimize the process parameters of friction stir welded low alloy steel plates", Vol. 5, No. 3, 2013.

[2] Ahmadi Hedi, Arab Mostafa Nasrollah Bani, Ghasemi Faramarz Ashenai, Archives Des Sciences, " Application of Taguchi method to optimize friction stir welding parameters for polypropylene composite lap joints", Vol 65, No. 7, 2012.

[3] Aydin Hakan, Bayram Ali, UDK Materials and Technology, " Application of grey relation analysis and taguchi method for parametric optimization of friction stir welding process",ISSN 1580-2949 2010.

[4] Barlas and Ozsarac U welding journal, " Effects of FSW parameters on joint properties of AlMg3 alloy", Vol. 91, 2012.

[5] Bilici M. K., Express Polymer Letters, "Effect of tool geometry on friction stir spot welding of polypropylene sheets", Vol.6, No.10, 2012.

[6] Chandu K.V.P.P, Rao E.Venkateswara, Rao A.Srinivasa, Subrahmanyam B.V., International Journal of Research in Mechanical Engineering & Technology. "The Strength of Friction Stir Welded Aluminium Alloy 6061". Vol. 4, Issue Spl. 1, 2014.

[7] Chand A. Gopi, Bunyan V John., International Journal of Engineering Research & Technology (IJERT), "Application Of Taguchi Technique For Friction Stir Welding Of Aluminum Alloy AA6061",Vol. 2 Issue 6, 2013

[8] Chen Z.W., Yazdanian S, Journal of achievement in material and manufacturing engineering, "Friction Stir Lap Welding: material flow, joint structure and strength". Vol 55, Issue 2, 2012.

[9] Dalu Shrikant G and Shete M T, International journal of mechanical engineering and robotics research, "experimental investigation on effect of rotational speed and tool pin geometry on aluminium alloy 2014 in friction stir welding of butt joint". Vol. 3, No. 3, 2013

[10] Jayaraman M, Sivasubramanium R Journal of scientific and industrial research, "Optimization of process parameters for friction stir welding of cast aluminum alloy A319 by Taguchi Method", Vol. 68, 2009.

[11] Kalyani K.Venkata, Kumar K.Sunil Ratna, International Journal of Research in Engineering and Technology, "Optimizing process parameters of friction stir butt welded joint on aluminium alloy AA-6061 T6".Vol. 3, 2014**.**

[12] Krishna G.Gopala , Reddy P.Ram, Hussain M.Manzoor, International Journal of Engineering Trends and Technology, "Mechanical Behaviour of Friction Stir Welding Joints of Aluminium alloy of AA6351 with AA6351 and AA6351 with AA5083", Vol. 10 Number 4 , 2014.

[13] Lorrain Olivier, Favier Véronique, Zahrouni Hamid, Lawrjaniec Didier, Journal of Materials Processing Technology, "Understanding the material flow path of friction stir welding process using unthreaded tools". vol. 210, 2010.

[14] Mangla Lokesh, Rajiv, Chaudhary Ravinder, International journal of research in engineering & applied sciences, " Experimental study of friction stir welding of AA6061 & AA5083 by taguchi technique"., Vol 4, ISSUE 6 , 2014.

[15] Moghddam M.Sarvghad, Parvizi R, Haddad-Sabzevar M, Davoodi A, Material and design, "Microstructure and Mechanical properties of friction stir welded Cu 30 Zn brass alloy at various feed speed : influence of stir bend" Vol 4 2011.

[16] Mohanty H.K., Mahapatra M.M., Kumar P., Biswas P, Mandal N.R., journal of marine science and application, “Effect of tool shoulder and pin probe profile on friction stirred alluminium welds” ISSN :1002-2848 2012.
[17] Nandan, Roy R., Lienert G.G., T.J. and Debroy, Act Material, “Three-dimensional heat and material flow during friction stir welding of mild steel”, vol. 55, 2007
[18] Nourani Mohamadreza, Milani Abbas S., Yannacopoulos Spiro, International Journal of Research in Engineering and Technology “Taguchi Optimization of Process Parameters in Friction Stir Welding of 6061 Aluminum Alloy”, Vol 4 2011.
[19] Pawar Satish P., Shete M.T., International Journal of Research in Engineering and Technology ,“Optimization of friction stir welding process parameters using taguchi method and response surface methodology”, Volume 02, Issue: 12 , 2013.
[20] Patil H. S., Soman S. N. International Journal of Engineering, Science and Technology, “Experimental study on the effect of welding speed and tool pin profiles on AA6082-O aluminium friction stir welded butt joints” Vol. 2, No. 5, 2010.
[21] Petry Zheng, D., Rapp H., Wierzbicki T., Thin-Walled Structures,“A characterization of material and fracture of AA6061 butt weld”, Vol 4,2008.
[22] Prasanna P., Penchalayya Dr.Ch., Rao Dr.D.Anandamohana, American Journal of Engineering Research, “ Effect of tool pin profile and heat treatment process in friction stir welding of AA6061 aluminium alloy”, Volume-02, Issue-01, 2013 .
[23] Prakash Prashant, Jha Sanjay Kumar, Lal Shree Prakash, International Journal of Innovative Research in Science, Engineering and Technology, “A study of process parameters of friction stir welded AA 6061 Aluminium Alloy”, Vol. 2, Issue 6, June 2013.

`