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Development of Zn-Mg in Situ Composite using Friction Stir Processing

Gaurav Kumar Singh[1], Shubham Verma[2] and Joy Prakash Misra[3]

[1]PG Student, Deptt. of Mechanical Engineering
National Institute of Technology
Kurukshetra, Haryana, India
[2]Ph.D. Scholar, Deptt. of Mechanical Engineering
National Institute of Technology
Kurukshetra, Haryana, India
[3]Assistant Professor, Deptt. of Mechanical Engineering
National Institute of Technology
Kurukshetra, Haryana, India
E-mail: [1]gauravks3110@gmail.com, [2]shubham6140005@gmail.com, [3]jpmisra@nitkkr.ac.in

Abstract—*Friction stir processing (FSP) is a unique technique to develop surface composite and to enhance microstructural and mechanical properties of a metal. In present study, an attempt has been made to fabricate surface composite of zinc with magnesium (nano-powder) via FSP. The experiment is carried out at a rotational speed of 1400rpm and welding speed of 20mm/min. It is observed that hardness enhances from 41.3 Hv to 65.1 Hv owing to presence of magnesium particle. Another reason for increase in hardness is refinement of grains due to dynamic crystallization. EDX (Energy-dispersive x-ray spectroscopy) analysis has been carried out to find out the key elements in the processed zone.*

Keywords- *Friction stir processing, Bio-implant materials, Biodegradable and Energy-dispersive x-ray spectroscopy (EDX).*

1. INTRODUCTION

Metallic implants are an advance approach in orthopedic field compared with ceramic and polymer based implants. These implants play a pivotal role in replacement, repair or augmentation of lost or diseased parts of the skeletal system. The use of stainless steels, cobalt based alloys and titanium and its alloys are well established for bio-implant due to their good biocompatibility, satisfactory mechanical strength and superior corrosion resistance. These conventional metallic biomaterials generally used as permanent implants in patients. In small type of injuries, where implant is no longer required after healing the injury, permanent implant needs a further treatment to extract the implant which is expensive and has chances of more injuries. In such applications, we require a temporary type of implant.Biodegradable metals represent an alternative approach for such type of implantation. These metals corrode progressively over a time period with no harm during the healing period and dissolve completely after healing completion. Recently, magnesium and iron, pure as well as alloy, emerged as biodegradable materials. These materials have appropriate mechanical properties and also they are essential nutrition elements for human body. However, these biodegradable alloy systems have disadvantages as magnesium has high degradation rate and iron as low degradation rate like permanent implants. Zn is an alternate biodegradable implant approach. But Zn has low strength and to improve its strength another nutrient element Mg is mixed with it.

Friction stir processing (FSP) is a technique for modification of microstructure properties of materials and also for development of composites. This unique processing technique was introduced by Mishra et al.[1] by modification in a solid state welding technique friction stir welding (FSW), successfully and widely used in industries, which was invented by The Welding Institute (TWI) in UK (1991) [2,3]. Initially FSP was developed for refining grain size of metals to enhance their mechanical properties. Later Mishra et al. [4] used FSP technique to fabricate a composite by introducing reinforce particles of a metal into surface layer of other metal.

Traditional methods to fabricate Metal matrix composites (MMCs) like casting [5], powder metallurgy [6], spray deposition methods [7,8]etc. are liquid state process which leads to several problems like gas inclusion, formation of intermetallic reactions and undesirable phases between reinforcement and base metal. These techniques require precise processing controls to acquire desired microstructure. Whereas, FSP is a solid state technique so composite is fabricated with little or no interfacial reaction.

The basic process principle of friction stir processing is similar as friction stir welding. During FSP, A revolving tool with probe (pin) and shoulder presses into a metallic piece and transverse along the desired processing direction. The contact between tool and workpiece generates friction and this friction provides heat in contacting surface. This heat increases the temperature of workpiece and softens metallic surface and plastic deformation occurs. As the tool progresses, processing occurs on plastically deformed surface and ultimately the surface with refined grains and enhanced mechanical properties is obtained. FSP is schematically illustrated in Fig. 1

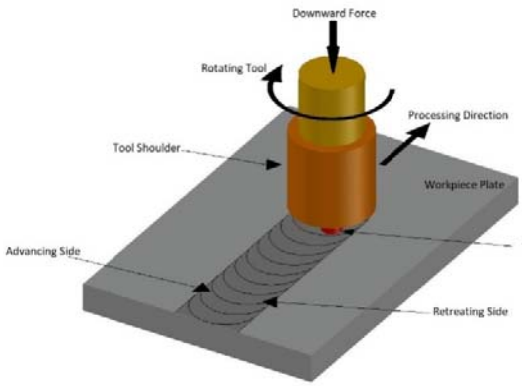

Figure 1. Schematic illustration of FSP

FSP has different approaches to fabricate composite. Fabrication of composite by providing groove for filling reinforced particles is most common method [9] but chances of agglomeration of particles are very high in this method so another approach of fabrication composite is by providing blind holesinstead of groove[10].In the present study, blind hole approach in zig zag formation is used to deposit Mg nano powder and Zn-Mg composite is developed by FSP.

2. EXPERIMENTAL DETAILS

For the development of composite, pure zinc plate dimension of 120x100x3 mm^3 is used. Friction stir processing is performed on vertical milling machine with the tool made of hardened H13 tool steel. Tool has shoulder diameter of 14mm with concentric circular pin diameter of 4mm and 2.8mm length. For dispersion of Mg nanoparticles in Zn plate, tiny blind holes of 1mm diameter and 2.8 mm length were drilled in zigzag formation and filled with Mg powder. Holes before and after the deposition of Mg powderare shown in fig. 2.For closing the powder filled holes, a pin less tool having shoulder 14mm diameter with rotational speed is 1400rpm and 16mm/min feed rate is used whereas processing is carried out at 1400rpm rotational speed and 20mm/min transverse speed. Pin of rotating tool is plunged into plate and friction generates heat between the shoulder and plate which soften the material and as the tool transverse composite is developed. Composite during the fabrication is shown in fig. 3.

Figure 2.Holes before and after the deposition of Mg powder

Figure 3. Composite during the fabrication

Hardness of the developed composite is measured on digital micro Vickers hardness tester (Blue Star Ltd) at 100gm load for 15 sec. For this, sample is cut across the processed zone and polished by different grades of emery papers followed by diamond paste polishing. Sample prepared for hardness testing is shown in fig. 4. EDX analysis is performed to examine the key elements present in the processed zone.

Figure 4. Sample prepared for hardness testing

3. RESULTS AND DISCUSSIONS

In this study, we examine microhardness and EDX analysis of the surface composite after the processing and compare it with pure metal.

3.1 Microhardness

The microhardness values of pure Zn and Zn-Mg composite are obtained as 41.3 Hv and 65.1 Hv respectively. Indentation on the sample is shown in fig. 5.It is observed from the data that approximate 50% increment in hardness is obtain after processing and inclusion of Mg powder. This is due to presence of Mg powder in Zn plate, refinement of grains and heat treatment of the surface by heat produced during processing.

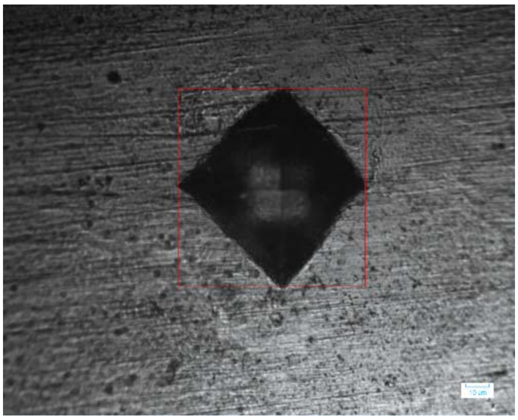

Figure 5.Indent on the sample

3.2 EDX Analysis

EDX analysis shows the amount of dispersion of Mg powder in base metal. Data obtained from EDX analysis is shown in table. 1 and analysis image is shown in fig. 6. It is found that 1.46% Mg is present in composite developed.

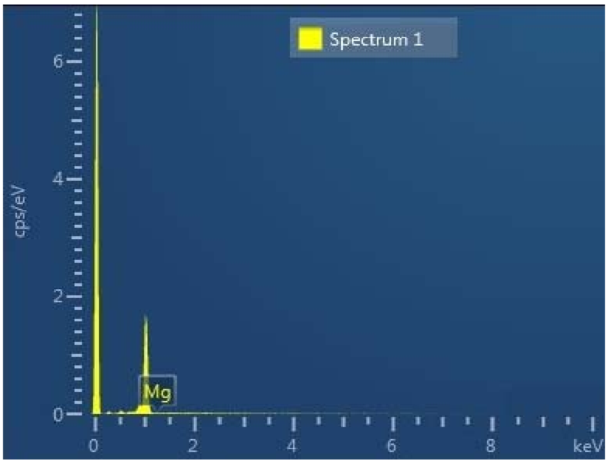

Figure 6. EDX Analysis

Table 1: Data obtained from EDX analysis

Element	Line Type	Weight %
Zn	L Series	98.54
Mg	K Series	1.46
Total		100

4. CONCLUSIONS

In this present study, FSP is used for successfully development of a Zn-Mg surface composite. Hardness data shows that Mg inclusion increases the hardness of the base metal and refinement of grains structure is also a reason for hardness increment. From EDX analysis, it is observed that 1.46% Mg inclusion increases hardness value by approximately 50%.

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