EFFECT OF FRICTION STIR PROCESSING ON MECHANICAL PROPERTIES OF A7075-T6 ALUMINUM ALLOY

Himansu Sekhar Dash[1], Ashok Kumar Pradhan[1], and Deepak Suna[1]

[1] Department of Production Engineering IGIT, Sarang, Odisha, India,

Corresponding authors: hsdash@igitsarang.ac.in, ashoknita001@gmail.com, deepaksuna4@gmail.com

ABSTRACT: Plastic deformation is plays an important role to change the microstructural and mechanical properties such as tensile Strength, hardness, toughness in the application of material in engineering application. In this paper friction stir processing (FSP) is proposed which is an advanced thermo-mechanical processing technique that uses localized plastic deformation to change the material's properties. A7075-T6 aluminum alloy was friction stir processed under different combination of process parameters such as rotational and translational speeds. The effect of these parameters on the microstructure and mechanical properties especially ultimate tensile strength (UTS) and hardness were identified and discuss. The results shows that the Rotational and translational speed is the dominant feature towards processing forces and surface morphology and has a significant effect on the control and optimization of the process.

Keywords- FSP, UTS, Hardness, A7075-T6 Aluminum Alloy

1. INTRODUCTION

Aluminum alloys have extensive application in industry, especially the aerospace industry, because of their high strength, toughness and good resistance to fatigue; however, improvements in mechanical properties and corrosion resistance are required [1] .Various surface treatments have been applied to control the surface characteristics of metals and alloys. Grain refinement is a widely accepted method of improving strength of metals and alloys. Among these, FSP is a promising method which refines the surface microstructure, results in densification and homogeneity of the processed zone through intense localized plastic deformation (i.e., severe plastic deformation) [2]. It is a new and trending thermo mechanical processing technique that changes the surface morphology and mechanical properties of the material to attain maximum performance with low production cost in less time [3]. During this method, a non-consumable tool is inserted forcibly into the workpiece and the tool is revolved in a stirring motion as it is pushed laterally through the thickness. These methods are often used for various aims such as: decoration, reflectivity, improved hardness, improved resistance to wear and prevention of corrosion [4]. In keeping with Ma [2], FSP was originated from friction stir welding (FSW) and originally developed for aluminum alloys. However, unlike FSW that is used to join two materials, FSP is employed on a single rigid metal. Regarding the FSP process, aluminum alloys have been the focus of most research because of their characteristics. Commercially pure aluminum was subjected to FSP by Yadav and Bauri [5]. FSP is a process in which heat does not enter or leave, the parent material is not melted and no solidification problems occur as the processed zone cools. However, temperatures are often high enough to cause precipitate dissolution and re-precipitation [6].

In [7] the author has studied the effect of using bobbin tool in friction stir welding of 6082-T6 AA material by investigate the microstructure, microhardness, and tensile properties of the welded specimens. The post weld natural aging (PWNA) plays a vital role in increasing the strength of the proposed material. The author in [8] used 6005A-T6 aluminum alloy for friction stir by varying the welding speed. Here the author give emphasis to the interaction of precipitate evolution within different zones and the local hardness. The effect of welding speed on TMAZ was not significant which is presented in this report. In [9] the 6082-T6 aluminum alloy were friction stir welded by bobbin tool with various welding speed. The welding speed affects the size of the grain in stirred zone. Extruded Mg–2.0Nd–0.3Zn–1.0Zr (wt.%) alloy was fiction stir processed by the author in [10]. Effect of various passes has been studied and analyzed in this paper.

In the literature it is found that the effect of friction stir welding on most of the material has been studied by the authors. Some of the material is also processed with friction stir processing. As the application aluminum alloys is increasing day by day in engineering application and the localized surface morphology may be changed by the Friction stir processing based on the objective therefore the author proposed the following method of FSP.

In the proposed work, 7075-T6 Aluminum alloy sheets were processed by friction stir and its effect on the mechanical properties such as UTS and hardness of the base material were studied. The process is carried out by using a conventional milling machine which is shown in Fig 1. Three different tool profile such as Conical, Columnar, Threaded type as shown in Fig 3 been used to carry out the FSP. The effect of these tools and process parameter by using a conventional milling machine to change the surface morphology has been studied and presented in this paper.

2. EXPERIMENTAL PROCEDURE:

The base material utilized in this experiment was commercial 7075-T6 Aluminum alloy sheets with a nominal thickness of 8 mm, and the samples were 30 X 150 mm^2 as shown in Fig 2. It has good mechanical qualities, including ductility, high strength, toughness, and intelligent fatigue resistance. According to ASTM B209, the approximate chemical compositions and the physical and mechanical properties of the material are shown in table 1 and 2 respectively. The sheets were friction stir processed under a conventional vertical milling machine with various combinations of translational and rotational speeds. Three FSP tools with different profiles, viz. Conical probe type, Columnar probe type, threaded Columnar probe type, have been used as shown in Fig. 3. The tools were made of up with H13 Tool Steel using CNC Turning Machine. To increase their durability, all of these tools were machined and flame hardened. The micro hardness of the friction stir treated AA7075 samples was measured using a Rockwell hardness tester in the transverse direction. The indentation time was 25 seconds and the test load was 100 Kgf. Various FS samples were evaluated at various rotational and translational speeds. A variety of longitudinal positions were also investigated. Within each measured location, the averages of three hardness values were used. A universal testing machine (UTM) was used to test the tensile strength of the samples. Table 3 shows the various parameters taken during the processing. Fig 4-6 shows the three different plates processed with three different tool profiles.

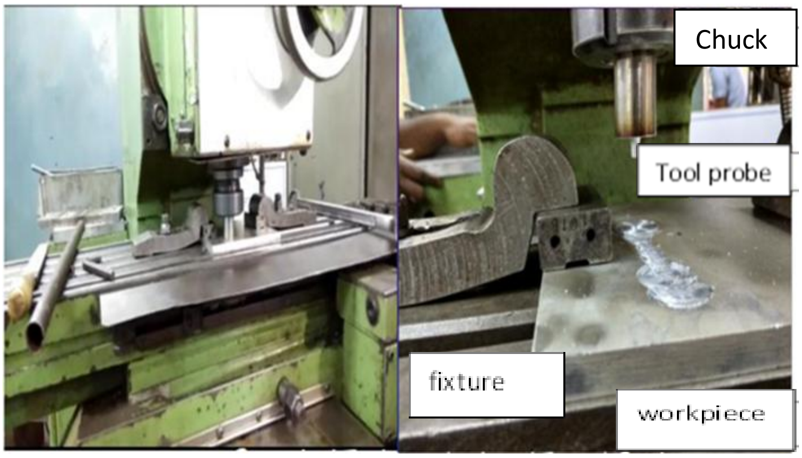


Fig 1: Experimental setup by using conventional vertical milling machine

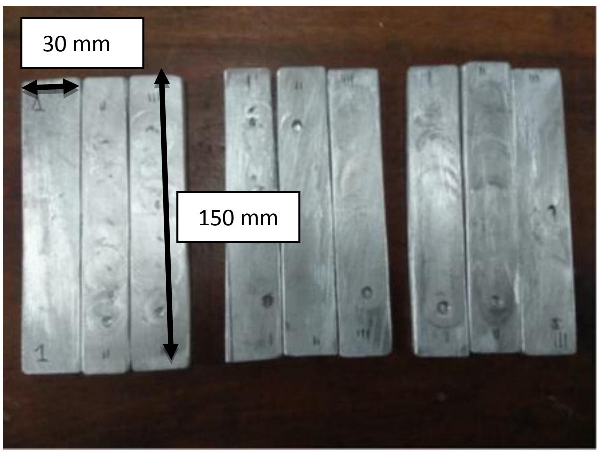


Fig 2: Preparation of Specimen

Al	Cr	Cu	Mg	Mn
90	0.23	1.6	2.1-2.9	2.5

Table 1:

Density	Melting Point	Specific Gravity	Tensile Strength	Modulus of Elasticity	Poisson's ratio
2.81gm/cc	483℃	7.75	220 MPa	70-80 GPa	0.33

Chemical composition of 7075-T6 Al alloy (mass %)

Table 2: Physical and Mechanical properties of 7075-T6 Al alloy.

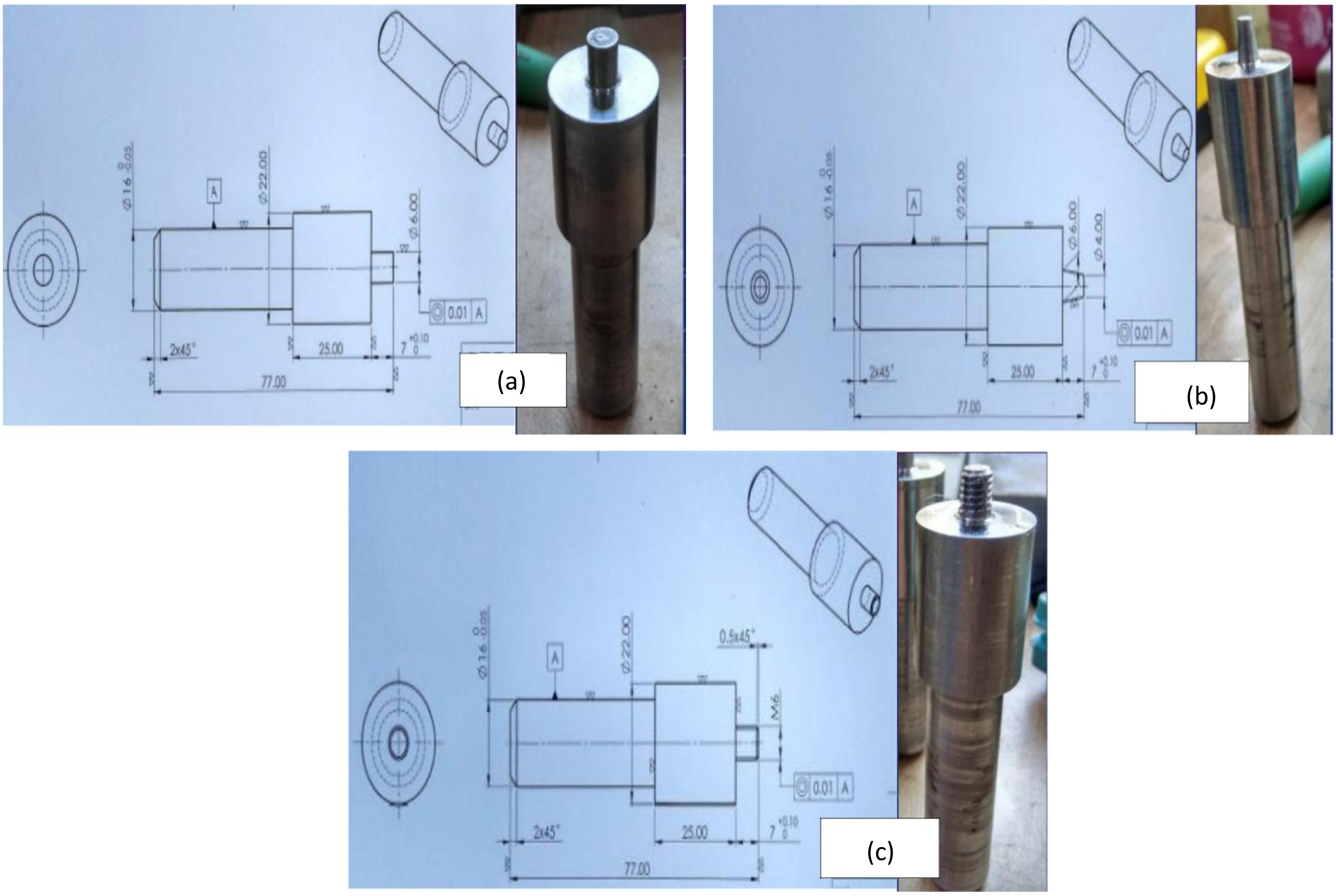


Fig 3: Three different tool profile (from left) (a) Conical (b) Columnar (c) Threaded

Sample No.	Tool Type	RPM	Translational Speed (mm/Min)	Depth (mm)
1	Base Metal			
2	Conical Tool	1000	25	6.8
3		1400	10	6.8
4		2000	16	6.8
5	Threaded Tool	1000	25	6.8
6		1400	10	6.8
7		2000	16	6.8
8	Columnar Tool	1000	25	6.8
9		1400	10	6.8
10		2000	16	6.8

Table 3: FSP process parameters

H13 Tool Steel is a versatile chromium-molybdenum hot work steel that is widely used in hot work and cold work tooling applications. Because of its high toughness and very good stability in heat treatment, H13 is also used in a variety of cold work tooling applications. In these applications, H13 provides better hardenability (through hardening in large section thicknesses) and better wear resistance than common alloy steels such as 4140. H13 tool steel is the most popular steel grade for various Industries. The main features of high alloyed Cr-Mo-V Hot Work tool steel is high wear resistance to thermal shock and to heat cracking, good mechanical characteristics & toughness in hot condition.H13 appears excellent machinability with constant hardness during production activities.

Fig 4: Specimens processed with conical tool

Fig 5: Specimen processed with threaded tool

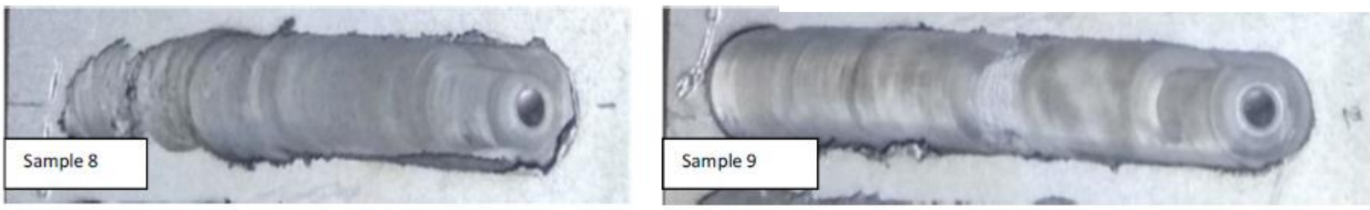
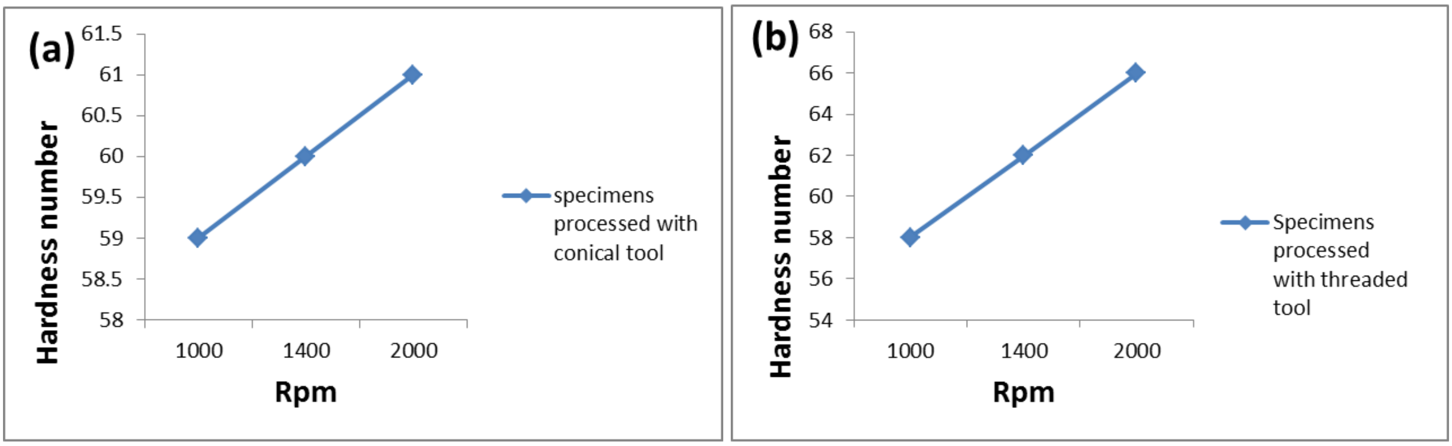


Fig 6: Specimens processed with columnar tool

3. RESULTS AND DISCUSION:



3.1 Microhardness:

Fig 7(a, b, c) and Fig 8 Shows the micro hardness of the various FSP samples with three various tool profile and with a different combination of translational and rotational speed. It has been noticed that the hardness value increases with increase in rotational speed. Higher hardness values are associated with the presence of optimum heat input fine grains and dislocation density or strengthening particles, according to Hall-Petch strengthening. According to [10], when speed is increased, the average grain size shrinks and dislocation density rises, resulting in an increase in micro hardness. The results reveal that FSP affects the material's hardness, and that the hardness of the FS treated area is even higher (for columnar type tool with translational speed 2000mm/min and rotational speed 16mm/min, HV 75) than that of the base material at specific combinations of rotational and translational speeds. Added to this, tool profile also has a significant effect on the hardness value. The columnar probe tool type provides higher hardness value. Furthermore, the conical and threaded samples' hardness gave a higher input of heat, causing the material to soften, lowering the hardness value. Table 4 shows the various hardness values.

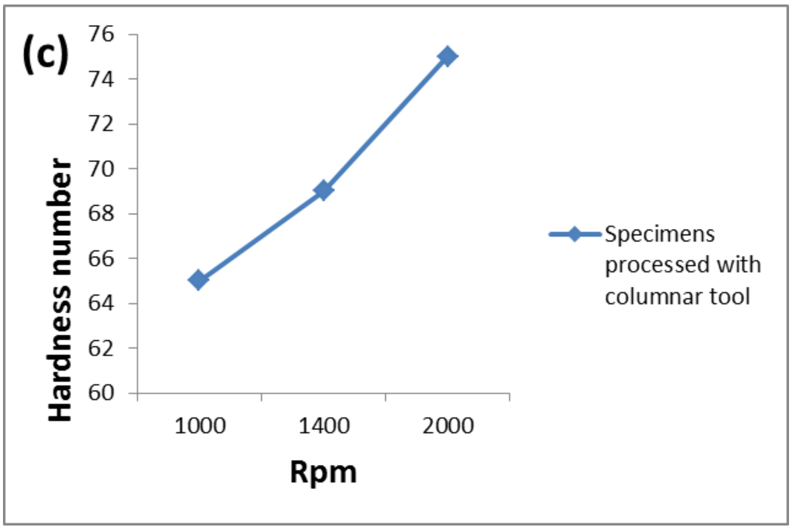


Fig 7 (a, b, c): Micro-hardness variation in different specimen at different Rpm.

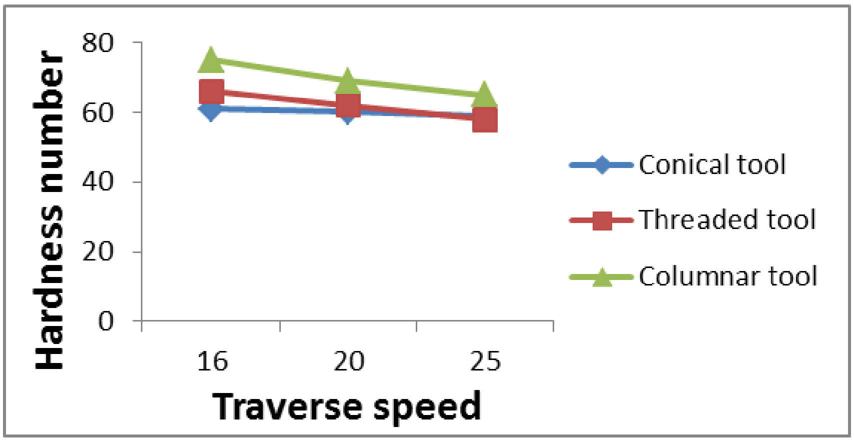


Fig 8: Micro-hardness variation with different Traverse speed

3.2 TENSILE STRENGHT

The tensile properties of the FSP samples with different rotational and translational speeds are shown in Fig10. The base material has a tensile strength of 211MPa. The lowest tensile strength is at 1400rpm, 20mm/min with conical tool profile (146 MPa), as shown in the graph (sample 3). The ultimate tensile strength is 172 MPa at a rotational speed of 1000rpm, 25mm/min with conical tool type (sample4). The elongation reached maximum at 1400rpm, 20mm/min with columnar type tool which was 69% (sample 9).The tensile strength of the samples decreases with friction processing. This may be attributed to the increase in heat which acts as stress raiser.

Sample number	Hardness value	Tensile strength (MPa)	Elongation (%)
1 (base metal)	61	211	36.5
2	59	150	25.0
3	60	146	26.5
4	61	172	29.0
5	58	166	20.5

6	62	162	33.0
7	66	158	35.5
8	65	163	46.5
9	69	167	69.0
10	75	171	40.0

Table 4: Hardness value, tensile strength and elongation of various samples

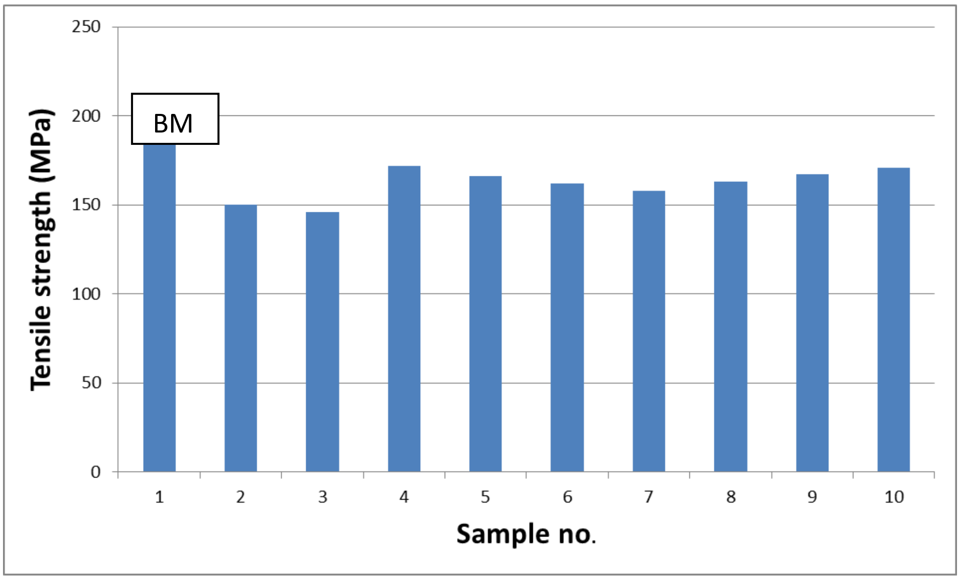


Fig 9: Tensile properties of the samples

4. CONCLUSION

In this paper, 7075-T6 aluminum alloy was successfully processed by FSP using different tool profiles, rotational speeds and translational speeds. The typical mechanical properties of every sample were investigated. The main conclusions can be summarized as follows.

- The hardness of the material is changed by FSP, and the hardness of the FS treated area is even higher than that of the original material at specific combinations of rotational and translational speeds.
- FSP improves the hardness value. A highest of 75 HV is obtained.
- As the traverse speed lowers and the rotating speed increases, the hardness of the FS treated area increases. The amount of heat generated has a considerable impact on the hardness value.
- The ultimate tensile strength is 172 MPa at a rotational speed of 1000rpm, 25mm/min with conical tool type and the lowest tensile strength is with 1400rpm, 20mm/min with conical tool profile (146 MPa).

5. REFERENCES

1. Dadaei, Mostafa, Omidvar, Hamid, Bagheri, Behrouz, Jahazi, Mohammad and Abbasi, Mahmoud. "The effect of SiC/Al2O3 particles used during FSP on mechanical properties of AZ91 magnesium alloy" International Journal of Materials Research, vol. 105, no. 4, 2014, pp. 369-374. https://doi.org/10.3139/146.111025 Ma ZY, Friction stir processing: a review, J Mater Process Technol 2008;39A:642–58.

2. Prakash, T., Sivasankaran, S. & Sasikumar, P. Mechanical and Tribological Behaviour of Friction-Stir-Processed Al 6061 Aluminium Sheet Metal Reinforced with Al2O3/0.5Gr Hybrid Surface Nanocomposite. Arab J Sci Eng 40, 559–569 (2015). https://doi.org/10.1007/s13369-014-1518-4.

3. M. Barati, M. Abbasi, M. Abedini, The effects of friction stir processing and friction stir vibration processing on mechanical, wear and corrosion characteristics of Al6061/SiO2 surface composite, Journal of Manufacturing Processes, Volume 45, 2019, Pages 491-497, ISSN 1526-6125, https://doi.org/10.1016/j.jmapro.2019.07.034.

4. Devinder Yadav, Ranjit Bauri, Effect of friction stir processing on microstructure and mechanical properties of aluminium, Materials Science and Engineering: A, Volume 539, 2012, Pages 85-92, ISSN 0921-5093, https://doi.org/10.1016/j.msea.2012.01.055.

5. Giles, Tanya & Oh-Ishi, Keiichiro & Zhilyaev, Alexander & Swaminathan, Srinivasan & Mahoney, Murray & Mcnelley, Terry. (2009). The Effect of Friction Stir Processing on the Microstructure and Mechanical Properties of an Aluminum Lithium Alloy. Metallurgical and Materials Transactions A. 40. 104-115. 10.1007/s11661-008-9698-8.

6. Darras, Basil M., "EXPERIMENTAL AND ANALYTICAL STUDY OF FRICTION STIR PROCESSING" (2005). University of Kentucky Master's Theses. 353. https://uknowledge.uky.edu/gradschool_theses/353

7. Li, Yp., Sun, Dq., Gong, Wb. et al. Effects of post weld aging on the microstructure and properties of bobbin tool friction stir-welded 6082-T6 aluminum alloy. Int J Miner Metall Mater 26, 849–857 (2019). https://doi.org/10.1007/s12613-019-1800-2

8. Dong, Peng & Li, Hongmei & Sun, Daqian & Gong, Wenbiao & Liu, Jie. (2013). Effects of welding speed on the microstructure and hardness in friction stir welding joints of 6005A-T6 aluminum alloy. Materials & Design. 45. 524–531. 10.1016/j.matdes.2012.09.040.

9. Li, Yupeng, Daqian Sun, and Wenbiao Gong. 2019. "Effect of Tool Rotational Speed on the Microstructure and Mechanical Properties of Bobbin Tool Friction Stir Welded 6082-T6 Aluminum Alloy" Metals 9, no. 8: 894. https://doi.org/10.3390/met9080894.

10. Zheng, F. Y., Wu, Y. J., Peng, L. M., Li, X. W., Fu, P. H., & Ding, W. J, Microstructures and mechanical properties of friction stir processed Mg–2.0Nd–0.3Zn–1.0Zr magnesium alloy, Journal of Magnesium and Alloys, 1(2), 122–127.