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CORROSION POTENTIALS OF THE ALUMINUM ALLOYS

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Aluminum alloys has many industrial applications, based on excellent corrosion properties of these alloys [1÷4]. This paper aims consist first on identifying of the corrosion potential of all classes of aluminum alloys, ie all 2xxx ÷ 7xxx series, performed in accordance with ASTM G69 and PO- 042, and secondly on achieving correlations between the aluminum alloys state and corrosion potential value. Samples were prepared in accordance with PO-043, with clear delineation of the areas subject to electrochemical corrosion. Electrochemical investigations were conducted on a potentiostat type ATLAS 0531. The conclusions drawn from experiments allow a hierarchy of electrochemical corrosion resistance of aluminum alloys depending on chemical composition and state condition.

Keywords: 2xxx- 7xxx series aluminum alloys, corrosion resistance, corrosion potential

1. Introduction

Aluminum is actually a very active metal, meaning that its nature is to oxidize very quickly. While a weakness for most metals, this quality is actually the key to its ability to resist corrosion. When oxygen is present (in the air, soil, or water), aluminum instantly reacts to form aluminum oxide. This aluminum oxide layer is chemically bound to the surface, and it seals the core aluminum from any further reaction. Aluminum alloys has many industrial applications, based on excellent corrosion properties of these alloys [1÷9]. This paper aims consist first on identifying of the corrosion potential of all classes of aluminum alloys, ie all 2xxx ÷ 7xxx series, performed in accordance with ASTM G69 and PO- 042, and secondly on achieving structural correlations between the aluminum alloys state and corrosion potential value.

2. Materials and Experimental Procedures

The alloys that were tested under corrosion are part of all commercial aluminum alloys, respectively 2xxx ÷ 7xxx series, made by SC ALRO SLATINA.

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The equipment used for structural investigations were: CUTO 20 cutting machine, SIMPLIMET 1000 mounting press machine, PHOENIX 4000 grinding machine, metallographic BX60M Olympus microscope, equipment for measuring of corrosion potential type ATLAS 0531. The sample were prepared according to PO-043 and were analyzed according to ASTM G69 and PO-042 internal procedure. Standard ASTM G69 is referred only to alloy 3003 and indicate that a sample which correspond to it should have a value of -751 +/- 20mV. The only data specified in the standard ASTM G69 regarding the corrosion potential values are shown in Table 1.

Table 1.

The corrosion potential values for different aluminum alloys

Alloy / State	1100 - H18	3003 - H18	5052 -H32 (MECH)	5052 -H32 (CHEM)	2024-T3	7075-T6
Corrosion potential, [mV]	759,2	750,7	756,5	738,4	605,6	725,2

The chemical composition of the experimental aluminum alloys is illustrated in table 2.

Table 2

Chemical composition of aluminum alloys used in experimental corrosion tests

Alloy	State	Lot	Charge	Chemical composition, %gr.													
				Cu	Fe	Si	Mn	Mg	Zn	Ni	Cr	Ti	V	Ca	Na	Ga	Zr
1350	H24	42568	S15090946	0.005	0.3	0.06	0.002	0.005	0.004	0.007	0.003	0.006	0.021	0.0002	0.0002	0.007	0.001
2014	T651	42539	S26015008	4.4167	0.2633	1	0.98	0.6733	0.062	0.009	0.06	0.058	0.017	0.0005	0.0002	0.009	0.001
2014	T651	42539	S26015008	4.4167	0.2633	1	0.98	0.6733	0.062	0.009	0.06	0.058	0.017	0.0005	0.0002	0.009	0.001
2017	T451	42666	S26015004	4.1	0.4033	0.5733	0.68	0.7733	0.11	0.011	0.085	0.04	0.017	0.0006	0.0002	0.009	0.0015
2017	T451	42666	S26015004	4.1	0.4033	0.5733	0.68	0.7733	0.11	0.011	0.085	0.04	0.017	0.0006	0.0002	0.009	0.0015
2024	O	43111	S25070653	4.5333	0.14	0.065	0.53	1.35	0.04	0.007	0.003	0.016	0.019	0.0003	0.0001	0.009	0.001
3003	H111	41509	S15070724	0.095	0.43	0.1967	1.2333	0.012	0.007	0.007	0.007	0.006	0.023	0.0002	0.0005	0.009	0.001
3003	H111	41509	S15070724	0.095	0.43	0.1967	1.2333	0.012	0.007	0.007	0.007	0.006	0.023	0.0002	0.0005	0.009	0.001
3003	H14	44321	S15121282	0.08	0.37	0.26	1.1333	0.002	0.007	0.005	0.003	0.017	0.021	0.0002	0.0004	0.009	0.001
5052	H22	43582	S35100941	0.012	0.23	0.07	0.029	2.2667	0.005	0.006	0.17	0.026	0.018	0.0007	0.0002	0.008	0.001
5754	H111	42606	S35090901	0.09	0.2333	0.26	0.15	2.9333	0.053	0.007	0.043	0.012	0.019	0.0021	0.0003	0.008	0.001
5083	H321	42557	S25111080	0.085	0.4067	0.33	0.5	4.5167	0.1	0.011	0.09	0.032	0.019	0.0014	0.0001	0.019	0.001
5083	H321	42557	S25111080	0.085	0.4067	0.33	0.5	4.5167	0.1	0.011	0.09	0.032	0.019	0.0014	0.0001	0.019	0.001
5083	O	43070	S25090857	0.02	0.22	0.06	0.58	4.7667	0.045	0.006	0.11	0.016	0.017	0.0007	0.0002	0.008	0.001
5083	O	43070	S25090857	0.02	0.22	0.06	0.58	4.7667	0.045	0.006	0.11	0.016	0.017	0.0007	0.0002	0.008	0.001
5083	H111	42881	S25121142	0.07	0.2867	0.25	0.22	2.9833	0.085	0.009	0.036	0.012	0.018	0.0006	0.0002	0.009	0.001
5083	H111	42881	S25121142	0.07	0.2867	0.25	0.22	2.9833	0.085	0.009	0.036	0.012	0.018	0.0006	0.0002	0.009	0.001
6061	T651	42834	S35111096	0.33	0.4	0.8	0.14	0.9533	0.065	0.013	0.18	0.018	0.022	0.001	0.0004	0.009	0.001
6061	T651	42834	S35111096	0.33	0.4	0.8	0.14	0.9533	0.065	0.013	0.18	0.018	0.022	0.001	0.0004	0.009	0.001
6061	T6	43528	S35121121	0.3	0.3633	0.8	0.025	1	0.02	0.008	0.15	0.009	0.02	0.0004	0.0003	0.008	0.001
6061	T6	43528	S35121121	0.3	0.3633	0.8	0.025	1	0.02	0.008	0.15	0.009	0.02	0.0004	0.0003	0.008	0.001
6063	O	42523	S35060545	0.015	0.2233	0.5067	0.045	0.76	0.012	0.006	0.005	0.015	0.021	0.001	0.0004	0.009	0.001
6082	T651	43727	S15121190	0.05	0.2633	1.0667	0.74	0.8767	0.022	0.008	0.18	0.015	0.023	0.0009	0.0008	0.009	0.001
6082	T651	43727	S15121190	0.05	0.2633	1.0667	0.74	0.8767	0.022	0.008	0.18	0.015	0.023	0.0009	0.0008	0.009	0.001
6082	T6	42525	S35121139	0.075	0.3333	1.0667	0.7	0.8533	0.055	0.023	0.17	0.012	0.021	0.0015	0.0003	0.009	0.001
6082	T6	42525	S35121139	0.075	0.3333	1.0667	0.7	0.8533	0.055	0.023	0.17	0.012	0.021	0.0015	0.0003	0.009	0.001
7020	T651	41886	S25100994	0.03	0.13	0.069	0.15	1.2333	4.8	0.005	0.18	0.029	0.021	0.0006	0.0001	0.007	0.084
7020	T651	41886	S25100994	0.03	0.13	0.069	0.15	1.2333	4.8	0.005	0.18	0.029	0.021	0.0006	0.0001	0.007	0.084
7022	T651	43275	S25111069	0.8	0.17	0.1467	0.23	3.1667	4.8167	0.006	0.18	0.033	0.022	0.0007	0.0002	0.008	0.034
7022	T651	43275	S25111069	0.8	0.17	0.1467	0.23	3.1667	4.8167	0.006	0.18	0.033	0.022	0.0007	0.0002	0.008	0.034
7075	T651	44028	S25111123	1.3	0.21	0.12	0.08	2.4	5.7	0.007	0.19	0.034	0.022	0.0007	0.0002	0.008	0.01
7075	T651	44028	S25111123	1.3	0.21	0.12	0.08	2.4	5.7	0.007	0.19	0.034	0.022	0.0007	0.0002	0.008	0.01
7175	T7351	43527	S25111061	1.3333	0.09	0.04	0.004	2.4833	5.6333	0.005	0.2	0.025	0.022	0.0005	0.0002	0.007	0.001
7175	T7351	43527	S25111061	1.3333	0.09	0.04	0.004	2.4833	5.6333	0.005	0.2	0.025	0.022	0.0005	0.0002	0.007	0.001

The samples were cut at equal sizes (150x20mm), barb was removed by polishing at machine grinding 4000 Phoenix using abrasive paper and were degreased with acetone. The attack surface was defined as is shown in Figure 1 (between 1 to 2 cm^2 for the exposure surface). Then, the rest of the sample was coated with an acrylic resin, measuring for each sample the surface that was exposed to attack. After being prepared, each sample was separately tested and were taken measurements at 30 minutes and respectively 60 minutes for comparison.

Fig.1. Samples for measuring corrosion potential (left),
and with delimitation of the attack zone (right)

3. Results and Interpretations

Experimental results regarding the corrosion potential values after 30 minutes, respectively 60 minutes are illustrated in figures 2 and 3.

According to ASTM G69 the corrosion potential is positively influenced by the copper concentration and in a negative way by the zinc concentration. Thus, in figure 4 is given the corrosion potential variation in terms of the copper concentration, indicating the aluminum alloy grade, and in figure 5 is specified the corrosion potential value obtained after testing in terms of the zinc concentration value.

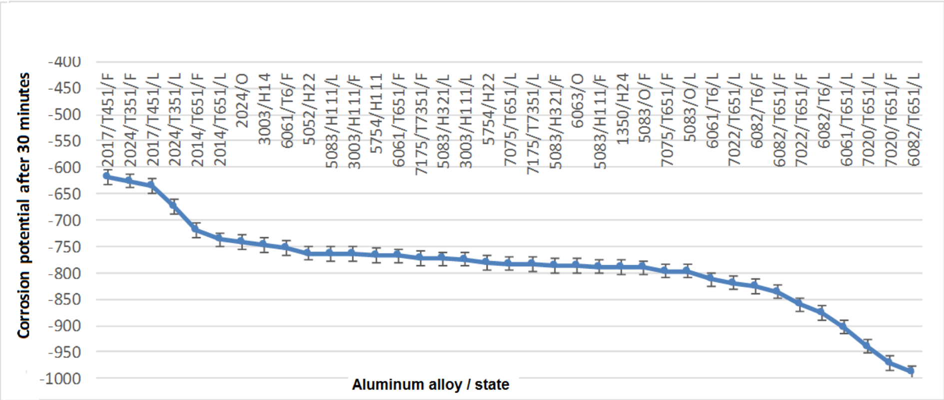

Fig. 2- Corrosion Potential of the 2xxx÷7xxx series aluminum alloys

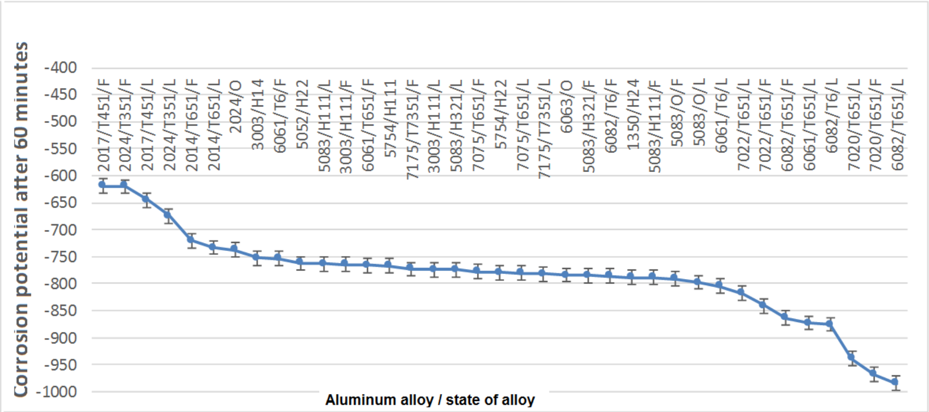

Fig. 3- Corrosion Potential of the experimental aluminum alloys

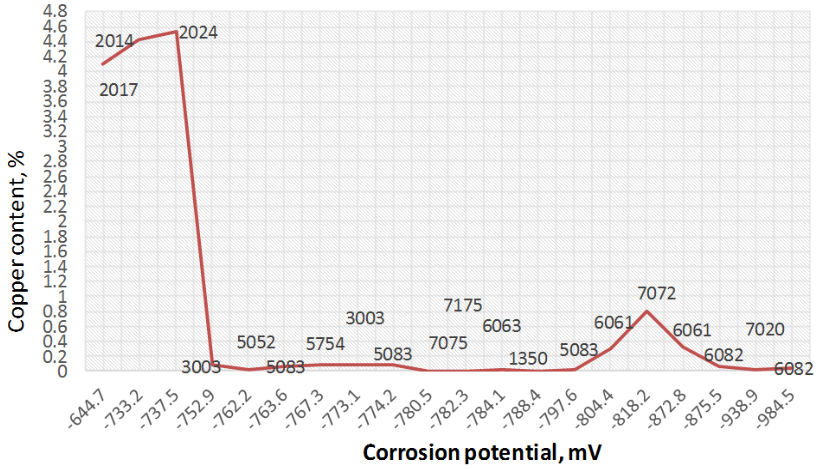

Fig. 4. Copper content versus corrosion potential of the experimental aluminum alloys

The experimental results shown that the alloys from 2xxx series (2014, 2017, 2024) had the smallest corrosion potential, X_{mean}= -618,8mV. In the 3003 alloy can be noticed a stability in terms of corrosion potential, the analyzed samples both of sheets and plates (whether of the milled or laminated surface) have approximately the same values, the samples being appropriate to ASTM G69. In case of alloys from 5xxx series, as in the 3003 series, the potential values are close both between the milled front and rolled face and the measuring ranges between 30 or 60 minutes. For 6xxx series alloys yielded the highest X_{mean}=-988,8mV. Also, in these alloys we remarked the biggest differences between the alloys with the same delivery grades and alloys with different delivery conditions (both on the rolled face and on milled one).

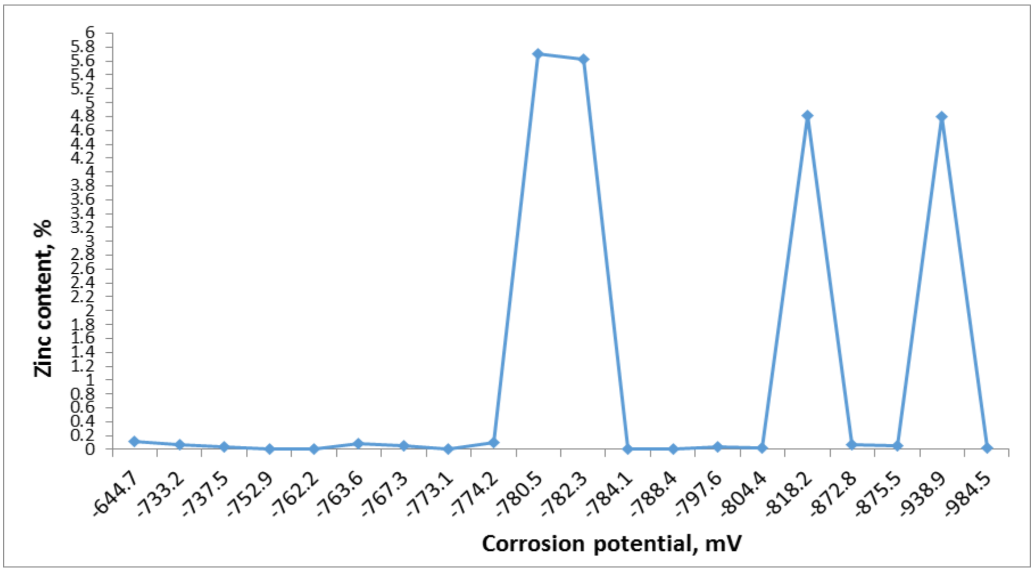

Fig. 5. Zinc content versus corrosion potential of the experimental aluminum alloys

For the 7xxx series alloys was observed substantial differences between the alloys of the same grade but with different chemical composition and the milled and rolled face. Only for 7075 alloy are not observed noticeable differences between the milled face and rolled one. The best values for corrosion potential values were obtained in case of 2017 alloy (-644,7mV), 2014 alloy (-733,2mV) and 2024 alloy (-737,5mV), these alloys having a solid solution Cu concentration of 4.1%; 4.4%; and respectively 4.5%, and the concentration of Zn in these cases being 0.11%; 0.06%; and respectively 0.04%. The average values for corrosion potential were obtained for 7075 alloy (-780,5mV) and 7175 alloy (-782,3mV), which had a Cu concentration in solid solution of 1.3%, and the Zn concentration around 5.7%, in according with ASTM G69. The lowest corrosion potential values for the tested alloys were obtained for 7020 alloy (-938,9mV), this having a Cu concentration of 0.03% and in case of Zn 4.8%.

4. Conclusions

Analysis of the obtained results after identifying the aluminum alloys corrosion potential allowed the detection of the corrosion potential specific values in conjunction with the alloy grade and ranking of the aluminum brands in terms of corrosion behavior. It highlighted the need for retesting of corrosion potential for the alloys that have achieved the best values (2017, 2014, 2024), the weakest values (7022,7020), but also for those that were obtained averages (7075, 7175). It must also be taken into account that testing must be done from at least 3 different samples for each alloy. It carried out a correlation between the aluminum alloys chemical composition and the corrosion potential values.

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