

THE STUDY OF CORROSION BEHAVIOUR OF AL ALLOY WITH PURE AL ON THE SURFACE

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Abstract: The paper deals with the corrosion research of wrought aluminium alloy (AlCu4Mg1) coated by 99.5% aluminium. As the corrosive medium the neutral salt spray of 5% NaCl aqueous solution was used. The times of exposition were up to 1000 hours. The weight losses were measured and calculated in g/m^2 and $mm/year$. Depth of corrosion attack was observed at light optical microscope and scanning electron microscope.

Key words: Aluminium, Al Alloy, Corrosion, Coating

1. INTRODUCTION

Aluminium and its alloys are attractive in many technological applications due to its characteristics such as light weight, durability and good corrosion resistance (Abd El Rehim et al., 2004). Frequent uses of these materials are in the automotive and aerospace industry (Ghali, 2010).

However, untreated aluminium alloys based on Al-Mg-Cu are susceptible to corrosion in aggressive atmosphere like NaCl aqueous solution. This is main reason for using protective coatings (Domínguez-Crespo et al., 2009).

2. EXPERIMENTAL MATERIAL

The AlCu4Mg1 wrought aluminium alloy with 99.5% Al coating was used in the present study. The material was received as a sheet with dimensions of 100 x 150 x 1 mm. Fig. 1 shows original microstructure of experimental material. The grains and surface coating were revealed by etching using a FUSS solution (7.5 ml HF, 8 ml HNO₃, 25 ml HCl and 1000 ml H₂O). The chemical composition of pure Al on the surface and substrate under this coating was measured by glow discharge optical emission spectroscopy (GDOES) using Spectrumat GDS-750 device (see Tab. 1). The same device was used for measuring of concentration profiles of elements with depth; (Fig. 2.)

	Si	Fe	Cu	Mn	Mg	Zn	Ti
Surface	0.12	0.20	0.01	0.00	0.01	0.02	0.02
Substrate	0.19	0.21	4.40	0.44	1.69	0.03	0.04

Tab. 1. The chemical composition of pure Al on the surface and the main alloying elements of AlCu4Mg1 alloy in substrate

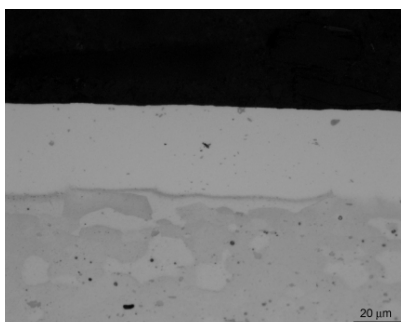


Fig. 1. Microstructure of the AlCu4Mg1 with coat of 99.5% Al

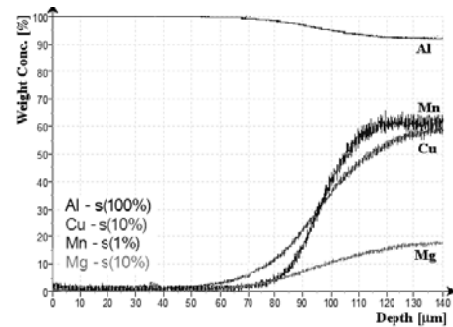


Fig. 2. Concentration profiles of AlCu4Mg1 with coat of 99.5% Al as measured by GDOES

3. EXPERIMENTAL PROCEDURE

The corrosion test chamber Angelantoni DCTC 600 P machine was used for salt spray tests (according to ISO 9227, 2007). The experiments were carried out with increasing exposition time of 48, 96, 240, 480, 720 and 1000 hours. Final cleaning of the specimens after exposition was carried out by dipping in a solution of CrO₃ + H₃PO₄ + H₂O; according to Czech standard (ČSN 03 8452, 1989). The weight loss was measured at analytical balances ($d = 0.1$ mg) after each experiment and calculated in g/m^2 and $mm/year$.

4. RESULTS

The weight losses and corrosion rate of experimental material as a function of time exposure are presented in Fig. 3. Metallographic evaluation was performed according to applicable standard (ČSN 03 8137, 1990). The corrosion attack after 96, 480 and 1000 hours of exposition observed by light microscope on metallographic cross-section cuts shows Fig. 4.

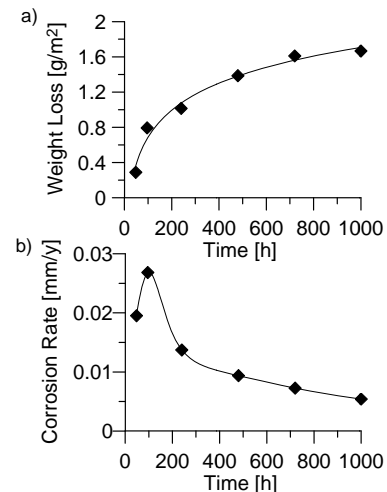


Fig. 3. (a) Weight losses and (b) corrosion rate of AlCu4Mg1 with coat of 99.5% Al as a function of exposure time in corrosion chamber

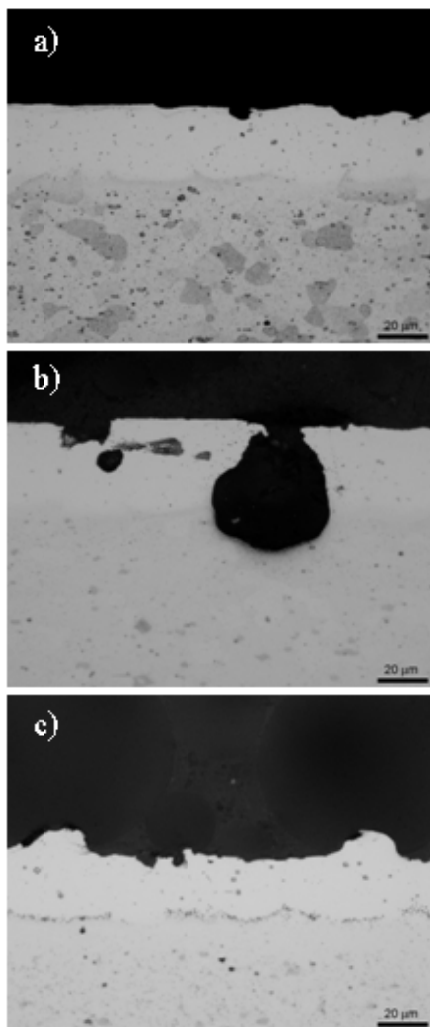


Fig. 4. Surface profile of specimens after exposure a) 96, b) 480 and c) 1000 hours of exposition, observation by light microscope, FUSS

The microstructure of this material after 96 hours of exposition obtained by scanning electron microscopy PHILIPS XL-30 device is shown in Fig. 5. The local chemical analysis found out that the phase 1 is based on Al-Fe-Si and inclusions 2 and 3 contain Al-Cu-Fe-Mn and Al-Cu-Mg, respectively.

Coating thickness and depth of corrosion attack were detected by PC software Olympus Analysis 5. The results of measuring the depth of corrosion attack are presented in Tab. 2.

Exposure time [h]	48	96	240	480	1000
Average depth [μm]	2.01	2.11	4.30	8.30	14.75

Tab. 2. Average depth of corrosion attack after exposition

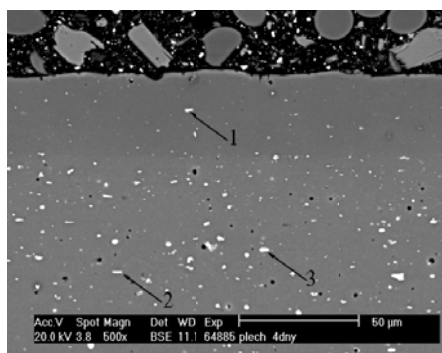


Fig. 5. The SEM cross-sectional image of Al alloy with coat of 99.5% after 96 hours of exposition

5. DISCUSSION

The wrought aluminium alloy with pure aluminium on the surface was studied. The samples shaped as a sheet were used for testing in neutral salt spray test. The thickness of Aluminium coating detected by image software was $41 \mu\text{m}$ before exposition. The diffusive smooth transition to core material in this depth beneath surface is distinct in Fig. 2. The local chemical analysis by EDX found out that the experimental material contained isolated phases based on Al-Fe-Si in the surface coating. There were oval-shaped inclusions contain Al-Cu-Mg and angular inclusions based on Al-Cu-Fe-Mn.

Fig. 3 shows weight losses and corrosion rate as a function of exposure time. It is clear that weight losses are increasing with longer times. The dependence of corrosion rate on exposure time shows the greatest decrease between 96 and 240 hours, and further progress was only slightly decreasing.

Metallographic evaluation was carried out on cross-section cuts. Fig. 4a shows corrosion pitting with average depth $2.11 \mu\text{m}$. After times longer than 240 hours pitting was observed to be deeper than thickness of Al coating (see Fig. 4b). On the samples after exposition 1000 hours the places attacked by uniform corrosion were clearly visible (see Fig. 4c). However, this appearance can be caused by lateral joining of multiple pitting defects. Thickness of the coating on these samples was determined $28.30 \mu\text{m}$.

6. CONCLUSIONS

The AlCu4Mg1 aluminium alloy with 99.5% Al coating was used for salt spray tests in 5% NaCl aqueous solution with neutral pH. The dependence of corrosion rate on exposure time shows the greatest decrease between 96 and 240 hours but further progress was only slightly decreasing. Metallographic evaluation of corrosion attack identified corrosion pitting after every time of exposition. The average depth of this damage was deeper with longer times. In addition the uniform corrosion was found on the samples after 1000 hours exposition in the corrosion test chamber.

7. ACKNOWLEDGEMENTS

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