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Influence of Friction Stir Processing Parameters on Mg ZE 41-SiC Surface Composite

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Abstract*: *In this study, the influence of friction stir processing process parameters (FSP), such as tool rotational speed, tool traverse speed, and the tool tilt angle on the mechanical properties of Sic reinforced surface magnesium rare earth ZE41 alloy composite was studied. The process was carried at tool rotational speeds of 710, 900, 1120, 1600, 1400 and 1800 rpm, tool traverse speeds of 16, 25, 40 and 63 mm/min and tool tilt angle of degree 1. Nano-particles of SiC (40 microns) were used as reinforcements to produce a composite surface. The grain refinement of the processed specimens was analyzed using scanning electron microscope. It is observed from the results that FSP process parameters influenced the surface composite area, SiC particles distribution and micro hardness of the composite. The outcomes indicated that the higher micro hardness was obtained at rotational speed of 1100 RPM, traverse speed 40mm/min and tilt angle 1^0.

***Index Terms*: FSP, Mg ZE41,SiC, Hardness**

I. INTRODUCTION

Magnesium has the potential to substitute steel, aluminium alloy, and plastic-based materials due to great strength to low weight-ratio but poor in erosion confrontation. Gusieva et al [1] stated that minor incorporation of rare earth metals to magnesium enhances the corrosion resistance. The applications of magnesium alloy in automobile sector have gradually increased by improving the properties of magnesium alloys [2-3]. In spite of that, major mechanical properties and deprived resistance to corrosion are the major setback which curtails the magnesium component applications. Aatthisugan et al. [4] found that incorporation of carbide particles notably improve the wear resistance of mg alloys. Apart from bulk modifications, several procedures including heat treatment, composite layer formation, laser cladding process are appertain to the alloys of magnesium, for revamping mechanical properties also enhancing resistance to corrosion [5– 6]. A conventional method of producing composite encounters few obstacles, namely deprived wettability, also particles with intermittent dispersion which were reinforced, however, the friction commotion dispensation is a superficial work practise centred on abrasion stirring bonding [7]. The surface composite method of processing at solid state is beneficial as it can elude the unwanted interfacial reaction amongst matrix and reinforcements. Grain refinement is processed utilizing friction stir solid state processing technique, of which non-esculent rotating device accompanied by specifically contrived pin. The shoulder is leaped hooked on the superficial of the case and navigated laterally the line to be salted. From mechanical work, the frictional heat and pressure spawned are utilized by FSP through intense plastic deformation to accomplish refinement of grain. Magnesium-rare earth alloys were processed and analyzed using FSP to emanate hardness and refinement of grain revamped in the treated area [8]. Lee et al. [9] demonstrated that after paltry Friction Stir processing phases, the nano-sized SiO2 particles were unvaryingly dispersed. The hardness was almost doubled when contrasted with the base material and high strainrate super-plasticity likewise observed in the zone of friction stir of SiC particles with a homogeneous distribution, and grain structure is recrystallized and disclosed the wear attributes and hardness of the FSPzone. Asadi et al. [10] reported that FSPed AZ91/SiC nano hardness was better owing to ounce refinement of base material and uniform dispersion of SiC particles. Shamsipur et al. [11] found that the uniform dispersion of reinforcements in FSPed Ti/TiN composite surface layer cause for increasing the hardness. Morisada et al. [12] stated that higher hardness was observed in FSPed nanostructured tool steel compared to base material. Until now, numerous researches have been carried on wrought magnesium alloy based on aluminium.

The objective of the present work is to evaluate the influence of friction stir treating structures such as rotational speed of tool and traverse speed on the properties of hardness and microstructure of SiC reinforced magnesium ZE41 rare earth alloy.

II. EXPERIMENTAL WORK

The specimens were cut into prerequisite size (100mm X 80 mm) from the base material magnesium rare earth ZE41 alloy using wire cut EDM. The Friction stir (FSP) treating was carried on vertical milling machine mechanism with the location of the tool fixed relative to the outward surface of the piece as exposed in Fig.1. A groove of 80 mm × 1 mm × 3 mm on the surface of the specimens were machined, at that point it is filled with commercially accessible SiC particles. The process was carried at rotational speeds of 700, 900, 1120, 1400, 1600 and 1800 RPM with varying tool traverse speeds 16, 25, 40 and 63 mm/min at constant tool tilt angle 10.

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The selected samples and parameter conditions is shown in Table 1. At the beginning, the samples were friction stir processed using the tool which consisted of single shoulder unaccompanied by the pin in order to inhibit SiC from being dislodged out of the groove. The non-consumable taper cylindrical tool of hardened H13 comprises of a pin with 3 mm height, 6 mm diameter and diameter of the shoulder is 18 mm was used in order to blend SiC particles with the base material. The chemical composition of base material used in this work is shown in Table 2.

Fig.1. (a) Investigational arrangement of the FSP process

Fig.1. (b) FSPed Sample

Table1: Parameter conditions

Sample No.	1	2	3	4	5	6	7	8
Rotational Speed (RPM)	700	900	1100	1400	1800	1100	1100	1100
Traverse speed (mm / min)	25	25	25	25	25	16	40	65

Table 2: Chemical composition of base material magnesium ZE41 rare earth alloy (Wt %)

Element	Zn	Mn	Cu	TR	Zr	Mg
(Wt %)	4.2	0.02	0.05	1.2	0.54	Bal

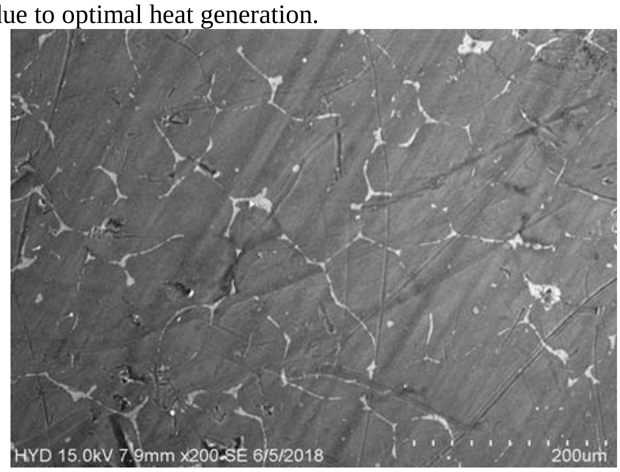
The surface of base substantial and the handled trials were metallographically elegant by altered sorted emery pieces monitored by enhancing utilizing diamond paste and etched with acetone. The microstructure of the base material and processed samples was examined using scanning electron microscopy (SEM). Vickers hardness was observed in the SZ i.e stir zone by digital Vickers Micro hardness mechanism model OMN Tech MVH Auto and it was linked with the microstructural changes.

III. RESULTS AND DISCUSSION

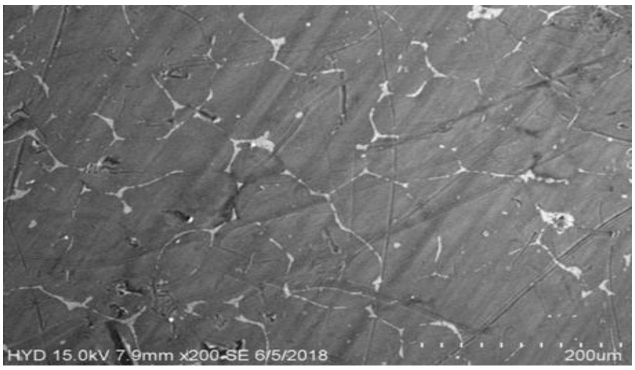
3.1. Microstructural analysis

The Sic reinforced magnesium rare earth ZE41 alloy surface composite was successfully fabricated using FSP process for various combinations of process parameters. Microstructure (MS) of base material and friction stir processed ZE41 samples for various combinations of process parameters is shown in Fig 2. It is observed from Fig 2 that, the microstructure exhibited more uniformity and refined grains smaller than the base metal after the FSP process. This is due to generation of insufficient heat and dynamic recrystallization instigated by moving deed of pin during the process [13]. It is also observed that the structure of substrate encompassed of coarse grains and Mg17Al12 (β) at grain boundaries network is precipitated. The strengthening units are consolidation hastens of ZE 41 alloy that isolated in the Mg matrix due to formation SiC clusters in the SZ after FSP pass. Samples 1-3 show that microstructure with a mixture of coarse and fine grains and inhomogeneous distribution of SiC particles. This is due to insufficient heat generation and poor plasticization zone caused by the lower rotational speed and traverse speed With the increase in the rotational speed (samples 4 -5) has produced penetrating malleable twist and adequate frictional heating generation for complete deformation resulting formation of fine grains homogenous dispersal of SiC particles in composite.

The microstructures show that the traverses speed also has more significant on grain refinement of material and distribution of particles. Increase in the traverse speed decreases the grain size. The increase in traverse speed at constant rotational speed (Samples 6-8) has again resulted in homogeneous micro structure and uniform dispersal of SiC particles. Sample 7 shows equated homogenized grains with unchanging dispersal of SiC particles in the stir zone, this is due to optimal heat generation.



Base Material



Sample-1

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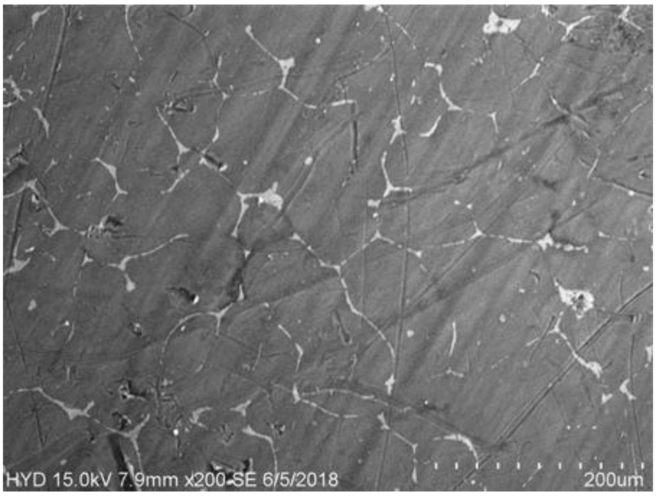

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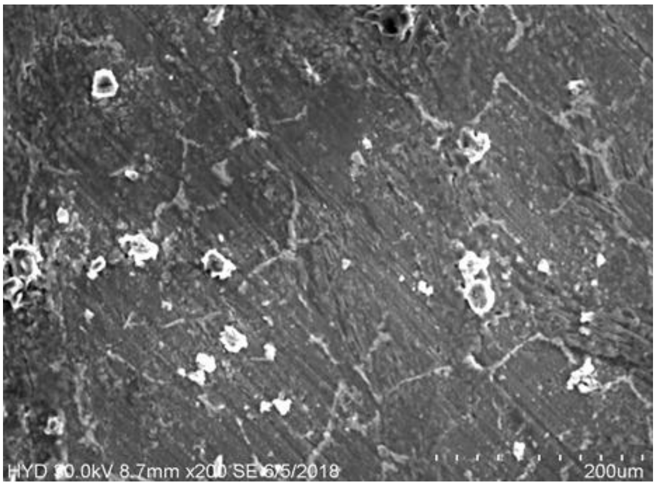
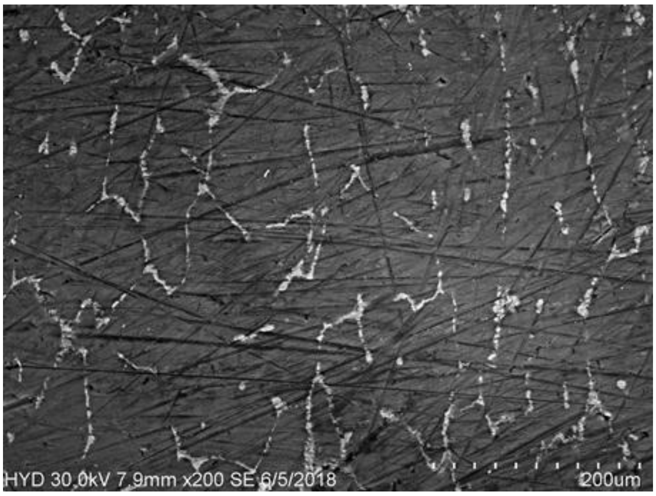
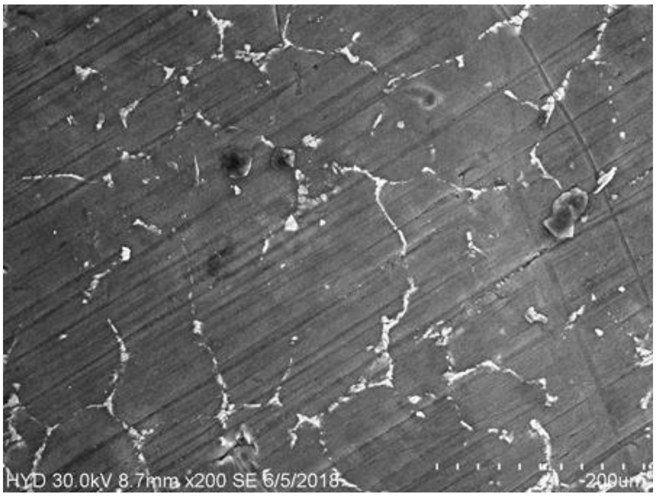


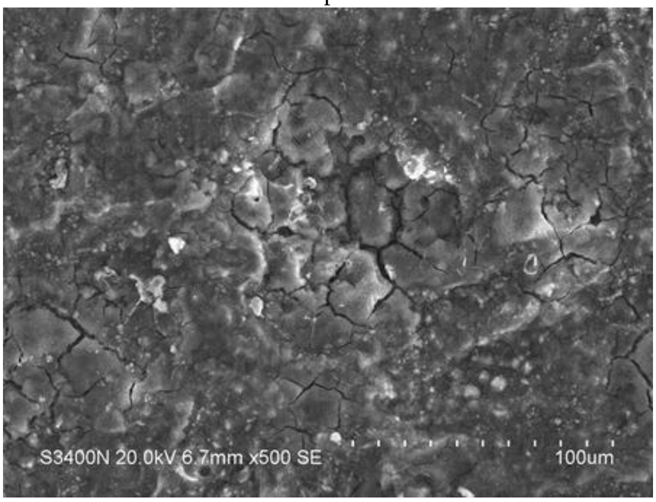
Sample-5



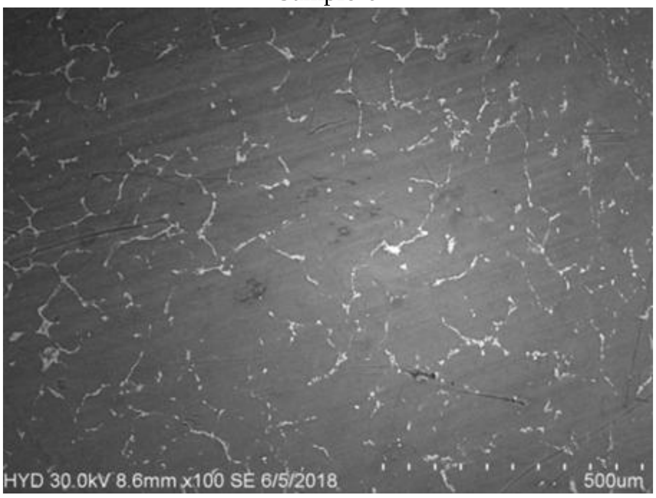
Sample-3



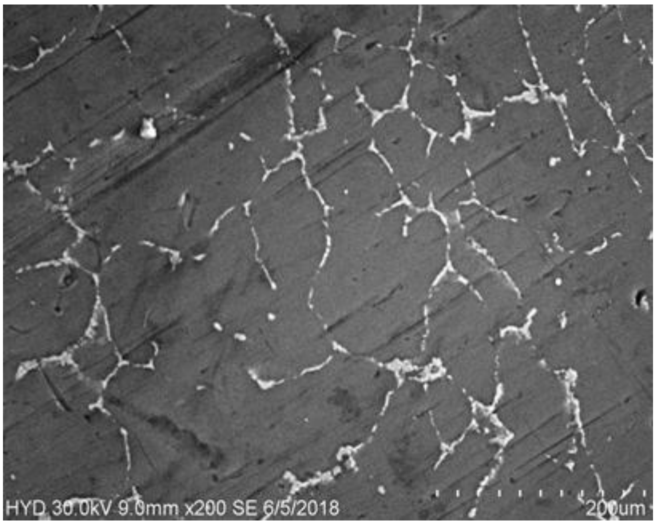
Sample-6



Sample-4



Sample-7



Sample-8

Fig 2: Microstructures of FSPed magnesium ZE41 alloy -SiC surface composite for different samples

3.2. Microhardness:

The Vickers micro hardness test was performed according to ASTM B 117 standards on friction stir processed specimens and the distribution of hardness in the material are tabulated in Table 3. The hardness of unprocessed ZE41 was observed as 61.43 Hv. The surface composites hardness varies from 70-100Hv. The FSPed samples hardness value is significantly upgraded due to assimilation of SiC particles and grain size refinement compared to base metal. The hardness of the surface composite is contingent upon grain size, shape of Mg matrix and SiC in matrix [14]. The detailed hardness values for various processed samples are presented in Table 3. It is observed that, poor hardness in sample 1 due to inadequate heat generation and stirring.

The tool-rotational-speed (w) and the traverse-speed (v) of the tool, in addition to the ratio of rotational-speed to traverse-speed (w/v), assumes an imperative role in producing a good surface composite. The rate of increased hardness substantially relies upon the manner limits implement rotating speed and tool-traverse-speed. The hardness value increased with increase of rotational speed (samples 2-5) at a persistent traverse-speed (25 mm / min), as the obligatory heat input tied with thrilling to the substantial has caused in reduction in GS and unvarying dispersal of SIC-particles. The highest hardness value is found to be 100.48 HV in sample 7.This is due to dispersion of SiC particles homogeneously in equiaxed fine grains. This is as of the intense plastic distortion by the optimal heat-input.

Table 3. Microhardness for various samples

Sample No.	Tool Rotational speed (RPM)	Tool traverse speed (mm / min	Hardness value (Hv)
1	700	25	71.10
2	900	25	84.10
3	1100	25	94.30
4	1400	25	83.13
5	1800	25	99.43
6	1100	16	91.33
7	1100	25	94.30
8	1100	40	100.48
9	1100	65	91.33
Base material			61.48

IV. CONCLUSION

In the current work, the effect of friction stir processing parameters such as rotational-speed of tool and traverse speed on the properties of hardness and microstructure of SiC reinforced magnesium ZE41 rare earth alloy has been discussed. The following conclusions are arrived from this work are :

1. Mg ZE 41-SiC surface composite was fabricated effectively by FSP with triangular tool.
2. Traverse speed is more significant factor on the dispersion of the SiC particles in the nugget zone.
3. Incorporation of SiC particles through Friction Stir Processing and composite layer formation additionally refined structure of the grain results enhanced hardness.
4. Higher hardness value (100.48 Hv) is observed in Mg ZE41-SiC surface composite at the optimal FSP process parameters tool rotational-speed 1120 RPM, traverse speed 40 mm / min and tool tilt angle 1^0.

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