International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 7, July-2018

Friction stir processing of Zamak Z5 Zinc alloy sheets

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Abstract

Friction stir processing (FSP) was employed to fabricate biomaterial implants by altering surface properties through SiC micro particles embedment in base metal. Consequence of machine parameters such as tool speed, feed & tool plunge depth on, microstructure & surface roughness were examined. Optical & SEM were used to studies microstructure. It was deduced that it is an effective method for the improving mechanical and tribological properties of implant material for achieving good interfacial integrity and major grain modification. It was noticed that rpm and traverse speed are directly influencing grain size i.e. with increase in rpm and traverse speed (which is feed here) causes reduction in grain size. Plunge depth (PD) is very important and effective variable responsible for the production of good exterior layer. Plunge depth value was affected to large degree by rotational speed and feed speed. In this experimental study it was unearthed that by embedding SiC particles of grain size 5µm in base metal refines or reduces grain size up to 1.838µm in stir zone (SZ)

Keywords— Zinc Z5, FSP, plunge depth & Microstructure

INTRODUCTION

From past few years, friction stir processing is used as a thermo mechanical solid state process for modifying properties and. It works on the principle developing new materials of Friction stir welding which is a solid-state joining technique invented at The Welding Institute Cambridge (UK) in 1991**[1]**. FSP is seen as viable methods for refining grain size of cast or wrought aluminium based combinations by means of dynamic recrystallization **[2]**. In FSP a non-consumable rotating tool with a specially designed pin and shoulder plunged into the surface of the work piece and then travelled as the shoulder of the tool touches the plates for localized micro-structural modification for specific property improvement. Magnesium alloys has leaning of showing privileged mechanical properties and offer major weight savings has excited research activities recently **[3]**. There are two factors responsible for giving preference to Zinc alloy over magnesium as an alternate bio-material one is zinc alloys have better counter corrosion properties in simulated body fluid (SBF) and secondly its low corrosion speed results in small rates of enlarged pH value and hydrogen evolution **[4]**.

It is probable to manufacture surface composite layer such as Al–Al_3Ti nano-composite layer by FSP by this process and Hsu et al. **[5]** to get superior Young modulus and the tensile strength properties of Al. It was educated that Young's modulus of the Al–Al_3Ti composite improves manifolds through higher vol. fraction of Al_3Ti in the matrix. By mixing 15vol. % of Ti, the Young modulus can reach as high as 114GPa, which is 63% superior than that of Al. Zinc Z-5 alloy composition is represented in table1 is utilized for the creation of castings for various purposes, particularly to slide heading expected for high load/low speed applications. Heat treatment of the conventional Zn-Al combination diminishes the degree of dimensional changes yet falls apart their hardness and elasticity properties, while malleability and sliding wear conduct were enhanced following the treatment. The primary hindrances of the Z-5 combination are porosity (because of the wide temperature amongst solidus and liquidus temperatures), deterioration of mechanical property at temperatures over 80 °C **[6, 7]** 100 °C **[1,8]** and 120 °C **[9].**The objective of this experimental work is to embed reinforcement particles of SiC having grain size about 5µm in zinc Z5 alloy and study the evolution of microstructure and surface roughness by applying FSP technique.

2. EXPERIMENTAL PROCEDURE

Commercially available micro reagent having particles size approximately 5µm SiC were embedded. Particles were filled into grooves of $3 \times 90 mm^2$ as shown in fig.1 machined on Z5 Alloy on demand casted through hot forged die casting technique having composition Zinc Z-5

Fig.1 Unfilled groove of $3 \times 90 mm^2$

Elements	Al	Cu	Fe	Pb	Cd	Sn	Zn
Composition	3.5- 4.5	0.75- 1.25	0.1	0.005	0.004	0.003	balance

Table1:- Zn Z-5 alloy composition (wt. %).

Two tool as shown in fig. 3(a) one without pin tool was used to ensure holding of SiC powder in grooves with varying depth i.e. 1.5 to 2.5mm & (b) tool with square pin with a 6mm diameter and a max. 2.5mm length was used to stir the reagent particles in base metal at varying tool rotation & feed speed on CNC vertical milling machine. The PD was varied between 1.5- 2.5mm to optimize optimum value for producing defect-free samples. Samples were etched with an etchant solution to eliminate any such scaling and surface impurities.

In this study samples of 100×30×6mm were prepared from a plate produced by HPDC of 625×100×12mm thick plate. Two HSS M35 tools were used as shown in Fig. 2 with and without pin having 16mm diameter respectively. Fifteen such plates were FSPed by varying the depth of the groove (0, 1.5, 2 and 2.5) mm therefore four levels of volume fraction of SiC particles (0, 50.71, 51.66 & 62 vol. %) were used. These values of vol. fractions were calculated by employing following simple equations.

Vol. fraction = (groove area/ probe area) ×100

Groove Area = Groove (width × depth)

Probe area = Probe (diameter × length)

S. No	Tool rotation speed (rpm)	Traverse speed (mm/min)	Plunge depth (mm)
1	1500	20	1.5
2	1750	30	2
3	2000	40	2.5

Table2:- Process parameter used for FSP

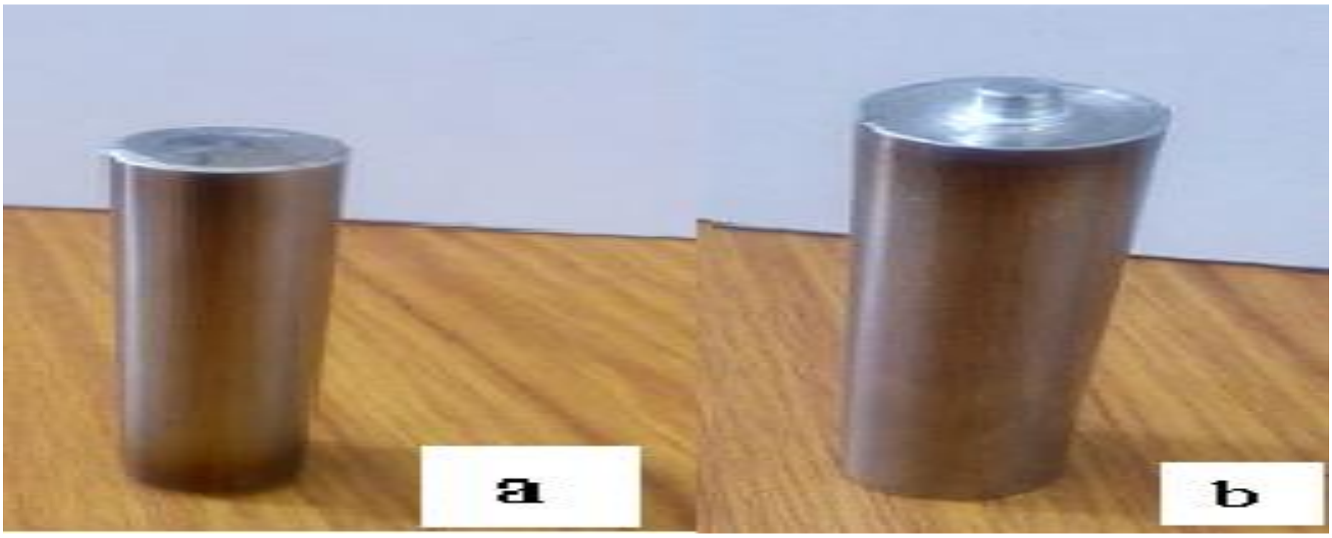

Fig.2 FSP tool (a) without pin/probe for preparing the specimens, (b) with square pin/probe for FSP.

3 RESULTS &DISCUSSIONS

Two tool of same material were used while processing, first tool had no pin therefore no stirring action takes place the only function of without pin tool is to hold the reagent particles in grooves. Since there is no stirring action for producing enough heat not to soften the material but enough to roughen the surface for softening by second tool with pin. There were failure encountered due to imbalance between the process parameters and tool geometry such as tunnelling defect because base metal was not sufficiently softened at low rpm due to lower friction heat production at the tool shoulder and work piece interface also, sticking of base metal material on tool tip which fails the tool. At high rpm and low traverse/feed speed tunnelling effect no is eliminated, plus the tool pin comes out of the work piece leaving behind a dimple of pin shape. The experiments were conducted on VMC on the basis of 3 factors 3 levels full factorial design by design expert software 11 . The optimum range of tool rotational and traverse speed & plunge depth used in this experimental study are given in Table1. The processed Z-5 zinc alloy plates were subjected to tribological tests and metallographic characterization as per ASTM standards. To hold reinforcement particles intact in the groove processing was done by without pin tool, processing was done at above mentioned parameters with dwell time of 15seconds so that material at the point where tool & base metal meets softens and this softened material moves along the retrieving side of the tool tip leaving behind processed zone with modified properties. On one hand there is brittle fracture at low plunge depth due to in sufficient softening of material under shoulder due to low friction heat in the processed zone

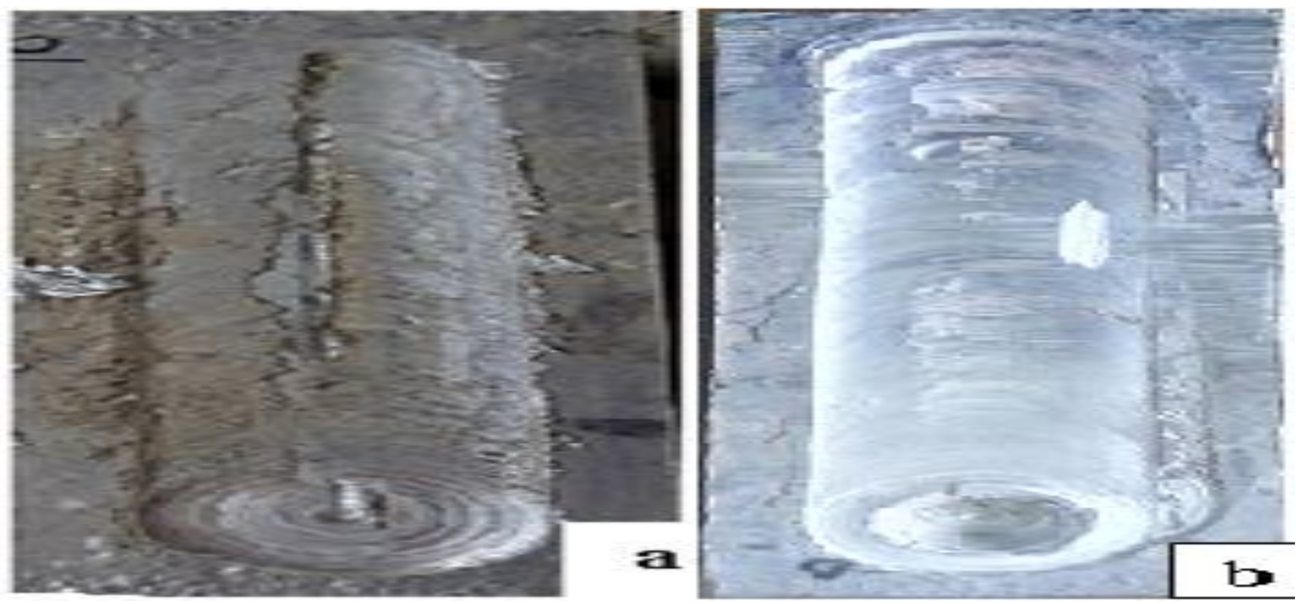

Fig. 4(a) Tunnelling defect (b) Defect free specimen

While on other hand there is sticking of work piece on tool pin which fails tool profile, as seen in fig4 (b), may be due to change in friction type i.e. from sliding friction to sticking friction. The outcome of vol. fraction of SiC reagent micro size particles on the microstructure of the surface of FSPed surface containing embedded micro particles is shown in the SEM micrographs depicted in Fig. 5. Fraction zero refers to reagent free friction stir processed zinc alloy which shows dynamically re-crystallized grains. SEM micrographs shows the divergence of microstructure as a function of vol. fraction of SiC particles with 1000×magnification in Fig. 5 uniformity of reagent particle size in the SZ is refined and as small as negligible As the number of reagents increases along with the space between adjacent grain particles size reduces when the volume fraction increases. In SZ there was uniform dispersion of SiC grains that can be due to severe frictional heat generation that lead to stirring of particles in softened base metal this material flows uniformly in the SZ was observed that grains are fine in stir zone but they are becoming coarse and elongated in the form of dendrite structure in direction away from the SZ till HAZ. These structures were more in number at boundary bet TMAZ and HAZ zone. One thing noted here is that hardness in SZ was maximum it also decreases toward HAZ.

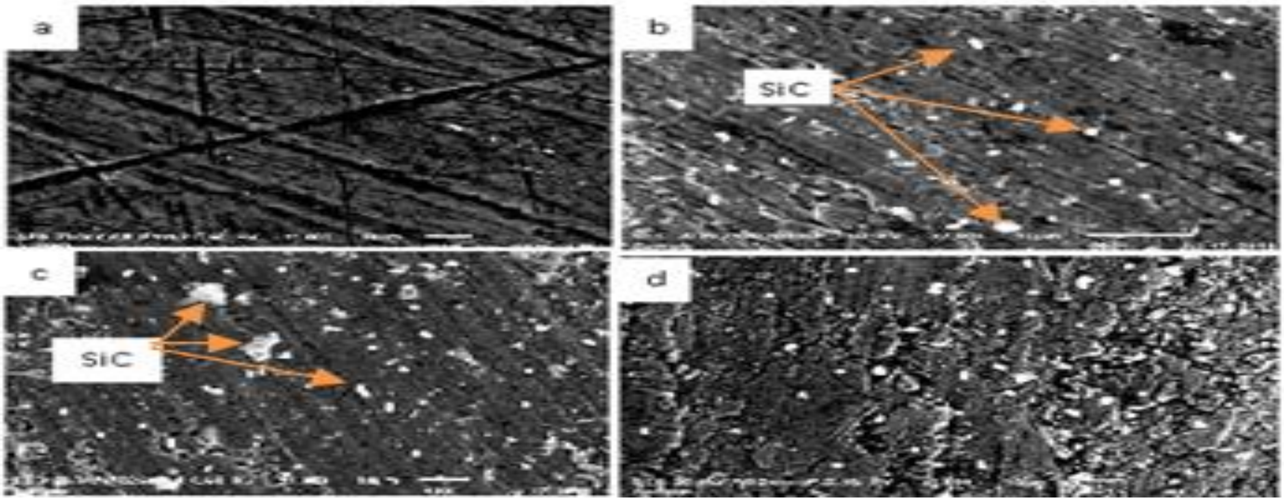

Fig. 5. SEM Micrograph of SiC embedded in zinc Z5 alloy plates; ((a) 0, (b) 50.71, (c) 51.66 & (d) 62) vol.%

The crossing point at SiC particles and the zinc matrix looks spotless and voids bounded by any or response items. Since FSP is a solid state processing technique, the temperature is enough to start any sort of interfacial feedback between SiC molecule and the magnesium network. A cleaner interface gives legitimate bolding between SiC particles and zinc matrix and enhances mechanical and tribological properties [10].

4 CONCLUSIONS

In this research an effort was done to study the consequence of SiC on the microstructural and surface roughness by friction stir processed Z5 zinc alloy. The following conclusions were made:

- Z-5 zinc alloy (0, 50.71, 51.66 & 62 vol. %) SiC were successfully embedded into the surface of parent material using the novel FSP technique. Microstructure was observed via SEM.
- FSP can be effectively used to modify microstructure and refine grain size without major defects.
- SiC reagents micro particles were dispersed consistently in the zinc alloy by avoiding accumulation of particles in cluster form

ACKNOWLEDGMENTS

The author is appreciative to the Department of Mechanical Engineering, National Institute of Technical Teachers Training & Research Chandigarh, India for extending their facilities to carry out this research and also very thankful to Mr. Mukesh Kumar (NITTTR Chandigarh) assistance which he offered to accomplish the above work.

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