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An Analytical Investigation on the Effects of Heat Input on Microstructures, Phase Transformations and Mechanical Properties of Ultrafine Grained Mg Alloys Fabricated by Friction Stir Processing in Different Velocity Ratios

M. Navazani[a,*],K. Dehghani[a,b]

[a]*Faculty of Mining and Metallurgical Engineering, Amirkabir University of Technology (AUT), P.O. Box 15875-4413, Hafez Avenue, Tehran, Iran*

[b]*Centre of Excellence in Smart Structures and Dynamical Systems, Iran*

Abstract

Friction stir processing is a solid state technique for partial modification of microstructures in surface layers of metals. Heat input is one of the efficient factors in this process which can vary the mechanical properties and the grains size even up to nano scale. In the present study, the effects of different rotational to traverse velocity ratio and also the circumstances of each one's effects on heat input were investigated during FSP of Mg alloys. Microstructure analyses were implemented in order to gain some concepts of heat input effects on the structures of the stirred zone. In the next step, the microhardness measurements were also calculated by a hall-petch type equation according to the grains size of the microstructures. The results indicate that increase in heat input leads to increase in grain size and decrease in hardness in the process zone. This phenomenon occurs because of complex interactions between dynamic recrystallization and grain growth during increasing heat input. The results also showed that there is always an optimum velocity ratio which disorder the balance, thereby maximizes the dynamic recrystallization and minimizes the grain growth in order to gain the minimum possible grain size in this process.

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Keywords: Heat input; friction stir process; dynamic recrystallization; mechanical properties; grain size; rotational speed; traverse speed.

* Corresponding author. Tel.: +98-912-466-3855.
E-mail address: mohammad.navazani@aut.ac.ir

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1. Introduction

The applications of Magnesium alloys in transportation industries are evolving everyday. As Cavaliere and Marco (2007) expressed Mg possesses the minimum density among light structural metals like Aluminum and Titanium. Alongside with that, it can be recycled easily. However, its benefits have been limited due to its hexagonal structure which leads to low ductility and hardness. Fortunately, Commin et al. (2009) and also Chang et al. (2007) have been proved that this problem can be solved by grain refining.

Several investigators such as Hu et al. (2008), Matsubara et al. (2003), Lin et al. (2005), Mishra and Mahoney (2001) have been reported friction stir processing (FSP) as appropriate option to refine the grains via sever plastic deformation and dynamic recrystallization. In addition, diverse parameters affect the microstructure and the mechanical properties resulted by FSP. Traverse and rotational speeds are the two striking ones which can modify the properties. A notable point which has been mentioned in several works, is that since the increase of rotational speed and decrease of translation speed boost the frictional heat, the ratio of the rotational speed to traverse speed is directly linked with heat input and are assumed equal.

In this project, analytical studies are being implemented in order to gain a reasonable relation between heat input, grain size and hardness based on the studies of Chang (2007). The effects of different velocities on heat input are also studied.

Nomenclature

FSP	Friction Stir Processing
Mg	Magnesium

2. Materials and method

A workpiece of AZ31 Mg alloy with grain size of 75 microns and hardness average of 50 vickers(HV) was utilized in the project. The chemical composition of the alloy is indicated in Table 1. The thickness of the used plate was 10 mm. A cylindrical threaded Pin with a diameter of 6mm and a shoulder of 18 mm was used. The tilt angle was 3 degrees and the velocities were changed according to Table 2 and 3.

Table 1. Chemical composition of the AZ31 workpiece.

Element	Mg	Al	Zn	Mn	Si	Fe	Cu	Ni
Wt%	Bal.	3.02	1.01	0.3	0.0067	0.0028	0.0031	0.0001

Table 2. Values of heat input in constant traverse speed.

Rotational speed (rpm)	600	800	1000	1200	1400	1800
Traverse speed (mm/min)	90	90	90	90	90	90
Raito of ω/v (heat input)	6.67	8.89	11.12	13.34	15.56	20