Experimental Approach of Surface Modification of Magnesium Alloys By Friction Stir Processing

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Abstract- *Magnesium has highly attractive properties for the manufacturing industry. It has low density and low affinity to steel and also it has excellent cast ability, high dimensional stability, high strength to weight ratio and low melting temperature. The AZ91D magnesium alloy has its applications in automobile sectors for instrument panels, seat frames, intake manifolds, cylinder head covers, steering wheels and steering components. Surface modification of magnesium alloys involves development of low temperature processing techniques which can modify the surface without degrading the properties of base material. It is expected that the process will improve the material properties. Friction Stir processing is an emerging technique for making surface modification. It is proposed to modify the surface of AZ91D magnesium alloy with the addition of aluminium nitride powder and to test wear behavior, micro hardness, tensile strength of the surface modified specimen. strength of the surface modified specimen.*

Keywords- AZ91DMagnesiumAlloy, Surface Modification, Micro Hardness Friction Stir Processing, Tensile strength.

I. INTRODUCTION

Surface composites exhibit enhanced characteristics of composites on the surface while retaining properties of the base material. Friction stir processing (FSP) is one of the techniques for fabricating surface composites and modifying microstructural features FSP was introduced by as an adaptation of friction stir welding (FSW). Initially, FSP was used for producing super plastic aluminum alloys with ultra-fine grain size and high grain boundary misorientations. Numerous studies have demonstrated that severe plastic deformation (SPD) is an effective method of producing ultrafine-grained materials (There are many well established SPD techniques for grain refinement like equal-channel angular pressing high- pressure torsion multi-directional forging accumulative roll-bonding etc., while FSP is a relatively late entrant in this list (The microstructure evolution during FSP is unique with dynamically recrystallized microstructure possessing a large number of high angle grain boundaries Further, most SPD techniques modify bulk properties. In contrast, SPD by FSP involves only surface modification while the bulk material structure and properties are retained. [1].

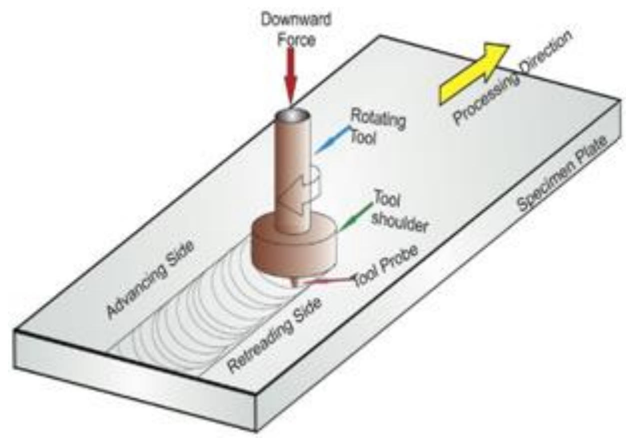


Figure 1. Schematic illustration of FSP technique

The various steps in groove method are explained in the first step, the groove is machined on the plate and the reinforcement particles are filled in the groove. These cond step consists of applying tool without probe (pin) on the groove. The groove is completely packed in this step. In the last step, the tool with probe is applied on the packed groove. The dimension, shape and number of grooves can be varied to achieve required volume fraction of the second phases. Surface composite fabrication by drilled- hole method is shown in showed that the intermediate step of packing the groove by probe-less tool can be eliminated by incorporating reinforcement through drilled holesin fabrication of Tic/Ti-6Al-4V surface composites. The blind holes of 1 mm diameter with varying depth from 0.5-2 mm were drilled on work-piece to accommodate the reinforcement particles. Several other approaches have also been applied to fabri-cate surface composites. Friction stir surfacing was used by many researchers to fabricate surface composite coating over the substrate. In this process, a consumable tool is filled with reinforcement particles and is consumed to form layer of composite on the work-piece fabricated the functionally graded surface composite layer of AZ91D by friction stir surfacing.[2]. The Aluminium Nitride reinforcement particles were packed in blind drilled holes in a 20 mm diameter rod of AA6082-T6.

Tool geometry mainly includes shoulder diameter, shoulder feature, probe shape, probe size and probe feature. Flow of plasticized material in processed zone is affected by tool geometry as well as traverse and rotational motion of the tool. Nano-sized grains can be achieved by proper cooling arrangements. Cooling during FSP also serves the additional function of reducing tool wear in a study of FSPed interstitial free(IF) steel, FSP followed by quenching resulted information of a nano-grain layer of 150μm thickness and 50100 nm average grain size.[3].Su et al, studied the resulting microstructure of friction stir processed commercial 7075 Al alloy. The grain structure of FS processed area was examined by TEM. Su et al. observed that the microstructure of FS processed area did not have a uniform grain size distribution. The average grain size slightly decreases from top to bottom of the tool. [4]

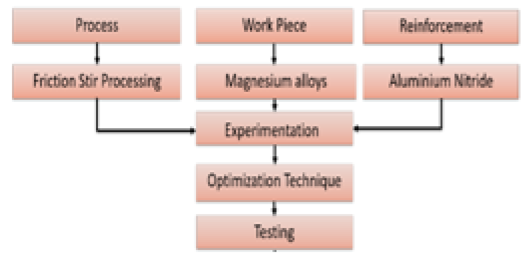
Peel et.al, The parent AA5083 was observed that almost all the plastic flow occurred within the recrystallized weld zone and the synchrotron residual stress analysis indicated that the weld zone is in tension in both the longitudinal and transverse directions.[5].Mahoney et al., investigated the microstructure of friction stir processed NiAl Bronze alloy, they reported the initial microstructural evolution and resultant mechanical properties for the variety of the microstructures created by FSP which include Widmanstatten, equiaxed fine grain and banded or lamellar structure. [6-7].

Bensavides,et.al.investigated the microstructures of Al 2024 observations are consistent with the grain growth relations which states that there is a direct relation between temperature and grain growth. The average grain sizes obtained were measured to between 3 and 0.65 μm. [8-9]

Dutta et al., performed a deep cup forming by superplastic punch stretching of multiple overlapping passes of friction stir processed 7075 Al alloy plate. [10] Forming at different strain rates was done. Figure 2-16 shows three cups punch formed of as received and FSP plate at different strain rate. FEM simulation of the forming process was also done to predict the load and thickness variations, the simulation results showed good prediction of the load as well as the thickness variations up to the beginning of instability. There is not much work that has been done in modeling friction stir processing. [11].

II. MATERIALS AND METHODS

The experimental work that has been done includes; investigation of the effects of process parameter (rotational and translational speeds) on the resulting microstructure,



hardness and quality of the FS processed pass of AA5052 sheet. In this chapter, the material that been processed as well as experimental setup and procedures have been discussed. Grain structure and void analysis have been also discussed. The effects of rotational speed, translational speed, and position within the processed area on hardness of the material.

Figure 2. Magnesium and Aluminumnitrate powder

One of the most important features of FSP is the utilization of readily available machines such as a milling machine, and using a simple inexpensive tool simple to conduct the process. In this section; the experimental setup and the basic equipment required to conduct FSP process are discussed. FSP tool is very important and critical element of the process. The tool assembly which is shown in Figure 3-1 consists of a shoulder and concentric pin. The tools which are used in this work are made of

Figure 3. Experimental setup

H13 tool steel. Different tool configurations were used; shoulder diameter of ½” and ¾”, and shoulder with and without concavity are used. The pindiameter is ¼” and the height of it is slightly shorter than the thickness of the sheet which is ⅛”. Threaded and non-threaded pin are used by this process.

III. EXPERIMENTAL PROCEDURE

The sample that need to be friction stir processed have to be clamped firmly before the processing starts, so especially designed grooved baking plate and holding plates are used to hold the work piece and keep it fixed during the processing. Then a small hole with same diameter as pin is drilled, instead of using the pin of the tool to start penetrating the work piece, this drilled hole avoids too much load on the tool for penetrating. Then the pin of the FSP tool is forced into the work piece while it is rotating at the desired rotational speed, and the shoulder become in contact with the surface of the work piece. The rotating FSP tool is then transverse along the desired direction with specific translational speed. The(FAMU-FSU). Various microscopy techniques were used to investigate the microstructure of a material. The main techniques used are: Optical microscopy, Scanning Electron Microscopy (SEM) which was used to give topographic information, and Orientation Imaging Microscopy (OIM) which was used to give more quantitative information. The sample preparation for the microscopic investigation includes grinding, diamond polishing and electro polishing.

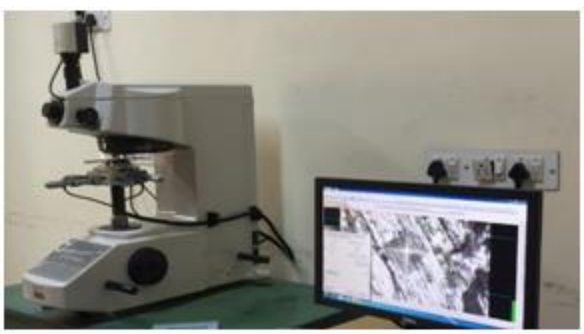


Figure.4. Microscope setup

Several samples with different combinations of rotational and translational speeds were investigated microscopically. Table.1 shows the processed samples at different combinations of rotational and translational speeds which were investigated.

Table 1. Samples FS processed at different process parameters

Sample No.	Rotational Speed (rpm)	Translational speed (in/min.)
1	600	2.0
2	600	2.5
3	800	2.0
4	800	2.5
5	1000	2.0
6	1000	2.5

The Vickers Hardness of friction stir processed AA5052 samples were measured using Vickers hardness tester. The test load applied was 200 gf and the dwell time was 5 seconds. Various samples FS processed at different rotational and translational speed were tested and also different longitudinal positions were also tested. investigation.

Figure 5. hardness test equipment

IV. RESULT AND DISCUSSION

The results show that the friction stir processed area has a higher Vickers hardness value than the original material. The effect of rotational speed on the resulting hardness and it is shown that as the rotational speed decreases the hardness increases and this agrees with the results reported. According to the Hall-Petch relationship the hardness increases as the grain size decreases, the hardness results supported the conclusion

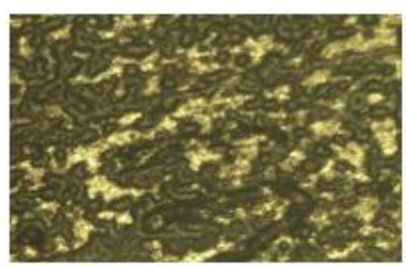


Figure 6. Observed for without fillers

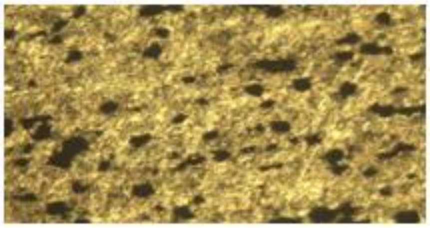


Figure7. Observed at stir zone

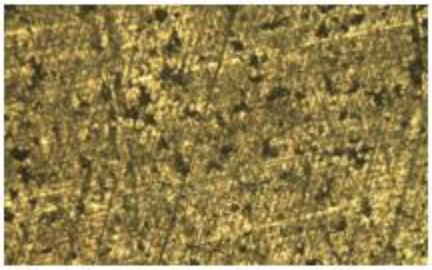


Figure 8. Observed at base metal

that more grain refinement is obtained at lower rotational speed. The effect of translational speed on the hardness was also investigated and the results show that, generally, as the translational speed increases the hardness increases. The temperature increases the hardness decreases and this might be explained by the fact that more grain growth is taking place at higher temperature. Therefore, larger grain sizes are produced according to the Hall-Petch relation at lower hardness values.

The hardness profile at a transverse section of sample FS processed at 500 rpm and 2.0 in/min. The hardness profile shows that the hardness values at the center of the deformation zone (nugget zone) is higher than the other zones, and as going farther from the nugget the hardness decreases till it reaches its minimum value at edge of the deformation zone (heat affected zone) and then increases again. These results agree with those in the literature such as the results.

FS PROCESSED QUALITY

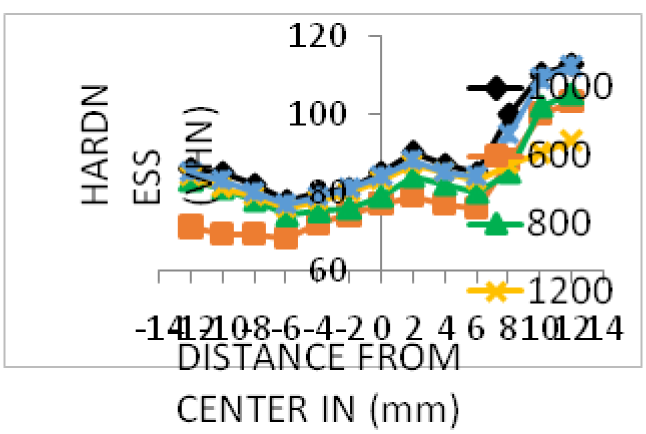


Figure 9. Hardness graph

The effects of rotational and translational speed on the surface quality of the FS processed material were also investigated.

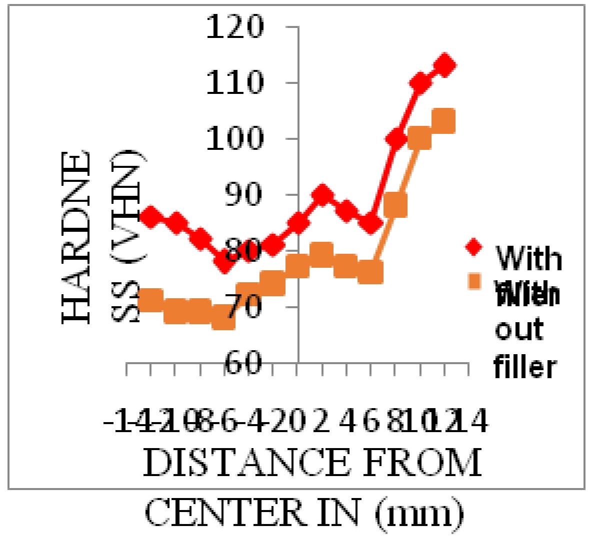


Figure 10. Hardness graph for samples

The microstructural results using Orientation Imaging Microscopy (OIM) show the difference in grain size and homogeneity. The deformation zone consists of three zones: the nugget, the thermomechanical zone (TMZ), and the heat affected zone (HAZ). The grain size distributions are shown, and it is obvious that grain size within the nugget region is much smaller than other regions. Also, it is observed that the heat affected zone is larger for the sample processed at 800 rpm than that processed at 600 rpm and this is because of the higher rotational speed which means more heat generated by friction. The OIM map for the as received sample shows average grain size of 13.41 µm; the average grain size is reduced to about 1.67 µm when FS processed at 600 rpm and 2.5 in/min. and to 4.49 µm when FS processed at 1000 rpm and 2.5 in/min.

V. CONCLUSION

Friction stir processing is an effective microstructural modification process that produces very fine and homogenous grain structure. The results for FSP commercial Magnesium alloy AZ91D showed a significant grain refinement with fine homogenous grains. Generally, smaller grain sizes are obtained at lower rotational speeds but the effect of translational speed is not significant on this resulting grain size.

The results of the hardness profiles shows that the hardness has higher values at the bottom of the processed zone and has lower values at the edge of the processed zone. It is observed that the hardness of FS processed area increases as the rotational speed decreases and translational speed increases. These observations suggested that the generated heat has significant influence on the resulting hardness on Magnesium alloy AZ91D.

REFERENCES

[1] E.D.Thomas,J.C.Nicholas,M.G.NeedhamP.Murch, C.J. Temlesmith, “An analytical model for the heat generation in friction stir welding” Patent Application No. 9125978.8, December 1991.
[2] C.J. Dawes, W.M. Thomas: Annual North American Welding Research Conference 1995, p. 301.
[3] R. Johnson and S. Kallee, “Friction Stir Welding”. Materials World, Vol. 7 no. 12 pp. 751-53 December 1999.
[4] J. Su, T. Nelson and C. Sterling. “Friction stir processing of large-area bulk UFG aluminum alloys”. Scripta Materialia 52 (2005) pp.135-140.
[5] M. Peel, A. Steuwer, M. Preuss and P. Withers. “Microstructure, mechanical properties and residual stresses as a function of welding speed in aluminum AA5083 friction stir welds”, Acta Materialia, Volume 51, Issue 16, (2003), pp. 4791-4801.
[6] M. Sutton, B. Yang, A. Reynolds and R. Taylor. “Microstructural studies of friction stir welds in 2024-T3 aluminum”. Materials Science and Engineering A323 (2002) pp. 160-166.
[7] M. Mahoney, W. Bingel, S. Sharma and R. Mishra. “Microstructural modification and resultant properties of friction stir processed Cast NiAl Bronze”. Material Science Forum Vols. 426-432 (2003) pp. 2843-2848.
[8] K. Jata and S. Semiatin. “Continuous dynamic recrystallization during friction stirs welding of high strength aluminum alloys”. Scripta Materialia, Volume 43, Issue: 8, pp.743-749.
[9] S. Benavides, Y. Li, L. E. Murr, D. Brown and J. McClure. “Low-temperature friction-stir welding of 2024 aluminum”**,** Scripta Materialia, Vol. 41, Issue 8, (September 1999) pp. 809-815.
[10] Y. Kwon, I. Shigematsu and N. Saito. “Mechanical properties of fine-grained aluminum alloy produced by friction stir process”. Scripta Materialia 49 (2003) pp. 785-789.
[11] R. Itharaju and M. Khraisheh. “On the forces generated during friction stir processing of aluminum 5052 sheets”. Ultrafine Grained Material III TMS, 2004.