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Effect of Friction Stir Processing with TiC Particle on Grain size and Hardness of AZ61

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***Abstract*-Friction Stir Processing (FSP) is a novel solid state technique and might be used for fabricating metal matrix composites. In the present work, an attempt has been made to synthesize AZ61/TiC magnesium matrix composites using FSP and to analyze the microstructure using scanning electron microscopy. An array of holes of diameter 2mm and depth of 4 mm were prepared in a 7 mm thick AZ61 magnesium alloy plates and compacted with TiC particles. Multi pass FSP was carried out using a tool rotational speed of 850 and 900 rpm, traverse speed of 100 and 150mm/min. Scanning electron microscopy was employed to study the microstructure of the synthesized composites. The results indicated that TiC particles were distributed uniformly in the magnesium matrix without the formation of clusters. There was no interfacial reaction between the magnesium matrix and the TiC particle. TiC particles were properly bonded to the magnesium matrix**.
Keywords: Friction stir processing,scanning electron microscopy,vicker hardness.

I. INTRODUCTION

Friction stir welding (FSW) is a new and promising welding process. It was invited by The Welding Institute (TWI) of United Kingdom in 1991.FSW basically used for low melting temperature materials, such as aluminium and its alloys, and other similar material joining have now been commercialised in the aerospace, marine, and transportation industries and in recent years, considerable interest has been generated in joining dissimilar materials. The need for joints between dissimilar materials often arises in industrial applications which are experiencing complex loading conditions. This provides the platform for the need / or the availability of a sound joining technique for dissimilar materials, because of the requirements, such as light weight and high performance. Friction stir processing (FSP) is based on FSW which is widely adopted these days for developing composites.In FSP a specially designed rotating cylindrical tool that comprises of a pin and shoulder that have dimensions proportional to the sheet thickness. The pin of the rotating tool is plunged into the sheet material and the shoulder comes into contact with the surface of the sheet, and then traverses in the desired direction. The contact between the rotating tool and the sheet generate heat which softens the material below the melting point of the sheet and with the mechanical stirring caused by the pin, the material within the processed zone undergoes intense plastic deformation yielding a dynamically-recrystallized fine grain microstructure.

II. LITERATURE REVIEW

In FSP tool heats the work piece and moves the material in stir zone to produce joint. Finally resulting the movement of this material fine and equiaxed recrystallized grains generated. Also FSW can be applied to various types of joints like Butt Weld joint, T-joint and lap joint etc.

The paper develops by Morisada.et.al. [1] fabricate AZ31 magnesium alloy with SiC via using friction stir processing.They reported that with the increase in travel speed grain size of the composite decreases. Micro vicker hardness tester with a load of200 g was used to measure microhardness and it shows a maximum value of69.3 Hv for FSPed AZ31 with SiC particles and 48.1Hv and 60.0Hv for as-received AZ31 and FSPed AZ31 respectively. Finally these values showed a good agreement with the experimental results.Morisada.et.al. [2] studied the influence of addition of multi walled carbon nano tubes on grain size and hardness of AZ31 magnesium composite prepared through friction stir processing .Hardness of 78Hv was observed for AZ31/MWCNT as compared with hardness of 41Hv of as received AZ31.Chang et. al. [3] investigated the effect of Nano-ZrO_2 and Nano-SiO_2 particulates reinforced in AZ31-Mg on microstructure and mechanical properties based composites fabricated by friction stir processing.The average grain size of the AZ31 matrix of the 4P FSP composites could be effectively refined to 2-4µm, as compared with the 6 µm in the FSPed AZ31 alloy (without particles) processed under the same FSP condition. The hardness and tensile properties at room temperature of the AZ31 composites with nano-fillers were appreciably improved, as compared with the AZ31 cast billet.

Yang. et.al. [4] in their study, liquation in Mg alloys was investigated using as-cast AZ91E Mg and compared this with 6061-T6 Al alloy welded by FSSW.They determined that heat input, from the torque and the axial force, was much less with AZ91E Mg than 6061 Al. They finally purposed a method to explain the liquation susceptibility and the curves of temperature vs. fraction solid (T-fS) during solidification were calculated. Asadi. P. et.al.[5] studied the effect of parameters like rotational speed, transvers speed, tool penetration depth and tilt angle on microstructure properties like cracks, tunneling cavity and sticking of tool with material along with mechanical properties of fabricated AZ91/SiC composite via friction stir processing.Their investigation also shows that penetration depths were also affected by transverse speed, rotational speed and tilt angle. Finally the outline of the work shows that the hardness increases and grain size decreases in stir zone i.e 63 to 96Hv and 150 to 7.17µm. Asadi. P.et.al. [6] produced AZ91/SiC with ultra-find grain structure via friction stir processing they focus their studies in investigating the micro structure and micro hardness studies which were influenced by parameters like rotational speed, transverse speed and number of passes and direction of FSP. They concluded that increase in number of pass results in refined grains with higher hardness and similar results was obtain when tool rotating direction is changed. Finally observations suggested that better grain size can be achieved when transvers speed is increased.Faraji.G.et.al.[7],synthesized Z91/Al_2O_3 composite by using friction stir processing;Their work included three different size nano particles ranging from nanometer to micrometer scale. Findings of their work suggests that grain size in triangular tool is less than square tool but follows opposite trend in case of hardness. Finally theconclusion drawn from their work suggests that decrease in size of nano particle increases hardness of the composite. Azizieh.M. et.al. [8] Examine the effect of process parameters like tool profile, rotational speed and number of passes on microstructural and mechanical properties of FSPed fabricated AZ31/Al_2O_3.OM, SEM and micro hardness tests was conducted to examine the etched sample. Finally cavity formation was noticed when non-threaded tool was used also they reported that use of threaded pin leads to good grain size along with uniform distribution of nano particles. In case of threaded pin with flute they observed low homogeneity along with tunneling effect. Azizieh, M. et.al. [9] synthesized AZ31/Al_2O_3 composite by using friction stir processing. They considered parameters like rotational speed and number of passes to find out their effect on particle distribution, grain refinement, hardness and temperature changes in the magnesium metal composite.If number of passes increases nano particle agglomeration decreases and hardness increases which is good. Finally work concludes that at 800r.p.m hardness is higher as compared to 1000 and 1200 r.p.m. Srinivasan M.et.al. [10] developed AZ31B/Al_2O_3 magnesium metal matrix nano composites through friction processing. The effects of the processing parameters like friction pressure, friction time, upsetting pressure and upsetting time were investigated by microstructure and mechanical properties. They concluded that as the friction time increases the joint efficiency decreases and micro hardness variation is due to thermal distribution caused by the friction pressure and friction time.

Balamurgan, G.et.al.[11] applied ANOVA to study the effect of two different shoulder profiles i.e concave shoulder tool of 18mm shoulder diameter and 5mm pin diameter with strait flutes and other is step shoulder tool with 18mm shoulder diameter and 5mm pindiameter with strait flutes on mechanical properties of AZ31B magnesium alloy. They also considered tool rotation speed and feed rate as process parameters. The outline of the work concludes that concave shoulder shows significant role on the properties of magnesium alloy. Finally they concluded that use of step shoulder tool increase hardness and ductility.

III. PROBLEM FORMULATION

FSP is an emerging field in manufacturing industries for fabricating composites. Literature survey reveals that lot of work have been done in the field of fabrication of composites via FSP. As FSP fabrication of the composites involves number of process parameters like tool rotation speed, transverse speed, axial force, % of reinforced particle, number of FSP passes, tool geometry & penetration depth etc. So all these process parameter are needed to be selected with great care to obtained good responses.

Also it is always a challenge for the authors to fabricate a right composite with variety of applications. Literature survey also shows that lots of Aluminum based alloys are widely used with several nano particles to form composites via FSP. But still a need is there to form a cheaper value and high strength to weight ratio composite. The aluminum alloys used today for aerospace applications are already optimized concerning aeronautic requirements such as strength, fatigue and damage tolerance properties. The following are the advantages of the magnesium over aluminum alloy which motivates the need of the present research work to be carried out.

• Weight reduction of single components up to 35% compared to aluminum.
• Cost efficient processes for manufacturing of magnesium semi-finished products (sheets, extrusions)
• Flammability behavior of magnesium wrought components.
• Corrosion behavior of environmentally friendly surface protected components comparable to aluminum.

Until today, FSP is used to fabricate aluminum composites used in the marine, aerospace, railway and automotive industry. In the recent years, FSW/FSP to fabricate magnesium composites has been investigated worldwide.

Based on the need and scope the following objectives will be tried to accomplish in the purposed research work.

1. To fabricate an Mg based composite via friction stir processing.
2. To study the hardness and SEM properties of the developed composite to validate the strength of composite.

IV.EXPERIMENT FORMULATION & MACHINE DETAILS

4.1 Parameter selection

FSP involves complex material movement and plastic deformation. A few major factors affecting parameters for FSP process such as tool rotation speed, transverse speed and number of passes are explained in table1.

Table 1 Working Parameters

S.No	Parameters	Values
1	Tool Rotational Speed (rpm)	850 and1250
2	Transverse Speed (mm/min.)	100 and 150
3	Tool Pin Profile	Taper Cylindrical
4	Number of FSP Passes	Single, two and three
5	Doping Method	Holes

4.1.1 Tool rotation and traverse speeds

There are two tool speeds to be considered in friction stir processing that is how fast the tool rotates and how quickly it traverses along the interface. In order to produce a successful surface composite it is necessary that the material surrounding the tool is hot enough to enable the extensive plastic flow required and minimize the forces acting on the tool. If the material is too cold then voids or other flaws may be present in the stir zone and in extreme cases the tool may break excessively high heat input, on the other hand may be detrimental to the final properties of the composite.

4.1.2 No. of Passes/Multi-Passes

A complete uniform distribution cannot be achieved and it is recommended that multiple passes are needed to improve the distribution of Nano particles in the metal matrix. Multiple passes are needed to be utilized in order to achieve homogenization. It is postulate that in order to improve the strength and elongation of MMC layers produced by FSP, one could use the multi-pass friction stirprocessing (MFSP) which could lead to higher levels of dispersion as shown in table 3.

4.2 SEM Test

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, in wet conditions (in environmental SEM), and at a wide range of cryogenic or elevated temperatures. By scanning the sample and collecting the secondary electrons that are emitted using a special detector, an image displaying the topography of the surface is created. This test has been conducted to study the microstructure of the specimen.

4.3 Reinforced particles selected for composite fabrication

- Titanium carbide (TiC) nanoparticles are selected as reinforced particles for composite fabrication.
- Titanium carbide (TiC) show good chemical inertness and good conductivity

Applications

- In the manufacture of wear-resistant tools, cutting tools
- As a coating for abrasive steel bearings, wear resistant tools
- In the form of nano titanium carbide ceramic in optics applications
- Enhance the conductivity of materials and as a nucleating agent.

4.4 Tool material and tool design

- A cold-work tool High carbon, high chromium oil hardened type steel tool that comprises of outstanding high temperature strength, high temperature toughness, high temperature wear resistance and good machine ability.

- This tool steel selection was also motivated by its cost, availability and machine ability.
- Chemical composition of High chrome high carbon steelis shown in table 2.

4.5 Tool Design

Tool design for FSP as shown in fig 1 and fig 2.

4.6 Experimentation Scheme

There are several parameters in FSP e.g. tool rotation speed, transverse speed, no. of passes, tilt angle and % addition of reinforced particles, which can be varied during the machining process. These parameters are having wide working range. But for the optimization of the process a suitable range has to be selected.

The following table suggests about the experimentation scheme. All the parameters were selected after extensive trails.

V. RESULT

In these chapters, the experimental findings related to the effect of various input parameters on the performance characteristics of FSP have been given after trial experimentation. The effect of addition of Nano particles in the microstructure of AZ61/TiC MMCs is shown in the SEM micrographs presented in Fig. 2. The SEM micrographs as presented in Fig.2 show that the microstructures at 1000x and 15000x magnification.

VI .CONCLUSION

In the present work, AZ61/TiC MMCs were successfully synthesized using the novel method FSP. The microstructure of the composite was analyzed using scanning electron microscopy.The following conclusions were derived as in table 3 from the present work. Maximum hardness and minimum grain size is observed at 1250 tool rotation speed and at 150mm/min transverse speed with three no. of passes. TiC particles were distributed uniformly in the magnesium matrix without the formation of clusters. There was no interfacial reaction between the magnesium matrix and the TiC particle. TiC particles were properly bonded to the magnesium matrix.

REFERENCES

[1] Y. Morisada, H. Fujii, T. Nagaoka and M. Fukusumi"Effect of friction stir processing with SiC particles on microstructure and hardness of AZ31" *Materials Science and Engineering,* vol. 433, pp. 50–54, 2006.

[2] Y. Morisada, H. Fujii, T. Nagaoka and M. Fukusumi,"MWCNTs / AZ31 surface composites fabricated by friction stir processing" *Materials Science and Engineering,* vol. 419, pp. 344–348, 2006.

[3] C. I. Chang, Y. N. Wang, H. R. Pei, C. J. Lee, X. H. Du, and J. C. Huang, "Microstructure and Mechanical Properties of Nano-ZrO2 and Nano-SiO2 Particulate Reinforced AZ31-Mg Based Composites Fabricated by Friction Stir Processing," *Key Engineering Materials*, vol. 351, pp. 114–119, 2007.

[4] Y. K. Yang, H. Dong, H. Cao, Y. A. Chang, and S. Kou, "Liquation of Mg Alloys in friction stir spot welding " pp. 167–177, 2008.

[5] P. Asadi and G. Faraji, "Producing of AZ91 / SiC composite by friction stir processing (FSP)" pp. 247–260, 2010.

[6] P. Asadi, M. K. BesharatiGivi and G. Faraji"Producing Ultrafine-Grained AZ91 from As-Cast AZ91 by FSP " *Materials and Manufacturing Processes*, February 2015, pp. 37–41, 2010.

[7] G. Faraji, O. Dastani, S. A. Asghar, and A. Mousavi, "Effect of Process Parameters on Microstructure and Micro-hardness of AZ91 / Al_2O_3Surface Composite Produced by FSP," vol. 20, pp. 1583–1590, 2011.

[8] M. Azizieh, A. H. Kokabi, and P. Abachi, "Effect of rotational speed and probe profile on microstructure and hardness of AZ31 / Al_2O_3nano composites fabricated by friction stir processing," *Materials and Design*, vol. 32, no. 4, pp. 2034–2041, 2011.

[9] M. Azizieh, H. S. Kim, A. H. Kokabi, P. Abachi, and B. K. Shahraki, "fabrication of AZ31 /Al_2O_3 nano composites by friction stir processing" vol. 28, pp. 85–89, 2011.

[10] M. Srinivasan, C. Loganathan, V. Balasubramanian, Q. B. Nguyen, M. Gupta, and R. Narayanasamy, "Feasibility of joining AZ31B magnesium metal matrix composite by friction welding," *Materials and Design*, vol. 32, pp. 1672–1676, 2011.

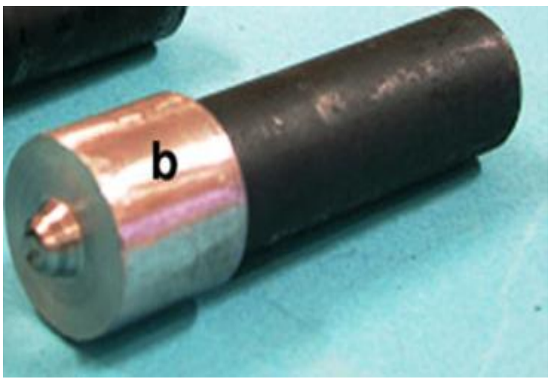
[11] K.G. Balamurgan,K. Mahadevan and D. Peter Pushpanathan "Investigation on the effect of tool types on the mechanical properties of friction stir processed AZ31B magnesuim alloy." *IOSR journal of mechanical and civil engineering*, vol. 2, issue 2, pp.44-47, 2012.

Table 2 Composition of tool

Elements	C	Mn	Si	Cr	Ni	Mo	V	Co	Cu	P	S	Fe
Wt%	1.40-1.60	0.60	0.60	11-13	0.30	0.7-1.20	1.10	1.10	0.25	0.03	0.03	Balance

Table 3 *Grain Size and Hardness Comparison*

Specimen No	T.R.S (rpm)	Transverse speed (mm/min)	No. of FSP passes	Base Metal grain size	Grain size	Base Metal Hard-ness	Hardness
1	850	150	Single	75µm	20µm	60Hv	80Hv
2	850	150	Double	75µm	17µm	60Hv	84 Hv
3	850	150	Triple	75µm	12µm	60Hv	90 Hv
4	850	100	Single	75µm	22µm	60Hv	78 Hv
5	850	100	Double	75µm	18µm	60Hv	81 Hv
6	850	100	Triple	75µm	13µm	60Hv	89 Hv
7	1250	150	Single	75µm	23µm	60Hv	75 Hv
8	1250	150	Double	75µm	16µm	60Hv	83 Hv
9	1250	150	Triple	75µm	10µm	60Hv	97Hv
10	1250	100	Single	75µm	21µm	60Hv	76Hv
11	1250	100	Double	75µm	15µm	60Hv	82Hv
12	1250	100	Triple	75µm	13µm	60Hv	92Hv



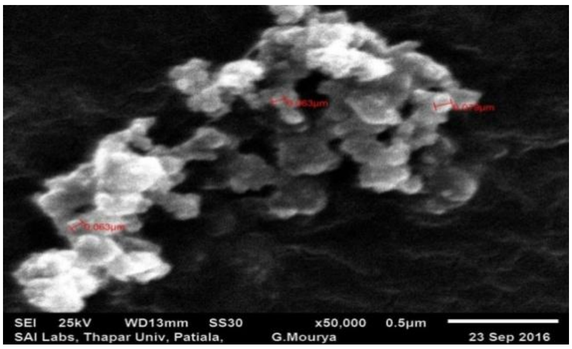


Fig 2 SEM Micrographs