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The Influence of the Over-Aging in 7075 Aluminium Alloy Plates on the Corrosion Behaviour

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Abstract
A study for establishing the influence of the duration of the artificial aging heat treatment stage on the intergranular corrosion for 7075 aluminium alloy, T651 temper was carried out. Therefore, several tests were conducted by increasing the duration of the holding time in the Artificial Aging Heat Treatment from 10 hours to 20 hours, at every two hours. The experiments were done on 7075 aluminium alloy plate with a thickness of 30 mm. A dependence of the intergranular corrosion on the holding time of the artificial aging treatment was established, thus more than 37 minimum holding hours are needed for the 7075 aluminium alloy plates to have corrosion problems, which is very difficult to achieve in practice.

Keywords
over-aging, 7075 aluminium alloy, corrosion

1. Introduction

Due to the specific thermal treatments applied, as well as the high content of copper, magnesium and zinc, the 7xxx series aluminium alloys were developed to be used in special applications with hostile working environments, respectively in the aeronautical industry. The specific chemical composition and special thermal treatments of the 7xxx series alloys determine a superior resistance to corrosion.

Due to the different mode of attack of the material, two main types of corrosion can be found in aluminium alloys, respectively pitting corrosion and intergranular corrosion [1]. Thus, while by pitting the surface of the material is attacked, by intergranular corrosion, the attack is carried out at the boundaries of the grains and the corrosion makes its way inside the material in parts that appear to be intact from the surface [1].

The influence of alloying elements and impurities on the corrosion of 7xxx series aluminium alloys was studied in several works [2-5]. Due to the anodic behaviour in relation to the surrounding aluminium matrix of the intermetallic compounds containing Zn and Mg [6, 7], and on the other hand to the cathodic behaviour determined by the intermetallic particles containing Fe, Cu and Mn, severe galvanic micro-coupling corrosion results, making in finally, the predisposition to the corrosion of the 7xxx series aluminium alloys [8].

The main factors induced by the solution heat treatments on intergranular corrosion are the cooling rate and the solution temperature.

As a result of the solution heat treatment and quenching, the alloying elements can concentrate at the grain boundary to form intermetallic compounds that differ electrochemically from the adjacent matrix and the metal adjacent to the grain boundary.

The study focused in this work on determining the influence of the duration of the artificial aging treatment stage on intergranular corrosion for a 7075 aluminium alloy plate.

Depending on the metallurgical temper and the product standard according to which a product is obtained, the parameters of the artificial aging heat treatment may vary. The parameters of the artificial aging heat treatment used to obtain the T651 state for the 7075 alloy, were according to the AIR 9048 standard [9], respectively 135 °C (±3 °C) / 12 h. Therefore, in this study the tests were carried out by varying the holding time from 10 hours to 20 hours, at every two hours.

2. Experimental

The 7075 aluminium alloy samples subjected to the artificial ageing heat treatment in the laboratory were obtained from a slab with the chemical composition according to Table 1, which was milled and hot rolled, then subjected to the solution heat treatment and quenching, followed shortly by the stretching operation.

Table 1. Chemical composition of 7075 aluminium alloy plate used in the experiments (mass fraction, %)

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Other elements		Al
								Each	Total	
0.05	0.10	1.32	0.002	2.7	0.18	5.63	0.028	≤0.05	≤0.15	89.97

Finally, samples were taken from the obtained plate with a thickness of 30 mm, for the laboratory tests. It should be mentioned that the solution heat treatment operation was carried out on the *Independent Equipment for the Research of Aluminium Alloy Quenching Process* (Figure 1).

Fig. 1. Independent Equipment for the Research of Aluminium Alloy Quenching Process

The age hardening process conducted in the lab is summarized in the Figure 2. For the laboratory simulation of the artificial aging treatment, the heating rate up to the holding temperature, respectively 135 °C, was very important. For this, the heating rate recorded in the industrial case was considered.

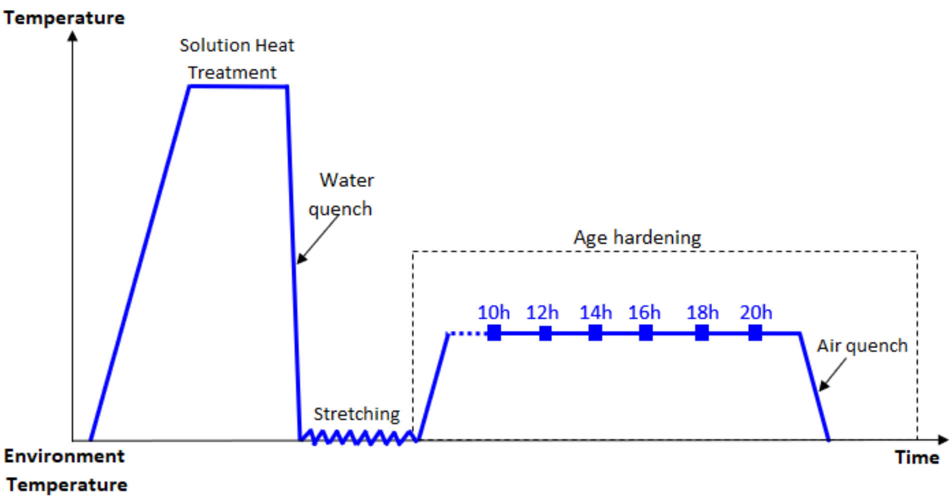


Fig. 2. Schematic representation of the heat treatment for 7075 aluminium alloy plates. The age hardening process was conducted in the lab at 135 °C for 10, 12, 14, 16, 18 and 20 h

Considering that parameters 135 °C (±3 °C) / 12 h are used to obtain the T651 temper for 7075 aluminium alloy plates, it was supposed that after the 12-hour level, the samples will pass into another temper, i.e. over-aging.

Two approaches were used to determine the intergranular corrosion. The first was based on mass loss after exposure to Nitric Acid [10] and second by immersion in Sodium Chloride and Hydrogen Peroxide solution [11].

3. Results. Discussion

Table 2 shows the results of the mass loss after exposure to Nitric Acid obtained on samples treated with different aging stages.

Table 2. Intergranular corrosion results by mass loss after exposure to Nitric Acid for 7075 aluminium alloy samples with different levels of ageing holding time

Sample No.	Holding time [h]	Initial Mass [g]	Final Mass [g]	Δ Mass [g]	Length [mm]	Width [mm]	Thickness [mm]	Total area [cm²]	Mass loss [mg/cm²]
1	10	10.329	10.272	0.0574	25.02	25.16	6.03	18.6418	3.1
2	12	10.366	10.304	0.0624	25.08	25.23	6.02	18.7127	3.3
3	14	10.317	10.259	0.058	25.03	25.13	6.02	18.6193	3.1
4	16	10.347	10.286	0.0603	25.02	25.04	5.91	18.4471	3.3
5	18	10.369	10.298	0.0708	25.04	25.04	5.94	18.4895	3.8
6	20	10.629	10.55	0.0799	25.14	25.13	6.02	18.6879	4.3

Also, in Figure 3 the dependence of corrosion on the duration of the holding time for artificial ageing heat treatment is graphically represented.

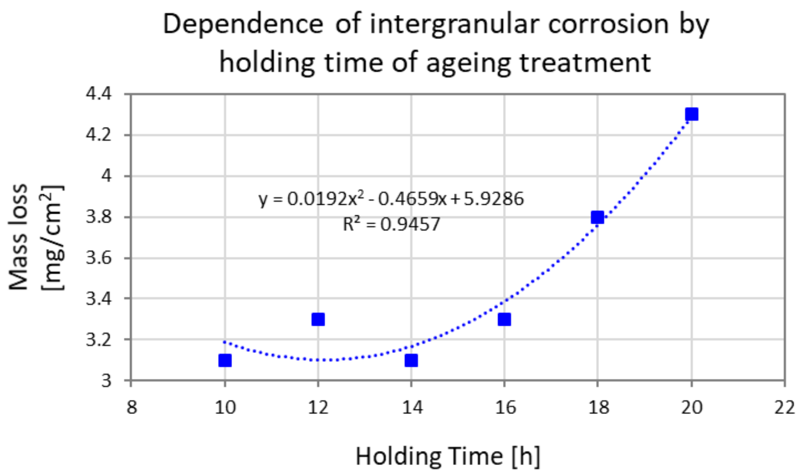


Fig. 3. Correlation between intergranular corrosion results by mass loss and holding time of ageing treatment, for 7075 aluminium alloy samples

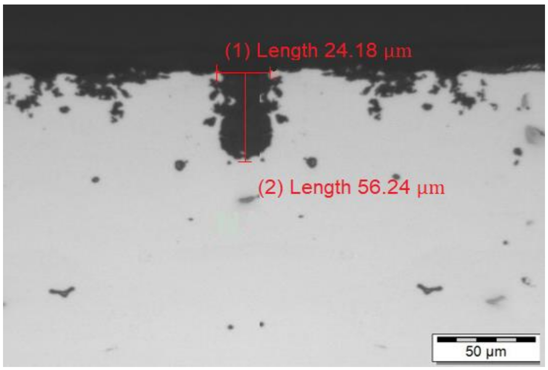
From the analysis of the obtained data, it can be observed that up to 16 hours of holding time, relatively equal values of mass loss were obtained, this characteristic increasing only at holding time durations of 18 and 20 hours, these durations correspond to a pronounced over-aging treatment. It is also observed that the results in the range of 3.1 – 4.3 mg/cm² obtained are far below the limit of 15 mg/cm², the maximum limit for a material resistant to intergranular corrosion.

Using the regression equation obtained (1) with a value of the coefficient of determination of 0.95, it is possible to estimate the time required to reach the limit of 15 mg/cm².

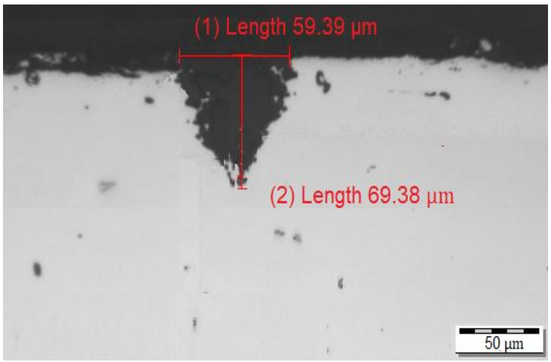
$$Mass\_Loss\ [mg/cm^2] = 0.0192 \cdot (Holding\_Time)^2 - 0.4659 \cdot Holding\_Time + 5.9286 \quad (1)$$

Therefore, it can be predicted that after a period of approx. 37 h for holding time of ageing treatment the limit of 15 mg/cm^2 for corrosion is reached, respectively a very long period of time to be achieved in reality for 7075 aluminium alloy plate obtained under the given conditions – chemical composition, thermal treatments applied, etc.

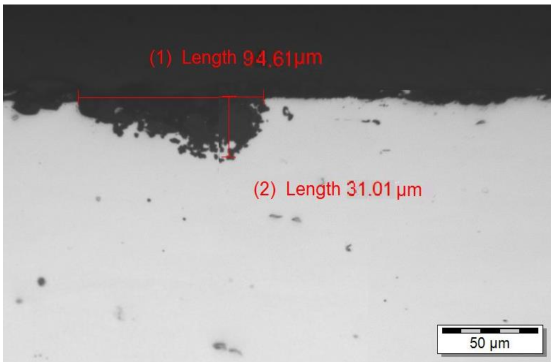
Figure 4 shows the images captured for the determination of maximum pitting opening (Lp) and maximum pitting depth (Hp), by immersion in Sodium Chloride and Hydrogen Peroxide solution of the 7075 aluminium alloy samples treated for each aging stage considered.



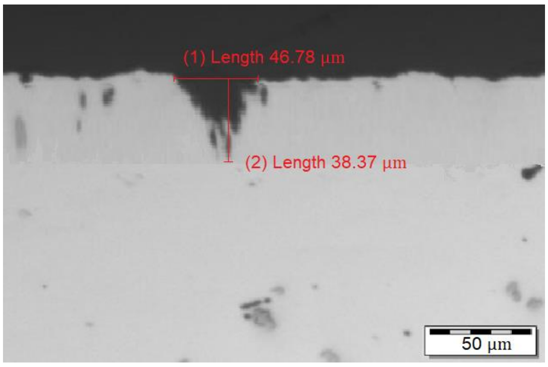
a. 10 h



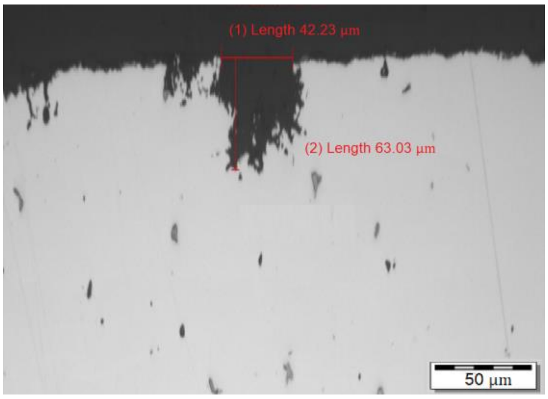
b. 12 h



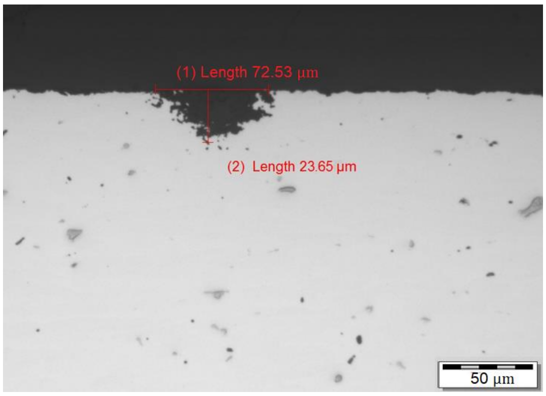
c. 14 h



d. 16 h



e. 18 h



f. 20 h

Fig. 4. Images captured for the determination of maximum pitting opening (Lp) and maximum pitting depth (Hp), by immersion in Sodium Chloride and Hydrogen Peroxide solution of the 7075 aluminium alloy samples treated for different aging stage

Table 3 shows the values of corrosion results on two directions, maximum pitting opening (Lp) and maximum pitting depth (Hp), by immersion in Sodium Chloride and Hydrogen Peroxide solution of the 7075 aluminium alloy samples treated with different aging stages.

Table 3. Intergranular corrosion results by immersion in Sodium Chloride and Hydrogen Peroxide solution of 7075 aluminium alloy samples with different levels of ageing holding time

Sample No.	Holding time [h]	Maximum pitting opening – Lp [µm]	Maximum pitting depth – Hp [µm]
1	10	24.18	56.24
2	12	59.39	69.38
3	14	94.61	31.01
4	16	46.78	38.37
5	18	42.23	63.03
6	20	72.53	23.65

Also, in Figure 5 the dependence of corrosion on the duration of the holding time for artificial ageing heat treatment is 3D represented schematically.

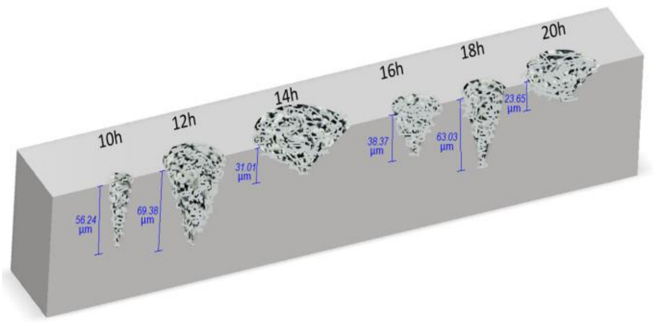


Fig. 5. Evolution of intergranular corrosion results by immersion in Sodium Chloride and Hydrogen Peroxide solution of 7075 aluminium alloy samples with different levels of ageing holding time – 3D schematic representation

From the metallographic analysis it appears that regardless of the holding time for Artificial Aging Heat Treatment, the samples being treated between 10 and 20 hours, no intergranular attack was evident, so the samples do not show susceptibility to intergranular corrosion. From the graphic representation of the penetration depth, since the values obtained are random, it is not possible to establish a dependence between the holding time for Artificial Aging, even up to the state of over-aging, and the intergranular corrosion.

4. Conclusions

The results of the mass loss after exposure to Nitric Acid on the samples treated with different aging stages, respectively 10 h, 12h, 14h, 16 h, 18 h and 20 h show a polynomial dependence of the second degree. Thus, in order to reach the intergranular corrosion limit, it is necessary for the 7075 aluminium alloy plates to be subjected to an artificial aging thermal treatment of at least 135 °C/ 37 h, which in practice is neither realistic nor productive.

It should be noted here that the low values achieved for corrosion are also influenced by the special chemical composition and the solution heat treatment applied to the 7075 aluminium alloy plates.

On the other hand, metallographic investigations carried out using the method of determining intergranular corrosion by immersion in Sodium Chloride and Hydrogen Peroxide solution of 7075 aluminium samples did not show any correlation with the holding time for the Artificial Ageing Treatment.

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