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## The corrosion characteristics of aluminium matrix composites reinforced with SiC particles\*

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The paper presents results of the studies on the susceptibility of 359/20%SiC composite to corrosion. The corrosion resistance were carried out by accelerated electrochemical studies using the potentiodynamic method in a typical corrosive environment (3.5% NaCl). The corrosion potentials determined in electrochemical studies and analyses of the anodic polarisation curves, for both, composite and matrix alloy, are very similar. However, the numerous and deeper pits occurred in the case of the composite material and the pits located in the  $\alpha$ -Si eutectic and between SiC particles. The study didn't show significant influence of SiC particles on the increase of susceptibility to pitting corrosion in comparison to matrix alloy.

### 1. INTRODUCTION

The dynamic development of high technology requires extensive search for new materials which could provide obtaining of higher properties [1]. The above requirements are fulfilled by the metal composite materials (MMC) based on the light metal alloys (Ti, Al, Mg) reinforced with ceramic particles. The composites can be used in the production of parts for driving mechanisms and engines (pistons), suspension, steering systems, bodies and parts of the braking systems (mainly brake disks) [2-4].

However, the addition of the reinforcing particles could significantly influence the corrosion behaviour of these materials. Generally published literature on the corrosion of aluminium-based composites is rather limited and often contradictory [5,6]. Composite materials can have lower resistance to corrosion than aluminium alloys of which they have been made. The main reasons for this are: (1) formation of galvanic couples between active aluminium and more noble reinforcing metal, e.g. SiC, (2) metallic phases release - formation of „cathode patches” with good conductive properties on the passive layer, and (3) microstructure of interface reinforcement/matrix (chemical composition, porosity) [7-10].

The paper presents results of the studies on the susceptibility of aluminium matrix composite containing silicon carbide particles to corrosion. The aim of the investigation was determination of influence of SiC on pitting corrosion in a typical corrosive environment in relation to unreinforced matrix alloy.

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## 2. EXPERIMENTAL

The subject of the examinations was a composite marked as F3S.20S (Duralcan) on a base of 359 alloy (8.5-9% Si; 0.45-0.65 Mg) containing 20% of SiC with the nominal dimension of 20  $\mu\text{m}$ . This material has been produced in the Foundry Research Institute in Cracow by the method of gravity casting (vortex method) and it was in non-heat treatment state.

The corrosion resistance experiments were carried out by accelerated electrochemical studies using the potentiodynamic method. The potentiodynamic measurements were made in the 3.5 wt.% NaCl aqueous solution of pH 7.0 at 25°C, with Pt counter-electrode. Polarization was started at a potential of -1900 mV shifting the potential towards the anodic side till a clear increase in the current density and the measurements were recorded again on the cathodic side (shift at a rate of  $10^{-3}$  V). The potential was controlled with an EG-20 type generator, EP-20 potentiostat and a PC equipped with reference to a saturated calomel electrode.

The microstructure was studied using an optical microscope (ZEISS model) and a scanning electron microscope (LEO 1430VP with EDX-Roentec).

## 3. RESULTS AND DISCUSSION

The microstructures of 359/20%SiC and matrix are presented in Fig. 1. Silicon carbide particles were seen in the matrix against the background of dendrites of the  $\alpha$ -Al solid solution, a fine-grained eutectic  $\alpha$ +Si. Distribution of SiC particles in the whole volume of composite was quite uniform [11]. The SiC particles are present in the interdendritic regions between  $\alpha$ -Al dendrites due to pushing on silicon carbide particles by growing  $\alpha$ -Al dendrites during solidification [12].

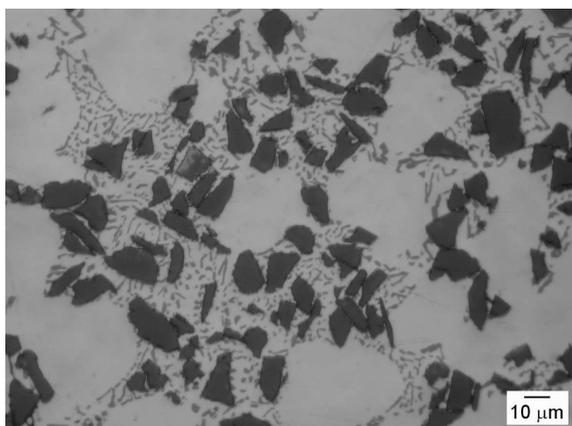


Fig. 1. Microstructure of 359/20%SiC composite.

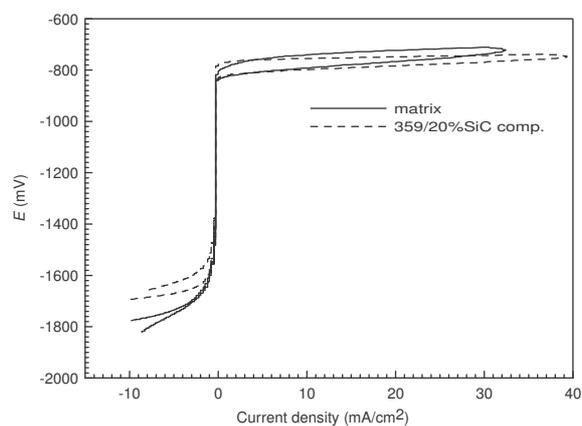


Fig. 2. Potentiodynamic polarization curves of the 359/20%SiC composite and matrix alloy.

Characteristic potential values such as: pitting potential ( $E_{pit}$ ), corrosion potential ( $E_{corr}$ ) and repassivation potential ( $E_{rp}$ ) were determined from the electrochemical studies and analysis of anodic polarisation curves. Fig. 2 presents the polarisation curves of the studied materials, while the values of the potentials are listed in Table 1.

The nature of the potentiodynamic polarization curves in the 3.5% NaCl solution reveals typical characteristics of the metal undergoing spontaneous passivation. The shape of polarization curves (Fig. 2) and the determined electrochemical potentials of the 359/20%SiC composite and matrix alloy are very similar (see Table 1) and differences are not significant.

Table 1

Characteristic corrosion potentials obtained from the electrochemical studies

Material	$E_{corr}$ [mV]	$E_{pit}$ [mV]	$E_{rp}$ [mV]	$\Delta E_{pit}$ [mV]	$\Delta E_{rp}$ [mV]
matrix alloy	-830	-787	-831	49	44
359/20%SiC	-820	-767	-827	53	60

$$\Delta E_{pit} = E_{pit} - E_{corr}, \Delta E_{rp} = E_{pit} - E_{rp}$$

Figure 3 present typical examples of the microstructure of the surfaces of samples after corrosion. In the microstructural images of the studied materials there are numerous pits which depths ranged between 10 and 24  $\mu\text{m}$  for the composite and 8 and 16  $\mu\text{m}$  for the unreinforced aluminium alloy. The corrosion pits for both the 359/20%SiC composite (Fig. 3b) and matrix alloy (Fig. 3a) are formed in the  $\alpha$ +Si eutectic and between silicon carbide particles in case of the composite.

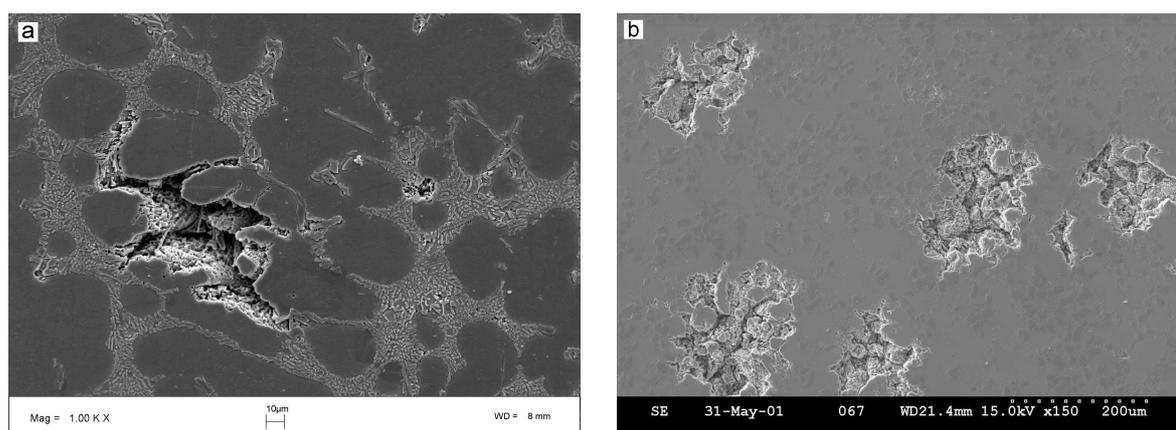


Fig. 3. Scanning electron micrograph of pitting corrosion on the surfaces of: (a) matrix alloy and (b) 359/20% SiC composite.

Aluminium alloys generally pit in solutions containing  $\text{Cl}^-$ . Pit initiation involves the adsorption of  $\text{Cl}^-$  at the flaws in the surface oxide films (for example: casting defects, second-phase particles), followed by chemical reaction between the  $\text{Cl}^-$  and the oxide [13]. The presence of very large number of second phase particles and mostly more noble eutectic silicon or SiC in the composites led to extensive pitting of the matrix and of the composites in general. [13,14]. Pitting in composites has often been observed at the reinforcement-matrix interfaces. It may be a result of the presence of an interfacial reaction products formed during composite fabrication [8]. These are segregation of alloying elements and formation of intermetallic precipitates at the interface [15]. The higher number of corrosion pits in the composite than in the matrix alloy could have resulted from the increase of interfacial area which was due to addition of 20% SiC [16].

Trzaskoma, Modi and Nunes [13,16,17] showed that while the pitting potentials and anodic polarisation curves of the reinforced and unreinforced aluminium alloys were similar,

the corrosion behaviour of the two materials was different. They have also observed the occurrence of more numerous and deeper corrosion pits in the composites and their privileged location in the  $\alpha$ -Si eutectic.

#### 4. CONCLUSIONS

The conducted investigations of corrosion resistance of 359/20% SiC composite and matrix alloy showed that the pitting potentials (such as:  $E_{corr}$ ,  $E_{pit}$ ,  $E_{rp}$ ) and anodic polarisation curves were similar for both. The corrosion pits located in the  $\alpha$ -Si eutectic and between SiC particles. However, numerous and deeper pits occurred in the case of the composite material. The study didn't show significant influence of SiC particles on the increase of susceptibility to pitting corrosion in comparison to matrix alloy. The microstructure and kind of matrix are of large significance for the corrosion behaviour of these materials.

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