INFLUENCE OF TOOL DESIGN ON THE MECHANICAL PROPERTIES IN FRICTION STIR WELDING OF ALUMINIUM ALLOY AA 6082-T6

A.Ramesh[1], Dr. M Indira Rani[2], A.Pransanth[3],

Abstract-Friction-stir welding (FSW) is a solid state joining process carried out with a non consumable rotating tool and is a Solid-state joining process.The present study involves the investigation of friction stir welding (FSW) of aluminum alloy 6082 to study the mechanical properties such as tensile strength and hardness. The two most important friction stir welding process parameter Tool rotating and welding speed are taken into the consideration. Study of tensile strength and hardness at different weld condition were carried out.The development of this process was a significant change from the conventional rotary motion and linear reciprocating friction welding processes. It provided a great deal of flexibility within the friction welding process group. Joints between dissimilar materials of 6082 – T6 in aerospace structures mostly made by riveting which causes stress concentration and increase the weight of the final joints. Dissimilar welding of aluminum alloys is a core demand Of the aircraft industries to substitute the traditional joining technologies with low cost and high efficiency ones such as friction stir welding in the future advanced design.The aim of this research study is to investigate the effect of tool design on the mechanical properties in friction stir welding of aluminium alloy AA 6082-T6.

Keywords — frictions stir welding (FSW), rotary motion, dissimilar welding, tool design, aluminium alloy AA 6082-T6 and process parameter.

1 INTRODUCTION

Friction Stir Welding (FSW) is a solid state welding process in which the relative motion between the tool and the work piece produces heat which makes the material of two edges being joined by plastic atomic diffusion.

This method relies on the direct conversion of mechanical energy to thermal energy to form the weld without the application of heat from conventional source. The big difference between FSW and fusion welding (other than the lack of melting) is the ability to manipulate peak temperatures by choice of different welding parameters. This paper summarizes the results of an experimental campaign in which the aluminum alloy AA 6082-T6 was Friction stir Welded, using various combinations of process parameters (rotational and tool pin profile). Mechanical properties of the test welds were assessed by means of static tensile test, Vickers hardness measurement

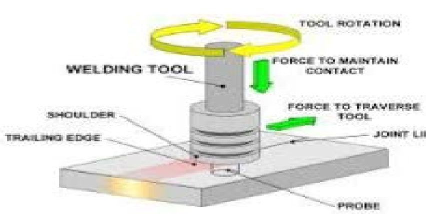


Fig 1. Schematic diagram of FSW process

A.Ramesh, Assistant Professor,
Department of Mechanical Engineering,
Mobile number: 9491868404
Malla Reddy Engineering College, Dhullapally, Hyderabad,
Telangana, India, E-mail: ramesh340mech@gmail.com
Dr. M Indira Rani,Professor
Mechanical Engineering
JNTUH College of Engineering Hyderabad (Autonomous)
Email: marpuindira@rediffmail.com
A.Prasanth, Assistant Professor,
Department of Mechanical Engineering,
Mobile number: 8790833371
Malla Reddy Engineering College, Dhullapally, Hyderabad,
Telangana, India, E-mail: adunuri327@gmail.com

ALUMINUM ALLOY 6082

The 6082 is high strength Al-Mg-Si alloys that contain manganese to increase ductility and toughness. Aluminum alloy 6082 has the highest strength among the 6000 series alloys with excellent corrosion resistance property. Alloy 6082 is known as a structural alloy.

2. EXPERIMENTAL PROCEDURE

The base metal (BM) sheets of 3 mm thick Aluminum were welded by butting two plates and stirring them together with a rotating tool assembly by using vertical milling machine (Make HMT FM-2, 10 hp, 3,000 rpm). Mechanical properties of the BM are presented in Table .H13 tool steel is chosen as tool material because of its high strength at elevated temperature, thermal fati- gue resistance, and low wear resistance. The trial experi- ments were conducted with TC tool pin profile on FSW of copper by varying tool rotation speed and welding speed, and the optimum rotational speed and welding speeds are found to be 900 rpm and 40 mm=min, respect- ively; which resulted in better mechanical properties . Keeping the welding conditions such as tool rotation speed at 900 rpm and welding speed 40 mm=min con- stant and varying the tool pin profiles such as TT, SQ, and TR, , the joints were fabricated and are shown in Fig. 1. The welding parameters and tool dimensions used to fabricate in FSW process are pre-sented in Table 1. The FSW joints were fabricated with different tool pin profiles and found to be defect-free, and the surface morphologies of the FSW joints are shown in Fig. 2. From the surface morphology, it is observed that the amount of flash is low in the jointsfabricated by SQ tool pin profile compared to other tool pin.

Fig. 2. from the surface morphology

ISSN 2229-5518

3. FSW TOOLING USED IN THIS INVESTIGATION:

This section details all the requirements, considerations and features for designing and implementing friction stir welding tools. The friction stir welding tools for use in this investigation were designed by taking into consideration, the fundamental principles of the FSW process. The tooling was designed using 3D CAD software to produce detailed engineering drawings which were either sent to the mechanical engineering workshop in the case of the simple probed tools or to an independent tool maker for the more complex tool designs.

4. Tool material selection

4.1Tool steel

Tool steel is used in the manufacturing of a tool by cutting, machining, or shaping of material. The first used tool was of plain carbon tool steel which was modified by the addition of other alloying elements to increase the ability of the material for more service severe conditions. The performance of the tool depends mainly on four factors that are the design of the tool, manufacturing accuracy, proper material selection and proper heat treatment selection. The heat treatment provides some properties like wear resistance, resistance to deformation, breaking under high loads, and resistance to softening at elevated temperatures

There are many types of tool steels:

1. High Speed Steels.
2. Hot Work Steels.
3. Cold Work Steels.
4. Shock resisting Steels.
5. Low-alloy, Special-purpose tool steels.
6. Water Hardening tool steels.

From the above types, the Hot Work Tool Steel H13 was selected based on the criteria of the weighted properties selection.The most widely used types in this group are H13, H12, H11 and, to a lesser extent, H19. All of the chromium hot work steels are deep hardening. H11, H12, H13 may be air hardened to full working hardness in section sizes up to 150mm, other group H steels may be air hardened in section sizes up to 300mm. The air-hardening qualities and balanced alloy contents of these steels result in low distortion during hardening. Chromium hot work steels are especially well adapted to hot die work of all kinds, particularly dies for extrusion of aluminium and magnesium, as well as die-casting dies, forging dies, mandrels and hot shears.

5. Tool design:

The FSW tool Nomenclature used for the friction stir welding of 6082 Aluminium alloy and the fabricated FSW tool for friction stir welding of 5mm thick aluminium alloy plates are shown in the Figure

For FSW of aluminium alloy plates, the tool material selected is H13 Tool Steel and the tool dimensions used are: D= 19mm,d = 6mm and L = 5.5mm

Five types of friction stir welding tools were designed and fabricated for use in this investigation are as listed below:

Tool 1: Square Pin
Tool 2: Straight Cylindrical Pin with Threading
Tool 3: Tapered screw thread pin

These five tools have been designed using 3D CAD software to produce detailed engineering drawings which facilitate the fabrication of tools. And the complete procedure for tools modeling, design and fabrication is as follows:

5.1 Square Pin:

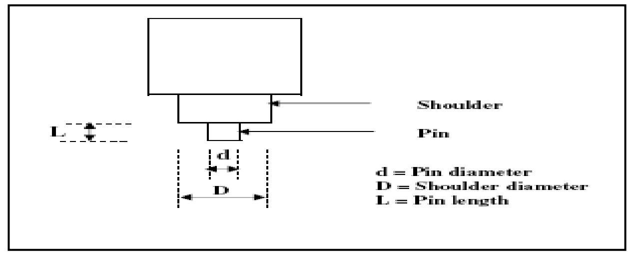


Figure 3. FSW Tool Nomenclatures

The FSW tool with square pin profile to weld 5mm thick Aluminum 6082-T6 plates is shown in Figure 4.2. The pin for this tool has a square profile with a cylindrical shoulder.

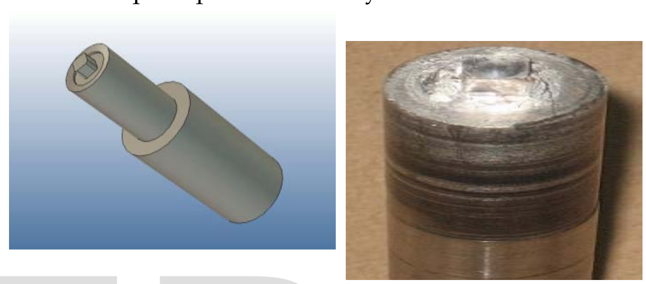


Fig. 4. From the surface morphology

5.2 Tapered screw thread pin:

The FSW tool with Tapered screw thread pin profile to weld 5mm thick Aluminum 6082-T6 plates is shown in figure 5. The pin for this tool has a standard threading of M6 on a tapered profile and a cylindrical shoulder.

Figure 5. Taper screw thread pin profiled tool

6. EXPERMENTAL PARAMETERS

Table 1: Parameters:

PROPERTIES	VALUE
Density	2.70 g/cm³
Melting point	555 °C
Thermal expansion	24 x10-6 /K
Modulus of rigidity	70 GPa
Thermal conductivity	180 W/m.K
Electrical resistivity	0.038 x10-6 Ω .m

ISSN 2229-5518

Table 2: Parameters:

Rotational speed(rpm)	900
Welding speed(mm/min)	40
Axial force(KN)	5
Tool shoulder Diameter, D(mm)	18
Pin diameter, d(mm)	6
D/d ratio of tool 3	3
Pin length, L(mm)	5.5
Tool inclined angle(degrees)	2
Shoulder deepness inserted into the Surface of base metal(mm)	5.5

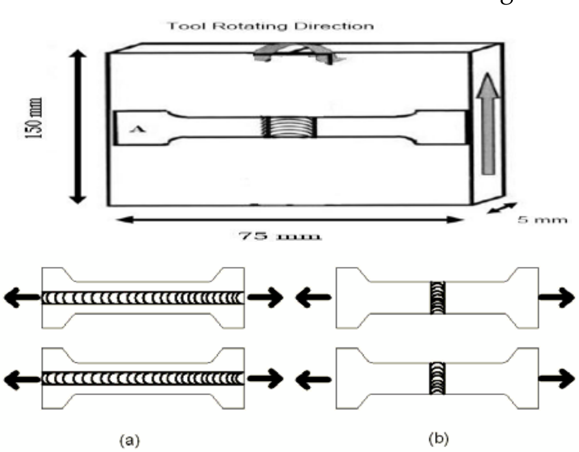
7. TESTING OF WELD

7.1 Tensile Testing

Tensile testing specimens were blanked out of the welds using a punch and die mounted to a ball-screw press. Care was taken during this stage to align the centre of the weld with the centre of the tensile specimen. Tensile testing was carried out on an MTS make tensile testing machine for accurate readings for the displacement.

7.2 Sample Preparation

The both side of the weld zone divided into the retreating side and the advancing side from the relation between the tool rotation direction and plate travel direction. Tensile test specimens were sectioned from the welded specimens in the transverse direction to the weld zone as shown in Figure



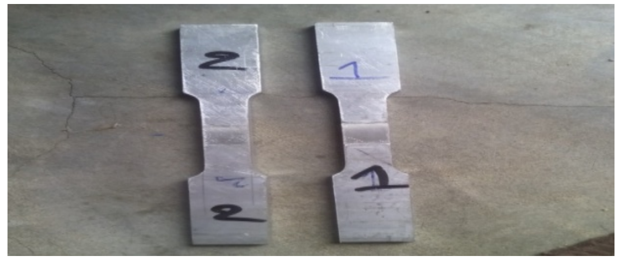
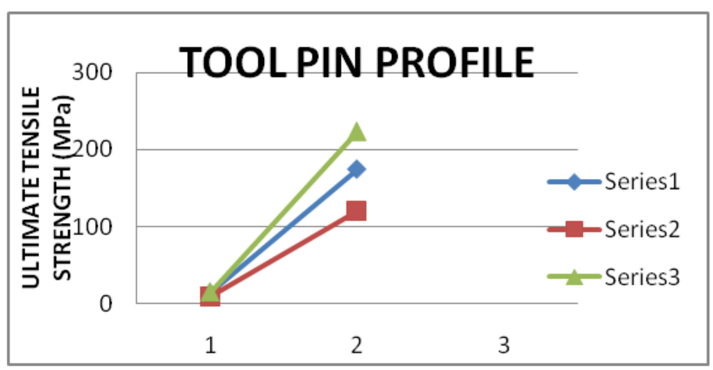


Figure 6 Schematic illustrations of tensile test specimens in the transverse direction to the weld zone.

Distribution planning of the specimens on the sheet material is shown inMacro views of tensile test samples were obtained with the OM. Values of yield strength, ultimate tensile strength and percentage elongation of each specimen were obtained as test results

RESULT OF TENSILE TEST:

SNO	PROFILES	ULTIMATE LOOAD (KN)	ULTIMATE TENSILE STRENGTH (MPa)
1	TRINGLE	13.500	174.757
2	SQUARE	9.360	120.961
	taper cylindrical threaded	14.54	223.3



7.3 Hardness Testing

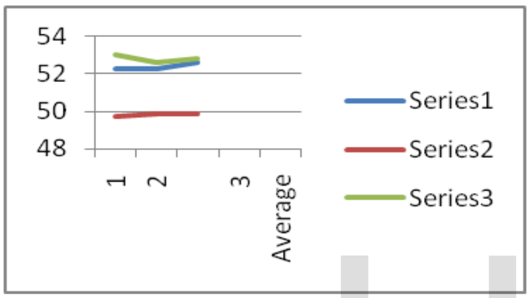
The microhardness of the welded joints was measured on a Vickers micro hardness tester. The micro hardness tester has

ISSN 2229-5518

an eyepiece and a rhombus shaped indentor to measure the

S.NO	Identification	Location	Impression			
			1	2	3	Average
1	Triangle	ON SURFACE	52.3	52.3	52.6	52.4
2	Square	ON SURFACE	49.7	49.9	49.9	49.83
3	taper cylindrical threaded	ON SURFACE	53	52.6	52.8	52.94

micro hardness of the material. The load on the indentor be set using a knob on can the tester.



4 IMPACTIMPACT TEST:

The Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative.

TABLE: 2. for impact test

S.NO	Sample	Impact values,J
1	Triangle	18J
2	Square	14J
3	taper cylindrical threaded	21J

8. APPLICATIONS:

An application 6082 is typically used in:
1. Highly stressed applications
2. Trusses,
3. Bridges,
4. Cranes
5. Transport applications
6. Ore skips,
7. Beer barrels,
8. Milk churns

9. CONCLUSION

The effect of the variant pin geometries on the mechanical and microstructural properties of AA 6082-T6 alloy welds was investigated via FSW.

1. The addition of the interface geometry between the pin and shoulder of the tools has been found to significantly increase the tool life.

2. The effect of tool pin profile and process parameters on the appearance of the weld is presented and no obvious defect was found. The results indicate that the shape of the pin has a significant effect on the joint structure and the mechanical properties.

3. For the given set of parameters, tool rotation speed as 900 rpm, welding speed as 40 mm/min, of the Two tool profiles used concave shoulder taper cylindrical threaded tool pin profile (R = 3.5mm) gave good mechanical properties.

4. The weld joint obtained using a SQ pin profiled tool Possesses 85% joint efficiency compared to the joints

10. REFERENCES

1. Chinese Welding Society. Welding Handbook; 2nd ed., vol. 2. China Machine Press: Beijing, 2001; 608–643.
2. Esmaeili, A.; Givi, M.K.B.;Rajani, H.R.Z. A metallurgical and mechanical study on dissimilar friction stirs welding of aluminum 1050 to brass (CuZn30). Mater.Sci. Eng.A 2011, 528 (22–23), 7093–7102.
3. Sakthivel, T.; Mukhopadhyay, J. Microstructure and mechanical properties of friction stir welding of copper. J. Mater. Sci. 2007, 42 (19), 8126–8129.
4. Sinclair, P.C.; Longhurst, W.R.; Cox, C.D.; Lammlein, D.H.; Strauss, A.M.; Cook, G.E. Heated friction stir welding: An experimental and theoretical investigation into how preheating influences process forces. Materials and Manufacturing Processes 2010, 25, 1283–1291.
5. Anderson, C.G.; Andrews, R.E. Fabrication of containment canisters for nuclear waste by Friction Stir Welding. In Proceedings of First International Symposium on Friction Stir Welding, Thousand Oaks, CA, June 14–16, 1999.
6. Okamoto, K.; Doi, M.; Hirano, S.; Aota, K.; Okamura, H.; Aono, Y.; Ping, T.C. Fabrication of backing plate of copperalloy by friction stir welding. In Third International Symposium on Friction Stir Welding, Kobe, Japan, September 2001.
7. Yadava, M.K.; Mishra, R.S.; Chen, Y.L.; Carlson, B.; Grant, G.J. Study of friction stir welding of thin aluminium sheets in lap joint configuration. Sci. Technol. Weld Join 2010, 15 (1),70–75.
8. Choi, D.H.; Ahn, B.W.; Lee, C.Y.; Yeon, Y.M.; Song, K.; Jung, S.B. Effect of pin shapes on joint characteristics of friction stir spot welded AA5J32 sheet. Mater. Trans. 2010, 51 (5), 1028–1032.
9. Hirasawa, S.; Badarinarayan, H.; Okamoto, K.; Tomimura, T.; Kawanami, T. Analysis of effect of tool geometry on plastic flow during friction stir spot welding using particle method. J. Mater. Process.Technol. 2010, 210 (11), 1455– 1463.
10. Zhao, Y.H.; Lin, S.B.; Wu, L.; Qu, F.X. The influence of pin geometry on bonding and mechanical properties in friction stir welds 2014 Al alloys. Mater.Lett. 2005, 59 (23), 2948–2952.

ISSN 2229-5518
11. Aissani, M.; Gachi, S.; Boubenider, F.; Benkedda, Y. Design and optimization of friction stir welding tool. Materials and Manufacturing Processes 2010, 25 (11), 1199–1205.