Microstrutral and Mechanical Behavior of Magnesium Base Composite Synthesized via FSP.

Sanjeev Kumar[1], Munish Mehta[2], Sushma[3], Sanjay Raheja[4]

[1]Student M.Tech. (H.C.T.M. Kaithal)
[2]Assistant Professor & H.O.D. (H.C.T.M. Kaithal)
[3,4]Assistant Professor (T.I.T. College, Bhiwani)

Abstract

Friction Stir Processing (FSP) is a newly developed method used these days for the fabrication of different metal matrix composites. Present work,is an demonstration of magnesium base metal matrix composite prepared by FSP. An array of holes of diameter 2mm and depth of 4 mm were prepared in a 7 mm thick AZ61 magnesium alloy plates completely filled with TiC particles. One ,two and Three passes of FSP was carried with a threaded cylindrical tool using a tool rotational speed of 800 and 1200 rpm, traverse speed of 60 and 100 mm/min. Micro structural and micro hardness properties have been studied. It has been observed that TiC particles were perfectly distributed in the base metal with no defect formation.

Keywords: Friction stir processing, scanning electron microscopy, Vicker hardness.

1. INTRODUCTION

Friction stir welding (FSW) is a newly formed 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 aluminum and its alloys, and other similar material joining have now been commercialized in the aerospace, marine, and transportation industries and in recent years, considerable interest has been generated in joining dissimilar materials. Friction stir processing (FSP) is based on FSW which is widely adopted these days for developing composites. In FSP rotating cylindrical tool having some pin length is plunged into the material. And then this tool rotates and advances in the desired direction. The vigorous action of rotating tool creates lots of friction between tool and metal which results in developing high amount of thermal energy. This softens the material below its melting point. Also this mechanical processing of the material above its re-crystallization temperature result in forming new grains. Hence the process is beneficial in producing material with new grain with different mechanical properties..

2. LITERATURE REVIEW

[1] **Morisada. et.al.** 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.

[2] **Morisada. et.al.** 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.

[3] **Morisada. et.al.** Investigated the effect of Nano-ZrO2 and Nano-SiO2 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.

[4] **Yang. et.al.** 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.

[5] **Asadi. P. et.al.** 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.

[6] **Asadi. P. et.al.** 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.

[7] **Faraji. G. et.al.** ,synthesized Z91/Al2O3 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.

[8] **Azizieh. M. et.al.** Examine the effect of process parameters like tool profile, rotational speed and number of passes on microstructural and mechanical properties of FSPed fabricated AZ31/Al2O3.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.

[9] **Azizieh M. et.al.** Synthesized AZ31/Al2O3 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.

[10] **Srinivasan, M. et.al.** developed AZ31B/Al2O3 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.

[11] **Balamurgan, G. et.al.** 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 pin diameter 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.

3. 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 this process parameter is 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. 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.

4. EXPERIMENT FORMULATION

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.

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.

Table 1 Working Parameters

S. No.	Parameters	Values
1	Tool Rotational Speed (rpm)	800 and 1200
2	Transverse Speed (mm/min.)	60 and 100
3	Tool Pin Profile	Threaded Cylindrical
4	Number of FSP Passes	Single, two and three
5	Doping Method	Holes

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 stir processing (MFSP) which could lead to higher levels of dispersion.

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) nano-particles are selected as reinforced particles for composite fabrication.

4.4 Tool material and tool design

A cold-work tool High carbon steel 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.

4.5 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.

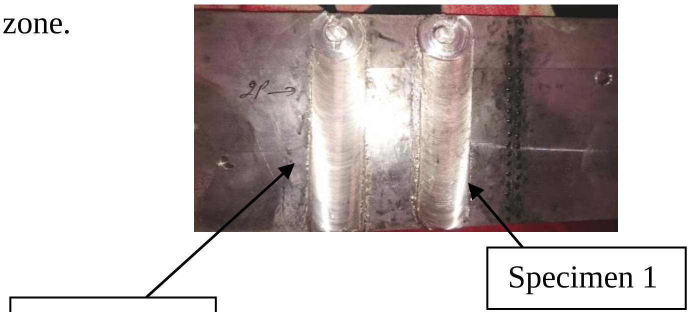
RESULT AND DISCUSSION

5.1 Result

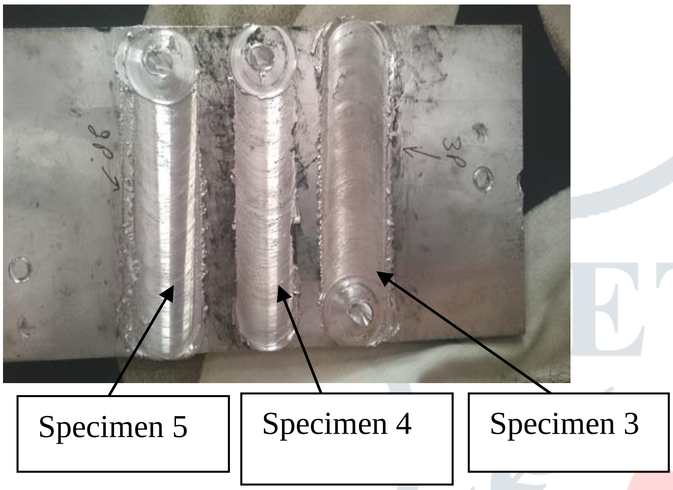
In these chapters, the experimental findings related to the effect of various input parameters on the performance characteristics of FSP have been given after trial experimentation. Trial experimentation is shown in fig 5.1.

Fig. 5.1 Trial Experimentation before final run

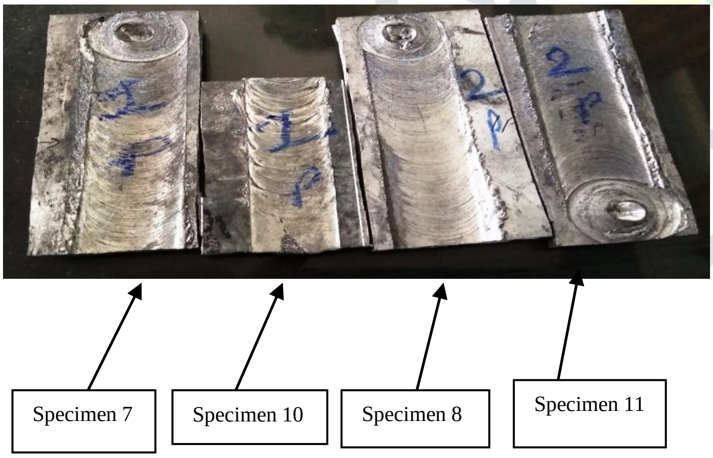
The results obtaine d from experi mentati on were analyzed. The optimum conditions for different performance parameters have been calculated by evaluating their response to the various combinations of the input parameters.AZ61/TiC MMCs were successfully synthesized using FSP. Fig. 5.1(a), 5.1(b), 5.1(c), 5.1(d) and 5.1(e) shows the pictorial views of the sample prepared and FSP zone.



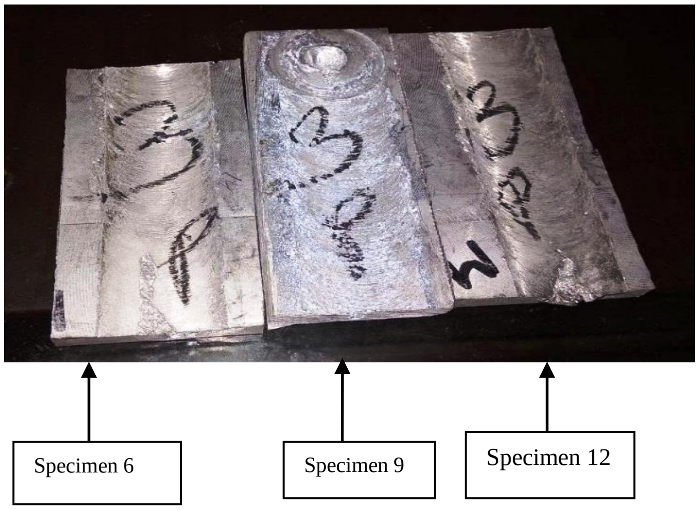
FSP ZONE Fig 5.1(a)



FSP ZONE Fig 5.1(b)



FSP ZONE Fig 5.1(c)



FSP ZONE Fig 5.1(d)

FSP ZONE Fig 5.1(e)

5.2 Loading of Work-pieces on fixture on milling machine:

As shown in Fig 5.2 work piece have been loaded on milling machine for further operation

Fig 5.2 Milling machine with loaded work piece

Basically no defect was found in FSW. No defects like crack, tunnel, pin hole, piping and worm were observed in FSP region. The metal matrix composite is present in FSP zone.A macrographs view suggests that the entire hole is completely bound from all sides. The pin length was kept 0.5 mm higher than that of the groove depth which is observed to be adequate to produce full penetration. Hence defects do not arise at the bottom side of the holes.

The impression of the tool on the holes generates frictional heat. Which further plasticizes the magnesium based alloy which makes it to reach at semi solid state. The energetic stirring action of the tool distributes the packed TiC particles into the plasticized magnesium alloy.

The advancement of the tool moves the molten solid composite from one side to other side, i.e advancing side to retarding side. At this moment no zones can be identified because of the absence of boundary. But as the tool advances and forge the composite back all the zones like stir zone, heat affected zones etc. can be attributed. The nano particle is very absolute in size as shown in fig below.

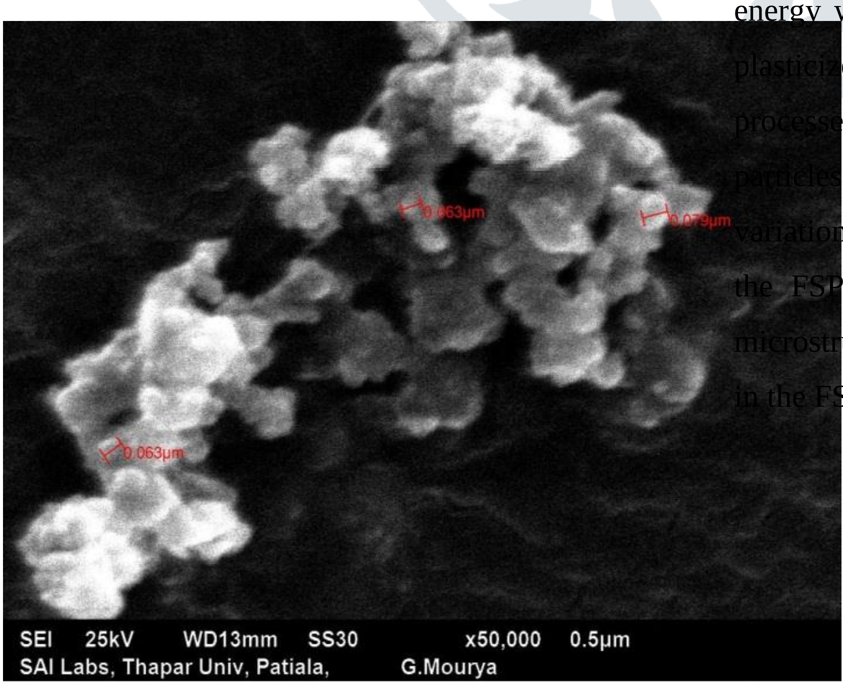


Fig 5.3. SEM Micrographs

The effect of addition of Nano particles in the microstructure of AZ61/TiCMMCs is shown in the SEM micrographs presented in Fig. 5.3. The SEM micrographs as presented in Fig. 5.4 show the microstructures at 1000x and 15000x magnification.

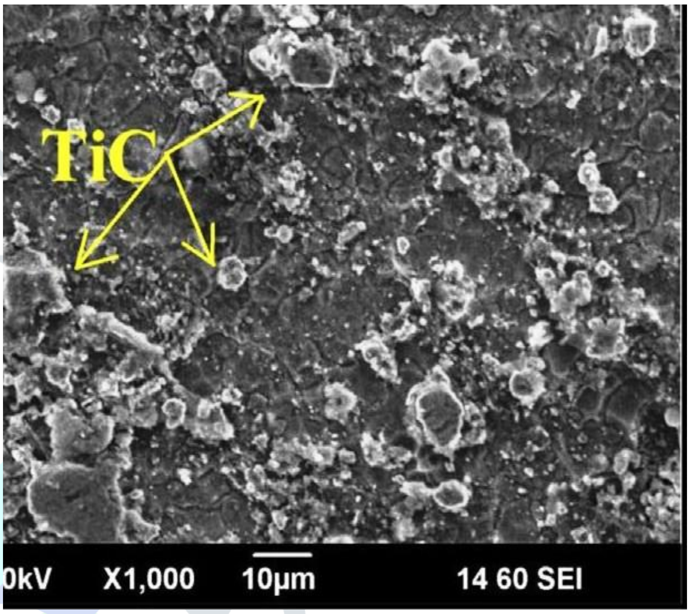


Fig 5.4 Uniform Distribution of TiC Particle

The uniform distribution of TiC particles can only be achieved by sufficient development of thermal energy which is produced by fiction, stirring and plasticized composite across the friction stir processed zone. Mild mixing of the reinforced particles are also noticed at some locations. The variation in the distribution of Tic particles across the FSP zone was found to be negligible. The microstructure was independent upon the location in the FSP zone.

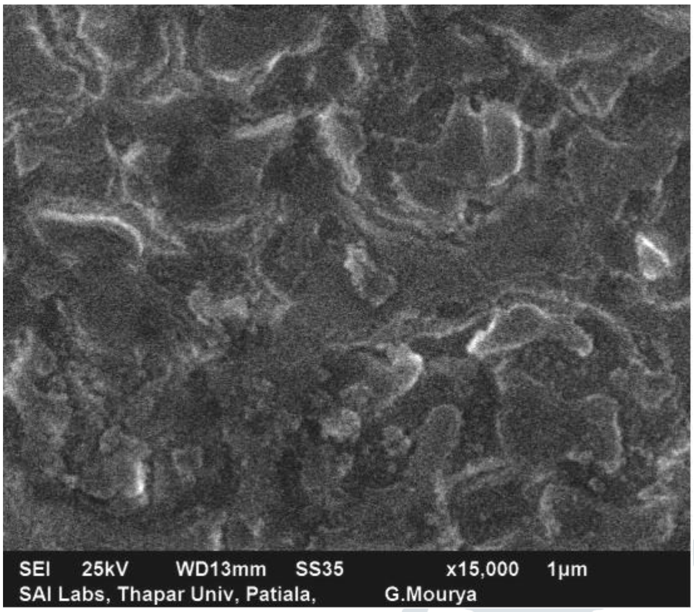


Fig 5.5 SEM IMAGE

Table 5.1 Final Results

Spec-imen No.	T.R.S (rpm)	Transverse speed	No. of FSP passes	Base Metal grain size (µm)	Grain size (µm)	Base Metal Hard-ness	Hardness (Hv)
1	800	100	Single	70	22	50	78
2	800	100	Double	70	19	50	82
3	800	100	Triple	70	14	50	88
4	800	60	Single	70	24	50	76
5	800	60	Double	70	20	50	79
6	800	60	Triple	70	15	50	87
7	1200	100	Single	70	25	50	73
8	1200	100	Double	70	18	50	81
9	1200	100	Triple	70	12	50	95
10	1200	60	Single	70	23	50	74
11	1200	60	Double	70	17	50	80
12	1200	60	Triple	70	15	50	90

5.3 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 from the experiment. Maximum hardness and minimum grain size is observed at 1200 tool rotation speed and at 100 mm/mim transverse speed with three no. of passes as shown in table 5.1 in 9 no. specimen. 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.

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