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Influences of Tool Pin Profile and Shoulder Diameter on Microstructur Behavior of Az31/Tic Composites Using Friction Stir Process

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Friction stir processing (FSP) is a novel solid state technique to synthesize metal matrix composites. In the present work, an attempt has been made to synthesize AZ31/TiC magnesium matrix composites using FSP with different tool pin profile shoulder diameter and to analyze the microstructure using scanning electron microscopy. A groove was prepared on 6 mm thick AZ31 magnesium alloy plates and compacted with TiC particles. Two different tool pin profiles are developed with two different shoulder diameter such as, straight cylinder, and square, with 18 mm, and straight cylinder 22 mm shoulder diameter. A single pass FSP was carried out using a tool rotational speed of 950 rpm, traverse speed of 36 mm/min and an axial force of 8 kN. Scanning electron microscopy was employed to study the microstructure of the synthesized composites. The results indicated that cylinder pin profile with 22 mm diameter affords uniform distribution 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: Magnesium alloy; Friction stir processing; TiC; tool pin profile, shoulder diameter; Micro structure;

1. INTRODUCTION

Magnesium alloys are very attractive materials due to their low specific gravity, high specific strength, and high recyclability. Magnesium alloys are progressively replacing aluminium and steel in the aerospace and automobile industries and plastic in the electronic and computer industries due to low weight and good thermal and electrical conductivity. However, magnesium alloys are used for high performance applications due to their low mechanical properties and wear resistance. But magnesium reinforced with ceramic particles, known as magnesium matrix composites (MMCs) provide enhanced mechanical and tribological properties [1]

The process takes place in the solid state and appears to offer a number of advantages over conventional fusion welding techniques, such as no need for expensive consumables such as filler wire and gas shields, ease of automation on simple milling machinery, good mechanical properties of the resultant joint, and low distortion. In addition, since welding occurs by the deformation of material at temperatures below the melting temperature it is possible to avoid problems commonly associated with the joining of dissimilar aluminum alloys [2]. Friction stir processing (FSP) is a novel solid state technique to fabricate metal matrix composites [3]. Mishra et al. [4] developed FSP, based on the principles of friction stir welding (FSW) to produce metal matrix composites. One method to produce composite using FSP is to prepare a groove of required depth and width, compact with ceramic particles, plunge the tool and traverse along the groove. The frictional heat softens the matrix alloy and the ceramic particles are dispersed within the plasticized matrix alloy due to the rigorous stirring action of the tool. Some studies on the production of MMCs using FSP techniques were reported in literatures. Azizieh et al.[5]

Most research studies have investigated the properties of magnesium composites containing different hard ceramic nanoparticles. SiC nano-particles have been added to the Mg and AZ91 magnesium alloy using an ultrasonic method [6]. Experimental results showed a relatively uniform distribution of SiC particles in the pure Mg with an interaction between SiC and the matrix of AZ91. Ferkel and Mordike [7] strengthened Mg with SiC nanoparticles using a powder metallurgy technique to improve creep resistance and tensile properties. Hassan and Gupta [8] studied the effect of different types of nano-sized oxide particulates on the microstructural and mechanical properties of elemental Mg using a blend-press-sinter technique.

2. OBJECTIVES

To synthesize metal matrix composites by friction stir processing (FSP). Due to severe plastic deformation, dynamic recrystallization, and grain growth retardation during the FSP processing, ultrafine grained microstructures with homogeneous distribution of the TiC particles with different tool pin profile and shoulder diameter increased plastic deformation and heat generation, increased grain size of the matrix, and simultaneously shattering effect of rotation cause a uniform distribution.

3. MATERIALS AND METHODS

Magnesium alloy AZ31B of size 100 mm x 50 mm x 6 mm were used for this study. The composition of AZ31B is given in Table 1. A groove of 4.5 mm deep was made in the middle of the plate using wire EDM and compacted with TiC powder. The average size of TiC particles used in this work was 4 µm. The SEM micrograph of TiC particles is shown in Fig. 1. A pin less tool was initially employed to cover the top of the groove after filling with TiC particles to prevent the particles from scattering during FSP. Three tools made of HCHCR steel, oil hardened to 63 HRC was used in this study. The tool have a shoulder diameter of 18 mm and 22 mm, with different tool pin profile having 6 mm dia , pin length of 5 mm and groove 4.5mm X 1.2 mm depth and width .The FSP was carried out on an indigenously built FSW machine. The process parameters employed were: tool rotational speed of 950 rpm, traverse speed of 36 mm/min and axial force of 8 kN. The FSP procedure to produce surface composite is available elsewhere [9]. Three plates were friction stir processed with various tool profile shown in Fig2

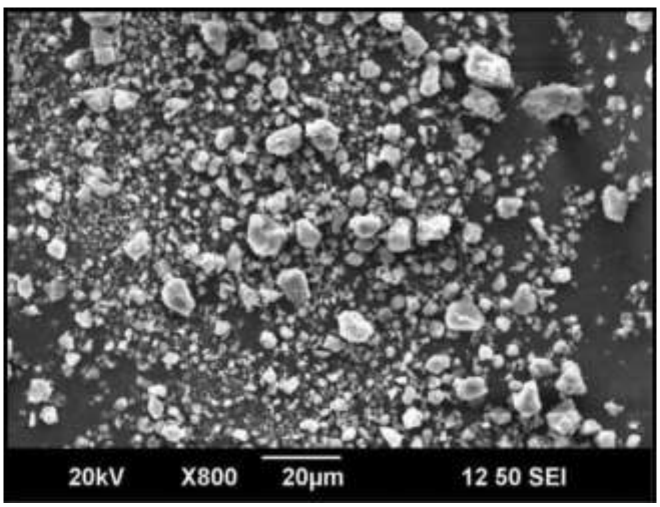

Figure 1. SEM micrograph of TiC powder.

Specimens were obtained from the centre of the friction stir processed plates and were polished as per standard metallographic procedure. The polished specimens were etched with an etchant containing 3.2 g picric acid, 10 ml acetic acid, 10 ml diluted water and 60 ml ethanol. The digital image of the macrostructure of the etched specimens was captured using a digital optical scanner. The microstructure was observed using a scanning electron microscope.

Table 1: The chemical composition of magnesium alloy AZ31B.

Elements	Al	Zn	Mn	Si	Cu	Ca	Ni	Fe
wt.%	3.12	0.68	0.23	0.01	0.00021	0.031	0.0048	0.0003

AZ31/TiC MMCs were successfully synthesized using FSP. Fig. 3 shows the macrograph of the FSP zone. A defect free FSP zone is observed. The FSP zone contains the composite. The grain structure within the mechanically affected zone is elongated and exhibits considerable distortions due to the mechanical action from the welding tool (tunnel, pin hole, piping and worm hole) are absent. It is evident from the macrograph that the groove is completely bonded to all sides. The pin length is 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 groove. The rubbing of the tool on the substrate generates frictional heat, which plasticizes the magnesium alloy which reaches the semi-solid state.

The vigorous stirring action of the tool distributes the packed TiC particles into the plasticized magnesium alloy. The translation of the tool moves the plasticized composite from advancing side to re-treading side and forges at the back of the tool. The FSP zone on the retreating side is not clearly identified by a boundary. The absence of clear boundary at the retreading side can be attributed to the material flow behavior of plasticized composite while forging at the back side of the tool to form the FSP zone.

Figure 2. (a) pin less tool (b) square tool pin (c) cylindrical tool pin with 18 mm shoulder diameter (d) cylindrical tool pin with 22 mm shoulder diameter

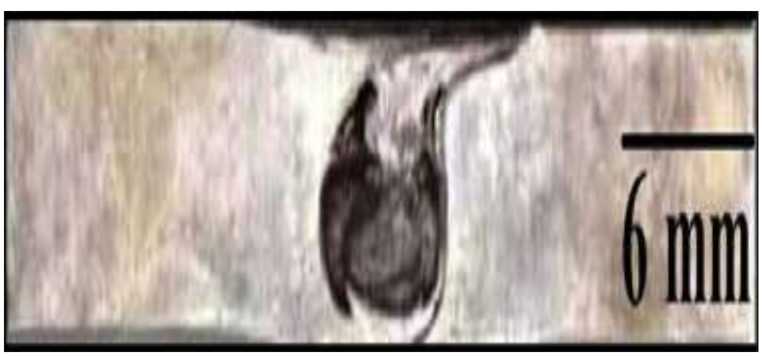

Figure 3. Macro graph of square tool pin profile /TiC MMC

The effect of tool on TiC particles on the microstructure of AZ31/TiC MMCs is shown in the SEM micrographs presented in Fig. 4. Pin less tool refers to friction stir processed magnesium alloy which displays dynamically recrystallized grains. The SEM micrographs as presented in Fig. 4 show the variation of microstructures as a function of tool on TiC particles at 1000x magnification. The number of particles increases as well as the spacing between particles reduces when using tool with 22mm shoulder dia. The uniform distribution of TiC particles can be attributed to adequate generation of frictional heat, stirring and plasticized material flow across the friction stir processed zone. Mild agglomerations are also noticed at few 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. This can be attributed to proper mixing and symmetric material flow during FSP. It is evident from Fig. 4 that the FSP zone is almost symmetric about tool axis. The TiC particles are subjected to the severe plastic flow of magnesium alloy during FSP. Several investigators observed a change in the size and morphology of ceramic particles during FSW [10].

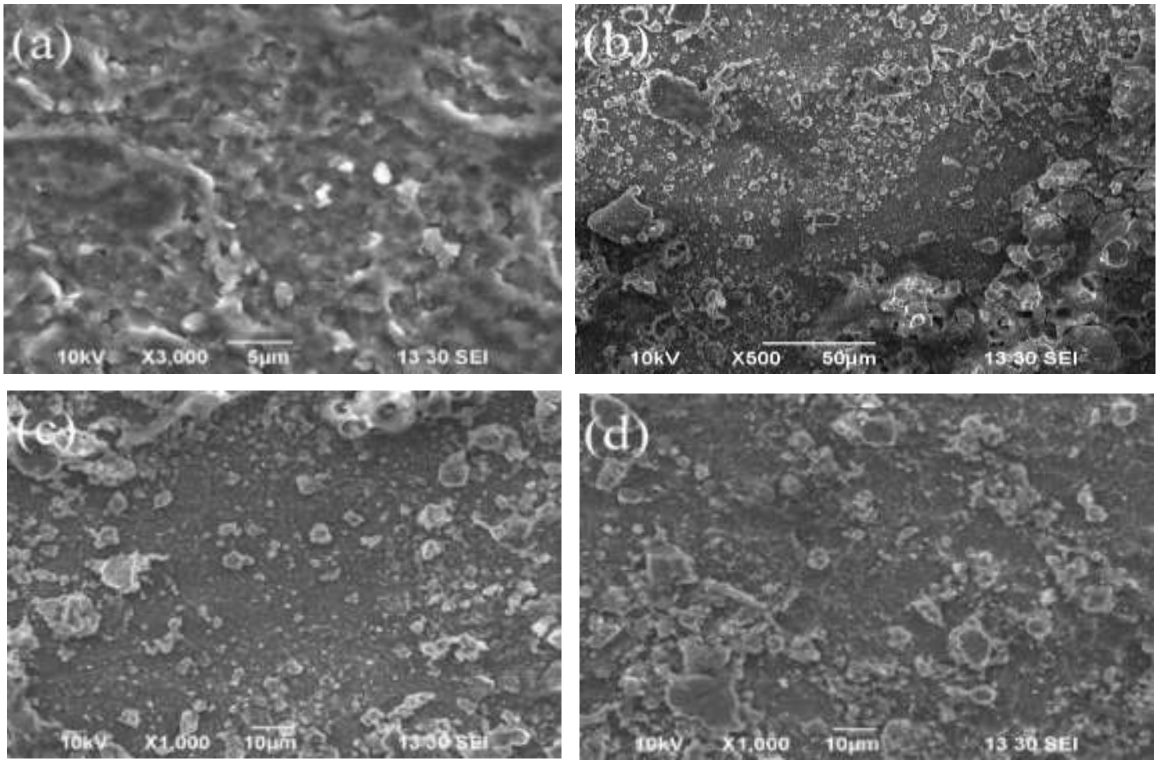

Figure 4.SEM Micrograph of AZ31/TiC MMC by tool profile and shoulder diameter (a) Pin less tool (b) Square tool pin18 mm shoulder diameter (c) cylindrical tool pin with 18 mm shoulder diameter (d) cylindrical tool pin with 22 mm shoulder diameter

No such fragmentation of TiC particles was observed with the 22 mm tool and process parameters described within this work. The variation of TiC particle size in the composite as seen in Fig. 4 is minimum and negligible. The variations in the morphology of the TiC particles before (Fig. 1) and after (Fig. 4) FSP are negligible. TiC particles retain the initial size and morphology. This can be attributed to the initial morphology and size of TiC particles which have a minimum number of sharp edges. The interface between TiC particles and the magnesium matrix appears to be clean and is not surrounded by any voids or reaction products. Reaction products used to surround the particles if the composite is fabricated using the liquid metallurgy route. Since FSP is a solid state route, the temperature during the process is insufficient to initiate any kind of interfacial reaction between the TiC particle and the magnesium matrix. A cleaner interface provides proper bonding between TiC particles and magnesium matrix and improves mechanical and tribological properties. Sufficient material flow and stirring create such a porosity free interface.

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