Effect of force on properties of joints produced in FSW of AA6063

[1]Dr. Pardeep Gahlot, [2]Dr. Narinder Kaushik

[1]Assistant Professor, Department of Mechanical Engineering, UIET, MDU, Rohtak
[2]Assistant Professor, Department of MAE, MAIT, Rohini, Delhi

Abstract: **In this paper the analysis of applied force during the FSW of plates of size 100*60*5 mm (l*b*t) of aluminum alloy AA6063 was done. A dynamometer was used to measure the force in all three directions (viz. along X, Y and Z directions) during the process of friction stir welding. The sound weld joints were produced by varying the input FSW process parameters such as tool rotation rate, tool feed rate and dwell time. The amount of heat generated and the joint properties are highly influenced by the amount of axial force applied and input process parameters during FSW. The software interface along with the dynamometer provided the plot of forces and moment in all three directions. A large variation was observed in the force acting in the Z direction. It was observed from the plots that the increase in the force is directly proportional to the tool feed rate. The force in the high tool feed region is almost three times the force in the low tool feed region. The joint properties such as tensile strength and hardness were than correlated with the applied force to produce high strength joints.**

Keywords: **Force, FSW, Tensile strength, Hardness**

I. INTRODUCTION

The evolution of friction stir welding (FSW) for joining of similar and dissimilar aluminium and its alloys has removed the customary joining methods and FSW confirmed engrossing technique, as it eradicates the common defects produced by traditional joining methods, viz., porosity, cracks, and gas occlusion (Kaushik and Singhaal, 2017; Kaushik and Singhal, 2018; Kaushik et. al., 2018; Kaushik and Singhal, 2019). Friction Stir Welding was invented by The Welding Institute (TWI) in 1991 (Reynolds, 2000). Since its development a large number of investigators have applied the process of Friction Stir Welding to join the similar and dissimilar aluminum metals and its alloys including the 6000 series of aluminum alloys (Venkateswaran et. al., 2009; Watanabe et. al., 2006; Adamowski et. al., 2007; Kumar and Murugan, 2014; Koilraj et. al., 2012).

The solid state joining techniques surpass a number of other complications such as porosity, brittle intermetallic development and cracking etc. as compared to the customary joining methods of aluminum and its alloys. (Zhou et. al., 1997). Light weight and corrosion resistant materials with high strength are the basic need of the present manufacturing industry. FS welded aluminum joints have acquired a great interest in the fabrication of lightweight and corrosion resistant structures for shipbuilding, automobile, sports, defense and the aircraft industry. (Hu et. al., 2015). In FSW, a cylindrical pin pointed tool is deliberately plunged and rotated along the joint line to produce the sufficient amount of heat and the welded joint takes place as the tool moves in the traverse direction. (Jariyaboon et. al., 2007). The two metal plates which are to be joined must be clamped onto a specially designed fixture equipped with a backing plate to provide the necessary axial force to develop a high strength joint. As the welding tool rotates and travel a distance in traverse direction the frictional heat is developed between the wear-resistant FSW tool and the material of the work pieces. This frictional heat creates softening of the work piece material before reaching its melting point and permits the FSW tool to travel in traverse direction along the joint line. The process resulted in a solid state joint and is called green welding. (Mishra and Ma, 2005)

Aim of this study is to analyse how the process variables have an effect on the mechanical properties and the impact of force on the process variables. A dynamometer was used to measure the force in all three directions (viz. along X, Y and Z directions) during the process of friction stir welding. The joint properties such as tensile strength and hardness were than correlated with the applied force to produce high strength joints.

II. MATERIALS AND METHODS

In this experimental study aluminum alloy AA6063 was used as base material to perform the welding experiments. AA6063 is an Mg-Si alloy. The composition of AA6063 with other alloying elements is depicted in the Table 1. The specimen plates having length 100mm, width 60mm and thickness 5mm (100*60*5) were cut from the base material AA6063 to perform the FSW experiments.

Table 1. Chemical composition of AA6063 al-alloy

Element	Mg	Si	Fe	Cu	Mn	Zn	Cr	Ni	Ti	Al
Wt. %	0.96	0.45	0.35	0.10	0.10	0.10	0.09	0.02	0.01	Remainder

An automated vertical milling machine was used to fabricate the FSW joints by utilizing a specifically developed fixture to generate the required axial force and to clamp the specimen plates firmly. The software interface along with the dynamometer provided the plot of forces and moment in all three directions. A large variation was observed in the force acting in the Z direction. The force in the high tool feed region is almost three times the force in the low tool feed region. The joint properties such as tensile strength and hardness were than correlated with the applied force to produce high strength joints. Force in the various directions during the process of friction stir welding was conducted using the Dynamometer. A Dynamometer was added to the apparatus and the forces along the X, Y and Z axis was measured. The software interface along with the Dynamometer provided the plot of forces and moment in the entire three axis. A large variation can be observed in the Forces acting in the Z direction. The graphs (Figure 3 a-d) represent the variation of the force acting in the Z axis during the entire course of Friction stir welding. The input process parameters and their levels to carry out the FSW process are shown in the table 2. Total 9 samples were weld in accordance with L9 taguchi orthogonal array and the output responses are then depicted in the table 3.

Table 2. The input process variables and their levels

			Factors at three levels		
Sr. No.	Input process variables	Symbol	1	2	3
1.	Tool Rotational speed	TRS	1700	1900	2100
2.	Tool Feed Rate	TFR	20	25	30
3.	Dwell Time	DT	40	60	80

Table 3. Values of different response characteristics.

	Input process variables			Output Response Characteristics	
Exp. No.	TRS	TFR	DT	Ultimate Tensile Strength (UTS)	Hardness (Hv)
1.	1700	20	40	82	40
2.	1700	25	60	60	35
3.	1700	30	80	98	29
4.	1900	20	60	84	45
5.	1900	25	80	105	33
6.	1900	30	40	80	41
7.	2100	20	80	86	37
8.	2100	25	40	89	39
9.	2100	30	60	85	34

III. RESULTS AND DISCUSSION

3.1 Tensile Test:

The tensile test for weld samples was conducted at the 40kN UTM (UNITEK-94100, supplied by blue star) Universal Tensile Testing machine. The specimens were cut in the uniform dimensions. The gauge length was 20 mm and the dimension of the tensile test sample was kept as: Width = 8mm, Thickness= 4.8 mm. The strain rate was 0.5 mm/min. The tensile strength variation was plotted for each sample prepared with varying parameters. Load Vs Displacement and Stress-Strain plots were obtained for the same. A comparative graph indicating the tensile strength at the weld centre was plotted with an aim to identify the weld with the superior tensile property. The following graph (Figure 1) represents the same. As evident from the above graph, Sample 5 represents the weld centre with the maximum tensile strength of 105 MPa, with its associated parameters as: TRS = 1900 rpm, TFR = 25 mm/min and DT = 80 seconds.

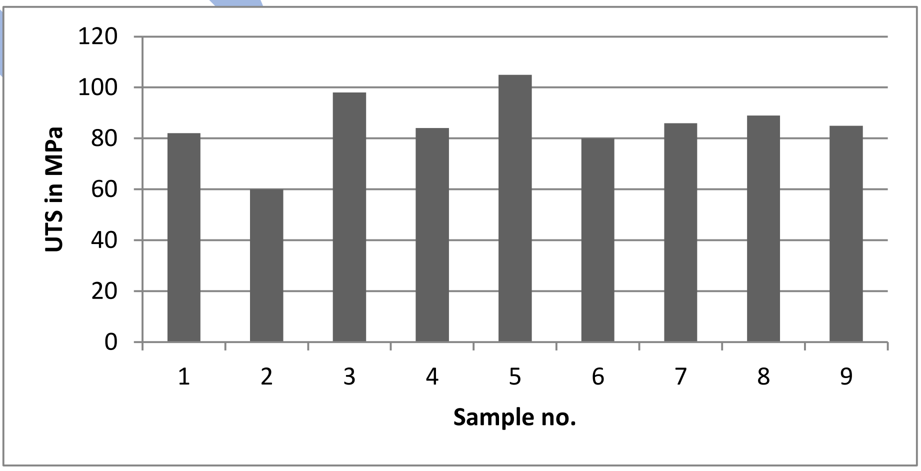


Figure 1: UTS v/s sample no

3.2 Macro hardness test

The macro hardness test was conducted for the weld samples using the vickers microhardness tester. The hardness measurements were executed at different spots on both sides of the weld section up to the base metal region at a constant load of 0.05kgf and dwell duration of 25 seconds.The hardness measure at the centre point of weld in each sample was plotted to identify the sample and associated parameters with the best hardness at the weld centre. Also it was tried to establish a trend in the hardness pattern as the parameters were changed. The following graph (Figure 2) represents the same. Observing the above graph, the hardness is maximum in Sample 4 as Hv = 45, with associated parameters as: TRS = 1900 rpm, TFR = 20 mm/min and DT = 60 seconds.

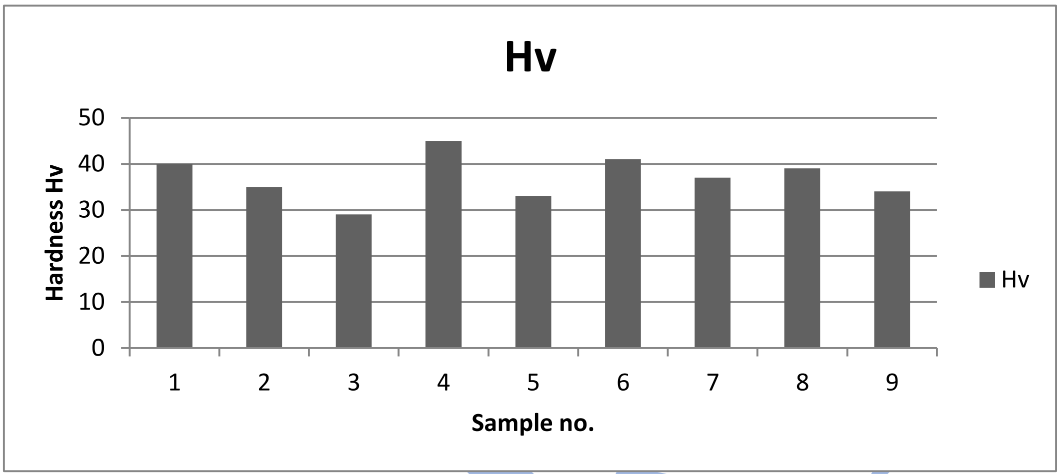
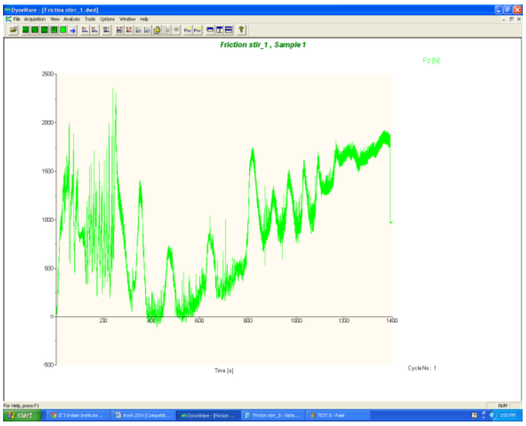


Figure 2: Hardness Hv v/s Sample no.

3.3 Force analysis

The graphs as shown in Figure 3 (a-d) clearly show that the value of Fz changes continuously as the parameters are varied in each samples. In the initial time of tool plunging, the value of Fz keeps on increasing with the increase in the depth of plunge, During the dwell time, the force decreases and it even changes its direction as the material exerts an upward force on the tool. Upon the end of the dwell time the feed starts and hence the force in the Z direction starts to increase again. It can be observed from the above graphs that the increase in the force is directly proportional to the feed rate. The force in the high feed region is almost three times the force in the low feed region. Thus the whole graph representing the force variation and pattern can be divided into five areas: Plunging, Dwell Time, Low Feed, Medium Feed and High feed.



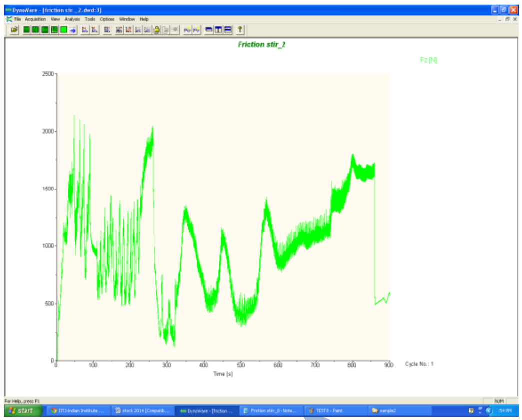
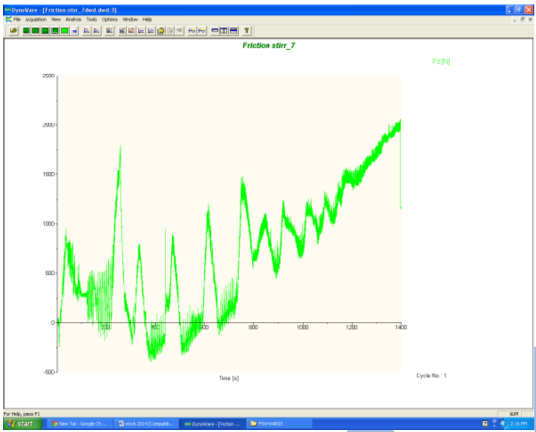
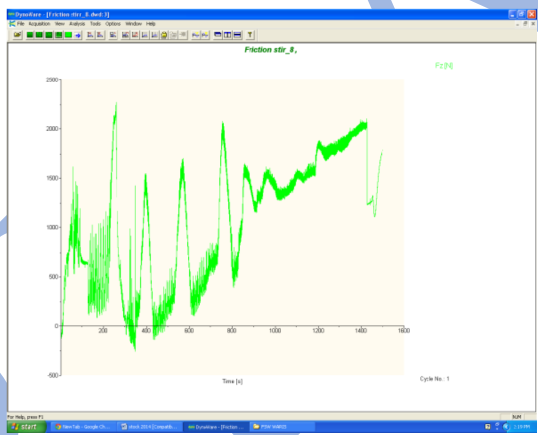


Figure 3: (a) Force variation sample 1 (b) Force variation sample 2





(c) Force variation sample 3 (d) Force variation sample 4

IV. CONCLUSIONS

This experimental study explores the impact of the process variables on the mechanical properties of butt welds produced by FSW. The optimal set of input variables in terms of improved mechanical properties was attained using the medium values of tool rotation rate and tool feed rate. These intermediate values of input variables resulted in low feed rate per unit revolution (F/S). The high heat contribution to the weld area is due to the low F/S ratio. A fine agreement between mechanical properties and force measurement was observed. Sample 5 and sample 4 turns out to be the one with best samples in terms of UTS and hardness values respectively.

REFERENCES:

[1]. Adamowski, J., Gambaro, C., Lertora, E., Ponte, M., & Szkodo, M. (2007). Analysis of FSW welds made of aluminium alloy AW6082-T6. *Archives of Materials Science and Engineering*, *28*(8), 453-460.

[2]. Chen, T. (2009). Process parameters study on FSW joint of dissimilar metals for aluminum–steel. *Journal of materials science*, *44*(10), 2573-2580.

[3]. Hu, Z. L., Wang, X. S., Pang, Q., Huang, F., Qin, X. P., & Hua, L. (2015). The effect of postprocessing on tensile property and microstructure evolution of friction stir welding aluminum alloy joint. *Materials Characterization*, *99*, 180-187.

[4]. Jariyaboon, M., Davenport, A. J., Ambat, R., Connolly, B. J., Williams, S. W., & , D. A. (2007). The effect of welding parameters on the corrosion behaviour of friction stir welded AA2024–T351. *Corrosion Science*, *49*(2), 877-909.

[5]. Kaushik, N., & Singhaal, S. (2017). Mechanical and metallurgical examinations of stir cast aluminum matrix composites: a review study. *International Journal of Engineering and Technology*, *9*, 3203-3217.

[6]. Kaushik, N., & Singhal, S. (2018). A case study of mechanical and metallurgical properties of friction stir welded AA6063 AMC. *International Journal of Microstructure and Materials Properties*, *13*(3-4), 240-255.

[7]. Kaushik, N., & Singhal, S. (2019). Experimental Investigations on Microstructural and Mechanical Behavior of Friction Stir Welded Aluminum Matrix Composite. *International Journal of Engineering* 32.1, 162-170.

[8]. Kaushik, N., Singhal, S., Rajesh, R., Gahlot, P., & Tripathi, B. N. (2018). Experimental investigations of friction stir welded AA6063 aluminum matrix composite. *Journal of Mechanical Engineering and Sciences*, *12*(4), 4127-4140.

[9]. Koilraj, M., Sundareswaran, V., Vijayan, S., & Rao, S. K. (2012). Friction stir welding of dissimilar aluminum alloys AA2219 to AA5083–Optimization of process parameters using Taguchi technique. *Materials & Design*, *42*, 1-7.

[10]. Kumar, B. A., & Murugan, N. (2014). Optimization of friction stir welding process parameters to maximize tensile strength of stir cast AA6061-T6/AlNp composite. Materials & Design, 57, 383-393.

[11]. Min, C. A. O., Li, L. I. U., Zhongfen, Y. U., Ying, L. I., & Fuhui, W. A. N. G. (2018). Exfoliation Corrosion Behavior of 2A02 Al-alloy in a Simulated Marine Atmospheric Environment. Journal of Chinese Society for Corrosion and protection, 38(5), 502-510.

[12]. Mishra, R. S., & Ma, Z. Y. (2005). Friction stir welding and processing. Materials science and engineering: R: reports, 50(1-2), 1-78.

[13]. Nikseresht, Z., Karimzadeh, F., Golozar, M. A., & Heidarbeigy, M. (2010). Effect of heat treatment on microstructure and corrosion behavior of Al6061 alloy weldment. Materials & Design (1980-2015), 31(5), 2643-2648.

[14]. Reynolds, A.P. (2000). Sci Tecnol Weld Joining, 5(2):120.

[15]. Venkateswaran, P., Xu, Z. H., Li, X., & Reynolds, A. P. (2009). Determination of mechanical properties of Al–Mg alloys dissimilar friction stir welded interface by indentation methods. Journal of materials science, 44(15), 4140-4147.