CORROSION RESISTANCE OF ALUMINIUM ALLOY IN THE AQUEOUS SOLUTION OF UREA

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Abstract: This paper deals with corrosion behaviour of the AlCu4Mg1 wrought aluminium alloy with 99.5% Al coating on the surface. Corrosion tests were performed as a modified OECD technique in two different kind of corrosion environment (aqueous solution inclusive 0.1 mol of urea and solution inclusive 0.1 mol of NaCl dissolved in the water). The main goal of this work was assessed the influence of urea at aluminium alloy in the aqueous solutions.
Key words: corrosion process, aluminium, urea, OECD

1. INTRODUCTION

Frequent uses of aluminium alloys are in the automotive and aerospace industry. However, untreated aluminium alloys based on Al-Mg-Cu are susceptible to corrosion in aggressive atmospheres (Fontana, 1978; Ghali, 2010).

The resistance of Al against corrosion in aqueous media can be attributed to a rapidly formed surface oxide film, which is composed mainly of Al_2O_3, $Al(OH)_3$ and $AlO(OH)$ phases. Nevertheless, the presence of aggressive ions like chlorides causes significant attack (Mishra & Balasubramaniam, 2007). The main corrosion process that is developed on the surface of Al alloys in a NaCl solution is the localized alkaline corrosion in the Al matrix surrounding Al(Mn, Fe, Cr) cathodic intermetallics (Szklarska-Smialowska, 1999).

2. EXPERIMENTAL MATERIAL

As experimental material the AlCu4Mg1 wrought aluminium alloy with 99.5% Al coating was used. The material was received as a sheet with dimensions 30 x 50 x 1 mm. 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).

3. EXPERIMENTAL PROCEDURE

Corrosion tests were performed as a modified OECD technique. The samples were placed into the small testing cells for provision no interaction of the samples. There were 30 ml of corrosion solution on the bottom of each cell and the samples were hung up above the surface. Testing mode was cyclical (8 hrs 35°C, 16 hrs 23°C – 1 cycle). The experiments were carried out with increasing exposition time (1, 5, 10, 20, 31 and 42 cycles).

Two different kind of corrosion environment were tested. One of them was the aqueous solution inclusive 0.1 mol of urea and the second type was solution inclusive 0.1 mol of NaCl dissolved in the water.

Final cleaning of the specimens after exposition was carried out by dipping in a solution of $CrO_3 + H_3PO_4 + H_2O$; according to Czech standard (ČSN ISO 8407, 1995). The weight loss was measured at analytical balances ($d = 0.1$ mg) after each experiment.

	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

4. RESULTS

After experimental cycles the weight losses were evaluated and the statistic analysis was performed. First the Dixon test of extreme deviations with evaluation of maximal and minimal values was performed. Subsequently, the weight losses [mg.dm^{-2}] and corrosion rate [g.m^{-2}d^{-1}] were calculated from the measured values. This data were fitted with optimal functions.

The weight losses of experimental material for system of aqueous solution inclusive 0.1 mol of urea as a function of time exposure are presented in Fig. 1a). The best fit for relationship of weight losses – time corresponds to function A.x^B, where A = 0.319; B = 0.391; correlation coefficient R = 0.708.

Fig. 1b) shows the dependence of corrosion rate on time of exposure in accordance with function A.x^B, where A = 0.031, B = -0.528; correlation coefficient R = -0.788.
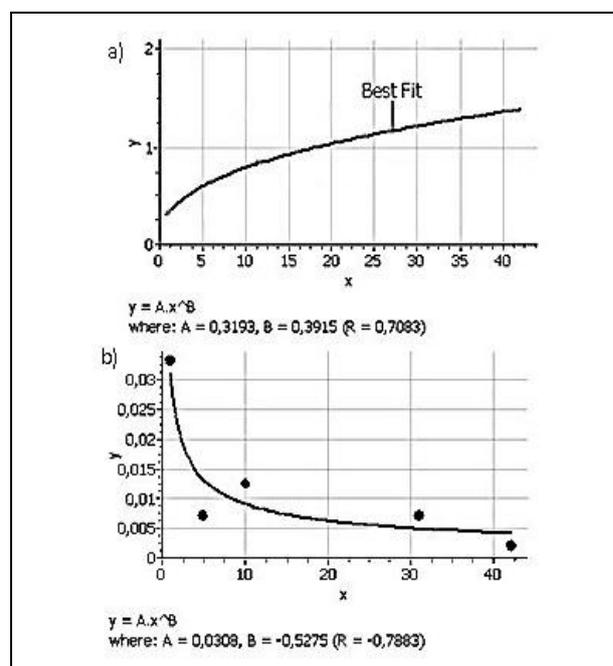

Fig. 1. The time dependence a) of weight losses of experimental material in the aqueous solution of urea (x – time in days, y – weight losses in mg.dm^{-2}); b) of corrosion rate of experimental material in the aqueous solution of urea (x – time in days, y – corrosion rate in g.m^{-2}d^{-1})

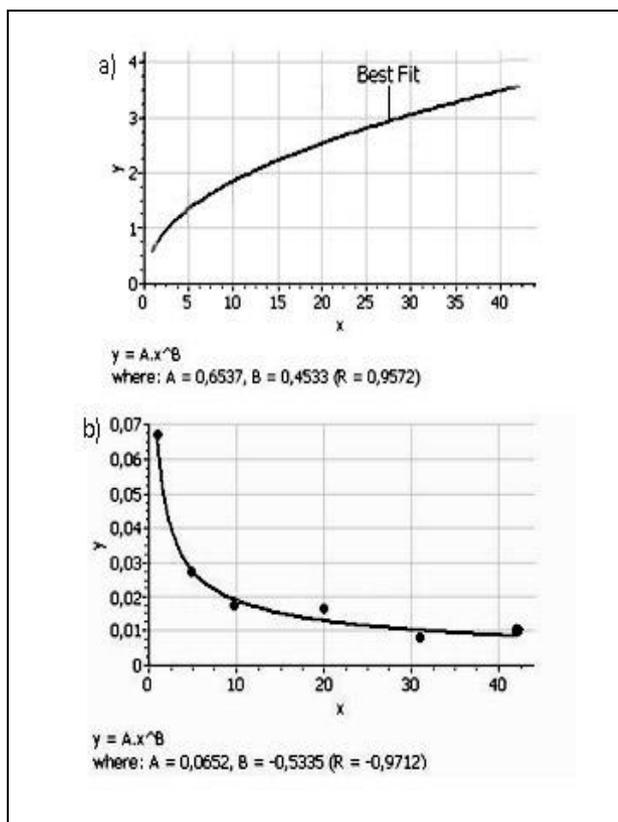Fig. 2.The time relationship in the aqueous solution of NaCl a) of weight losses (x – time in days, y –weight losses in mg.dm^{-2}); b) of corrosion rate (x – time in days, y – corrosion rate in g.m^{-2}d^{-1})

The relationship between time of exposure and weight losses of experimental material for system of aqueous solution inclusive 0.1 mol of NaCl is presented in Fig. 2a). The best fit for measured data of weight losses versus time of exposure are corresponding to the function A.x^B, where A = 0.654; B = 0.453; correlation coefficient R = 0.957.

The dependence of corrosion rate on time of exposure in accordance with function A.x^B, where A = 0.065, B = -0.534; correlation coefficient R = -0.971 is shown in Fig. 2b).

5. DISCUSION

The results of corrosion weight losses and corrosion rate for aluminium sheet (AlCu4Mg1 with pure Al on the surface) in two different corrosion environment (aqueous solution inclusive 0.1 mol of urea and solution inclusive 0.1 mol of NaCl dissolved in the water) are presented in this work.

The experimental technique was chosen in accordance with known experience that any particular relationship between resistance against salt fog and resistance against corrosion in other environments don´t exist. Therefore, the results of corrosion test don´t consider direct information about corrosion resistance in the particular environment. Consequently, the main goal of this work wasn´t testing of corrosion resistance in different environment but the influence of urea was assessed. As well, the effect of crypto-climatic conditions was ascertained.

Environment	[g.m^{-2}d^{-1}]	[μm/y]
Water + 0.1 mol of urea	0.033	3.26
Water + 0.1 mol of NaCl	0.067	6.61

Tab. 2.The corrosion rate after 1 day exposition and calculation of corrosion rate in μm per year

The results for aqueous solution of NaCl can be considered as expected. Therefore, the attention was focused on the issue of occurrence of the urea.

Three cases were considered:
- the urea will be distinguished on inhibitive effect, which is known for ferrous metal in aqueous solution,
- the urea will additive even synergically stimulate corrosion process of aluminium alloys in solutions inclusive chloride ions at elevated temperatures,
- the urea won´t significantly affected the character of corrosion process of aluminium alloy.

In first approach, it was estimate that the influence of urea wasn´t in this system the most significant. The results show that kinetics of corrosion process in the initial period was crucial and during longer times of exposure was observed relative stabilization of corrosion rate. It can be assume that the passivation of the surface of aluminium alloys was significantly applied and partially disrupted by stimulative effect of chloride ions.

Calculated values for initial period are presented in Tab. 2. The values after first days of exposition ware considered like the most dangerous. For initial period the confidence interval at 90% probability was determined: 4.65 μm/y ≤ corrosion rate ≤ 11.79 μm/y.

6. CONCLUSIONS

The cyclic corrosion tests were performed for laboratory testing of aluminium alloy. The results of this work confirm already known data about low corrosion resistance of aluminium alloys in aqueous solution with chloride ions. Nevertheless, the verification of the urea effect can be considered as contributing for other research (i.e. corrosion test of AlCu4Mg1 in the aqueous solution inclusive 0.07 mol of urea + 0.03 mol of NaCl).

The significant technical differences of corrosion process weren´t observed in system aluminium alloy/aqueous solution of urea. The inhibitive effect of urea (known for ferrous metal in the aqueous solution) hasn´t been confirmed. Even, any stimulative effect of urea on corrosion process of aluminium alloys wasn´t found out. For initial period the 90% probability that tested systems can be considered identical with expected non-uniform type of corrosion 10 μm/y exists.

7. ACKNOWLEDGEMENTS

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