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# EXPERIMENTAL INVESTIGATION OF WEAR RATE AND MICROSTRUCTURAL PROPERTIES OF 5754 ALUMINIUM ALLOY BY FRICTION STIR PROCESSING

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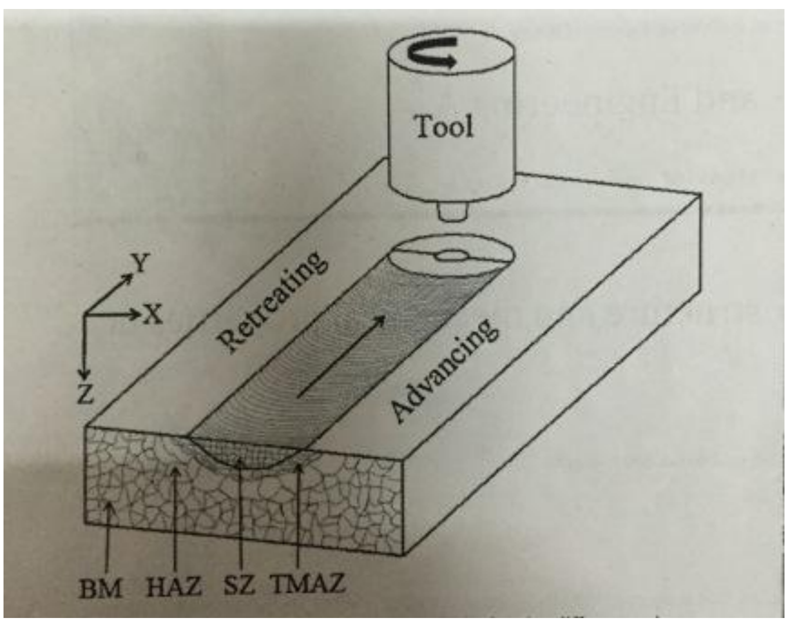
**Abstract: Plates of Aluminum Alloy 5754 are subjected to effective microstructural modification technique named Friction Stir Processing(FSP). FSP is one of the new thermomechanical process techniques which effect on the mechanical properties and microstructure of the material in single pass.The parameters of friction stir processing for 5754 aluminum alloys were studied at three different travelling speeds: 15, 20 and 25 mm/min under three different rotation speeds 1400, 1800 and 2200 rpm. In this research study, three different pin profiles of tools have been used. A CNC machine is used to carry on the FSP process. Consequently, the application of the friction stir processing is a very effective method for the mechanical improvement of semi-solid metal aluminum alloys. The choices of process material especially tool pin profile, rotational speed and traverse speed has significant effect on the mechanical and microstructural properties of Al 5754 alloy.**
**Keywords: FSP ,SEM , Al**

## 1. INTRODUCTION:

Friction Stir Processing is an emerging surface engineering technology that can redefine a material by refining microstructures, thereby improving the mechanical and surface properties of a material.[1]. As an important method for material strengthening through microstructure refinement, Friction Stir Processing has shown significant microstructure modification and improved mechanical properties for aluminium and its alloys.[2]Hence, FSP is a local themo-mechanical emerging metal working technique which enhances the local properties of the work material.[3] Friction Stir Processing is a technique in which microstructure has been improved in the solid state by using heat from friction for the aluminum casted alloy.[4,5] various process parameters improved the mechanical properties after friction stir processing due to refinement in grain size.[6-10] .Schematic below shows Friction Stir Processing with Different Regions[12].




Iordachescu et al.(2006) introduced the FSP fundamentals of the process and its perimeters, also approaching the material flow pattern due to the deformation process and the thermal profile. Various experiments regarding the influence of the Friction Stir Processing main parameters(tool rpm and advancing speed) on the material flow pattern around the tool was also

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considered.[3]Kurt et al.(2011) performed Friction Stir Processing for surface modification of aluminium. Samples were subjected to various tool rotations and traverse speeds with and without silicon carbide particles.The hardness of the produced composites surface was improved by three times as compared to that of base aluminium. Bending strength of the produced metal matrix composite was significantly higher than processed plain specimen and untreated base metal.[11] Mishra et al.(2005) have written about the current state of understanding and development of the Friction Stir Welding (FSW) and Friction Stir Processing(FSP). Particular emphasis had been given to the mechanism responsible for the formation of welds and microstructural refinement, effects of FSW/FSP parameters on resultant microstructure and final mechanical properties.[13].Miranda et al.(2013) studied surface modification by Friction Based Process. Friction based processes are based on two main processes, Friction Surfacing and Friction Stir Processing. Various fundamental things. Process parameters and their effect have been studied and explained in this paper. Friction Stir Processing is mostly used to eliminate casting defects and refine microstructures in selected locations, for property improvements and component performance enhancements.[14].Karthikeyan et al.(2010) studied about the role of process variables in the friction stir processing of cast aluminium A319 alloy. For certain combinations of variables, the processed alloy displayed an increase in value of around 50% in tensile strength and 20% in microhardness compared with those of as cast alloy. The ductility of the processed alloy was found to be increased by a factor which ranged from 1.5 to 5. Optical and scanning electron microscopy revealed that FSP reduces the size of the second phase particles, which contributes to the improvements in mechanical properties.[15]Thangarasu et al.(2014) studied the influence of traverse speed on microstructure and mechanical properties of AA6082-TiC surface composite fabricated by FSP. The traverse speed was varied during fabrication from 40 to 80mm/min in step of 20mm/min. The remaining parameters (groove width, tool rpm and axial force) were kept constant. Microstructure was analyzed by optical microscope and scanning electron microscope. Mechanical properties i.e. wear rate and microhardness was also analyzed. It was found that wear rate decreases with increase in traverse speed.[16]Salehi et al.(2014) fabricated and synthesized functionally graded Al-SiCnanocomposite by using a novel multistep friction stir processing.It was found that hardness was increased by 3.2 times in the enriched zone as compared to the particle enriched zone.[17]

## 2. EXPERIMENTATION:

Aluminium Alloy Plates: The selected aluminium alloy was 5754 aluminium alloy. It's 6 mm thick, 30 cm long and 21cm wide plates were bought. These sheets were then cut into pieces(30*10cm) which were further used for friction stir processing and testing.

Wear Rate Test: The wear test was performed on pin on disc machine. For all specimens, the load was 29.43N, speed was 300rpm at 10 min of time as shown in Table1.

Table 1 Wear Rate of Nine Specimen using OA

| S.No | rpm of tool | Traverse speed | Tool pin profile | Wear rate($mm^3$/min) |
|---|---|---|---|---|
| 1 | 1400 | 15 | Cylindrical | 0.21 |
| 2 | 1400 | 20 | Threaded | 0.22 |
| 3 | 1400 | 25 | Square | 0.13 |
| 4 | 1800 | 15 | Threaded | 0.24 |
| 5 | 1800 | 20 | Square | 0.09 |
| 6 | 1800 | 25 | Cylindrical | 0.17 |
| 7 | 2200 | 15 | Square | 0.18 |
| 8 | 2200 | 20 | Cylindrical | 0.23 |
| 9 | 2200 | 25 | Threaded | 0.29 |

Table 2 Mean Wear Rate value for each parameter

| Parameter | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| rpm of tool | 0.186 | **0.166** | 0.233 |
| Tool traverse speed mm/min | 0.21 | **0.18** | 0.19 |
| Tool pin profile | 0.203 | 025 | **0.13** |

- Effect of tool rpm:

The graph in figure 1 shows the variation of wear rate with respect to the variation in tool rpm. At 1400rpm the mean value of wear rate was 0.186$mm^3$/min, at 1800rpm it was 0.166$mm^3$/min and at 2200rpm it was 0.233$mm^3$/min. the lowest value of wear rate was obtained at 1800rpm after that it went on increasing. It was because the best result for hardness was also obtained at 1800rpm. So it was found that the hardness and wear rate are correlated. Higher the hardness of material, the resistance to remove the material during sliding increases. Therefore our result supports the Archard's Law[40]

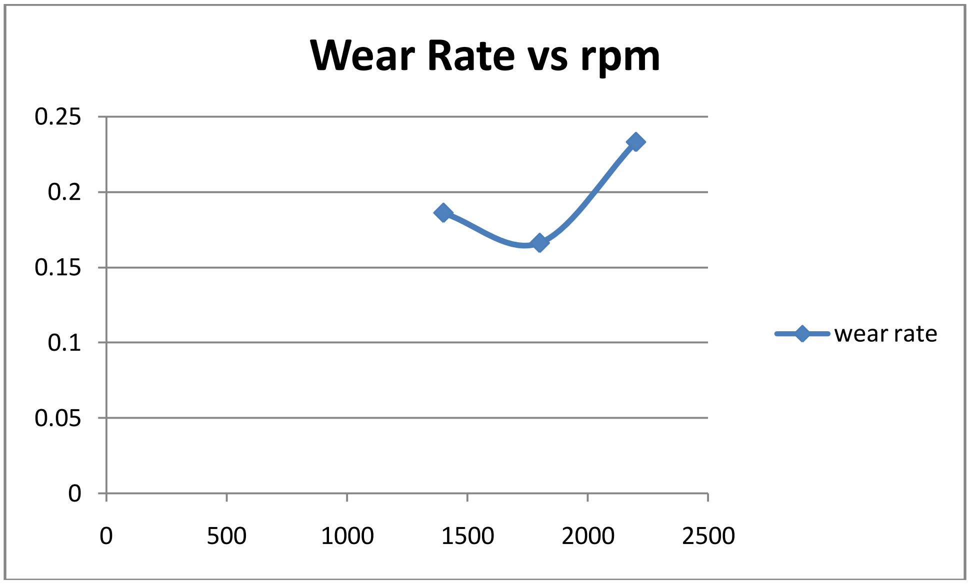


Figure 1. x-axis rpm, y-axis Wear Rate

- Effect of traverse speed:

The graph in figure 2 represents the variation in wear rate according to the change in traverse speed. Traverse speed is represented by x-axis and y-axis represents the wear rate.

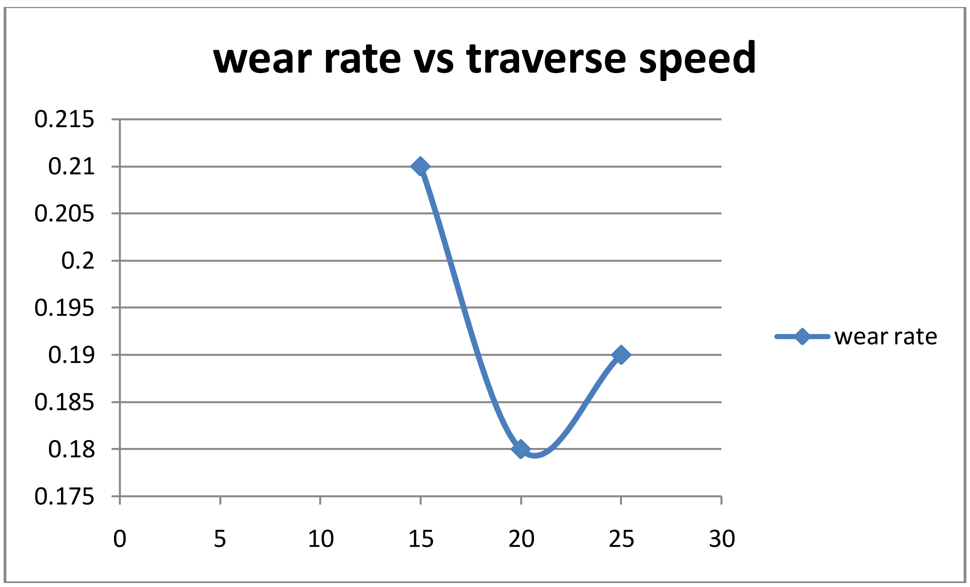


Figure 2 x-axis Traverse Speed, y-axis Wear Rate

At 15mm/min mean value of wear rate was 0.21mm³/min, at 20mm/min mean wear rate was 0.18mm³/min and at 25mm/min its mean value was 0.19mm³/min. Best wear rate result was obtained at 20mm/min traverse speed. After increasing the traverse speed after 20mm/min it was observed that wear rate starts increasing. So it is clear from figure 2 that wear rate was influenced by traverse speed of tool. It may be because, as the traverse speed varied there was also variation in heat input which effects the softening of material.

- Effect of Tool pin profile on wear rate:

Three different tool pin profiles were used. When cylindrical profile was used the mean value of wear rate was 0.203mm³/min, with threaded profile mean wear rate value was 0.25mm³/min and when square pin profile was used the mean wear rate value obtained was 0.13mm³/min. From the results, it is clear that wear rate was influenced by pin profile of tool. Square pin profile was proved better than the other two.

- Analysis of variance for wear rate of material:

The contribution of pin profile (Table 3) was found to be maximum in improving the wear rate of the material. The contribution of pin profile in improving the wear rate is 67.62% after it next wasrpm with a contribution of 23.27%. Traverse speed played least contribution of 7.80% in improving the pin profile.

Table 3 Contribution of various parameters using Annova Test

| Parameter | d.o.f. | s.s | m.s | F ratio | Contribution% |
|---|---|---|---|---|---|
| R.P.M | 2 | 17.8158 | 8.9079 | 17.87 | 23.27 |
| Traverse speed | 2 | 5.9726 | 2.9863 | 5.99 | 7.80 |
| Pin Profile | 2 | 51.7671 | 25.8836 | 51.92 | 67.62 |
| Error | 2 | 0.9971 | 0.4986 | | |
| Total | 8 | 76.5526 | | | |

Scanning Electron Microscopy: To investigate and to compare the microstructure of friction stir processed samples with the unprocessed Al5754, scanning electron microscopy was used. Figure 5 shows the microstructure of unprocessed Al5754 alloy. Microstructure can be seen and it is visible that it lacks homogeneity.

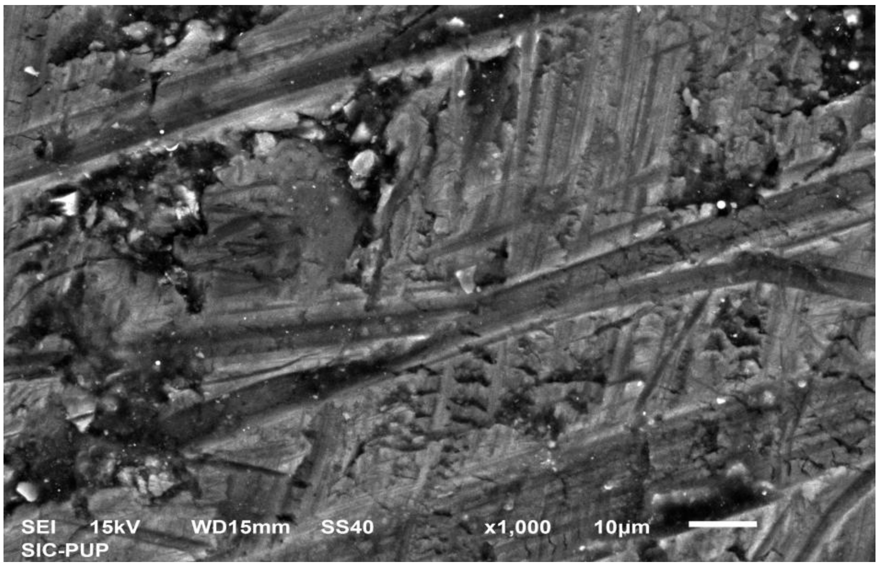


Figure5 SEM of base al5754 alloy.

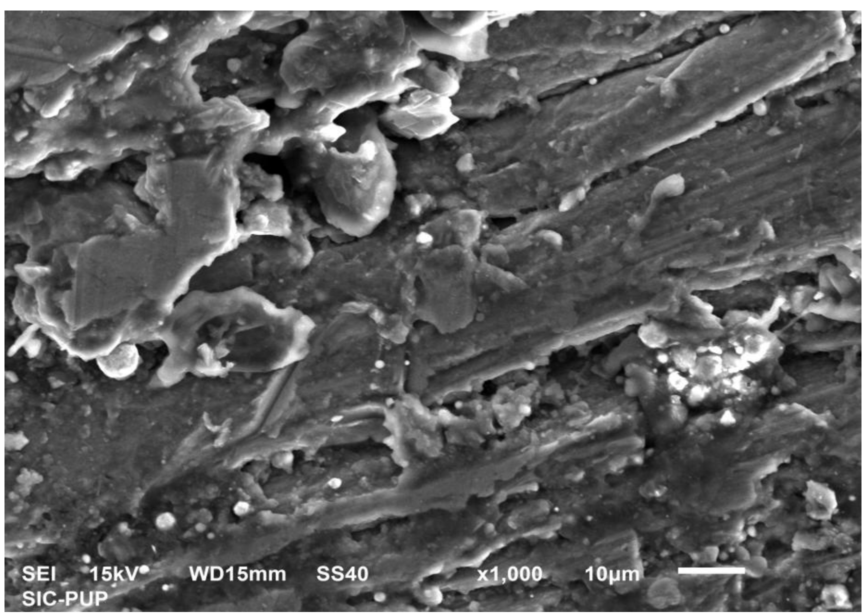


Fig.6 SEM of sample with poor wear rate among all

Figure 6 shows the sample with poor wear rate among all. The microstructure seems to be disturbed inand there is no homogeneity. Further the presence of voids leads to poor wear rate among all.

## 3. CONCLUSION

- Wear properties are improved by friction stir processing. Square pin profile at 1800rpm and 20mm/min traverse speed gave best results. Best result was 0.09mm$^3$/min.
- The microstructure seems to be disturbed in and there is no homogeneity.Microstructure was determined by Scanning Electron Microscope.Further the presence of voids leads to poor wear rate among all.

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