Investigation of the influence of different modifiers on the corrosion rate of AlSi18Cu3CrMn alloy

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Abstract. **The development of new hypereutectic Al-Si alloys with increased mechanical and improved operational properties is an up-to-date engineering task. The non-standardized hypereutectic aluminum-silicon alloy AlSi18Cu3CrMn is modified with different modifiers (standard modifier P and a complex of modifiers P, Ti, B and Be). The compositions thus modified are subjected to heat treatment (T6). Artificial aging after quenching was carried out under different parameters (temperature and time). The aim of the present study is to determine the influence of the used modifiers on the corrosion rate of the compositions under the same conditions. The gravimetric method was used.**

Keywords: corrosion rate, hypereutectic aluminum-silicon alloy, modification, heat treatment

I. Introduction

The influence of microstructure on the mechanical and performance properties of aluminum-silicon alloys has been addressed in various studies. In addition to the size, shape and distribution of the primary silicon crystals in the structure of the alloys, the size and shape of the eutectic silicon is also important. To obtain fine and rounded silicon crystals in the composition of the eutectic, modification of the α-solid solution is resorted to in order to reduce the distance between the dendrites of the α-crystals [4-10]. Through such metallurgical processing, conditions are created for obtaining modified eutectic silicon crystals, which, in turn, helps to increase the mechanical and operational properties of alloys from the Al-Si system. Based on the fact that intercrystalline corrosion is observed in aluminum-silicon alloys, a number of studies have been directed to the study of the relationship between the phase composition and the corrosion behavior of this type of alloys [11]-[15].

The microstructure of hypereutectic aluminum-silicon alloys is affected by the modifying treatment. According to the generally accepted classification of P. A. Rebinder, modifiers are divided into two groups. Type I modifiers are surfactants that adsorb onto the growing crystal seeds and reduce the growth rate of the solid phase. Type II modifiers are usually hard-melting substances with a crystal lattice, isomorphic and with close parameters to that of the crystallizing alloy. Distributed in the melt in a finely-dispersed to colloidally-dispersed state, they become independent centers of crystallization or form such as a result of interaction with elements of the composition of the melt. The complex modification with modifiers of the I and II species of the hypereutectic Al-Si alloys shows very positive results, simultaneously separating the initially separated Si crystals and the crystalline silicon in the composition of the eutectic.

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The set of the present study is to determine the effect of the modifiers used on the corrosion rate of AlSi18Cu3CrMn flux under certain conditions.

II. MATERIALS AND METHODS

The chemical composition of the studied hypereutectic Al-Si alloy AlSi18Cu3CrMn is listed in Table 1.

TABLE 1. CHEMICAL COMPOSITION OF ALLOY ALSI18CU3CRMN, WT.%

Si	Cu	Cr	Fe	Mn	Al
18.50	3.12	1.00	0.25	0,76	rest

The modifiers used to modify supereutectic aluminum-silicon alloy AlSi18Cu3CrMn are: standard modifier phosphorus, introduced into the melt via CuP10 ligature in an amount of 0.04 wt% and a combination of the modifiers phosphorus, beryllium, titanium and boron. The introduction of the modifiers Ti and B is carried out through the ligature AlTi5B1 in an amount of 0.015% Ti; 0.003% In wt%. Beryllium is introduced through beryllium bronze CuCo1Ni1Be.

After casting, the experimental castings were subjected to T6 heat treatment. Tempering was carried out at the following parameters: heating for tempering 510-515C°, holding time 6h and 30min. Hardening in water with a temperature of 20ºC. Subsequent artificial aging was carried out at 210ºC – 16h; 250ºC – 12h; 330ºC – 8h.

The method used to study the corrosion behavior of alloys in a 1M solution of H2SO4 consists in determining the mass loss of the test bodies. Before the test, the samples were immersed in ethyl alcohol for 5 min., washed with distilled water, dried and weighed on an analytical Acculab ATILON balance with an accuracy of ± 0.0001g. The samples were then placed in 1M H2SO4 at room temperature. The first measurement is performed after 72 hours, the next after 240 hours, and the maximum period of study is 360 hours. After each test period, the AlSi18Cu3CrMn specimens were brushed under running water, dried and weighed to the nearest ± 0.0001g. For each of the test periods of the samples, in a corrosive environment, the mass loss and the corrosion rate (CR) are calculated using formula (1):

$$CR = (m_1 - m_2)/S \cdot t \ [g/m^2 \cdot h] \qquad (1)$$

where, m1 is the mass of the starting sample in g; m2 is the mass of the specimen after the corrosion test in g; S is the area of the specimen in m2; t is the test time in h.

From the CR values obtained, conclusions are made about the corrosion behavior of the aluminum alloy samples under investigation.

III. RESULTS AND DISCUSSION

The corrosion rate results for the three reporting periods are shown in Table 2 for 72h, Table 3 for 240h and Table 4 for 360h, respectively.

TABLE 2. CR RESULTS AFTER 72 HOURS

Alloy №	Modifier	Artificial aging parameters	CR g/m².h
1	P	210°C/16 h	0,0132
2	P, Ti, B и Be	210°C/16 h	0,0128
3	P	250°C/12 h	0,0147
4	P, Ti, B и Be	250°C/12 h	0,0110
5	P	330°C/8 h	0.0175
6	P, Ti, B и Be	330°C/8 h	0,0130

TABLE 3. CR RESULTS AFTER 240 HOURS

Alloy №	Modifier	Artificial aging parameters	CR g/m².h
1	P	210°C/16 h	0,0126
2	P, Ti, B и Be	210°C/16 h	0,0123
3	P	250°C/12 h	0,0142
4	P, Ti, B и Be	250°C/12 h	0,0110
5	P	330°C/8 h	0,0165
6	P, Ti, B и Be	330°C/8 h	0,0132

TABLE 4. CR RESULTS AFTER 360 HOURS

Alloy №	Modifier	Artificial aging parameters	CR g/m².h
1	P	210°C/16 h	0,0126
2	P, Ti, B и Be	210°C/16 h	0,0124
3	P	250°C/12 h	0,0126
4	P, Ti, B и Be	250°C/12 h	0,0070
5	P	330°C/8 h	0,0135
6	P, Ti, B и Be	330°C/8 h	0,0121

The corrosion rate (CR) of the alloy modified with phosphorus and subjected to T6 heat treatment with different parameters of the artificial aging regime is shown graphically in Fig. 1. From the graph it can be seen that in the first reporting period (72h) the corrosion rate increases by -fast compared to the next two reporting periods. The alloys have the smallest mass loss at the longest reporting period (360h).

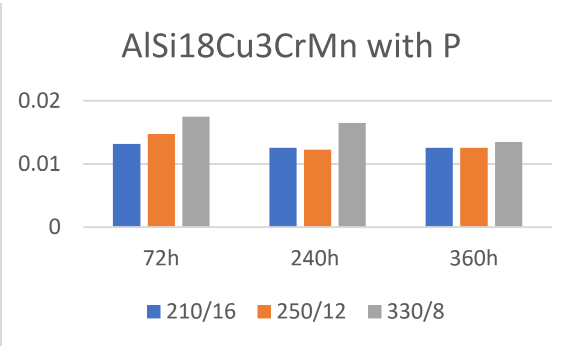

Fig. 1. Corrosion rate of AlSi18Cu3CrMn alloy modified with P

The alloy modified with a complex of modifiers demonstrated a significantly lower corrosion rate in all three reporting periods. The simultaneous introduction of modifiers of the first and second kind positively affects the size of both the primary segregated silicon crystals and the silicon crystals in the composition of the eutectic. In the microstructural analysis of the alloys thus modified, the conditional average size of the crystals of primary separated silicon, as well as that in the composition of the eutectic, was measured and calculated. Measurements show that both the primary separate silicon crystals and those in the eutectic composition are significantly smaller in size than the alloy modified with only standard phosphorus modifier.

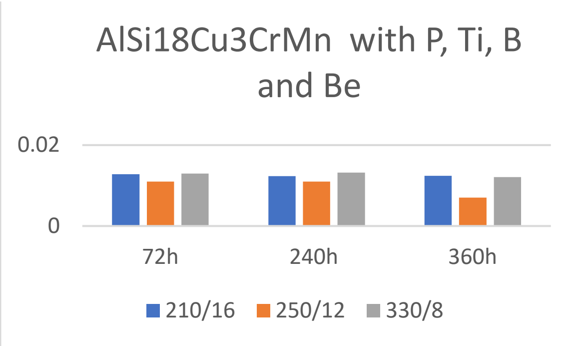

Fig. 2. Corrosion rate of AlSi18Cu3CrMn alloy modified with P, Ti, B, Be

From the graph shown in Figure 3, it can be seen that the mass loss in the first reporting period (72h), after retention in 1M H2SO4, the lowest corrosion rate has alloy #4 (AlSi18Cu3CrMn modified with P,Ti, B, Be – subjected to T6 with aging mode parameters 250˚C/12h). The probable reason for the high corrosion resistance of the alloy is the distribution of strengthening phases of the alloy after quenching and aging. In fig. 6 shows the microstructure of alloy №4.

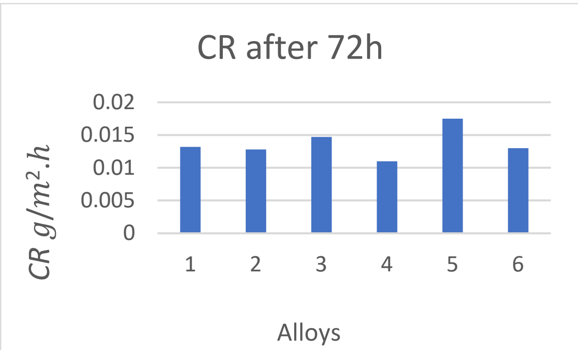

Fig. 3. Corrosion rate of AlSi18Cu3CrMn alloy after 72h stay in H_2SO_4

After 240h (Fig. 4) of the samples staying in 1M H2SO4 again alloy №4 has the lowest corrosion rate of all the investigated alloys. Alloy №5 (AlSi18Cu3CrMn modified with P subjected to T6 with parameters of the aging mode 330˚C/8h) at all reporting periods shows the highest CR. Figure 7 shows the microstructure of the thus modified alloy, which clearly shows larger copper-containing phases located around the primary separated silicon crystals. The likely cause of the high corrosion rate is precisely these coarsely separated phases.

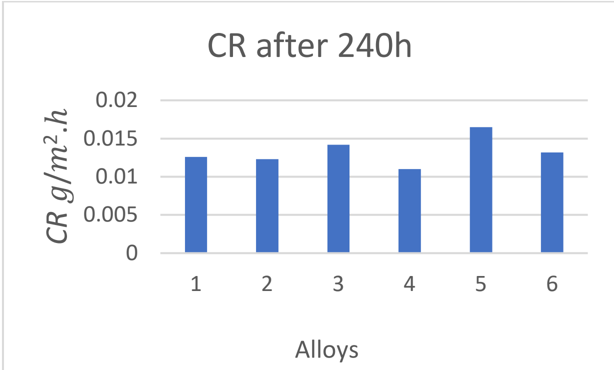

Fig. 4. Corrosion rate of AlSi18Cu3CrMn alloy after 240h stay in H_2SO_4

After 360h, all investigated compositions registered a lower corrosion rate compared to the first two periods of immersion in the solution. The presence of toughening phases, which separate differently after the different heat treatment regimes, explains the different amounts of mass loss in the different quenching and artificial aging regimes. In the alloy modified with P, Ti, B and Be, the silicon crystals in the composition of the eutectic are significantly smaller in size and rounded in shape. The refinement of the silicon crystals in the composition of the eutectic and the change in their shape have a positive effect on the corrosion rate.

Fig. 5. Corrosion rate of AlSi18Cu3CrMn alloy after 360h stay in H_2SO_4.

The observed trend is that after modifying the alloy with 0.04% phosphorus, 0.2% titanium, 0.04% boron and 0.007% beryllium and subjecting it to the T6 heat treatment regime, artificial aging at 210, 250 and 330°C leads to a decrease in the rate of corrosion and increase their corrosion resistance.

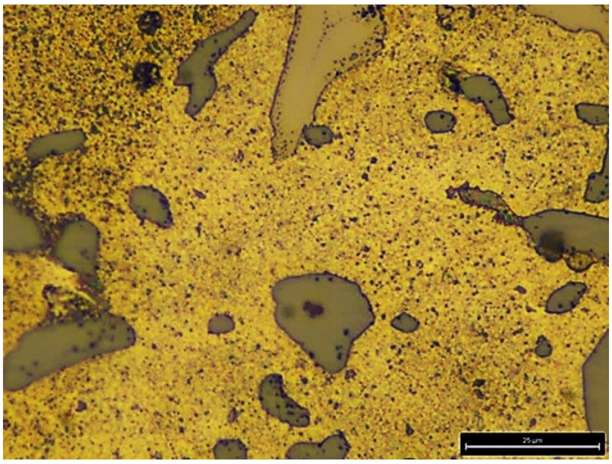

Fig. 6. Microstructure of AlSi18Cu3CrMn alloy (P, Ti, B, and Be) after T6 (250/12h aging mode parameters).

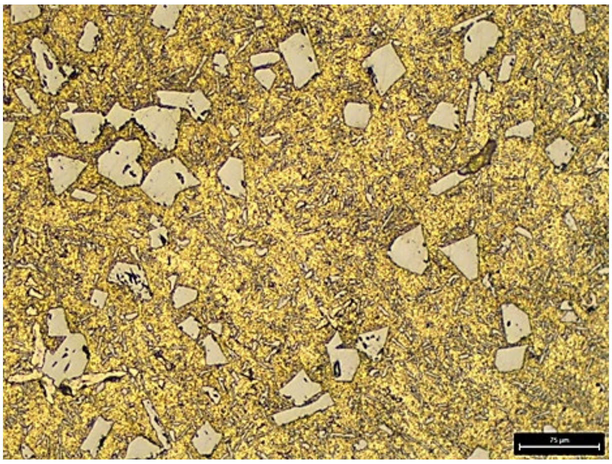

Fig. 7. Microstructure of AlSi18Cu3CrMn (P) alloy after T6 (parameters of aging mode 330/8h).

Characteristic of aluminum alloys is the good corrosion resistance due to the formation of Al_2O_3, studies in this direction show deterioration or improvement of corrosion resistance in relation to the morphology of the microstructure [1-3].

IV. CONCLUSIONS

The complex modifying treatment with modifiers of the first and second kind of the super-detectic complex alloy AlSi18Cu3CrMn has a positive effect on the corrosion resistance of the alloy in 1M H2SO4.

The studied alloy modified with P, Ti, B and Be and subjected to quenching with subsequent artificial aging at 250˚C for 12h demonstrated the lowest corrosion rate for all reported residence periods in 1M H_2SO_4. This is most likely due to the strengthening phases separated after artificial aging along the grain boundaries, preventing the intercrystalline corrosion characteristic of this type of alloy.

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