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INFLUENCE OF THE SELECTED STRUCTURAL PARAMETER ON A DEPTH OF INTERGRANULAR CORROSION OF Al-Si7-Mg0,3 ALUMINUM ALLOY

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The paper presents an influence of the Dendrite Arm Spacing (DAS) microstructure parameter on the intergranular corrosion of AlSi7Mg aluminum alloy. The samples were subjected to the corrosion process for: 2,5; 12; 24; 48 and 96 hours in NaCl + HCl + H_2O solution. It was noted that the DAS parameter significantly influenced on a distribution and depth of the intergranular corrosion of the hypoeutectic Al - Si - Mg silumin.

Key words: Aluminum alloy Al - Si - Mg, corrosion distribution, microstructure

INTRODUCTION

Aluminum-silicon casting alloys, thanks to their good mechanical properties compared to their relatively low density, have found a wide range of applications in various industry branches especially in automotive. The alloys are used inter alia for elements such as engine heads, steering column casings, suspension elements, etc.

Silumin casts are characterized by moderate/good corrosion resistance in water and air. However, corrosion progresses faster when the material is subjected to strong acid or alkaline environment [1 - 3]. Important factors influencing an intensity of the corrosion process are: chemical composition (Fe, Cu, Mn content), casts' thermal processing and corrosive environment [1, 4 - 7].

The most frequent corrosion types occurring in the aluminum alloys are: pitting and intergranular corrosion resulting from the difference in electrode potential between metallic matrix and internal precipitations [8, 9].

RESEARCH METHODOLOGY

The studies were carried out using plate-shaped casting of: 22 mm thickness, 120 mm width and 150 mm height. The technical silumin marked EN AC-AlSi7Mg0,3, with chemical composition presented in Table 1, was used.

Table 1 **Chemical composition of AlSi7Mg0,3 alloy / wt. %**

Si	Mg	Cu	Fe	Ti	Mn	Zn	Ni	Pb	Al
7,37	0,34	0,01	0,1	0,17	0,01	0,01	0,01	0,01	rest

The metallurgical process of alloy preparation was conducted in a laboratory resistance furnace Nabertherm K4/13 in a SiC crucible. Firstly, the charge was cleaned and dried. Secondly, after melting, a refining process was performed in order to remove a suspension of the Al_2O_3 oxides and modified with strontium and titan-boron Ti5B1 in a quantity of 250 ppm each. Before pouring, the liquid alloy was purged with nitrogen using a graphite lance.

Various conditions of alloy solidification were achieved using a copper chill, placed in a bottom part of a mould which was made of quartz sand, bentonite clay and dextrin. Repeatability of structure forming conditions was achieved by simultaneous pouring into a set of three moulds (Figure 1). The moulds were filled with the alloy which had a temperature of 720 ± 10 ºC.

The casting were subjected to T6 heat treatment (540 ºC / 12 hours; water cooling 160 ºC / 4 hours).

The DAS parameter was used to describe the microstructure refinement. A central part of the plate, as shown in Figure 2, was used to determine it.

The maximum distance from the surface which had been subjected to corrosive treatment was less or equal to 1 mm. For the DAS parameter calculations dendrites with at least 4 clearly visible arms were considered. A number of dendrites measured in a single measurement area was 30.

In order to describe an influence of the corrosive environment on the casting in a function of solidification parameters and microstructure the plate was separated and cut as shown in Figure 3.

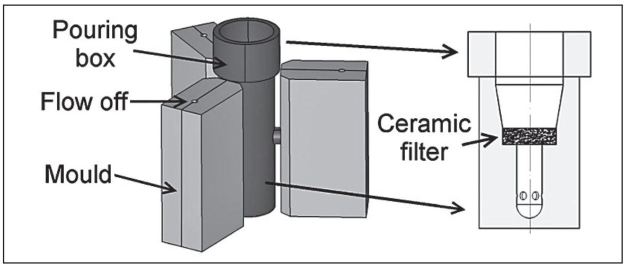

Figure 1 Set of molds and their position

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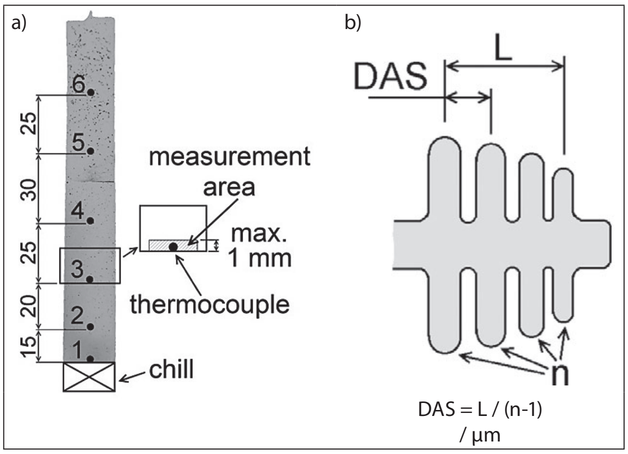


Figure 2 DAS measurement: a) measurement location, b) measurement scheme; where: L – the measuring length / µm, n – number of the dendrite arms

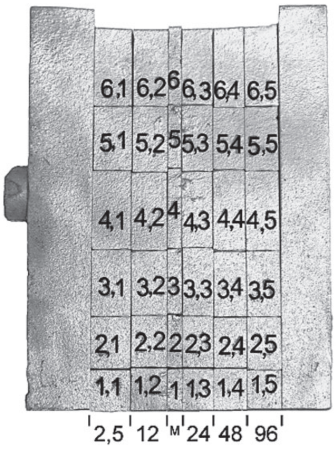


Figure 3 Plate division for examining corrosion: 2,5; 12; 24; 48; 96 – time of sample presence in corrosive environment, M – samples prepared for microstructure tests

The samples for corrosion tests were prepared in the following way:

- lower surface was polished with sand-paper with a granularity of 240,
- the surface was degreased using ethyl alcohol,
- the samples were immersed in a solution of: 1 000 ml H_2O, 20 g NaCl, 100 ml HCl (33 %), with the surface directed upwards.

The samples were kept in the solution for 2,5; 12; 24; 48 and 96 hours. A series of 6 samples underwent the experiment. The samples were placed at the bottom of the vessel and did not touch one another. All the tests were performed at ambient temperature of 22 ± 1 ºC and the solution was used only once. After the corrosion test, each sample was cleaned under water and then placed in an ultrasound washer for 8 minutes in deionized water.

Corroded surfaces were evaluated using a stereoscopic microscope MOTIC SMZ-168, in the area shown in Figure 4a (the boundary effect). After marking the most corroded areas (Figure 4b) the samples were cut laterally (Figure 4c) and polished sections were prepared afterwards. Observations of the polished sections were performed using a NIKON Optiphot-100 luminous microscope. Measurements of intergranular depth of corrosion

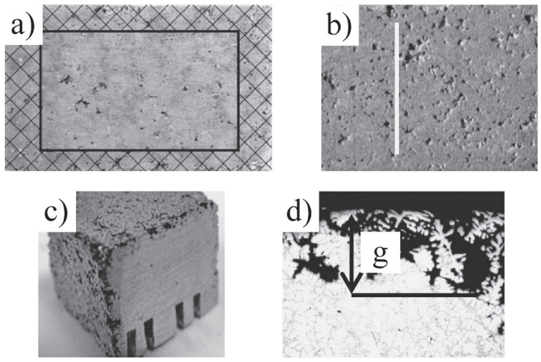


Figure 4 A sample subjected to the corrosion test: a) analyzed area, b) a line of cutting, c) cut sample, d) measured depth of the intergranular corrosion

were carried out for each sample, average results obtained from 5 measurements are presented in Figure 4d.

RESULTS

A refinement of casting microstructure depends on thermal conditions of solidification. Photos of casting microstructures in various distances from the chill are presented in Figure 5.

Metallographic structure of the casting was described using a distance parameter between dendrites' arms in a solid $\alpha_{Al\text{-}Si}$. The DAS parameter in a function of a chill distance is shown in Figure 6.

The greatest refinement of the microstructure was noted next to the chill where the DAS was approx. 21 µm. Similar values can be noted in casts produced in metal moulds. At a distance from the chill equal to 1,5 cm, the microstructure parameter value of the $\alpha_{Al\text{-}Si}$ phase increased by almost 50 % and was approx. 31 µm. In the place located where the chill was not operating (approx. 6,6 cm) the DAS parameter value was approx.

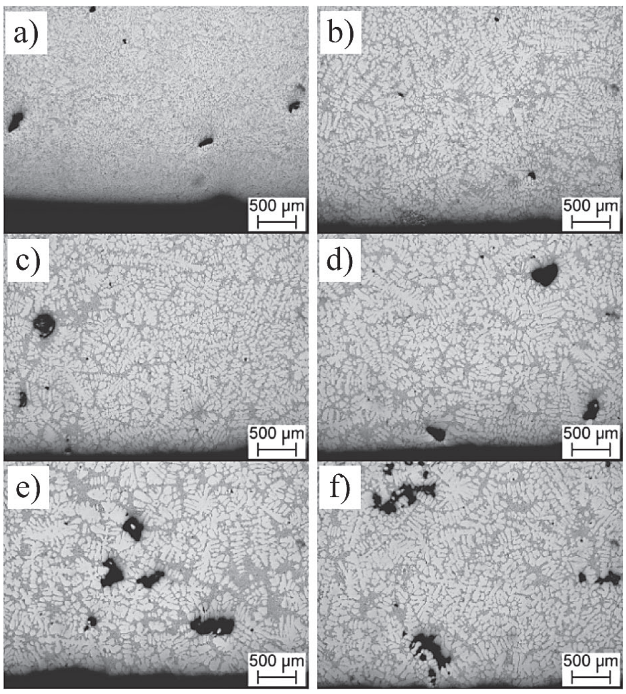


Figure 5 Casting microstructures in various distances from the chill: a) 0, b) 15, c) 35, d) 60, e) 90, f) 115 mm

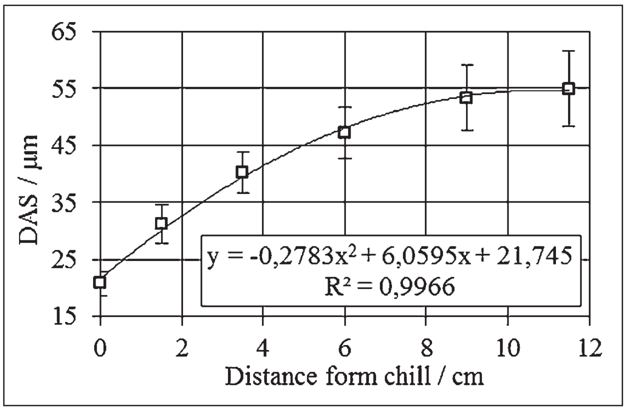


Figure 6 Dendrite Arm Spacing in a function of chill distance

50 μm (twice as high as next to the chill). When a distance from the chill was equal to 9 and 11,5 cm, the values of the DAS parameter were approx. 53 and 55 μm. The conducted analysis proofed usefulness of the DAS microstructure parameter for describing solidification conditions of the plate-shaped casts (R^2 = 0,997).

The values of the intergranular corrosion depth in a function of chill distance and time of subjecting them to corrosive environment are shown in Figure 7.

Independently on time when the samples were subjected to the corrosion test, the lowest corrosion depth values occurred adjacent to the chill. When the samples were subjected to the corrosive environment for 2,5 and 48 hours the depth of the corrosion was approx. 137 and 212 μm, correspondingly (Figure 8).

Together with an increase of the chill distance, the depth of the intergranular corrosion also increased. The

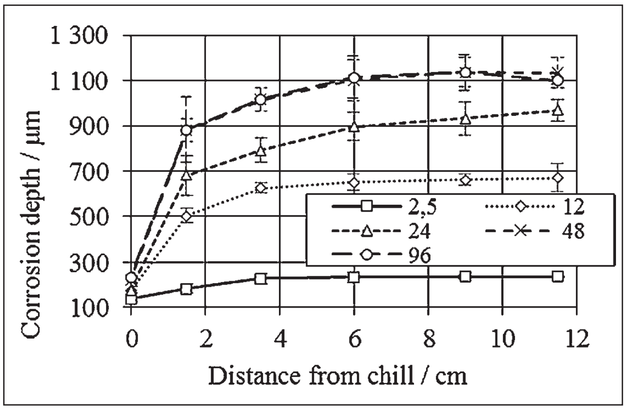
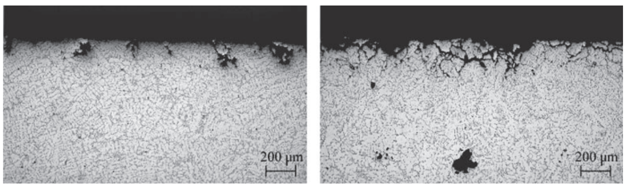


Figure 7 The values of the intergranular corrosion depth in a function of a distance from the chill and time of subjecting the samples to corrosive environment



a) **b)**

Figure 8 Depth of corrosion in the samples located near the chill: subjected to the corrosion environment for a) 2,5 hours, b) 48 hours

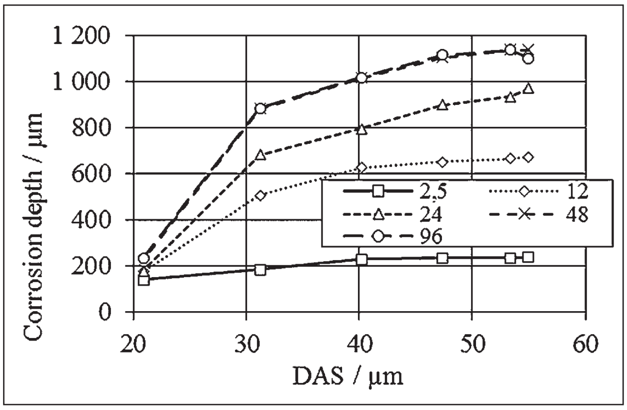


Figure 9 Corrosion depth in a function of the dendrite arm distance and time of subjecting samples to the corrosive environment

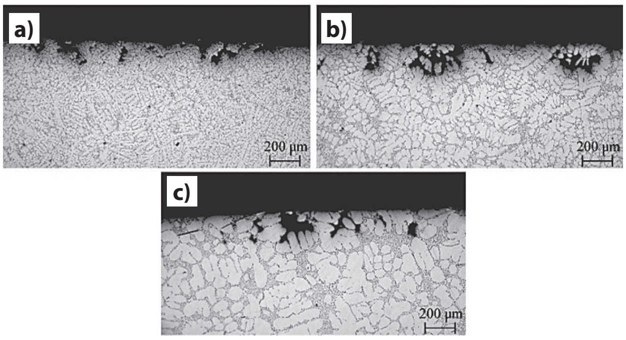


Figure 10 The corrosion depth for samples subjected to the corrosion test for 2,5 hours at a distance from the chill: a) 0 mm, b) 15 mm, c) 90 mm

longer the sample was subjected to the corrosive environment, the higher the difference was.

The analysis of the dendrites arm spacing values in a function of the distance from the chill revealed that the DAS microstructure parameter can be used to estimate the depth of intergranular corrosion (Figure 9).

The smallest kinetics of changes in corrosion depths was observed for the samples subjected to 2,5 hour bath in the corrosive environment (Figure 10). The highest kinetics was observed for the samples subjected to the corrosive environment for 48 and 96 hours (Figure 11).

Another crucial factor influencing a spacing and depth of the intergranular corrosion is pitting. It is present on casting surface and is an initialization point of the corrosion processes (Figure 12).

In the tested sample (12 hour test) located next to the chill, in spite of a very refined structure (DAS ≈ 21 μm), the corrosion depth increased from 174 μm (without pitting) to approx. 440 μm (Figure 13).

Similarly to the pitting that occurred on the sample surface are pores located directly below the casting surface (Figure 14) which are another essential factor influencing the intergranular corrosion depth.

Such an occurrence is of particular importance in case of casts subjected to additional machining. Such casts are prone to leak and reveal decreased fatigue strength and elongation. Defects of this type may appear as a result of: incorrectly performed refining process performed to remove hydrogen from alloy, gassing due to undried pro-

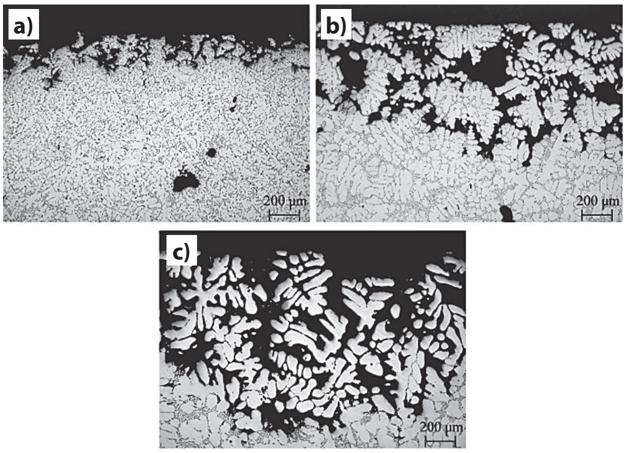


Figure 11 Depth of the corrosion in the samples subjected to the corrosion test for:a) 96 hours, 15 mm from the chill, b) 48 hours, 15 mm from the chill, c) 48 hours, 90 mm from the chill

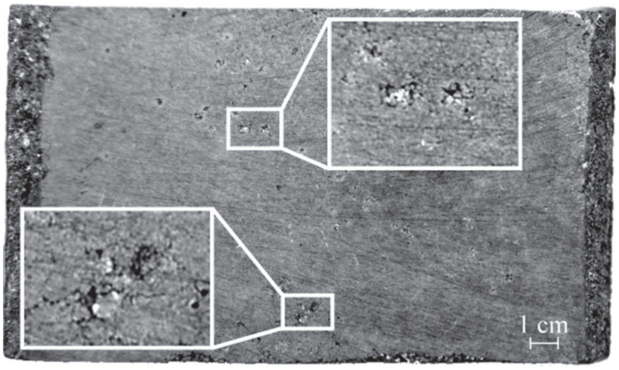


Figure 12 Pitting on the sample surface (from the chill) subjected to the corrosive environment for 12 hours

tective coating deposed on the mould cavity or a core emitting gas and having contact with the liquid alloy.

CONCLUSIONS

– Refinement of casting microstructure (AlSi7Mg), measured using the DAS parameter, increased material resistance and significantly influenced on depth of the intergranular corrosion.
– The smallest increase of the corrosion depth in a function of the DAS parameter was noted for the samples which had been subjected to the corrosive environment for up to 2,5 hours.
– An increase of the DAS parameter of the casting from 21 to 31 μm caused a three times the increase of the intergranular corrosion depth for the samples kept over 12 hours in the corrosive environment and over 3,5 times the increase for the samples kept for 24 hours.
– Damage of the casting surface during its use can contribute to an occurrence of pitting, and in turn can deepen the intergranular corrosion.
– In the casting material (AlSi7Mg) with the DAS value equal to 31 μm and greater, the subsurface porosity had a significant influence on depth of the intergranular corrosion.
– Effects of the corrosion process defined by a thickness of the corroded layer on the casting surface increased together with an increase of their contact time with the corrosive environment.

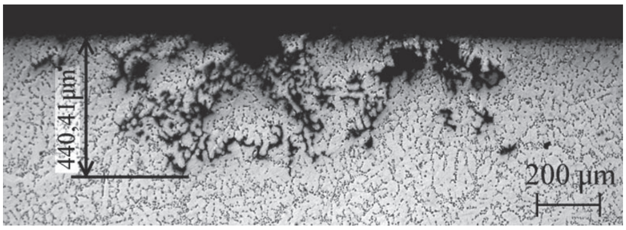


Figure 13 Corrosion resulting from pitting on the sample surface near chill, time of corrosion test 12 hours

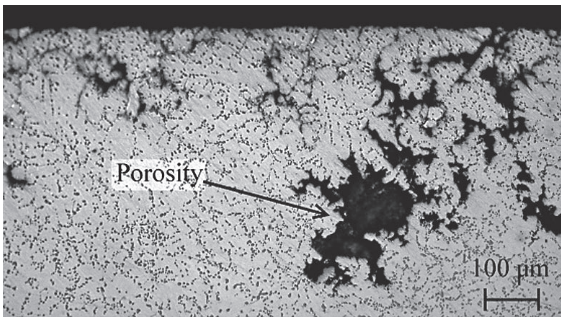


Figure 14 Corrosion resulting from the subsurface porosity, sample near the chill, time of the corrosion test – 24 hours

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Note: Janowska Barbara is responsible for English language, Poznan, Poland