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Full Length Article

Magnesium alloy AZ63A reinforcement by alloying with gallium and using high-disperse ZrO_2 particles

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Abstract

The aim of this work was to obtain an experimental magnesium alloy by remelting standard AZ63A alloy with addition of gallium ligatures and ZrO_2 particles. This allowed reinforcement of alloy and increase its hardness and Young's modulus. The chemical analysis of this alloy shows two types of structures which are evenly distributed in volume. Thus we can conclude that reinforcing effect is the result of formation of intermetallic phase Mg_5-Ga_2.
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Keywords: Magnesium; Gallium; Zirconium dioxide; Alloying; Reinforcement

1. Introduction

As known from our previous experiments [1–4] a reinforcement effect in diffusion zone of magnesium alloys was observed after contact with gallium at heating up to 300 °C by two different methods: long-term in vacuum oven and short-term passing a current. A homogeneous "wavy" microstructure of the diffusion zone was formed as a result of mass-transfer of molten gallium into volume of magnesium alloys with width approximately 50 µm; the chemical composition is 65 wt. % Mg and 35 wt. % Ga for both types of heating.

Another widely used method to improve the performance properties of alloys is their modification adding high-strength heat-resistant particles into a melt. This increases the number of crystallization points and leads to modification of microstructure with disperse hardening, improving mechanical and tribological properties.

Thus, the aim of this work was first to obtain an experimental magnesium alloy by remelting standard AZ63A alloy adding ligatures and modifiers, and second to get porous material with higher mechanical properties on basis of new experimental Mg-alloy.

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2. Experimental procedure

Magnesium alloy AZ63A (Table 1) is used to manufacture engine parts and other units operating in conditions of high corrosion resistance, static and dynamic loads. The maximum operating temperatures were: 150 °C – long-term, and 250 °C – short-term. Specific vibration strength is 100 times greater than that of aluminum. Alloy is magnetic and does not spark at hitting and friction. Young's modulus (E) is 43 GPa, and hardness (H) is 1,2 GPa. Melting temperature is 650 °C, and crystallization temperature is 610…400 °C.

Pure gallium (99,9Ga–0,01Zn–0,03Cu wt.%) was used for alloying of magnesium alloy. It is a soft brittle metal, with a melting temperature of 29 °C and crystallization temperature of 15 °C.

Nano-disperse (ø24 nm) particles of zirconium dioxide (ZrO_2) were used for disperse reinforcement [5]. Zirconium dioxide particles are colorless crystals, with a melting point of 2715 °C, conductive when heated, and used for heating elements. The mechanical properties were: H = 8 GPa and E = 200 GPa.

The remelting proportion were: 140 g of AZ63A, 5 g of ZrO_2 and 20 g of Ga. Gallium ligature should be evenly distributed over the volume of the ingot which is ensured by induction heating (Fig. 1) with intense mixing by eddy currents of magnetic induction in the argon shield gas. Technical parameters of this equipment are shown in Table 2.

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Table 1
Chemical composition of AZ63A alloy (ASTM B80; JIS H5203), wt. %.

Mg	Al	Fe	Si	Mn	Ni	Cu	Zr	Be	Zn	Other
88,4…92,85	5…7	<0,06	<0,25	0,15…0,5	<0,01	<0,1	<0,002	<0,002	2…3,5	0,5

Fig. 1. Induction heating with high frequency currents in the shield gas.

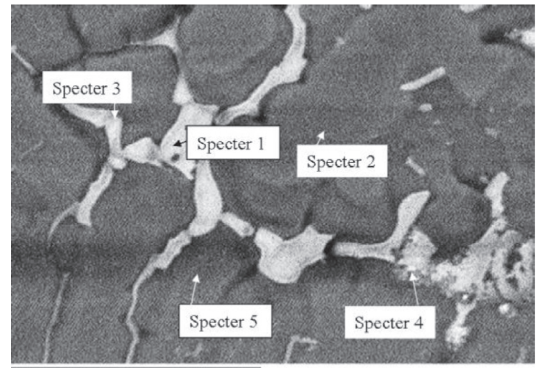
Table 2
Technical parameters of induction furnace.

Tube frequency converter	LZ-107
Capacity of frequency converter, kWt	100
The output voltage of the converter, V	800
The frequency of the current in the inductor, kHz	66,0
The voltage on the inductor, V	70…75

3. Results and analysis

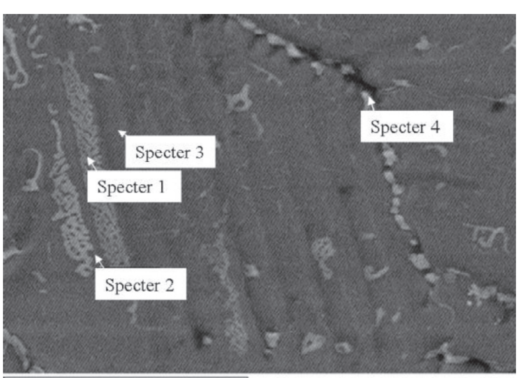
Phase composition, according to binary diagrams, is Mg_2Ga_5, $MgGa_2$, MgGa, Mg_2Ga and Mg_5Ga_2. Also, meta-stable phases $MgGa_3$ and $MgGa_4$ are known [6], which can form at concentrations of Mg below 10% and Ga above 90%.

The chemical compositions of the upper surface (Fig. 2), intersection (Fig. 3) and surface of fracture (Fig. 4) of the ingot were analyzed by scanning electron microscope (SEM). Specter



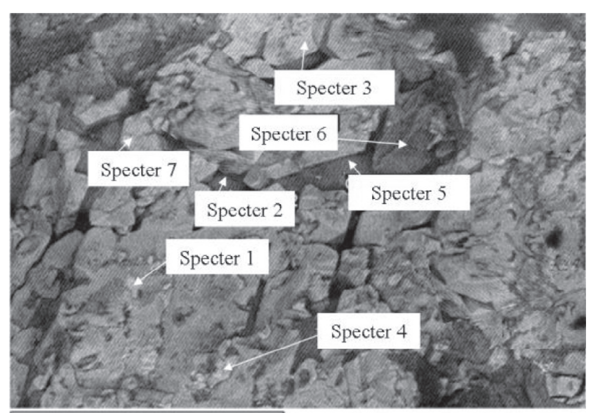
Specter	Mg	Ga	Zr	Phase
Wt. %				
1	46,94	50,49		Mg_5Ga_2
2	91,92	8,08		
3	45,12	48,97		
4	45,41	39,25	4,28	
5	87,15	6,52		

Fig. 3. Chemical distribution on intersection of AZ63A alloy ingot (SEM).



Specter	Mg	Ga	Phase
Wt. %			
1	51,70	48,30	Mg_5Ga_2
2	86,68	13,32	
3	84,32	15,68	
4	86,45	13,55	

Fig. 2. Chemical distribution on upper surface of ingot AZ63A alloy (SEM).



Specter	Mg	Ga	Phase
Wt. %			
1	38,03	50,17	Mg_5Ga_2
2	83,34	7,73	
3	26,87	62,36	Mg_2Ga
4	41,72	43,99	Mg_5Ga_2
5	44,69	44,13	
6	77,16	16,12	
7	86,61	10,40	
8	24,70	64,64	MgGa

Fig. 4. Chemical distribution on fracture surface of AZ63A alloy ingot (SEM).

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