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The Study of Rotational and Traversal Speeds Effect on Mechanical Properties Of 7075 Aluminium Alloy Friction Stir Welding

R. Karimdadashi[1]
[1]Department of Mechanical Engineering, Faculty of Engineering, University of Bonab, Bonab, Iran

Abstract*: FSW has been successfully used to weld similar and dissimilar cast and wrought aluminium alloys, especially for aircraft aluminium alloys generally present low weldability by traditional fusion welding process. In this article, effects of rotational and traversal speeds on the microstructure and mechanical properties of friction stir-welded 7075-T6 Al alloys were investigated. Good correlation existed between the rotational and traversal speeds and weld properties. It was found that with increase in the rotational and traversal speed, wider thickness of the heat-affected zone were obtained, and then grain coarsening, dissolution, and accumulation of hardening precipitates in grain boundaries. In addition, the highest toughness during tensile test was obtained at moderate rotational and traversal speeds of 325 r/min and 30 mm/min. However, the highest micro hardness was obtained at moderate rotational and traversal speeds of 325 r/min and 60 mm/min. It was imposed high temperature which cause of this different.
Keywords: Friction stir welding, 7075-T6 Al alloy, rotational speed, mechanical properties, Microstructure.

I. INTRODUCTION

Friction stir welding (FSW) is a relatively new joining technique developed by the welding institute (TWI) Cambridge, in 1991, [1]. In FSW, a rotary tool is used and the two pieces are held firmly together. The tool penetrates into work pieces with a rotational and linear motion to cause heating the work piece material due to friction between the tool and the work piece till the melt is formed. The linear and rotational movements of the tool in a molten pool create fusion of the work piece edges. After leaving the tool, the molten liquid freezes and two pieces are welded together [2, 3]. The process occurs in the solid state and offers a number of advantages over conventional fusion welding techniques. Low heat input, absence of melting and solidification, no need for expensive consumables such as filler wire and gas shields, ease of automation, fewer weld defects, low residual stresses, good mechanical properties of the resultant joints, low distortion and improved dimensional stability are some of its advantages [2, 4]. The most important benefits of FSW are its ability to weld materials that were thought difficult to weld such as plastics and composites [5].

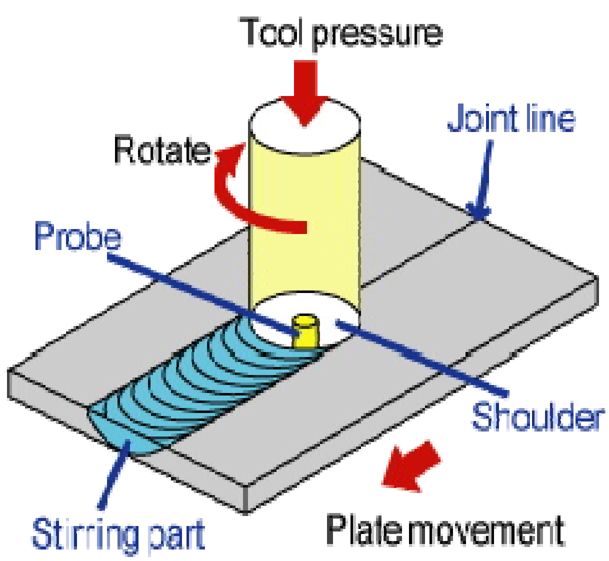

Fig. 1 schematic of friction stir welding process

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Aluminium Alloy AA7075 (Al–Zn–Mg–Cu) is one of the strongest aluminium alloys in industrial use today. Its high strength to weight ratio, together with its natural aging characteristics, makes it attractive for a number of aircraft structural applications [1]. The alloy derives its strength from precipitation of Mg2Zn2 and Al2CuMg phases. A major problem with this alloy is that it is not fusion weldable. It is extremely sensitive to weld solidification cracking as well as heat-affected zone (HAZ) liquation cracking due to the presence of copper. Friction stir welding (FSW) is a solid state welding technique invented in 1991 by the welding institute (TWI). This process is effective for welding of various aluminium, magnesium and copper alloys [2]. In FSW process a non-consumable rotating tool consisting of two parts, pin and shoulder, moves along the weld line. The joining is accomplished as a result of the localized frictional heat and plastic deformation associated with the movement of material from the front to the back of the rotating pin. It has been reported that the nature of the weldments materials as well as the FSW parameters such as tool rotational and traverse speeds, tool geometry, and joint design have a significant influence on the weld quality and consequently the determination of the optimum FSW conditions is very important [3-5]. Several investigations were carried out to study the effect of FSW parameters on the microstructural and mechanical characteristics of aluminium alloys. For instance, Shifting et al. [3] studied the effects of welding parameters (pin rotation speed, welding speed and welding pressure) on the quality and mechanical properties of the 01420 Al–Li friction stir welded joints. They found that the heat input for forming the defect free joints reduces with the increase of the welding speed or the decrease of the rotation speed. The heat input had little influence on the transverse tensile strength of the joints. Cavaliered et al. [5] studied the effect of welding parameters on mechanical and microstructural properties of AA6056 joints produced by FSW at several tool rotating (500, 800 and 1000 r.p.m) and traverse (40, 56 and 80 mm/min) speeds. The results showed that the material ductility reaches the highest values for 40 and 56 mm/min welding traverse speed and the lowest rotating speed (500 r.p.m), decreasing strongly as increasing the rotating speed and the welding speed. Moreover, the highest tensile strength is reached in correspondence of the higher rotating speeds (800 and 1000 r.p.m) for the highest welding speed (80 mm/min).

II. EXPERIMENTAL PROCEDURE

A vertical milling machine was used to provide rotational and traverse speeds needed for welding. A clamping fixture, as shown in Fig. 2, was utilized to fix the specimens to be welded on the milling machine, so that they would not separate during welding process.

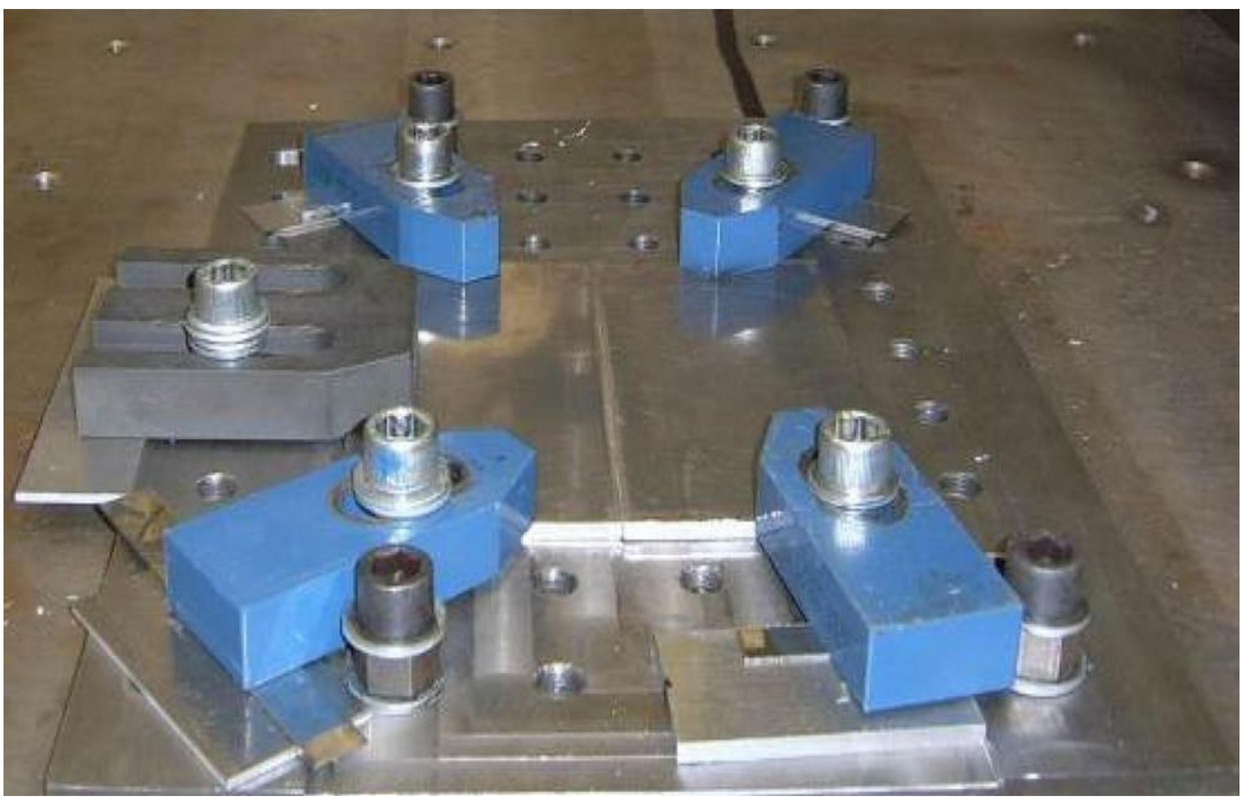

Fig. 2 Clamping fixture used in the experiment

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Besides, six threaded cylindrical tool made of chromium hot-work steels (H13) with a hardness of 50 HRC was used in the experiments. A 6-mm thick aluminium alloy AA7075-T6 was investigated in this research, which is typical for aeronautics applications. The chemical composition of the work piece is given in Table 1. The sheet metals were received in 1m×2m×6 mm thick blanks and reduced to rectangle specimens of 150_200 mm edges which were jointed. Alloy 7075 is a heat-treatable aluminium alloy that contains Zn and Cu in order to increase strength and permits precipitation hardening. A heat treatment was utilized to provide T6 condition as part of the experiments [9]. To eliminate any effects of previous. Operations on the sheets, the plates were annealed by holding them at 413ºC for 3 h followed by cooling in furnace. Then, it was solution heat treated at 482ºC, followed by quenching to room temperature in order to become supersaturated solid solution. Finally, the T6 condition was obtained through artificial ageing consist of holding at 121ºC for 24 h, followed by air cooling to room temperature.

TABLE I
CHEMICAL COMPOSITION OF THE MATERIAL

Chemical Composition Limits										Others	
Weight %	Al	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Each	Total
Minimum	Rem	-	-	1.2	-	2.1	0.18	5.1	-	-	-
Maximum		0.40	0.50	2.0	0.30	2.9	0.28	6.1	0.20	0.05	0.15

III.RESULTS AND DISCUSSIONS

To compare the surface quality of the joints, welds fabricated with different cylindrical tools are studied. It can be seen that the best smooth and regular surface of the welds in this study was achieved by cylindrical tool with the following geometrical characteristics: shoulder diameter equal to 20 mm and a pin with 6 mm diameter and 3.8 mm height. When the cylindrical tools was changed to smaller shoulder the surface of the welds became rougher covered with particles of aluminium with abrasive appearance. Such poor surface quality is created, because of low temperatures generated during welding, which is not enough to remove material from Rs to As. However, at high tool pressure during welding, the temperature generated on fixed tools geometrical is increased and the weld have a smooth and regular surface.

A threaded cylindrical tool was used with the following geometrical characteristics: shoulder diameter equal to 20 mm and a pin with 6 mm diameter and 3.8 mm height. Comparing the rotary speeds of 325, 825 and 1125 r/min at traverse speed of 60 mm/min, excessive flash was observed which was as a result of outflow of severely plasticized material from underneath the shoulder. However, when flash is formed, the volume of material in the stirred zone is not sufficient for filling the hole and consequently can produce void-like defects in the weld region.

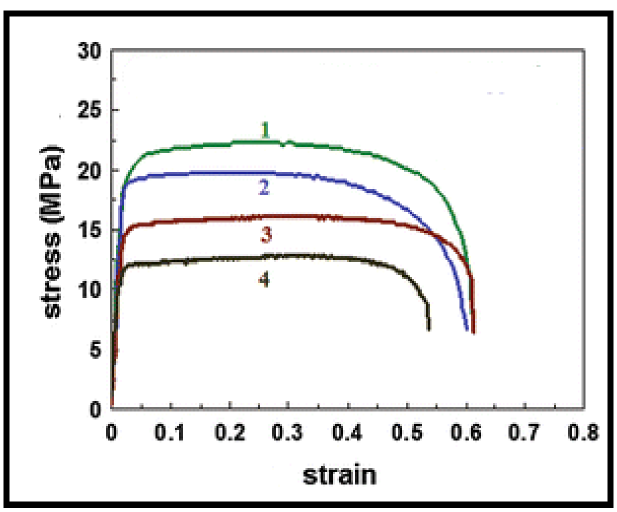

Fig. 3 stress versus strain curves of the FSW samples

Volume 5 Issue VI, May 2017
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Fig. 3shows the stress-strain carves of welded samples which no flash and void-like defects in the weld region. To reveal the effect of rotational and traversal speeds on microstructural evolution Grain structures in the weld zones were investigated using an optical metallographic. Fig. 4 show the variations of grain size and its distribution in the welded 7075-T6 under the different rotation and traverse speeds. As can be seen both welds exhibit a fine, equated grain structure in the WN. Grain refinement induced by FSW is related to dynamic recrystallization that happens during welding as a result of high strain rate at elevated temperatures. Moving away from the centre, the grain size is increased, and began to become less equated than those closer to the nugget zone (NZ). In the TMAZ, the grains are deformed, elongated, and rotated due to strain they were subjected during welding. In the HAZ, microstructure is similar to that of base material; the grains are slightly overgrown as a result of exposure to welding heat. The very fine grain structures formed in the nugget may be attributed to continuous dynamic recrystallization under extremely large deformation, high strain rates, and high temperature [8]. However, by distancing from the centre the size of recrystallized grain is decreased. It was found that boundary between HAZ and TMAZ in samples with higher rotation speed was smoother than samples with lower rotation speed. The samples, which were welded with higher rotation speed generated higher temperature and show lower toughness.

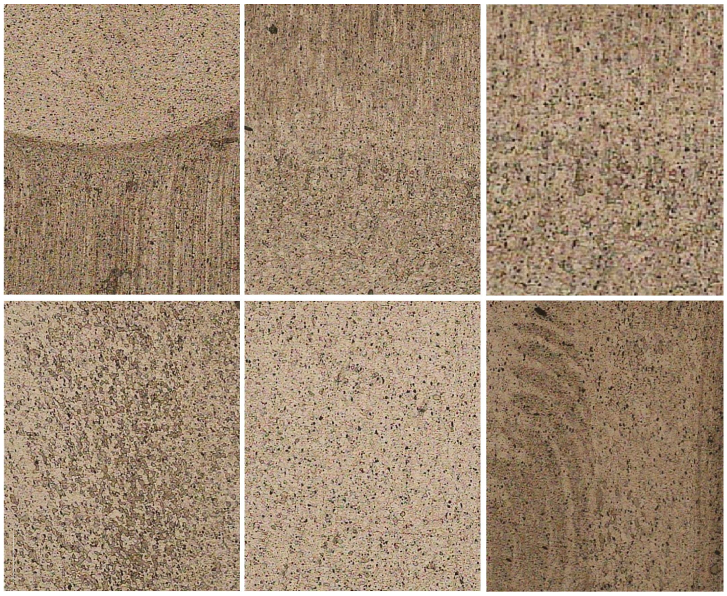

Fig. 4 Cross-sectional microstructure of the joint welded at different rotary and traverse speeds

IV. CONCLUSIONS

In this study, the microstructure, mechanical properties and micro hardness of friction stir-welded aluminum alloy 7075-T6 were examined with different rotational and traverse speeds. The results show that:

The best threaded cylindrical tool was used in the experiments with the following geometrical characteristics: shoulder diameter equal to 20 mm and a pin with 6 mm diameter and 3.8 mm height. In this case, the surface of the welds became smoother, without particles of aluminum.

Compared with rotary speeds below 825 and 1325 r/min in 60 mm/min traverse speed, excessive flash was observed resulting from outflow of severely plasticized material from underneath the shoulder. It can produce void-like defects in the weld region.

The samples were imposed high temperature by high rotation and traverse speeds have dissolved and re-precipitated particles along grain boundaries. Large amounts of zinc and copper were contained in the grain boundaries at nugget because of imposed high temperature.

The traverse speed is more effective than rotation speed on temperatures which cause of dissolved and re-precipitated particles along grain boundaries.

When using a high traverse speed of 30 mm/min which provide nearly the same temperatures on the two sides of the weld, so that the difference on the AS and RS would be ignorable and similar micro hardness would be expected on these two sides.

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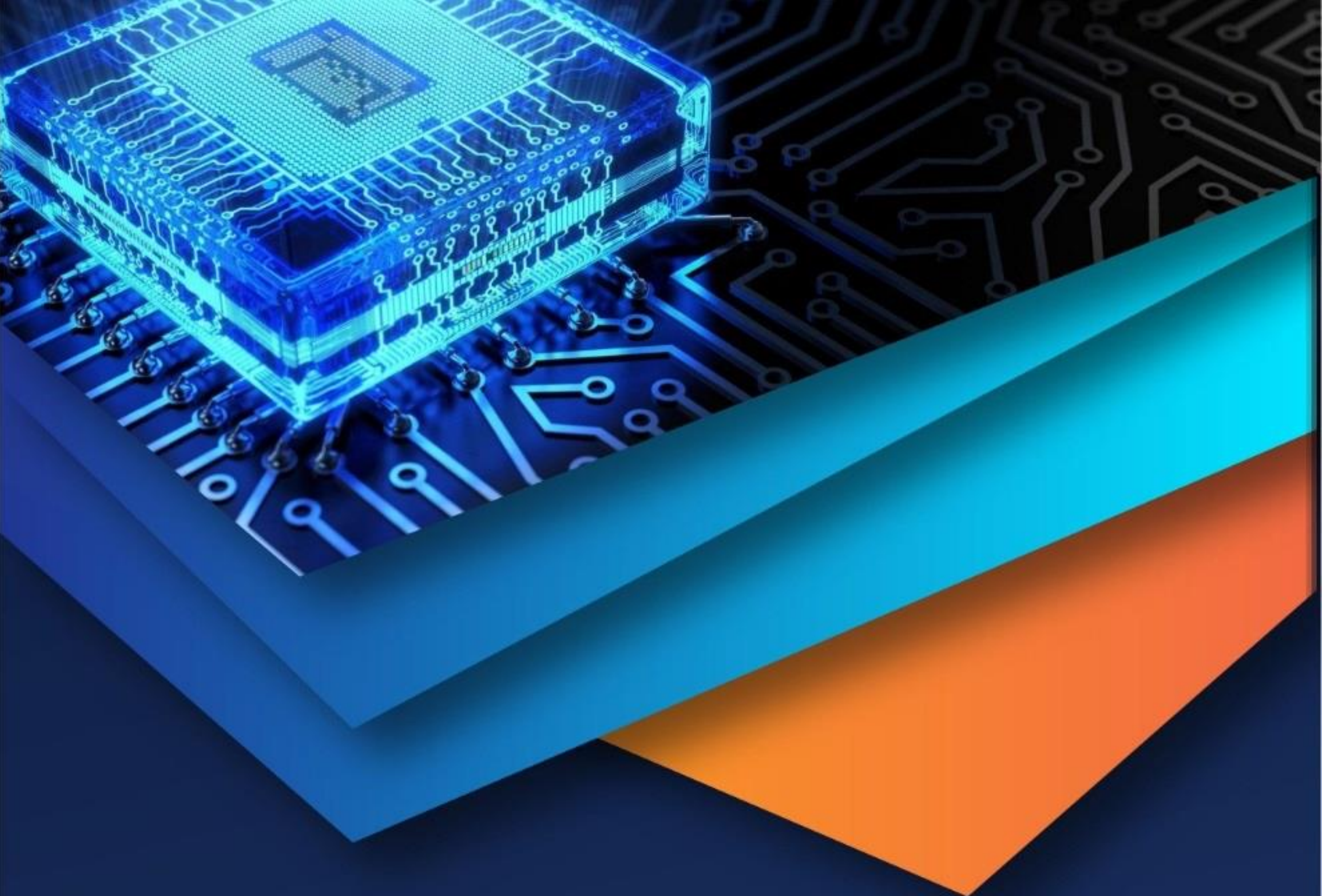

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