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Cite as: AIP Conference Proceedings **2449**, 060018 (2022); https://doi.org/10.1063/5.0090753
Published Online: 01 September 2022

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Abstract. This paper presents the results from a study of the corrosion behavior of an aluminum alloy AlSi18Cu3CrMn in acidic media. Corrosion tests by the weight loss method have been performed for different exposure times in 1M HCl and 1M H_2SO_4. The obtained results show that, with respect to the studied corrosion media, the rate of corrosion for the AlSi18Cu3CrMn alloy is higher in 1M H_2SO_4 than it is in 1M HCl.

INTRODUCTION

Hypereutectic aluminum-silicon alloys have found wide application in the automotive industry. Characteristic of this type of alloys is that their structure is a natural composite – there are primary silicon crystals with high micro-hardness in a relatively soft and plastic matrix. This is one of the reasons why they are the preferred material for making pistons for internal combustion engines. In order to improve the mechanical properties, heat resistance and wear resistance of these alloys, they are alloyed with Cu, Ni, Mg, Mn, and some of them with Cr. Phosphorus is most often used to modify the primary silicon crystals in their structure. The introduction of phosphorus into the melt is carried out with the help of the ligature of phosphorus copper - most often CuP10. The alloys are heat treated T6 (hardening and artificial ageing) to achieve hardening. The hardening phases, deposited during the process of artificial ageing, locate at the boundaries of the grains. The presence of a significant amount of θ-phase (CuAl2) at the inter-phase boundaries is a prerequisite for the alloys' corrosion resistance reduction.

Aluminum alloys' corrosion resistance has been the subject of a number of studies [1]. As these alloys are widely spread in a number of technological or natural environments, they are often in contact with aggressive components, causing their destruction. Therefore the study of their corrosion behavior and the search for conditions, under which the lowest metal loss is observed, are of great technological importance.

1M hydrochloric and sulfuric acid solutions are used for pickling the aluminum or for its chemical or electrochemical etching [2-3]. Therefore, the aim of the present work is to study the process of corrosion for the aluminum alloy AlSi18Cu3CrMn both in 1M HCl and 1M H_2SO_4, as well as to determine the corrosion rate, using the mass loss of the studied alloy.

10th International Scientific Conference "TechSys 2021" – Engineering, Technologies and Systems
AIP Conf. Proc. 2449, 060018-1–060018-5; https://doi.org/10.1063/5.0090753
Published by AIP Publishing. 978-0-7354-4397-6/$30.00

EXPERIMENTAL STUDY

In order to obtain complexly alloyed hypereutectic aluminum-silicon alloys, having a complex of properties, satisfying the technological and operational requirements toward them, it is necessary to study the alloy, used as a basis. In [4-5] the influence of the different types of modifiers and combinations of them on the structure, mechanical properties and wear resistance of the two-component hypereutectic aluminum-silicon alloy AlSi18, used as a basis for the studied AlSi18Cu3CrMn alloy, has been discussed.

For the purposes of the present work the two-component aluminum-silicon alloy AlSi18 was alloyed with copper, chromium and manganese. Table 1 shows the chemical composition of the studied alloy.

TABLE 1. Chemical composition of the alloy AlSi18Cu3CrMn, wt.%

Si	**Fe**	**Cu**	**Mn**	**Mg**	**Cr**	**Ni**	**Zn**	**Al**
18,5	0,25	3,1	0,71	0,01	0,9	0,01	0,13	rest

The studied alloy was also modified with phosphorus in a concentration of 0.04 %, as well as with a combination of the modifiers P, Ti, B, Be in the following concentrations - 0.04 % P; 0.2 % Ti; 0.04 % B; 0.007 % Be. Test samples were cast, from which metallographic sections were prepared to study the structure of the alloy. The phosphorus-modified alloy was subjected to T6 heat treatment (hardening and artificial ageing). The process of artificial ageing was conducted at the following operating parameters: temperature 250 ºC and 12 h exposure; temperature 330 ºC and 8 h exposure.

Weight Loss Method

Five types of samples, made of the five modifications of the hypereutectic aluminum-silicon alloy AlSi18Cu3CrMn, with a total surface area of 4.70 cm^2, were used to conduct the corrosion tests: unmodified AlSi18Cu3CrMn alloy; AlSi18Cu3CrMn alloy + 0.04 % P; AlSi18Cu3CrMn alloy + 0.04 % P + 0.2% Ti + 0.04% B + 0.007% Be; T6 heat treated AlSi18Cu3CrMn alloy + 0.04 % P, and artificial ageing was carried out both at 250 °C for 12 h and at 330 °C for 8 h. The used method is related to the weight loss of the studied alloys when exposed to solutions of 1 M HCl and H_2SO_4. Prior to the tests, the samples were immersed in ethyl alcohol for 5 minutes, washed with distilled water, dried and weighed on an Acculab ATILON analytical balance to the nearest of ± 0,0001g. Then they were placed at room temperature in 1M HCl and 1M H_2SO_4, respectively. The first measurement was made at the 72nd hour, and the next ones - every 144 hours with a maximum testing period of 360 hours. After each testing period, the AlSi18Cu3CrMn samples were brushed under running water, dried and weighed. For each testing period the mass loss and the corrosion rate (Km) in the corresponding corrosive medium were calculated, using the formula (1):

$$Km = \frac{(m_1 - m_2)}{S \cdot t} \qquad (1),$$

where m_1 is the initial mass of the sample, g; m_2 is the mass of the sample after the corrosion test, g; S is the area of the sample, m^2; t is exposure time, h.

Based on the obtained Km value, conclusions were made about the corrosion behavior of the samples, made of the studied aluminum alloys.

RESULTS AND DISCUSSION

Weight Loss Method

The obtained data on the corrosion rate of the AlSi18Cu3CrMn alloy both in 1M H_2SO_4 and 1M HCl are presented in Figure 1 and Figure 2. During the first 72 hours of the experimental study, the mass loss was greatest for all samples. They actively dissolved, and the corrosion rate of the AlSi18Cu3CrMn alloy in 1M H_2SO_4 was significantly higher compared to the case when 1M HCl was used. Then, over time, the mass loss of the alloys gradually decreased in both acids.

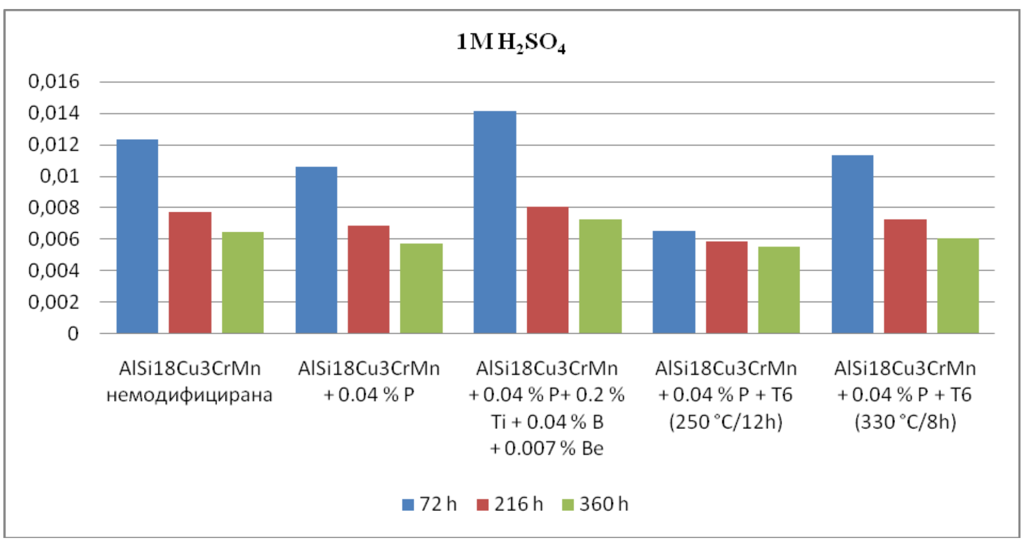

FIGURE 1. Comparison of corrosion rate vs. exposure time graphs for the five alloys AlSi18, immersed in 1M H_2SO_4

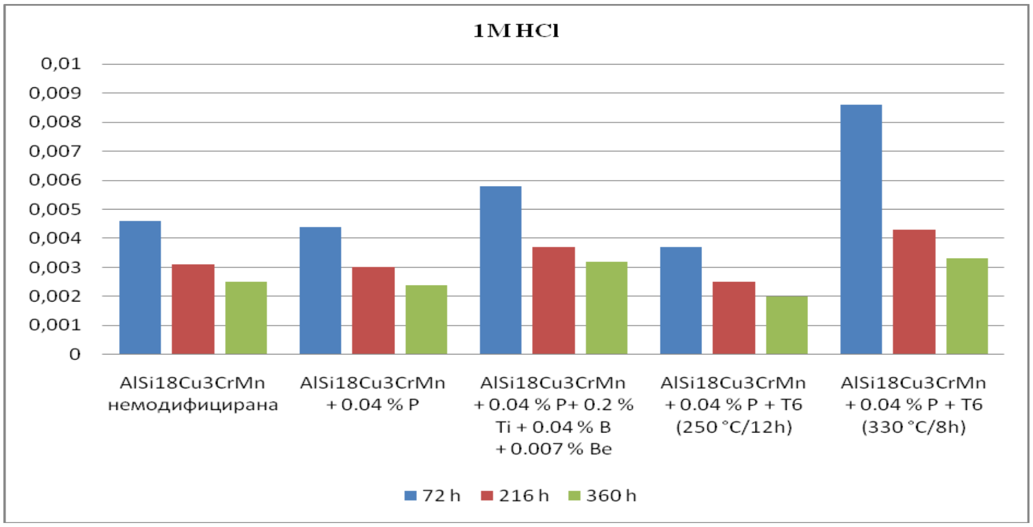

FIGURE 2. Comparison of corrosion rate vs. exposure time graphs for the five alloys AlSi18, immersed in 1M HCl

The probable reason for this is the aggressive action of the chloride ions, attacking the protective oxide layer and gradually destroying it [6]. Their influence is more significant at the beginning of the process and their activity decreases over time. At the end of the testing period, the Km values of the alloys, immersed in 1M HCl, were relatively close.

On the other hand, the sulphate ions in the solution probably passivate the alloy to some extent and the corrosion rate decreases over time [7]. This was more clearly observed after the 216 th hour of the corrosion behavior of the AlSi18Cu3CrMn alloy in 1M H_2SO_4.

In the studied acidic media, the AlSi18Cu3CrMn alloy, subjected to hardening and artificial ageing at 250°C for 12 h, dissolves the slowest. The obtained Km values for the case of immersion in acidic media show that the combination of phosphorus P, titanium Ti, boron B and beryllium Be leads to corrosion acceleration, more pronounced in 1M H_2SO_4.

CONCLUSION

- Unlike the two-component aluminum-silicon alloys, having a lower corrosion rate when the alloys are not modified (primary Si crystals with large size and irregular shape), the situation with the alloyed ones is just opposite – the alloys have a lower corrosion rate when their primary silicon crystals are modified.
- The obtained results show that within the conducted study with two types of acidic media - 1M H_2SO_4 and 1M HCl - the AlSi18Cu3CrMn alloy, hardened and subjected to artificial ageing at 250 °C for 12 h, demonstrates the lowest corrosion rate. This is, most probably, due to the parameters of the artificial ageing mode. When the ageing is carried out at a lower temperature for a longer period of time, the deposited hardening phases are finer and evenly distributed at the grain boundaries. This, in turn, impedes the corrosion processes and leads to lesser weight loss, i.e. to lower corrosion rate.
- When the artificial ageing is conducted at higher temperatures and shorter exposure time, coagulation of the hardening phases is observed, which explains the higher corrosion rate of the AlSi18Cu3CrMn alloy in the studied media.
- By selecting appropriate operating parameters (temperature and exposure time) during the artificial ageing of the hardened hypereutectic aluminum-silicon alloys and obtaining fine-dispersed hardening phases, both the mechanical properties of the alloys and their corrosion resistance improve.

- The combination of phosphorus (P), titanium (Ti), boron (B) and beryllium (Be) accelerates the process of corrosion for the AlSi18Cu3CrMn alloy, immersed in the studied acids, and this is more clearly observed for 1M H_2SO_4. The corrosion rate in this case, however, is not much greater than the corrosion rate of the other studied compositions. The structure of the alloy is well modified and the use of this combination of modifiers is advisable.

ACKNOWLEDGMENTS

The author would like to thank the Research and Development Sector at the Technical University of Sofia for the financial support.

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