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Corrosion influence on surface appearance and microstructure of compo cast ZA27/SiC$_p$ composites in sodium chloride solution

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Abstract: The influence of corrosion on the surface appearance and microstructure of particulate ZA27/SiCp composites was examined after 30 d immersion in a sodium chloride solution with the access of atmospheric oxygen. The composites with different contents of SiC micro-particles were synthesized via compo casting. Microstructural studies by means of optical microscopy (OM) and scanning electron microscopy (SEM) showed that corrosion occurred in the composite matrices, preferentially in regions of the η phase, rich in zinc. The corrosion processes did not affect the silicon carbide particles incorporated in the matrix alloy. According to the results of electrochemical polarization measurements, an increase in the content of SiC particles in the composite matrice has led to the lower corrosion resistance in the composites.

Key words: metal-matrix composites; ZA27 alloy; corrosion; microstructure; polarization resistance; corrosion rate

1 Introduction

Discontinuously reinforced metal matrix composites (DRMMCs) have been developed intensively over the past several decades, because of their superior physical, mechanical, electrical and tribological characteristics relative to monolithic metal matrices. The composites have been used in many structural and industrial applications that require light weight, high strength, specific thermal properties, wear resistance. The most common commercial DRMMCs are based on aluminum, magnesium and titanium alloys whereas much less attention has been given for development of composites with a base of zinc alloys. Ceramic particles such as particles of silicon carbide (SiC), alumina (Al_2O_3), boron carbide (B_4C), titanium carbide (TiC) or graphite particles have been mainly used as reinforcements for DRMMCs. With addition of hard ceramic particles, the composite hardness increases, which has a positive effect on the wear resistance of the composites [1−3].

Zinc–aluminum (ZA) casting alloys have been widely used for different applications. The alloys are characterized by a favorable combination of physical, mechanical and technological properties (low melting point, high strength and hardness, exceptional castability, easy machining, good corrosion resistance in atmospheric conditions) and low manufacturing costs. ZA alloys are also important bearing materials. Amongst the family of ZA alloys, the alloy with 27% aluminum (ZA27 alloy) is distinguished by the highest tensile strength and excellent wear resistance properties. The alloy has been used in sliding bearings and bushing applications, particularly for high-load and low-speed conditions [4]. However, at temperatures above 100 °C, a deterioration of the alloy properties was observed. To overcome this disadvantage, different thermally stable ceramic particles have been incorporated in the ZA27 alloy and the composites with the base of this alloy have been produced [5−9]. It was noticed that the presence of glass fibres [6] or hard particles of garnet [5], zircon [10] and SiC [7,8,11] in the ZA27 alloy led to a significant improvement in hardness and wear resistance of the composites relative to the matrix alloy.

The ZA27 alloy solidifies in a wide temperature range and is suitable for processing in the semi-solid state. MMCs with the ZA27 alloy matrices have been most commonly synthesized using the stir casting or compo casting technique. The compo casting technique involves intensively mixing of a semi-solid matrix alloy

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and a composite mixture, so that the primary phase becomes non-dendritic, giving thus a composite mixture with thixotropic properties [12−16].

Application of MMCs in various environments (atmospheric conditions, natural waters, water solutions etc.) requires the adequate corrosion resistance of the composites. The presence of discontinuous reinforcements and methods of producing MMCs can cause accelerated corrosion of the metal matrices relative to corrosion of monolithic matrix alloys [17]. Corrosion resistance of DRMMCs depends on the chemical composition of the matrix alloy and reinforcements, on the reinforcement shape, size, content and distribution in the metal matrix and also at the interface between the matrix and reinforcements. The presence of particulate reinforcements may influence the composite microstructure by inducing dislocation generation, formation of intermetallic compounds, the appearance of micro-cracks in the composite matrix [12] and crevice corrosion at the matrix/particle interface [1]. All this can significantly affect corrosion resistance of the MMCs.

There have been few studies on the corrosion behavior of composites with a base of the ZA27 alloy. It was revealed in these studies that corrosion rate decreases with increase in the content of reinforcements (zircon, graphite, glass fibers) in the composites [18−20]. However, there have been no reported results on the corrosion of composites with the ZA27 alloy as the matrix and SiC micro-particles as the secondary phase.

Electrochemical techniques may be also applied to obtaining corrosion rates of the composites, if corrosion is predominantly uniform on the composite surface. The linear polarization technique and recording of Tafel graphs have been commonly used to obtain the corrosion current density J_{corr}. Recently, these electrochemical techniques were applied to determining the corrosion rate of the ZA27 alloy [21,22].

Corrosion behavior of binary ZA alloys depends on their surface composition which may change due to selective dissolution phenomena [23]. Selective dissolution of zinc was observed at the initial stage of the exposure of a ZA alloy to the marine environment, while dissolution of aluminum from the alloy was noticed at the later stage [24,25].

MMCs with the base of ZA27 alloy and SiC particles as the reinforcements are intended for different tribological applications because of the high hardness and significantly improved wear resistance relative to the matrix alloy. Microstructural and mechanical characteristics, wear resistance and aging phenomena of these composites have been the subject of various studies [7,8,11,26], whereas much less research has been devoted to their behavior in different corrosive media.

The aim of this work was to study the influence of corrosion on the surface appearance and microstructure of the ZA27/SiC_p composites during their immersion in a sodium chloride solution. An attempt was also made to determine the effect of the relative content of the SiC particles incorporated in the metal matrix on the corrosion resistance of these composites.

2 Experimental

2.1 Materials

The commercially available ZA27 alloy was used as the composite matrix. The chemical composition of the alloy is given in Table 1.

Table 1 Chemical composition of ZA27 alloy (mass fraciton, %)

Al	Cu	Mg	Zn
26.3	1.54	0.018	Bal.

The ZA27 alloy was conventionally melted and cast. SiC particles with the average particle size of 40 μm were used as the reinforcement for the ZA27 alloy. The composites with 1%, 3% or 5% SiC particles were synthesized via compo casting using a suitable experimental equipment [27]. The matrix alloy was superheated above its melting temperature. The alloy melt was then cooled down to the operating temperature (465 °C) using the cooling rate of 5 K/min, when a homogenizing mixing (450 r/min) was applied for 10 min. After homogenization, SiC particles (preheated at 450 °C to remove the moisture) were added in the semi-solid melt of the matrix alloy, with simultaneous slow mechanical mixing (450 r/min). The addition was carried out at 465, 470 or 475 °C, for 3, 5 or 7 min, respectively, depending on the planned content of SiC particles in the ZA27/SiC_p composites. After the addition of particulate reinforcements, the mixing speed was increased to 1000 r/min (with isothermal mixing for 2.5 min), and then to 1500 r/min (with isothermal mixing of the composite mixture for 7.5 min). The composite mixture was cooled down to 460 °C with the cooling rate of 5 K/min and then poured into a steel mold preheated at 300 °C. Castings (20 mm × 30 mm × 120 mm) of the ZA27/SiC_p composites with different contents of SiC particles were cut to obtain composite samples (20 mm × 30 mm × 5.5 mm) for hot pressing. The samples were hot pressed at 350 °C, under the pressure of 250 MPa. Specimens for hardness measurements, microstructural examinations and electrochemical polarization measurements were cut from the hot pressed samples. Composite specimens with 1%, 3% or 5% SiC particles will be marked further as the C1, C2 and C3 composite, respectively.