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Metal-metal Cast Composites

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Abstract

Microstructure of experimental AZ91 magnesium matrix composite with Ti6Al4V particles is presented. Composite were fabricated by casting method. The obtained experimental composite exhibited uniform distribution of Ti6Al4V particles within the matrix alloy. Neither clusters of particles nor any new phases creating during component reactions are observed.

Keywords: Composite, AZ91 magnesium alloys, Ti6Al4V particles, Microstructure

1. Introduction

Magnesium alloys are light metallic structural materials, which have a unique combination of properties. They are very attractive in such applications as the automobile and aerospace industries. In lightweight magnesium alloys, aluminium constitutes the main alloying element, chiefly because of its low price, high availability, low density and advantageous effect on corrosion and strength properties. Aluminum improves the mechanical strength, corrosion properties and cast ability. The most commonly used magnesium alloys are the AZ and AM series [1].

Among various MMCs, magnesium matrix composites reinforced with ceramic or intermetallic particles deserve special consideration, due to their low density, high special stiffness and strength, high damping capacity and good dimension stability. Obtaining the designed properties of these materials depends on achieving the desired microstructure, which is the effect of numerous factors, like: distribution, size, volume fraction of reinforcement particles, type of matrix alloy, type and parameters of fabrication process and component bonding type. Nevertheless, the previous studies was clearly proved that brittle ceramic reinforcement (like for example SiC, C_{gr}, TiC, Al_2O_3 etc.) cause a strong decrease of the ductility of final material [2-3]. Therefore different materials – like for example metallic solids – are wanted as a reinforcement component for metal matrix composites. In comparison with ceramic particles, metallic reinforcements have better wettability with molten alloys, greater ductility and higher thermal and mechanical compatibility with the metallic matrix. Recently, some studies have described the effect of some metallic reinforcement such as Ni, Cu, and Ti and Ti6Al4V particulates on microstructure and properties of magnesium composites. Large part of these composites was prepared by powder metallurgy methods [4-11].

In the present paper, the new magnesium alloys matrix composite reinforced by Ti6Al4V particles was presented. The main objective of the study was to develop new type of composites with metallic particles fabricated by simply and non expensive casting method. For this purpose, one of the cheapest and most widely used alloys, AZ91 alloy, was selected as the matrix alloy.

2. Experimental procedures

The commercial AZ91 magnesium alloy fabricated by Hydro Magnesium Ltd., with nominal composition given in Table 1 was chosen as the matrix alloy in this study.

Ti6Al4V alloy in the form of spherical particles with the chemical composition listed in Table 2 were chosen as a component for composite fabrication. The fraction of particles used was in the range of below 45 μm (-325 mesh).

Composites were obtained by means of a simple and non-expensive casting method involving mechanical mixing of the molten metal with the introduced particles in a steel crucible under a protective atmosphere, and subsequent gravity cast into a metal mould. Fabrication process parameters, such as time and rate of a suspension stirring, mixing and casting temperatures, mould temperature, etc., were chosen experimentally.

Table 1.
Chemical composition of AZ91 alloy according to ASTM B93-94

Chemical composition [wt.%]*)							
Alloy	**Al**	**Zn**	**Mn**	**Si**	**Fe**	**Cu**	**Ni**
AZ91	8.5-9.5	0.45-0.9	0.17-0.04	max 0.05	max 0.005	max 0.003	max 0.002

*) Mg rest

Table 2.
Chemical composition of reinforced particles –Ti6Al4V according to ASTM B-348, grade 23, B214

Chemical composition [wt.%]*)						
Al	**V**	**C**	**N**	**O**	**Fe**	**Others each**
5.5÷6.7	3.5÷4.5	≥0.08	≥0.03	≥0.13	≥0.25	max 0.513

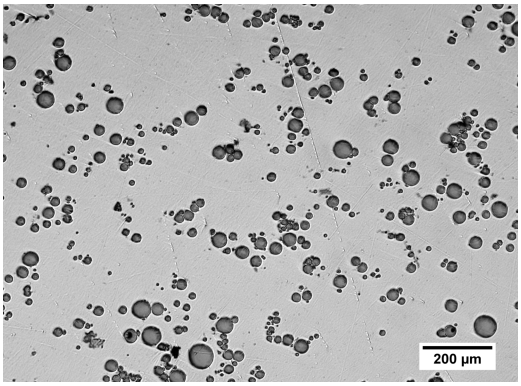
*) Ti rest

Microstructural examinations of fabricated composites were carried out by means of light microscopy (LM) - Neophot-21 (Carl-Zeiss Jena) and a scanning electron microscopy (SEM) - JEOL JSM-6610LV. Analyses of elements distribution were carried out by use of an energy-dispersive X-ray spectrometer (EDX). A standard metallographic technique was used for sample preparation which includes wet prepolishing and polishing with different diamond pastes. The specimens were etched in a solution of 1% nitric acid in alcohol. Phase constitutions of the alloy before and after annealing were analyzed by X-ray diffraction (XRD) using a Brucker D8 Advance diffractometer. $Cu_{K\alpha}$ X-ray radiation was used.

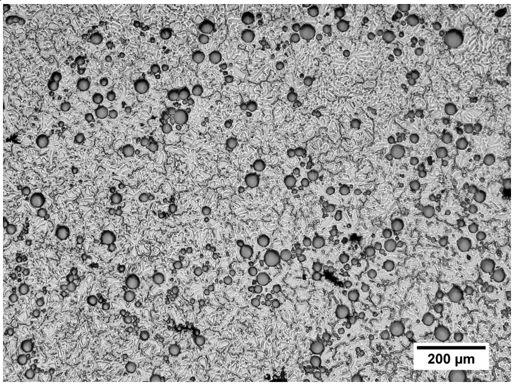
3. Results

Fig. 1 presents micrographs of an experimental cast obtained from the AZ91-Ti6Al4V$_p$ composite. The fabricated composite are characterized primarily by the uniform distribution of Ti6Al4V particles within the matrix. Neither clusters of particles nor any consequences of floating or sedimentation of the reinforcing phase, frequently occurring in gravity cast composites, are observed. Fig. 2 shows a details of the composite microstructure. The AZ91 matrix alloy has a dendritic microstructure, which is characterized by a very heavy segregation of the alloying elements. Non-equilibrium solidification conditions cause the formation of large crystals of the α(Mg) primary phase and pushing the alloying elements into the intedendritical spaces. At the last stage of solidification α+γ partially divorced eutectic was formed. Additionally, due to small amount of manganese, aluminum-manganese intermetallic phases, especially Al_8Mn_5, were created with a polygonal shape.

(a)



(b)



(c)

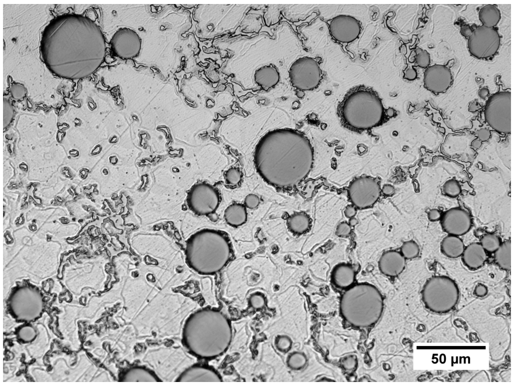


Fig. 1. Microstructure of AZ91-Ti6Al4V$_p$ cast composite (a) unetching and (b, c) etching section

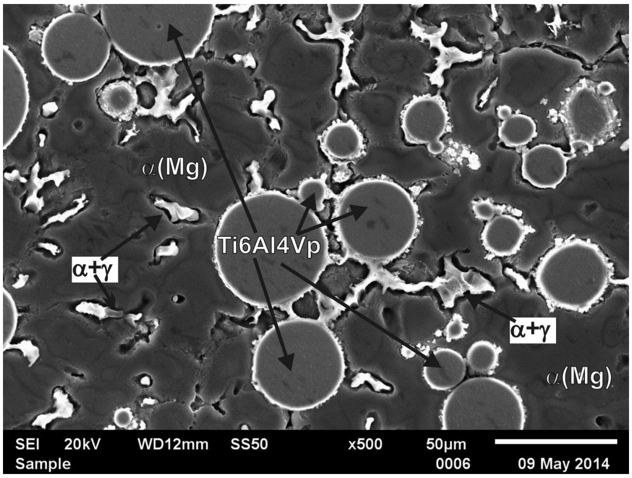
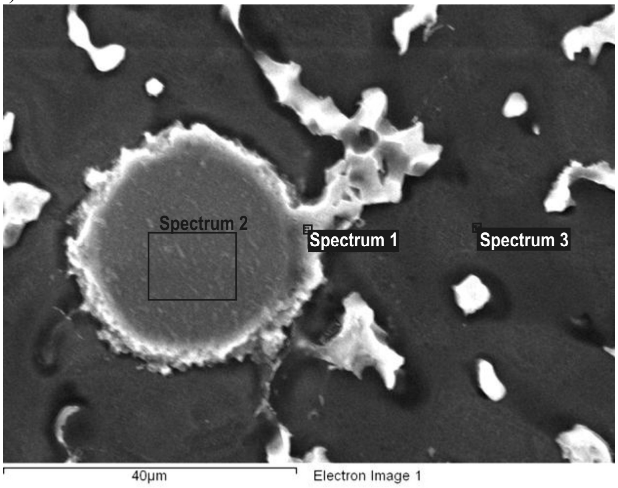


Fig. 2. Microstructure of AZ91 matrix composite reinforced with Ti6Al4V particles: (a) light microscopy, (b) SEM

(a)



(b)

Spectrum 1		
Element	Weight %	Atomic %
O K	10.74	17.08
Mg K	50.74	53.12
Al K	23.63	22.29
Zn K	2.09	0.81
Spectrum 2		
Element	Weight %	Atomic %
Al K	5.70	9.73
Ti K	88.53	85.06
V K	5.76	5.21
Spectrum 3		
Element	Weight %	Atomic %
Mg K	96.04	96.42
Al K	3.96	3.58

Fig. 3. Microstructure of AZ91-Ti6Al4V$_p$ composite; SEM (a) and with the chemical analysis of presented points; SEM+EDS (b)

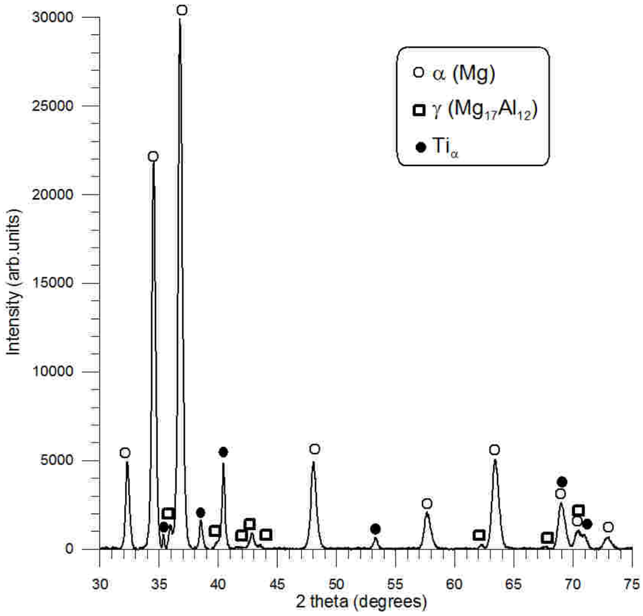


Fig. 4. X-ray diffraction pattern of AZ91-Ti6Al4V$_p$ composite

Fig. 3 presents secondary electron image with point analyses of AZ91-Ti6Al4V$_p$ composite. Analyses of alloying elements in the investigated material confirmed the presence of α+γ partially divorced eutectic (Spectrum 1) Ti6Al4V particles (Spectrum 2) and α(Mg) solid solution (Spectrum 3). It should be also noted that the presence of oxygen in the investigated material is caused by oxidation of the surface, and it does not occur in the analyzed phase (Spectrum 1). In order to identify the existing phases in the alloys XRD analysis was also performed. Fig. 4 shows a typical X-ray diffraction pattern of cast AZ91 magnesium matrix composite with Ti6Al4V particles. The diffraction lines were indexed as arising from three different phases. It can be seen that composite is mainly composed of α – Mg and γ ($Mg_{17}Al_{12}$-type) and $Ti_α$ phases. No aluminium-manganese phases were revealed because of too low amount of them in the alloy. With the addition, any new structural constituents (which could be eventually products of reaction between components) were observed.

4. Summary

The produced cast AZ91 magnesium matrix composite with Ti6Al4V particles is characterized by a uniform arrangement of the particles throughout the volume of the matrix. Such a uniform distribution has been possible owing to the good wettability of the titanium particles by the molten matrix alloy and the easy creation of a bond between components. The introduction of the Ti6Al4V particles into the matrix do not caused changes in the structural constituents of the AZ91 alloy. Any new phases (creating due to reaction between components) are also observed.

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