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RESEARCH ON CORROSION UNDER TENSION A ALUMINUM ALLOY AlZn5.7MgCu

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ABSTRACT

The paper presents the results of the research on the resistance to stress corrosion on some samples from the alloy. AlZn5.7MgCu which were previously subjected to various thermal and thermomechanical processing.

The gravimetric index or corrosion rate Vcr was used to evaluate the corrosion resistance under tension of the samples investigated in this regard.

KEYWORDS: aluminium alloy, heat treatment, corrosion, stress corrosion

1. Introduction

Aluminium is a very reactive metal, but it is also a passive metal. This contradictory nature is explainable, because it reacts with oxygen or water vapor and forms on the surface a compact and adherent oxide that prevents further reaction of aluminium with oxygen; for this reason, aluminium and most of its alloys have a very good resistance to corrosion [1-3].

Identifying the types of corrosion to which aluminium alloys are subject, as well as the way to achieve corrosion, are necessary to more easily find a solution to limit or eliminate this unwanted phenomenon.

The types of corrosion to which aluminium and its alloys are exposed are [3]: atmospheric corrosion, galvanic corrosion; corrosion in points (pitting); crevice corrosion; intercrystalline corrosion; exfoliation corrosion; fatigue corrosion; filiform corrosion; microbiological corrosion; stress corrosion.

Stress corrosion occurs if three conditions are met simultaneously [4]:

- the alloy should be sensitive to corrosion;
- the existence of a wet environment or water;
- the presence of a tensile stress, which will open the crack(s) and allow it(s) to propagate.

The corrosion resistance of Al-Zn-Mg alloys is comparable to that of Al-Mg-Si alloys, but when subjected to stresses, this property is greatly diminished. The formation of corrosion-sensitive zones at the weld boundaries is a general phenomenon in these alloys, regardless of whether they are rich or poor in zinc and magnesium [1, 4].

Aluminium alloys with a solid solution structure possess, due to their structural homogeneity, a good resistance to corrosion. Due to the fact that the precipitated phases during the aging and recovery of supersaturated solid solutions have a different structure and chemical composition from the base mass, they become sites with abnormal electrochemical activity as a result of different dissolution potentials. If the precipitate particle is anodic, it tends to dissolve in the presence of the electrolyte; if it is cathodic it is protected against corrosion, instead it will dissolve the base mass around it [5, 6].

Aluminium alloys from the Al-Zn-Mg-Cu system, both in cast and deformed state, due to the contents of Zn, Mg and Cu acquire very good mechanical properties following thermal and especially thermomechanical treatments.

Alloys of the Al-Zn system that do not contain Cu have a higher corrosion resistance than alloys of the same system, but that contain Cu.

Aluminium alloys that contain appreciable amounts of alloying elements soluble in aluminium, primarily copper, magnesium, silicon and zinc, are prone to stress corrosion.

Stress corrosion can occur in two ways [7]:

- corrosion under intergranular tension, which is the most common form;
- corrosion under transgranular stress.

Always corrosion under load was initiated by pitting corrosion and continued by intergranular attack at the grain boundary and then transgranular attack [8].

In the case of intergranular corrosion, the crack follows the grain boundaries. In transgranular stress

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corrosion, cracks appear by sectioning the grains [8], [9].

Stress corrosion represents the destruction of a metal or alloy that is subjected to the combined action of a corrosive environment and a static mechanical stress (elongation). It manifests itself through intercrystalline or transcrystalline cracks or even by breaking the part.

Stress corrosion cracking occurs when the stress value is close to the yield point, but it can also occur at lower stresses [8].

There are numerous chemical agents capable of causing stress corrosion but, in principle, chloride solutions are the most dangerous.

2. Experimental research

The investigation of the stress corrosion behavior of the studied alloy was carried out on samples that were previously subjected to various thermal and thermomechanical treatments according to Table 1.

Table 1. *The thermal / thermomechanical processing regime of the samples subjected to the stress corrosion test*

Proof coding	Thermal / thermomechanical processing regime
1	O + DPC + CPS + ÎN
2	O + DPC + CPS + ÎA
3	O + DPC + CPS + ÎA + DPR (ε = 10%) + ÎA
4	O + DPC + CPS + ÎA + DPR (ε = 20%) + ÎA
5	O + DPC + CPS + ÎA + DPR (ε = 30%) + ÎA

O – homogenization, CPS – solution hardening, ÎN – natural ageing
ÎA – artificial aging, DPC – hot plastic deformation,
DPR – cold plastic deformation with various degrees of deformation ε.

The tested samples have the dimensions of 60 x 30 x 3 mm and have the chemical composition presented in Table 2. The mechanical tension to which the samples were subjected (520N) resulted from the strength calculation. The test time was 20 days (480 hours) for each sample. The samples were weighed before corrosion, and after the corrosion test, they were weighed after carefully removing the corrosion products from their surface.

Table 2. *Chemical composition of the samples subjected to research*

Element / Alloy	Zn	Mg	Cu	Si	Fe	Pb	Cr	Mn	Al
AlZn5.7MgCu	5.76	2.61	1.55	0.15	0.19	0.021	0.19	0.10	rest

Test equipment and solution. Aluminium and aluminium alloys oxidize spontaneously, but in the presence of water molecules they form a hydrated oxide according to the reaction:

$$2Al + 6H_2O \rightarrow Al_2O_3\ 3H_2O + 3H_2$$

which can be dehydrated very easily by chlorine or sulphate ions, increasing the susceptibility to pitting corrosion.

The corrosive medium used in the experiments was a sodium chloride solution with a concentration of 3.5% NaCl.

Figure 1 shows the installation on which the stress corrosion tests were performed and which represents an original laboratory equipment designed and made based on resistance calculations.

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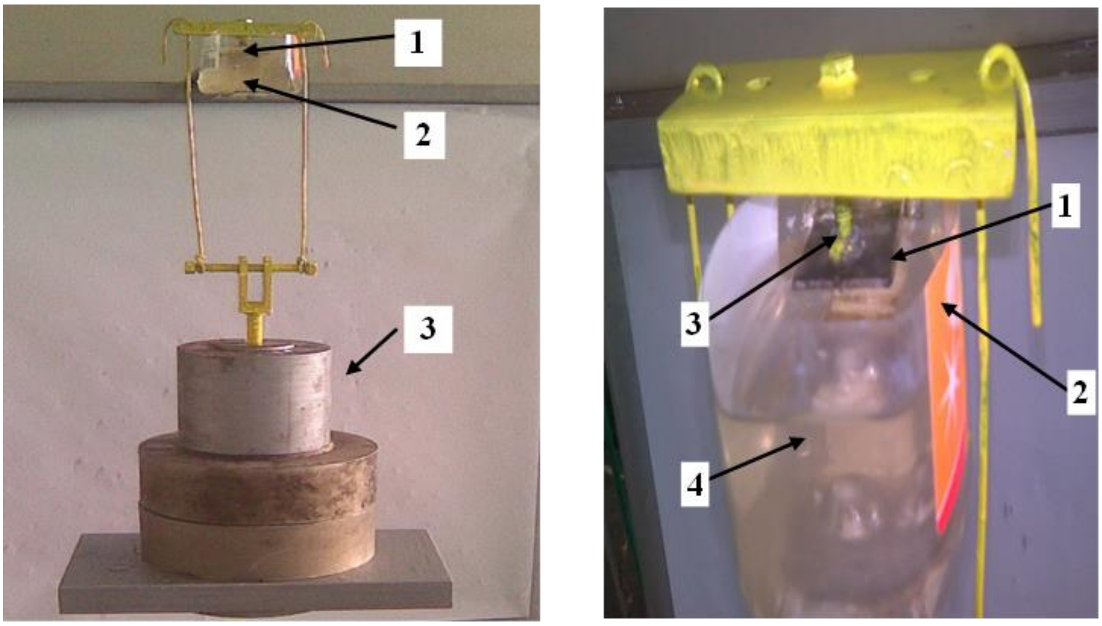

a b

Fig. 1. *a - The installation for testing the corrosion resistance under tension of the studied aluminium alloys: 1 - sample subject to corrosion; 2 - the container with the corrosion medium; 3 - mechanical voltage source. b - Detail image with the sample under tension in the corrosive environment: 1 - Al alloy sample; 2 - the container with the corrosive medium, 3.5% NaCl solution; 3 - the point of application of the force that generates the mechanical tension; 4 - the corrosive solution*

3. Results of experimental research

To assess the corrosion resistance of the samples that were subjected to the stress corrosion test, the gravimetric index or corrosion rate V_{cr} was used, which is calculated with the formula [4]:

$$V_{cr} = \frac{m_1 - m_2}{S \cdot t}, [g/m^2 h]$$

where: m_1 represents the mass of the sample before being subjected to corrosion, [g]; m_2 - is the mass of the corroded sample, [g]; S - the surface of the sample, [m²]; t - the time in which corrosion has occurred, [h]. The data resulting from the calculations are given in Table 3.

Table 3. *Results obtained for the gravimetric index (corrosion rate V_{cr}) in the case of the samples subjected to the stress corrosion test*

Proof coding	m_1 [g]	m_2 [g]	Δm [g]	S [m²]	Time [hours]	V_{cr} [g/m²·h]	Observation
1	15	14.978	0.022	0.0027	480	0.0169	resistant
2	15	14.986	0.014	0.0027	480	0.0108	resistant
3	15	14.977	0.023	0.0027	480	0.0177	resistant
4	15	14.956	0.044	0.0027	480	0.0339	resistant
5	15	14.927	0.073	0.0027	480	0.0563	resistant

The values of the gravimetric index (corrosion rate) indicate that all samples subjected to the stress corrosion test fall into the corrosion resistance group as being corrosion resistant, for which V_{cr}. is between the values of 0.01 and 0.1 g/ m² h.

Among all the samples subjected to the stress corrosion test, the samples coded with number 5, with the degree of deformation of 30%, recorded the highest mass loss, but even these samples can be classified as resistant to corrosion.

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3.1. Macrostructural aspects of the surface of samples subjected to stress corrosion

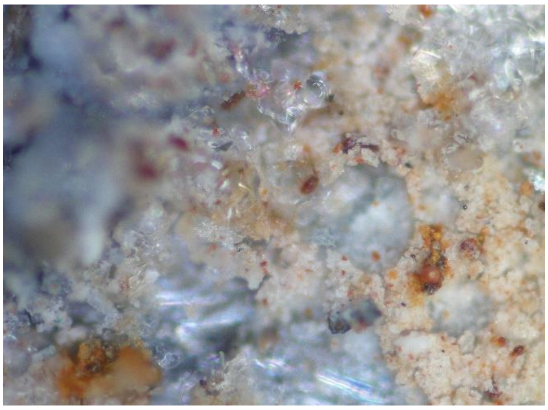

Fig. 2. *Sample 5 - Area near the place of maximum effort, Magnification: 400X*

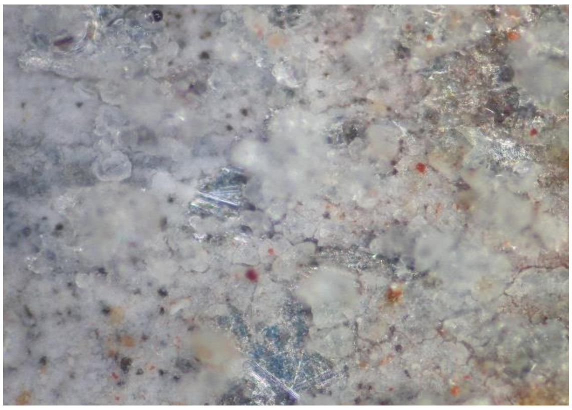

Fig. 3. *Sample 5 - Area near the force application point, Magnification: 400X*

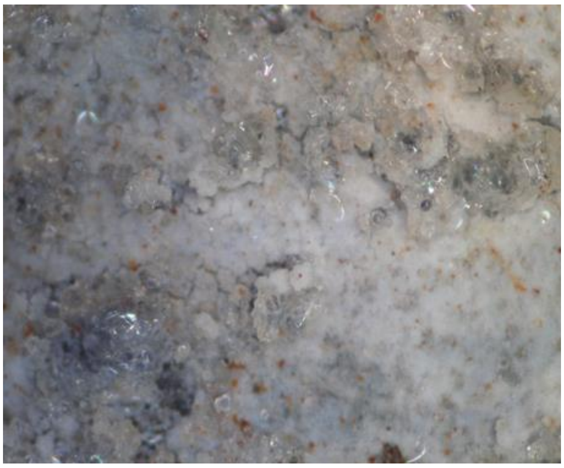

Fig. 4. *Sample 5. - Macro view of the stretched surface, Magnification: 100X*

Fig. 5. *Sample 5 - Macro aspect of the surface subjected to compression, Magnification: 100X*

4. Conclusions

The analysis of the surface of the corroded samples illustrates the point corrosion of the samples, as well as the exfoliation of the material, but without cracks or its breaking.

The amount of corrosion products decreases with the distance from the embedded area and the approach to the point of force application.

All the corrosion tests carried out in the work indicate that, near the place where the sample is embedded, i.e. in the place where the stretching effort was greater, the corrosion is more intense (expressed by the increase in the amount of corrosion products).

On an area equidistant from the end of the embedded sample, the amount of corrosion products is lower on the surface subjected to compression than on the surface subjected to tension.

Corrosion tests performed on samples 4 and 5 which were processed with a higher degree of plastic deformation, show a greater mass loss of the material, therefore a lower corrosion resistance.

Following the calculations of the corrosion rate V_{cr}, it can be stated that all samples subjected to this stress corrosion test can be rated as resistant.

For the alloys intended for the construction of airplanes with a low flight height, it is necessary to have a good resistance to corrosion because, due to the low flight height, they frequently come into contact with the humid atmosphere which negatively influences the phenomenon of corrosion by stress cracking.

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