Corrosion Behavior of Compocasted ZA27/SiC_p Composites in Sodium Chloride Solution

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A B S T R A C T

The corrosion behavior of particulate ZA27/SiC_p composites in an aerated sodium chloride solution was studied. The composites were synthesized via compocasting with addition of 1, 3 and 5 wt.% SiC particles in the matrix alloy. Composite samples were immersed for 30 days in the 3.5 wt.% NaCl solution open to the atmospheric air. Surface appearance and microstructure of the composites were examined by means of optical microscopy and scanning electron microscopy, while corrosion rates of the composites were determined using the weight loss method. It was revealed that SiC particles were not influenced by corrosion. General uniform corrosion occurred in the composite matrices, mainly in the region of the η phase. Local corrosion was noticed in micro-cracks and near clusters of particulate reinforcements. Results of microstructural examinations and immersion test indicate a slightly lower corrosion resistance of the ZA27/SiC_p composites compared to that of the matrix alloy.

1. INTRODUCTION

Particulate ZA27/SiC_p composites have been developed to improve mechanical and tribological properties compared to those of the matrix alloy. The composites are characterized with high strength and hardness [1-4].

The composite matrix (ZA27 alloy) has good physical and mechanical properties [5,6], as well as significant corrosion resistance [7] and high wear resistance [8]. The alloy has been widely used in many commercial applications,

especially in plain bearings. The ZA27 alloy has a wide solidification range [6] and is suitable for producing particulate composites via compocasting process [1,2,8].

Microstructural, mechanical and tribological properties of particulate composites with matrix ZA27 alloy have been extensively examined [1-3,9-11]. However, corrosion behaviour of these composites has not been studied on a large scale [12-14]. Corrosion characteristics of metal-matrix composites are deeply influenced by the microstructure of metal matrices [15,16]. The

ZA27 alloy is highly corrosion resistant in atmospheric conditions and natural waters [17]. The most common form of corrosion in these environments is general corrosion. Corrosion rate of the ZA27 alloy can be calculated using the weight loss method.

The aim of this work was to study the influence of corrosion processes on the surface appearance and microstructure of compocasted ZA27/SiC$_p$ composites. Corrosion resistance of the composites was evaluated after the immersion of composite samples in the sodium chloride solution.

2. EXPERIMENTAL

2.1 Materials

The ZA27/SiC$_p$ composites were produced using the ZA27 alloy as the composite matrix and SiC particles (with average diameter of 40 μm) as the reinforcements.

Chemical composition of the matrix alloy is presented in Table 1.

Table 1. Chemical composition of ZA27 alloy

Element*	Al	Cu	Mg	Zn
[wt.%]	26.3	1.54	0.018	Balance

*Concentration of other elements (Fe, Sn, Cd, Pb) is within acceptable limits.

The composites with 1, 3 and 5 wt.% SiC particles were synthesized via compocasting process. The particles were added into the semi-solid melt of the matrix alloy, with use of mechanical mixing.

Obtained composite castings were hot pressed, in order to reduce porosity. Samples for microstructural and corrosion studies were machine cut from the composite castings.

2.2 Methods

Microstructural examinations

Surface appearance and microstructure of the ZA27/SiC$_p$ composites were examined by optical microscopy (OM) and scanning electron microscopy (SEM) using a Carl Zeiss optical microscope and a JEOL JSM-5800 scanning electron microscope. Composite samples (5 mm in diameter and 8 mm in height) were ground and polished. Wet grinding was performed with successively finer abrasive papers (P240, P360, P600 and P800 grit SiC), while polishing was done using polishing cloth and diamond paste (particles size up to 2 μm). Aqueous solution of nitric acid (9 v/v % HNO3) was used for etching of the samples.

The composite samples were washed with ethyl alcohol and dried in the air before immersion in the 3.5 wt. % NaCl. After the immersion, the composite samples were prepared for metallographic examinations in the usual way.

Immersion test

Corrosion rates of the ZA27/SiC$_p$ composites were calculated after the immersion of composite samples, using the weight loss method. Preparation of the samples and testing procedure were carried out according to ASTM G31 [18]. The samples (18 x 28 x 3 mm), in triplicate, were immersed vertically in the sodium-chloride solution (3.5 wt.% NaCl, pH = 6.7) open to the atmospheric air. The test was performed at room temperature (23 ± 2 °C). After 30 days the samples were withdrawn from the test solution. Corrosion products were removed from the sample surface using the chemical procedure.

Calculation of the average corrosion rate *CR* [mm/year] was performed using the following expression:

$$CR = \frac{8.76 \cdot \Delta m}{d \cdot A \cdot \tau}, \qquad (1)$$

where: Δm [g] is the weight loss of the composite sample during the immersion test, τ is the immersion time (720 hours), A is the sample surface [cm^2] and d [g/cm^3] is density of the composite sample. Density [g/cm^3] of composites with 1, 3 and 5 wt.% SiC particles is 4.97, 4.92 and 4.87, respectively.

3. RESULTS AND DISCUSSION

3.1 Microstructure

Surface appearance and microstructure of the composites were examined before and after the

immersion test. Representative composite samples with 3 wt.% SiC particles are shown in Fig. 1. The SiC particles are uniformly distributed in the metal matrix (Figs. 1a and 1b). Several inclusions can be noticed on the surface of the composite sample, but also mechanical damages on the edge of the sample (Fig. 1a). The microstructure of the composite sample was revealed by etching (Fig. 1b). It can be seen that SiC particles are distributed in the regions of the η phase and regions of the phase mixture α+η.

Several clusters of SiC particles can be seen in the composite microstructure (Fig. 1b). Voids, due to the fallout of SiC particles from the composite matrix, are not visible. This indicates good bonding between SiC particles and the matrix alloy. In Figure 1b, main microconstituents in the composite matrix (α phase, η phase and α+η phase) can also be noticed. The microstructure of the metal matrix is non-dendritic, with large primary particles. The primary particles consist of a core (rich in aluminium) and a periphery (composed of the phase mixture α+η). Interdendritic η phase (rich in zinc) can be seen between the primary particles.

Surface appearance and microstructure of the composite sample after the immersion in the NaCl solution are shown in Figs. 1c and 1d. It can be seen that corrosion occurred in the composite sample. Corrosion started at the edge of the sample, around inclusions and in the agglomerates of SiC particles (Fig. 1c). Corrosion processes occurred in the composite matrix, in the regions of the η phase and in the regions of the phase mixture α+η (Fig. 1d).
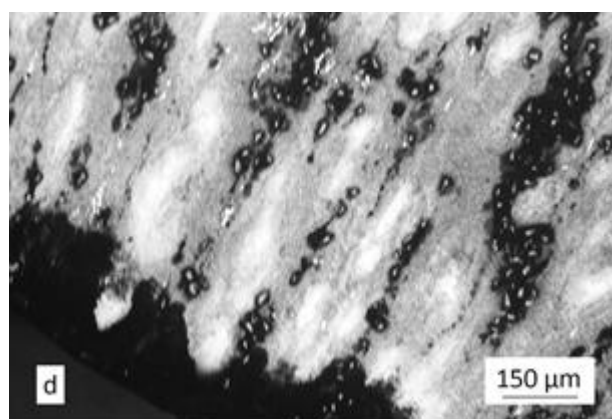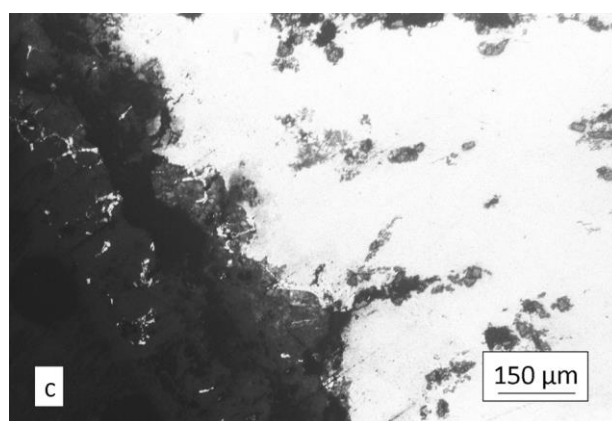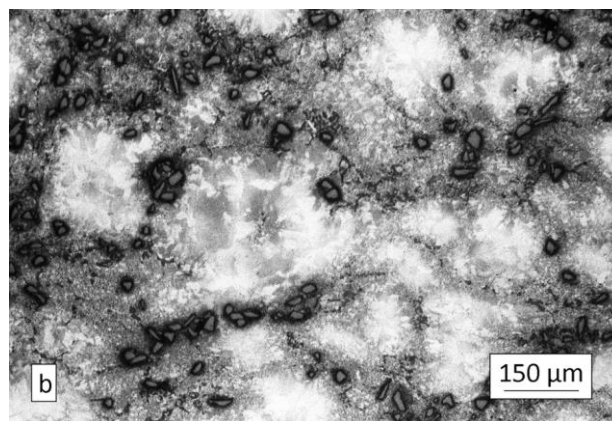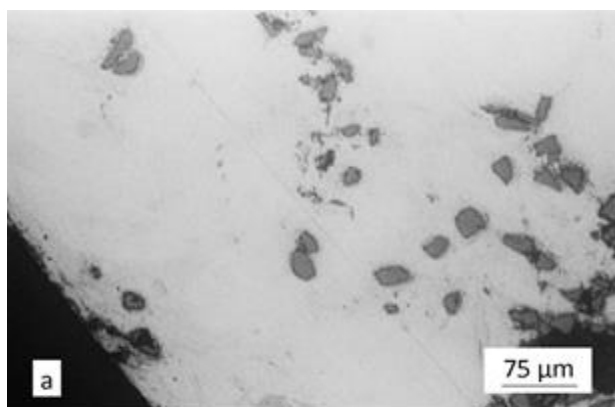

Fig. 1. Surface appearance of ZA27/3 wt.% SiC$_p$ (OM): (a) before immersion (polished), (b) before immersion (etched), (c) after immersion (polished) and (d) after immersion (etched).

After the immersion, micro-cracks in the metal matrix can be also seen (Fig. 1d). Initial micro-cracks were noticed in the composite samples before the immersion test (Fig. 1b). These micro-cracks were probably formed during solidification of the composite mixtures and during hot pressing. The presence of micro-cracks negatively affected corrosion resistance of the ZA27/SiC$_p$ composites.

It is clearly visible that corrosion did not influence the SiC particles in the metal matrices. However, these particles influenced corrosion resistance of the ZA27/SiC$_p$ composites, because of the presence of a large number of surface boundaries in the composite structure. In addition, the boundary surface matrix/particle is not continuous in the regions of agglomerated SiC particles. Micro-pores and micro-cracks may be formed in these places. Due to the retention of the sodium-chloride solution in the micro-cracks, the progress of corrosion in depth of the composite materials was noticed.

During the immersion in the sodium-chloride solution, corrosion products were formed on the surface of the composite samples. White, fibrous and brittle corrosion products of the composite matrix can be seen in Fig. 2a. A group of SiC particles surrounded with the corrosion products is also visible. The particles were not influenced by corrosion. This can be seen more clearly in Fig. 2b.
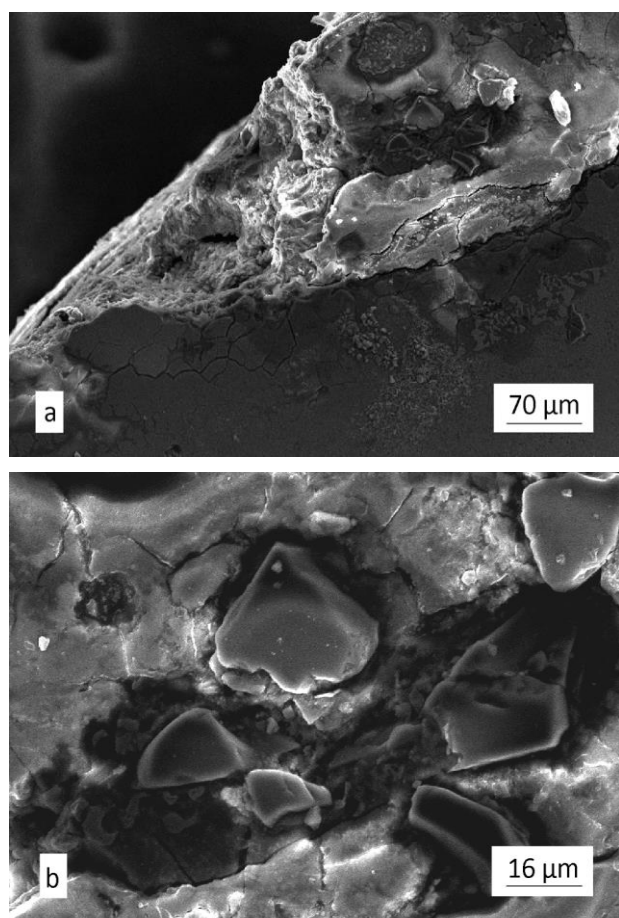

Fig. 2. Corrosion products on the composite sample (ZA27/3 wt.% SiC$_p$) after immersion in NaCl (SEM): surface appearance.

Microstructural examinations after the immersion of ZA27/SiC$_p$ composites in the sodium-chloride solution revealed that corrosion started on edges of the composite samples, around inclusions and near the agglomerates of SiC particles. Corrosion processes occurred in the composite matrices, in the η phase and in regions of the phase mixture α+η. In addition, the local progress of corrosion was noticed in micro-cracks. Corrosion did not influence SiC particles in the composites.

3.2 Corrosion rate

After the immersion of composite samples in the NaCl solution, corrosion products were removed from the surface of the samples by chemical procedure [19]. It was noticed that general uniform corrosion occured on the surface of composite samples. Corrosion rate, *CR* [mm/year], was calculated on the base of the mass loss of composite samples during the immersion test. Corrosion rates of the ZA27/SiC$_p$ composites are shown in Fig. 3.
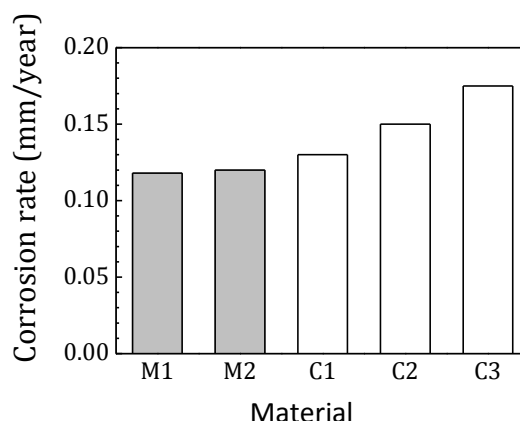

Fig. 3. Corrosion rates of ZA27 alloys and ZA27/SiC$_p$ composites after immersion in NaCl (M1: ZA27 as-cast; M2: ZA27 thixo; C1: ZA27/1 wt.% SiC$_p$; C2: ZA27/3 wt.% SiC$_p$; C3: ZA27/5 wt.% SiC$_p$).

Corrosion rates of the ZA27 alloy as-cast and thixo cast ZA27 alloy [20] are also shown in Figure 3, for comparison purposes. It can be seen that corrosion rates of the composites are slightly higher than those of both ZA27 alloys (as-cast and thixocast). The corrosion rate of the composites shows an increase with increase in the content of SiC particles, because of a larger number of boundary surfaces matrix/particle and the presence of agglomerates of SiC particles. According to the obtained results the

as-cast compocasted ZA27/SiC$_p$ composites indicate slightly lower corrosion resistance than the matrix ZA27 alloy. However, these composites have shown somewhat higher corrosion resistance when compared with compocasted and thermally treated ZA27/SiC$_p$ composites [21].

4. CONCLUSIONS

Based on the results of performed microstructural and corrosion studies the following conclusions can be drawn:

1) Relatively good distribution of SiC particles in the composite matrices was achieved in the ZA27/SiC$_p$ composites synthesized via compocasting.

2) Corrosion started at edges of the composite samples, on inclusions and in the agglomerates of SiC particles. Corrosion processes ocurred mainly in the composite matrix although the local progress of corrosion was noticed in the micro-cracks. However, corrosion did not affect SiC particles in the composites.

3) Corrosion resistance of the ZA27/SiC$_p$ composites is slightly lower compared to the corrosion resistance of the matrix alloy.

Acknowledgement

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