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Influence of process temperature on AZ91 matrix microstructure of composites with aluminosilicate glass cenospheres

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Abstract

AZ91 magnesium alloy matrix composites with aluminosilicate glass cenospheres were fabricated successfully by the pressure infiltration method. Different parameters of the fabrication process, such as temperature of the mould and temperature of cenospheres were used. Influence of the temperature variation of particular parameters on the microstructure has been investigated. The microstructure of AZ91 magnesium alloy and fabricated composites have been investigated by light microscopy (LM) and scanning electron microscopy (SEM). The results revealed that AZ91 magnesium alloy consists of α-Mg matrix and eutectic α-$Mg_{17}Al_{12}$ and a small amount of discontinuous precipitates of γ phase. The microstructure of matrix AZ91 in fabricated composites is characterized also by the presence of α-Mg matrix and eutectic α-$Mg_{17}Al_{12}$. However, in the composite fabricated by using the mould heated to 500 °C more discontinuous precipitates of γ phase were observed.

Keywords: AZ91 magnesium alloy; Metal matrix composites, Cenospheres

1. Introduction

Metal matrix composites (MMCs) have been a subject of intensive research for the past few decades. MMCs based on magnesium or magnesium alloy composites have been widely analysed because of their unique properties such as low density, high specific stiffness and damping capacity [1-3]. Mg-Al alloys such as AZ91 and AM50 are the most popular and commercially attractive from the others. The microstructure of cast Mg-Al alloys is mainly composed of solid solution of aluminium in magnesium (α phase) and α + γ eutectic, where γ is the intermetallic compound $Mg_{17}Al_{12}$ [4]. Magnesium alloys matrix composites can be fabricated by different methods such as die-casting method, compo-casting and pressure infiltration method. In every method, process parameters (e.g. mould temperature, casting temperature, holding pressure) have a big influence on the microstructure and mechanical properties of obtained materials [3, 5-8].

One of the possible reinforcement of metal matrix composites is aluminosilicate glass cenospheres separated from fly ashes. Therefore, fly ash cenospheres (FAs cenospheres) can be used for the fabrication of ultra-light composite materials due to its significantly low density [9-12]. Besides, they are relatively cheap as component and they are available in large quantities as a waste by-product in thermal power plants. Cenospheres with diameter range of 1 to 500 μm, with closed-porous solid walls (the wall thickness is generally about 5-10% of cenospheres diameter), are filled with N_2 and CO_2. The major chemical constituents of fly ash are SiO_2, Al_2O_3, K_2O + Na_2O, CaO, TiO_2. The phase-mineral composition of fly ash cenospheres commonly includes aluminosilicate glass, quartz, mullite, calcite, hematite, ferrite and alumina. The main characteristic of cenospheres are: hollow spheres with spherical morphology, particles sizes ranging from sub-micron to millimetres in size, ultra low density, low thermal conductivity, low water absorption, etc. Properties of cenospheres can vary depending on the place of their origin [13-17].

In this paper, the microstructure of matrix AZ91 magnesium alloy in composites with aluminosilicate glass cenospheres were presented.

2. Experimental material and procedures

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

Fly ash aluminosilicate glass cenospheres (FAs – fly ash cenospheres), supplied by Eko-Export S.A. (Bielsko Biała, Poland) with the chemical composition listed in Table 2 were chosen as a component of composite fabrication. The fraction of cenospheres used was in the range of 63÷125 μm.

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 aluminosilicate glass cenospheres

Chemical composition [wt.%]						
SiO_2	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**K_2O + Na_2O**	**TiO_2**
53÷63	21÷31	4.4÷5.6	1.5÷2.5	0.3÷0.7	0.8÷1.6	0.1÷0.7

AZ91 alloy composite with aluminosilicate glass cenospheres was fabricated by a pressure infiltration method. In the composites fabrication process different parameters, such as temperature of cenospheres and temperature of the mould were used, which is shown in Table 3.

Microstructural examination of fabricated composites was carried out by means of light microscopy (LM) a Neophot-21 (Carl-Zeiss Jena) and a JEOL JSM-6610LV scanning electron microscope (SEM). Analyses of elements distribution were carried out by use of energy-dispersive X-ray spectrometer (EDX) at 20 kV.

The specimens were prepared by grinding and polishing followed by etching in a solution of 1% nitric acid in alcohol. In order to supply a good conduction of electricity during analyses of elements distribution samples were sputtered by Au.

Table 3.
Parameters used in the composites fabrication process

Specimen	Temperature of cenospheres [˚C]	Temperature of the mould [˚C]
A	500	25
B	500	500
C	25	500

3. Results and discussion

Microstructure of AZ91 magnesium alloy, fabricated with the same process parameters as fabrication parameters of specimen B and C (temperature of the mould was 500 ˚C) is shown in Fig. 1. The microstructure consists of α solid solution of aluminium in magnesium (marked as 1 in Fig. 1) and α + γ eutectic (where γ is the intermetallic compound $Mg_{17}Al_{12}$) (marked as 2 in Fig. 1). Small amount of discontinuous precipitates (γ_{DP}) of γ phase with characteristic lamellar morphology (marked as 3 in Fig. 1) was also observed. Discontinuous precipitates formed from supersaturated solid solution due to slow cooling down of specimen below solvus temperature. Discontinuous precipitates were observed near eutectic regions. Because of a small amount of manganese in alloy aluminium-manganese compounds (Al_8Mn_5) (marked as 4 in Fig. 1) were formed.

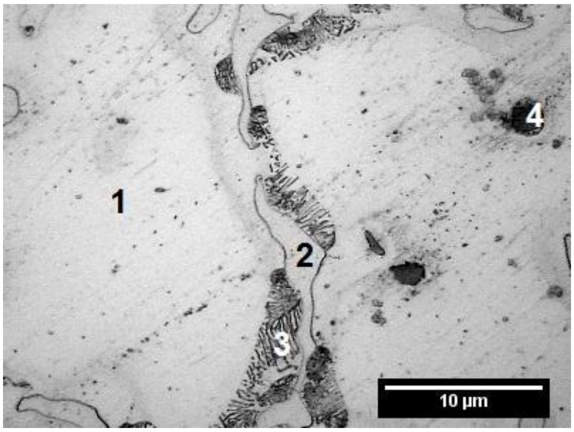

Fig. 1. Microstructure of AZ91 magnesium alloy; LM

Fig. 2 shows the microstructure of AZ91 magnesium alloy composites with ca. 60% vol. fly ash cenospheres. The microstructure of composite fabricated using cold mould (Specimen A) is shown in Fig. 2a. The microstructure of obtained composites are characterized by homogeneous structure with uncracked particles in whole volume of obtained material. The microstructure of matrix consists mainly of solid solution of aluminium in magnesium (α phase) (marked as 1 in Fig. 2) and α + γ eutectic (marked as 2 in Fig. 2). In comparison with the composite fabricated using the cold mould (Specimen A), in materials, where temperature of the mould was 500 ˚C (Specimen B and C) discontinuous precipitates (γ_{DP}) (marked as 3 in Fig. 2b and 2c) near eutectic regions were formed.

a)

b)

c)

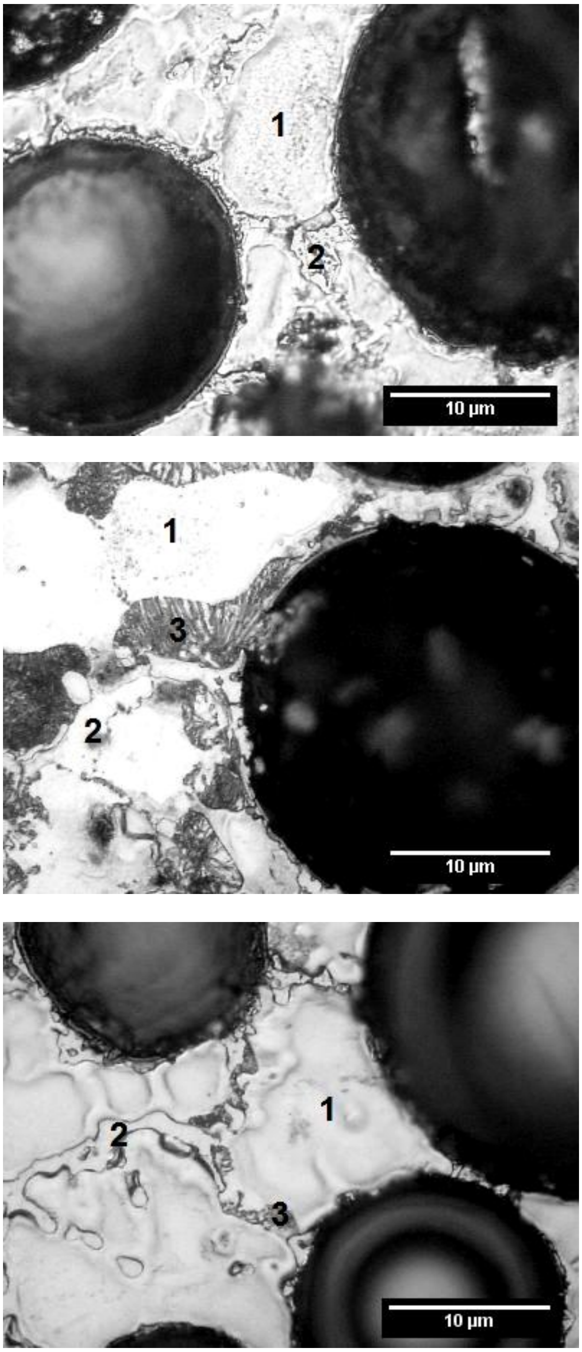

Fig. 2. Microstructure of fabricated AZ91 magnesium alloy composites with aluminosilicate glass cenospheres: a) Specimen A, b) Specimen B, c) Specimen C; LM

Fig. 3 presents secondary electron image with point analyses of AZ91 magnesium alloy composite with aluminosilicate glass cenospheres (Specimen B). The point analyses of the chemical composition of the matrix have shown the occurrence of Mg and Al in eutectic region and discontinuous precipitates. Moreover, the point analyses of the cenospheres wall have indicated elements such as Si, Al, O and K. It should be noted that presence of Au in the investigated material is caused by deposition of thin film of Au by sputtering on the surface in order to supply a good conduction of electricity.

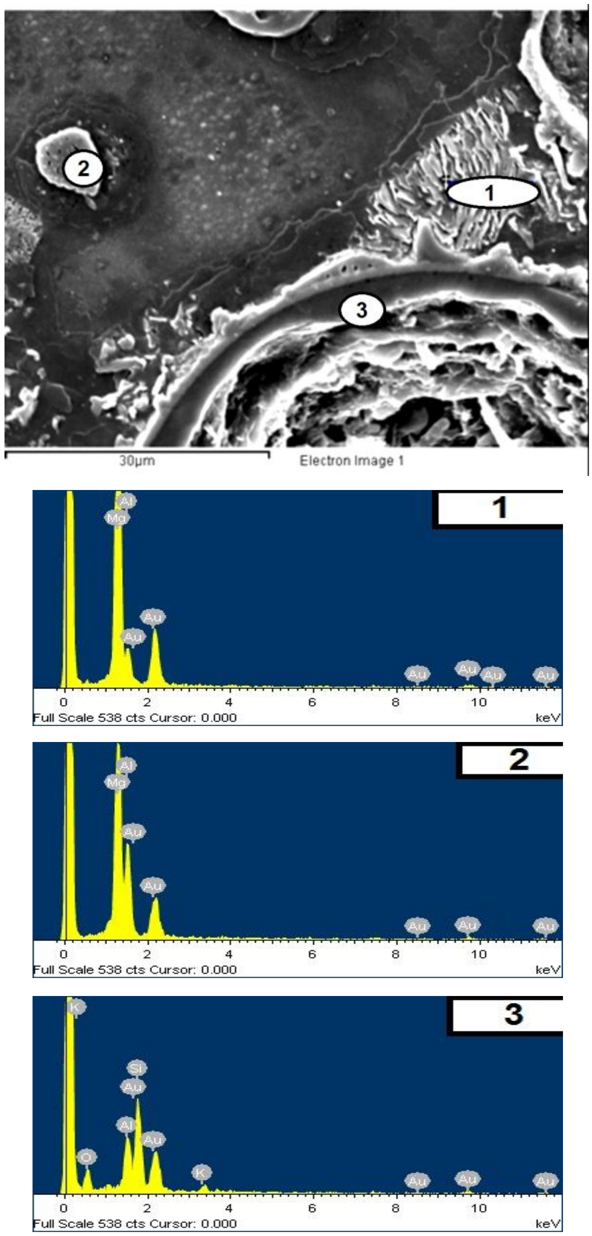

Fig. 3. Secondary electron image with X-ray analyses of AZ91 magnesium alloy composite with aluminosilicate glass cenospheres (Specimen B), SEM+EDX

4. Summary

The microstructure analyses of matrix AZ91 magnesium alloy in composites with aluminosilicate glass cenospheres were presented. The results revealed that the microstructure of matrix AZ91 in fabricated materials consists mostly of α-phase and eutectic $\alpha + \gamma$ (where γ is $Mg_{17}Al_{12}$). Additionally, the discontinuous precipitates (γ_{DP}) were also formed in the matrix in specimen 2 and 3 (where the temperature of the mould was 500 °C). It should to be noted that in the composite fabricated with cold mould, due to fast cooling down of specimen, the discontinuous precipitates of γ phase were not formed. The most important process parameter having a significant influence on the microstructure of fabricated composites with cenospheres is the temperature of the mould.

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