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Effect of welding parameters and tool shape on properties of friction stir welding of Aluminum alloy AA- 6061

Ahmad Hussain Albloushi, Maen M. Al-Rashdan
[1]*The public Authority for Applied Education and Training, Kuwait*
[2]*Department of Mechanical Engineering, Al-Huson Universoty College Al-Balqa Applied University, Jordan*

ABSTRACT
Friction stir welding (FSW) is a widely used solid state joining process for soft materials such as aluminium alloys because it avoids many of the common problems of fusion welding. It has many benefits when applied to welding of aluminum alloys. FSW process parameters such as welding speed, rotational speed and tool geometry play vital roles in the weld quality. The aim of this research is to investigate the effects of different welding speeds, rotational speeds and tool pin profile on the weld quality of a AA6061 aluminum alloy. A friction stir welding tool consists of rotating shoulder and pin that heats the working piece by friction and moves a softened alloy around it to form a joint. In this research work the effect of the tool shape and welding parameters (rotating speed and welding speed) on the mechanical properties of an aluminium plates will be investigated experimentally. The induced heat during the welding process played the main role in the mechanical and appearance of the joints, which is related to the welding parameters.
Keywords: Friction stir welding; Tool shapes; Aluminium.

I. INTRODUCTION

Friction stir welding (FSW) is a relatively new solid-state joining process. This joining technique is energy efficient, environment friendly, and versatile. In particular, it can be used to join high-strength aerospace aluminum alloys and other metallic alloys that are hard to weld by conventional fusion welding [1]. FSW was invented at The Welding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminium alloys [2]. In which the joined material is plasticized by heat generated by friction between the surface of the plates to be welded and the contact surface of a special tool, which is composed of two main parts; shoulder and pin. Shoulder is responsible for the generation of heat and for containing the plasticized material in the weld zone, while pin mixes the material of the components to be welded, thus creating a joint. This allows for producing defect-free welds characterized by good mechanical properties [3].

Three distinct zones can be recognized in the friction stir welding process namely, the stirred zone (SZ), the thermo mechanically affected zone (TMAZ) and the heat affected zone (HAZ) [4]. However, the material flow behavior is predominantly influenced by the FSW tool profiles, FSW tool dimensions and FSW process parameters [5].

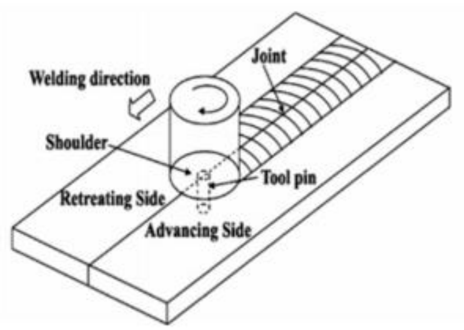

Fig. 1 Schematic of the friction stir welding process

Experimental work

The experiments were conducted on the aluminum alloy AA- 6061; its chemical composition is presented in Tables 1

Table1: Percentage of chemical composition AA 6061 alloy

Mg	Si	Fe	Cu	Zn	Ti	Mn	Cr	others	Al
0.8 -1.2	0.4-0.8	0.7	0.15-0.4	0.25	0.15	0.15	0.04-0.35	0.05	98.7

The aluminium plates to be welded were cut into rectangular pieces of 250 by 150 mm and then being welded by friction stir welding process, each two of them were butt welded using a conventional vertical milling machine by using a well-designed clamping fixture which tightly fixed on the milling machine table to prevent vibration from occurring which is used to fix the two sheets. Four high carbon steel shapes of probes used as a welding tool: Circular, triangle, square and hexagonal shape. A heat Recent Advances in Industrial and Manufacturing Technologies ISBN: 978- treatment process is done for the tools before welding.

Fig. 2 conventional vertical milling machine

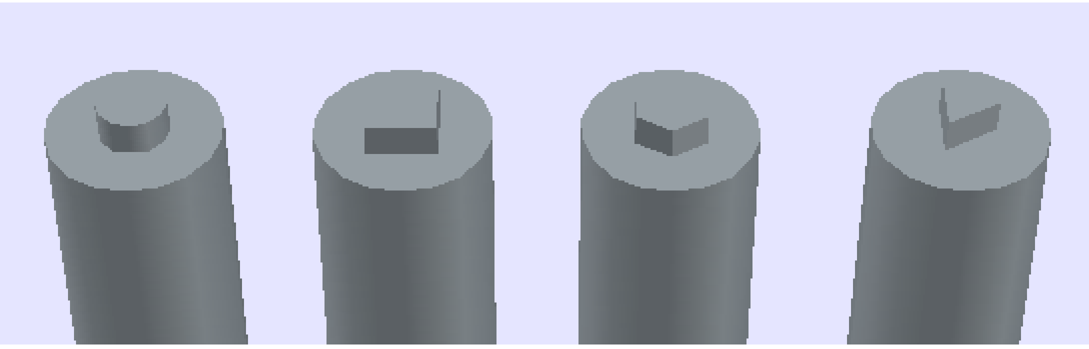

Fig. 3 Shapes of the probes

The welding process was carried out using five different tool rotational speeds, which were 600, 800, 1000, 1200, and 1800 rpm and five welding (traverse) speeds, which were 0.5, 1, 1.5, 2, and 2.5 mm/sec using only a single stir pass during the welding process. All other welding parameters were kept constant. Vickers microhardness was measured with 0.5 kgf load. This force is held for a predetermined amount of time (dwell time) to allow for elastic recovery of 10s. Several measurements were done for each hardness value. Also, a tensile test on a universal tensile testing machine was carried out to measure the tensile strength of the welded plates. The tensile samples were extracted along the transverse direction as per the American Society for Testing of Materials (ASTM E8M-04) as shown in figure 4.

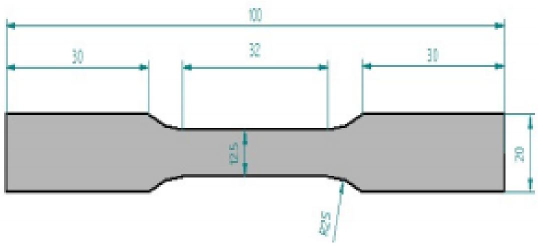

Fig. 4 Tensile test specimen as per ASTM Standards

II. RESULTS AND DISCUSSION

The predicted results are plotted as graphs and they are displayed in figures 5-8. Fig.5 shows the Appearance of top surface of the friction stir welded plates at different rotational speeds. The welding speed is kept at 1.5 mm/sec. Fig. 5 (A and B) shows a free defect weld at a rotational speed of 1000 and 1200 rpm. Fig.5(C) shows the Appearance of top surface at a rotational speed of 1800 rpm. Large defects presents as cracks were formed on a long the tool traverse direction near the center region of the SZ. These cracks may be resulted. When the tool moves forward the melt exposed to the ambient air were solidified as a layers more on advanced side.

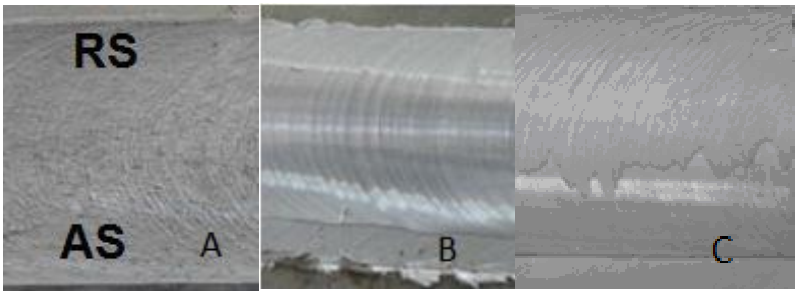

Fig.5 Appearance of top surface welded at (A) 1000 rpm, (B) 1200 rpm and (C) 1800 rpm

Fig.6 shows the appearance of the top surface of friction stir welded surface plates at welding speeds of (0.5, 1, and 1.5 mm/sec). The rotational speed kept constant at 1000 rpm. It can be seen that due to high rate of heat input per unit length at low welding speed a liquation melting of aluminium alloy occurred,. This liquid smeared and covering the surface under beneath of the shoulder face unequally, and solidified just exposed to air during the forward motion of the shoulder as shown in Fig. 6 (A) and (B). Fig 6 (C) shows that the surface becomes more smooth at higher welding speed of 1.5 mm/sec.

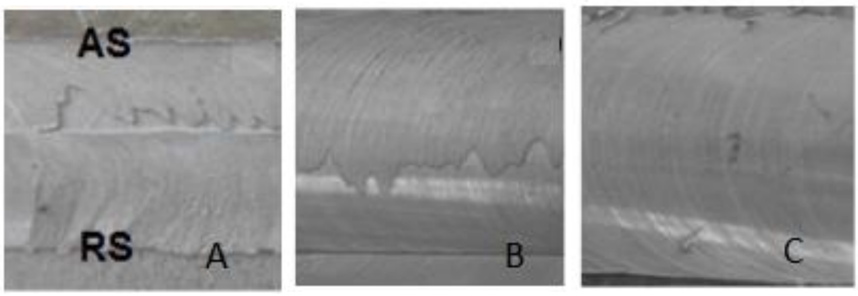

Fig.6 Appearance of top surface welded at (A) 0.5 mm/s, (B) 1 mm/s and (C) 1.5 mm/s

The effect of rotational speed and tool shape on the micro-hardness of the stir zone is shown in figure 7. It can be seen that the microhardness of the stir zone decreases with increasing the rotational speed at a constant welding speed. For the pin profile effect, it can be seen that the maximum hardness value achieved with triangle pin profile.

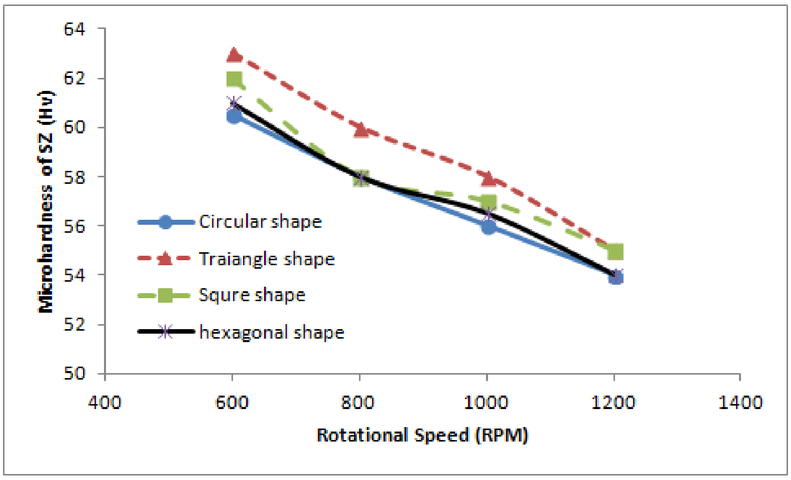

Fig. 7 Variation of surface microhardness of Friction Stir Weld plates with rotation speed for different tool shapes

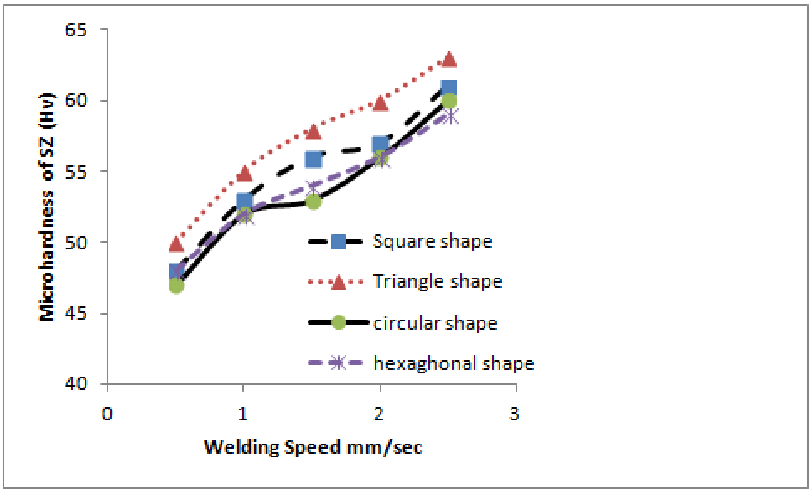

Fig. 8 Variation of surface microhardness of Friction Stir Weld plates with welding speed for different tool shapes

Fig.8 shows the effect of welding speed and tool shape on the micro-hardness of the stir zone. It has been found that the microhardness in SZ increases with increasing of the welding speed.

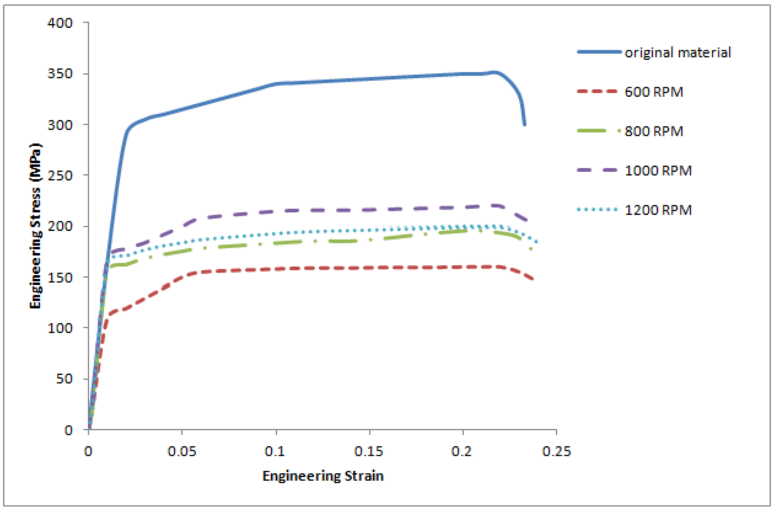

Fig. 9 Effect of rotational speed on Stress Strain Diagram

Fig.9 illustrates the effect of rotational speed on Stress of FSW joint. It has been found that the strength properties of all the welded joints are lower than that of the base material. As the rotational speed increased the ultimate strength of welded joints increased. But at higher rotational speed less heat input leads to more deformation of materials especially at the interface of SZ and TMAZ zones. So, little drop in ultimate tensile strength when the welding speed exceeds 1000 rpm.

III. CONCLUSION

FSW of a AA6061 aluminum alloy was performed In this study. The effect of the tool shape and welding parameters on the mechanical properties of the welded aluminium plates was investigated. The following conclusions were achieved:

1. The heat input into welding region during FSW process, affecting the weld surface morphology. So, a suitable combination of welding parameters, rotation speed and welding speed should be chosen to have free defect joint.
2. For a low rotation speed (600 rpm), the tool shape does not significantly affect the mechanical properties of the joints.
3. At low rotation speed of 600 rpm with higher welding speed of 2.5 mm/sec, the flow of plasticized metal under shoulder face is not sufficient, leads to a pitting weld surface
4. Ultimate tensile strength increased to an optimum value then starts decreased. This phenomenon is occurred with all FSW parameters

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