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Various Plunge Depth Effect on Mechanical Properties of Friction Stir Welded AA 7075

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Abstract
This research article is aimed to find the effect of various plunge depths on the double sided friction stir welding. Friction stir welding is performed on 7075 Al alloy. Tool pin length was varied to determine the effect on mechanical properties which are hardness and tensile strength of the resulted weld joint. The experiment was performed with conventional 3-axes milling machine. The experiment was performed at constant rotational and welding speed but with various pin lengths. The result showed that increase in pin length decreases the hardness while increases the tensile property of the weld. Hence overlapping phase in double sided friction stir welding increases the ultimate tensile strength.

Keywords
Friction Stir Welding, Aluminium Alloys, Welding Parameters, Plunge Depth, Pin Length

I. Introduction
Many industries, especially automotive and transportation are regarded to be major investor in advance welding research because of direct encroachment of the research outcomes on their product flexibility and quality. Also Aluminium is one of the lightest structural alloys that are commercially available with high stiffness and specific strength. Hence some more reliable welding process is required to back up these applications. However, formal fusion welding process has some problems, such as hot cracking, poor solidification, porosity, which limits the utilization of the Aluminium alloys [1]. To overcome the above mentioned demerits, Friction Stir Welding (FSW) can be used to weld Aluminium alloys.

Friction stir welding is an effective method to join materials in solid state. It was formulated by The Welding Institute (TWI) in 1991 which have made significant progress in the welding technology [2]. Friction stir welding can be considered as a hot plastic deformation process. Friction stir welding process is energy efficient, green and eco-friendly welding process. Its main feature is to join the material without reaching the melting temperature of material. In FSW, a non-consumable rotating tool is inserted into the interface of two stiffly clamped work pieces. The tool is composed of a shoulder and a pin which can be of different geometries as per the requirement. The tool is then moved along the joint interface once the shoulder of the tool makes contact with the work piece. The contact between the tool and material generates the frictional heat while tool pin rotation leads to material stirring, hence joining the work pieces together. The bond is created due to the plastic deformation and mixing of the material at high temperature without actual melting of the material. The main advantages of the friction stir welding are higher joint mechanical properties, low distortion and its automation compared to the fusion welding processes [3]. The schematic diagram of Friction stir welding is shown in fig. 1 [4].

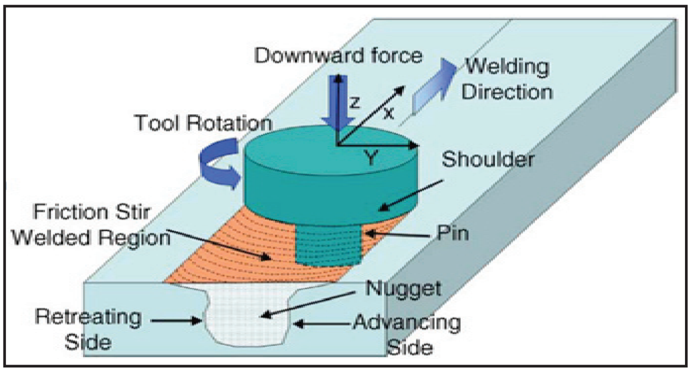


Fig. 1: Schematic Illustration of FSW

The properties and quality of the resulted friction stir weld depends on various parameters which can be welding parameters or geometrical parameters of the tool. Karami et al. (2016) interpreted the effect of welding parameters on FSW. Macroscopic analysis showed that at lower rotational speed or higher welding speed, probability of void or welding defect formation is relatively higher. Also FSW processed materials indicated higher yield strength and lower uniform elongation [5]. Chen at el. (2015) analyzed the sound joint produced by concave DSFW. With the help of concave tool, adoption of the lower rotational rate becomes feasible and the mean grain size of the stir zone increases for concave-DFSW at lower rotation rate [6]. Shahu et al. (2014) proposed the effects of shoulder diameter and plunge-depth on mechanical properties and thermal history. The results indicated that there is an increase in mechanical properties and peak temperature with increase in shoulder diameter [1]. Devanathan et al. (2013) indicated the plunge depth influence on the mechanical properties. Sound joint without defects were obtained at zero plunge depth and defects such as flash and voids were present when plunge depth was increased [7]. Puviyarasan et al. (2012) studied the feasibility of the friction stir welding process for joining two different aluminum alloy [8]. Cao et al. (2011) analyzed the change in tensile shear load because of change in the probe length. Results showed no significant variation in microstructure at various probe lengths. Also the cavity defects were appeared at relatively low heat input and sound lap joints were obtained at an advancing rate higher than 1.3 mm per revolution [9].

II. Experiment
The experimental alloy is Aluminium 7075 in the form of plates with dimensions of 100 x 50 x 12 mm and nominal composition of Zn 5.940 wt.%, Mg 2.110 wt.%, Cu 1.530 wt.%, Cr 0.189 wt.%, Fe 0.171 wt.% and the balancing Al. The conventional 3-axes vertical milling machine was used for friction stir welding. The two plates were clamped and fixed into the fixture rigidly to withstand the welding and frictional forces. Two plates were positioned such as their adjoining sided touches each other completely. The welding carried out was butt joint welding. The rotational tool of H13 tool steel was used for the experimental purpose. The main alloying elements of H13 tool steel are Cr 4.840 wt.%, and Mo 1.260 wt.%.

The rotational tools having a diameter of 22mm and a pin length of 4mm, 6mm and 8mm with conical pin geometry were used. The figure 2 shows the three different tool pin length of the tool.
For the study of different pin length on the resulting weld by friction stir welding, two different set of welding parameter were considered. For the first part of study, 1600 rpm tool rotational speed along with the 20 mm/min of welding or transverse speed was selected. The welding was performed with three different pin lengths on both the side of the plates to be joined. For the second part of the study, 2000 rpm along with 16 mm/min of welding speed was selected. The welding process was performed similarly as first part. Table 1 shows the appearance of the Double sided friction stir welding.

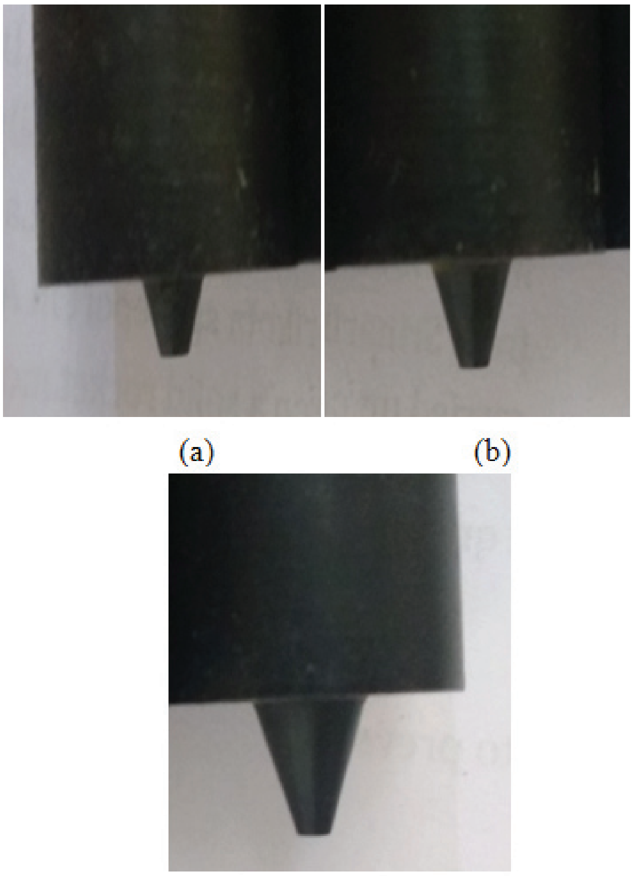
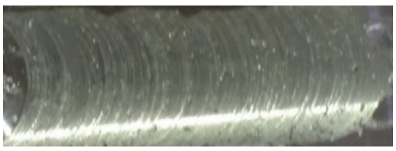
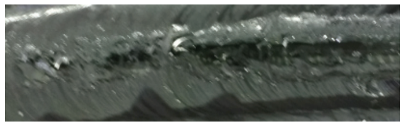
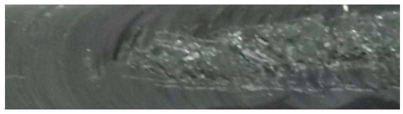
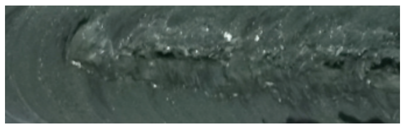


Fig. 2: Three Differrent Pin Length of the Rotationg Tool (a) 4mm (b) 6 mm (c) 8mm

Table 1 : Appearance of the Double Sided Friction Stir Welding

Welding Parameter	Side	Appearance
(a) 1600 rpm, 20 mm/min, 4 mm pin length	Front	
(b) 1600 rpm, 20 mm/min, 4 mm pin length	Back	
(c) 1600 rpm, 20 mm/min, 6 mm pin length	Front	
(d) 1600 rpm, 20 mm/min, 6 mm pin length	Back	
(e) 1600 rpm, 20 mm/min, 8 mm pin length	Front	
(f) 1600 rpm, 20 mm/min, 8 mm pin length	Back	
(g) 2000 rpm, 16 mm/min, 4 mm pin length	Front	
(h) 2000 rpm, 16 mm/min, 4 mm pin length	Back	
(i) 2000 rpm, 16 mm/min, 6 mm pin length	Front	
(j) 2000 rpm, 16 mm/min, 6 mm pin length	Back	
(k) 2000 rpm, 16 mm/min, 8 mm pin length	Front	
(l) 2000 rpm, 16 mm/min, 8 mm pin length	Back	

III. Result and Discussion

The mechanical properties of the welded joints were evaluated by means of tensile test and hardness test. The specimens for tensile and hardness were cut from the welded plate as shown in fig. 3.

(a) (b)

Fig. 3: Specimen for Mechanical Property Testing (a) Tensile Specimen (b) Hardness Specimen

A. Hardness Test

Hardness test was carried out in Brinell sclae using brinell hardness testing machine. The hardness values were measured for each welded piece. Table 2 shows the value of the Brinell hardness for each joint.

Table 2 : Hardness Value of Different Joint

Sample ID	Rotational Speed (rpm)	Welding Speed (mm/min)	Pin Length (mm)	Hardness (BHN)
Base Material	-	-	-	162-165
1	1600	20	4	100-101
2	1600	20	6	100-101
3	1600	20	8	80-81
4	2000	16	4	104-106
5	2000	16	6	103-104
6	2000	16	8	91-92

Hardness test indicated that as the pin length increases from 4mm to 8 mm the hardness value decreases. Also for same pin length, the increase in rotational speed and decrease in welding speed increase the hardness value. 4 mm pin length along with the 2000 rpm and 16 mm/min welding speed gives the best hardness value. Hence shorter the pin length, higher the hardness value.

B. Tensile test

Tensile test were carried out to determine the tesnile properties of the weld material using Fie make universal testing machine. The tesnile results are presented in Table 3.

Results showed that for any particular welding parameter set, as the pin length increases, the value of the ultimate tensile strength is increased. For maximum pin length of 8mm, due to overlapping of the weld area, the UTS increases. Similarly for same pin length, the higher rotational and lower welding speed gives lower value of the UTS.

Table 3 : Tesnile Propertie of Weldment

Sample ID	Rotational Speed (rpm)	Welding Speed (mm/min)	Pin length (mm)	Ultimate tensile strength (Mpa)
1	2000	16	4	31.245
2	2000	16	6	60.473
3	2000	16	8	62.221
4	1600	20	4	49.814

IV. Conclusion

In double sided friction stir welding, pin length and welding parameters have great influence on the resulted weld joint. The above experiment shows different results,

- As the pin length increases for any particular welding parameter, it gives higher value of ultimate tensile strength and for pin length higher than half the thickness of the specimen, overlapping of the weld area increases the ultimate tensile strength.
- For hardness, as the pin length increase for predefined welding parameters, the value of hardness decrease. However, for fixed pin length, higher hardness can be achieved with higher rotational and lower welding speed relatively.

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Mohitkumar K. Kathrotiya. received his B.E. degree in Mechanical Engineering from LDRP-ITR College, Gandhinagar, India, in 2015. His research interests include friction stir welding and production engineering. At present, he is engaged in pursuing master of engineering's degree in production stream which is hopefully to be complete in May 2017.