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Influence of the degree of polishing of alloy AA 5083 on its behaviour against localised alkaline corrosion

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Abstract

A study has been conducted of the influence of the surface finish on the behaviour against the corrosion of samples of alloy AA 5083 immersed in aerated solutions of NaCl at 3.5%. Samples polished from 80 to 1200 grit have been tested, utilising as experimental techniques, measurements of weight loss, optical and scanning electron microscopy, linear polarisations and electrochemical noise measurement (ENM).

In the conditions studied, the principal corrosion process that takes place is localised alkaline corrosion (LAC). This type of corrosion occurs as a consequence of the alkalinisation of the area surrounding the Al(Mn,Fe,Cr) cathodic precipitates that exist in the alloy.

The results obtained indicate that the samples polished to 1200 grit present a greater susceptibility to processes of localised alkaline corrosion than the samples polished to 80 grit. It has been found that the degree of polishing conditions the number of intermetallic particles exposed. Hence the differences of behaviour observed between the sets of results obtained have been interpreted as an effect function of the density of cathodic intermetallic particles exposed on the surface.

Keywords: Corrosion; AA 5083; NaCl; Rugosity; ENM

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1. Introduction

The behaviour against corrosion of metallic materials is affected by many experimental factors. Thus, properties of the metallic material such as its microstructure [1–6] or its surface state [6,7] are among the factors that most clearly determine the behaviour of the alloy against corrosion. Because of this dependence, when corrosion tests are carried out, it is a customary practice to homogenise the surface state of the samples to be studied. The most extensively used procedure in the preparation of metallic surfaces for corrosion tests consists of the application of a mechanical polishing process [8] followed by cleaning and degreasing stages.

In the bibliography, contradictory data can be found in respect of the effect of the surface finish of different alloys on their behaviour against corrosion. Whereas in [9] an increase in the susceptibility to localised corrosion is described when the degree of polishing of the samples is increased, in [10,11] results are presented that point in the opposite direction. In short, there is no unanimity in the bibliography of criteria regarding the effect of the surface finish on the behaviour against corrosion of different alloys.

This paper presents the results obtained from a study of the influence of the surface finish of alloy AA 5083 on its behaviour against corrosion in aerated solutions of NaCl at 3.5%.

In [1], a detailed study of the corrosion process of this alloy in an aerated solution of NaCl at 3.5% was studied, employing samples with a surface finish of 500 grit. The duration of the test varied from 1 to 30 days. Furthermore, in [2] was accomplished a microstructural characterisation of the particles and their volume fractions. In [1] it is concluded that, in the conditions of exposure studied, the principal corrosion process that takes place is that termed localised alkaline corrosion (LAC). This process occurs as a consequence of the alkalinisation of the area surrounding the Al(Mn,Fe,Cr) cathodic precipitates that exist in the alloy. The results included in [1] indicate that the pits formed as a result of this process have irregular morphologies, and can be clearly differentiated from crystallographic pitting. In parallel, in the zones of the matrix that are free of precipitates, a process takes place that leads to the formation and growth of a layer of oxide.

The study presented here has been directed towards two objectives: first, to identify whether the degree of surface finish has an influence on the type of corrosive attack, and second, whether the finish influences the intensity of the attack.

2. Experimental

The experiments were performed using 30 × 25 × 5 mm sheets of AA 5083 (Al–Mg) wrought alloy in O-temper state. The chemical composition of this alloy, in wt.%, is show in Table 1. The degree of surface finish of the samples was controlled by means of wet grinding with SiC papers of 220, 500, 800 and 1200 grit. Next the samples were degreased with ethanol of 99% purity and rinsed with distilled water. In order

Table 1
AA 5083 alloy nominal composition (%)

Composition	Mg	Mn	Si	Fe	Ti	Cu	Cr	Al
%	4.9	0.4	0.13	0.3	0.03	0.08	0.13	Rest

to avoid a prolonged exposure to the atmosphere, the samples were tested immediately after the grinding and degreasing processes.

Corrosion test were carried out in oxygen saturated 3.5% NaCl aqueous solutions, at room temperature. In the immersion tests, the rate of corrosion was controlled by measuring the loss of weight undergone by the samples, in accordance with the ASTM-G31 standard [12]. To determine the loss of weight, once the period of immersion was finished, the samples were descaled in HNO_3 at 70% for two minutes, washed with abundant distilled water and then weighed again [13].

The surface rugosity of the samples has been measured by means of a perthometer rugosimeter, model M4Pi/CNOMO, that allows parameters of rugosity to be evaluated in accordance with the DIN/ISO and CNOMO standards [14–16].

The electrochemical data were obtained in a EG & G Flat Cell attachment connected to a 1287 model solartron instruments potentiostat. The linear polarisation curves were recorder at 10 $\mathrm{mV\,min^{-1}}$. As reference electrode an Ag/AgCl was used. In the electrochemical noise experiments (EN), the experimental procedure described in [17] has been followed.

The measurements were made employing two types of working electrode, some polished employing exclusively SiC paper of 80 grit, and others polished successively employing SiC papers of 220, 500, 800 and 1200 grit. In each EN experiment, records of 2048 points were made, stored at a rate of 2.15 points s^{-1} every 10 h for 90 h. As the aggressive medium, a oxygen saturated 3.5% NaCl aqueous solutions, at room temperature, has been utilised.

3. Results and discussion

As it has already been stated, in order to study the effect of the surface finish, the samples of alloy AA 5083 were submitted to a grinding process with SiC papers of various different grit numbers. This type of treatment gives rise to samples with different degrees of surface rugosity. In Table 2 the experimental values of the arithmetical mean rugosity of each profile R_a (μm) are given. In this table it can be observed how the mean surface rugosity diminishes as the "grit" number increases.

Table 2
Value of R_a in function of the degree of polishing

Sample	S1	S2	S3	S4	S5
Grit no.	80	220	500	800	1200
R_a (μm)	2.02	0.46	0.29	0.27	0.13

Normally, the effect of the degree of grinding on the value of the area exposed is not taken into account. This effect can be seen by observing the profiles of rugosity recorded on each of the samples, Fig. 1. In this figure it can be observed that there is a considerable difference between the most extreme profiles; this suggests that the areas exposed in each case could become very different. From the profiles recorded on each of the samples, the increase of area in comparison with a completely plane surface has been determined.

In order to determine the correction factor for the area, the true area of the samples has been estimated on the assumption that a uniform finish is obtained by utilising mechanical polishing. If we take a squared fraction of the surface of side l, where l is the scanning length utilised to record the rugosity profile, the nominal area of that zone will be l^2. However, since the surface is not completely flat, the true area of the square considered will be greater, the higher its rugosity. The true length of the side of the square, l_R, has been estimated from the length of the rugosity profiles. By this method, the true surface area will be l_R^2. What the correction factor for the area determines is the relationship between the true and the nominal surface area. To test the validity of this method, another method based on [18] has been employed, in which it is proposed that the curve that an area generates can be substituted by a polygonal. In our case, this polygonal is constructed by joining each pair of points of the rugosity profile, by rectilinear segments.

Applying both methods, similar values are obtained for the factors of correction of area, which are given in Table 3. The results obtained indicate that in the samples of low rugosity, polished to 1200 grit, the surface area of the samples coincides with the geometric surface area. In contrast, in the samples of greatest rugosity, the real area is actually more than twice the geometric area. Factors of this type should be taken into account in those cases where results must be expressed as a function of the area exposed, such as, for example, weight loss or corrosion current.

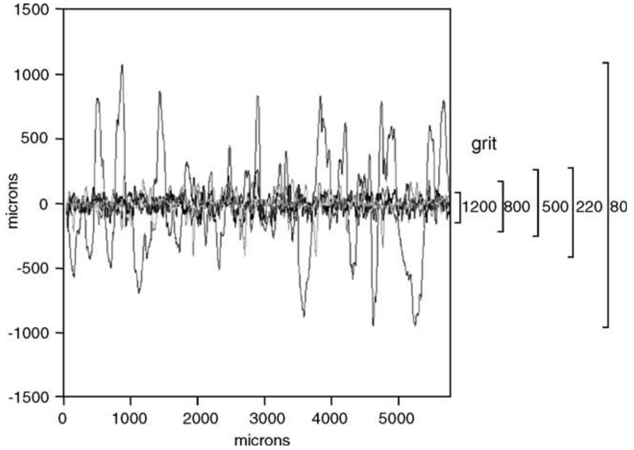

Fig. 1. Profiles of rugosity acquired on the samples polished to the degrees indicated.

Table 3
Area correction factors (f_a)

Sample	S1	S2	S3	S4	S5
Grit no.	80	220	500	800	1200
f_a	2.02	1.54	1.44	1.18	1.02

A metallographic study was carried out to evaluate the influence of the polishing level in the density of superficial intermetallic particles. HF 5% aqueous solution saturated in MoO_3 was employed to etch samples ground at different levels. In Fig. 2, it can be observed that the density of surface precipitates increases whenever the polishing level of the sample is increased.

In order to study the influence of the degree of finish surface on the behaviour of the samples, various tests have been conducted in solutions of NaCl. Thus total immersion tests, utilising a cell constructed following the recommendations of the ASTM standard G-31 [12], have been carried out. In Fig. 3(a) are included the optical microscopy images corresponding to samples submitted to tests of 15 days duration. Fig. 3(b) presents an SEM image and the corresponding EDS spectrum taken on an Al(Mn,Fe,Cr) precipitate affected by LAC. In this figure it can be observed that the samples of less surface rugosity present a higher degree of attack. The morphology of attack is analogous to that described in [1] as localised alkaline corrosion (LAC). This type of damage is related to the number of cathodic precipitates exposed. Therefore, the increase in the damage observed indicates that, as the rugosity of the surface decreases, the number of cathodic precipitates exposed on the surface increases. This increase of the number of cathodic particles on the surface can be explained by the mechanical phenomena produced during the polishing process.

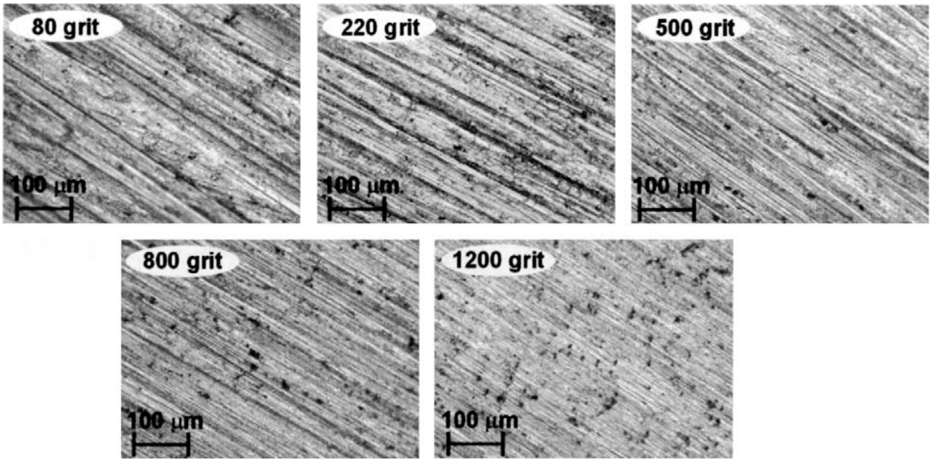

Fig. 2. Metallographic images of samples of alloy AA 5083 with different degrees of surface finish.

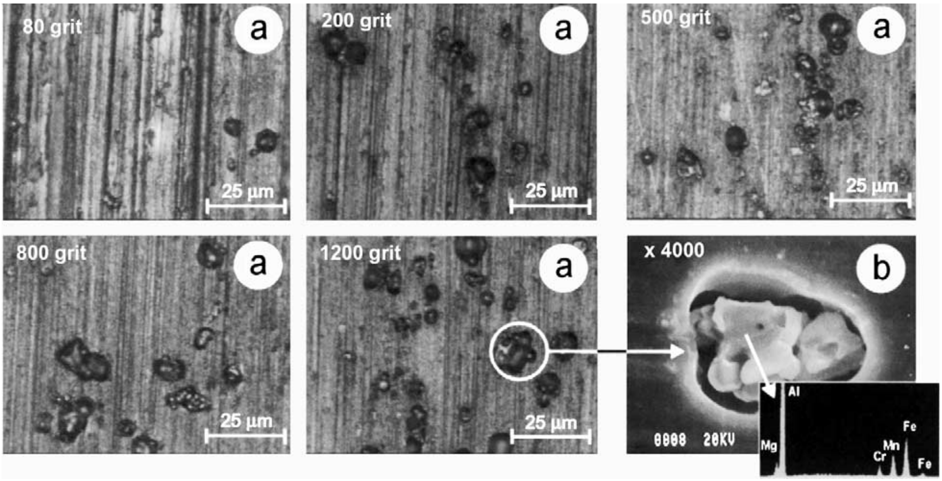

Fig. 3. (a) Optical microscopy images of samples of alloy AA 5083 with different degrees of surface finish, after 15 days of immersion in solution of 3.5% NaCl. (b) SEM image and EDS spectrum of an Al(Mn,Fe,Cr) precipitate.

In accordance with the preceding comments, by utilising papers of low grit number, the true surface of the samples is greater. Thus, even in the case of no variation in the number of intermetallic particles, their surface density would diminish when papers of lower grit number are utilised. Additionally, the surface density of SiC particles (the number of grits) is directly related to the distance between the particles on the abrasive paper. In comparison with a conventional cutting process, this distance is equivalent to the feed [19]. Thus, working with a greater number of grit produces a situation that is similar to what we would have when cutting with lower feed velocities. This would give rise to less surface rugosity. On the other hand, polishing with papers of lower grit number (equivalent to a greater feed rate) produces a situation closer to a rough dressing process, which would give rise to surfaces of more rugosity. When polishing with lower grit numbers, the SiC particles, which are of larger size and spatially widely separated, would act as cutting blades that would tend to eliminate from the surface those intermetallic particles with which they came into contact. In contrast, when the density of SiC particles is increased, we are working with particles of smaller size and less spatial separation, which are capable of wearing away part of each intermetallic particle encountered, but not of removing it completely from the surface [20]. This would explain the decline observed in the density of intermetallic particles when papers of lower grit number are employed, Fig. 2.

In Fig. 4 are represented the values of the loss of weight by unit of surface area, corresponding to samples submitted to immersion tests of 15 days duration. The results from this figure demonstrate that, when the surface rugosity is diminished, an increase is produced in the value of the weight loss. In other words, as was concluded from the optical microscopy images, the results of weight loss indicate that, when the

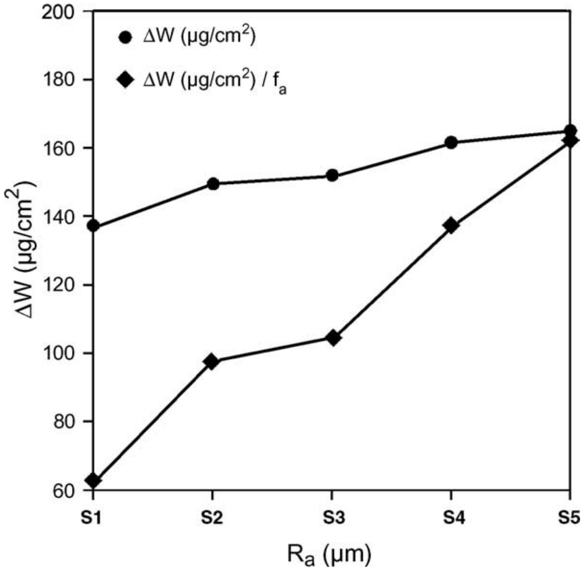

Fig. 4. Weight loss of samples of alloy AA 5083 with different degrees of surface finish, after 15 days of immersion in solution of 3.5% NaCl, with and without correction of area.

surface rugosity is diminished, an increase is produced in the sample's susceptibility to corrosion. An increase in this effect is seen if the values of weight loss are referred to the corrected area instead of the geometric area. After the correction of the area, it can be observed more clearly how the samples that present a finer surface finish also present a greater loss of weight.

A similar conclusion is drawn from the analysis of the values of polarisation resistance (R_p) calculated from the corresponding curves of linear polarisation. Thus, in Fig. 5 the values of R_p as a function of the surface rugosity are represented. In this figure it can be appreciated how, in line with the results of weight loss, there is a fall in the values R_p, and therefore an increase in the activity of the system, when the surface rugosity of the samples decreases. In [21,22] similar results are described for other aluminium alloys, such as AA 7075 and AA 6061.

Further, curves of anodic polarisation have been recorded, with the object of determining the influence of surface rugosity on the nucleation of crystallographic pits, Fig. 6. In this figure it can be observed how the surface rugosity of the samples only produces changes in their corrosion potentials, without appearing to alter the potential of pitting nucleation, the value of which is about −720 mV Ag/AgCl. Therefore, these results would indicate that the degree of surface finish of the samples does not influence the process of nucleation of crystallographic pits in the samples.

With the aim of following the evolution of the systems studied with the time of exposure, electrochemical noise measurements (EN) have been made. In Fig. 7 the evolution with the time of immersion of the values of noise resistance (R_n) are shown corresponding to the two types of sample studied. In this figure it can be confirmed,

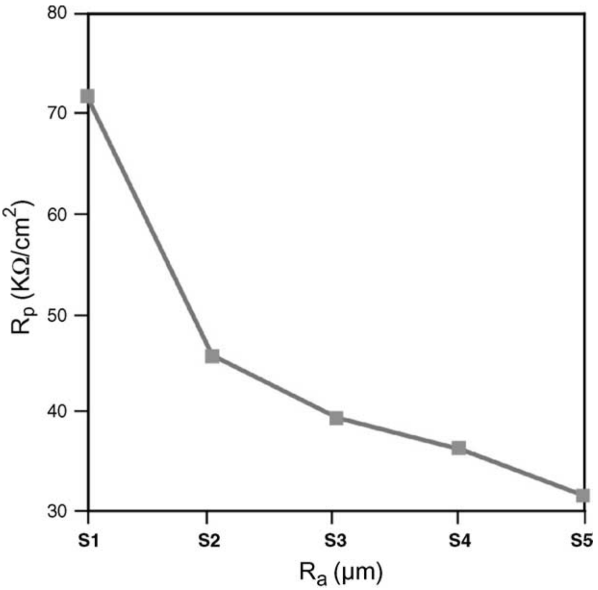

Fig. 5. Evolution of the resistance to polarisation (R_p) of samples of the alloy AA 5083 in 3.5% NaCl, in function of the surface finish (R_a).

in the first place, that the values of R_n for the samples polished to 1200 grit increase progressively with the time of exposure. In turn, the values of R_n obtained for the samples polished to 80 grit hardly vary at all over the length of the period of exposure studied. On comparing the behaviour of the two samples, it can be confirmed that, during the first 20 h of exposure, the values of R_n are similar. On increasing the time of exposure, the values obtained for the samples polished to 1200 grit are considerably higher, which would indicate that in these samples a reduction of the activity is produced.

In Fig. 8 mean values of corrosion potential (V_m) for different exposure times corresponding to the two samples studied are presented. Each mean value plotted in Fig. 8 is the result of averaging 2048 potential data. On analysing this figure, it can be observed how the potential for the samples polished to 80 grit increases asymptotically with time, until a potential of about −745 mV is reached after two days of immersion. On the other hand, in the samples with less rugosity, a maximum in the potential appears, during the first hours of immersion; this potential is more noble than that recorded for the samples polished to 80 grit. Later, the potential of the samples polished to 1200 grit falls rapidly, so that after 48 h of immersion, the potential is situated at about −755 mV, a value slightly more active than the stabilisation potential of the samples polished to 80 grit.

The results obtained can be interpreted by considering the number of Al(Mn, Fe,Cr) particles exposed to be dependent on the rugosity of the samples. Hence, the values recorded for V_m will depend on the facility with which the cathodic reaction

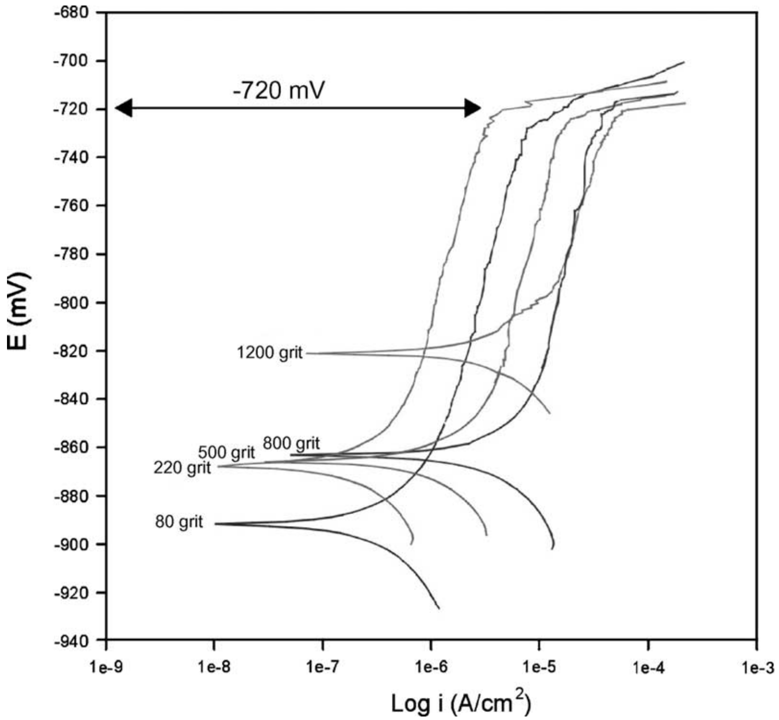

Fig. 6. Anodic polarisation curves of samples of alloy AA 5083 in 3.5% NaCl, with different degrees of surface finish.

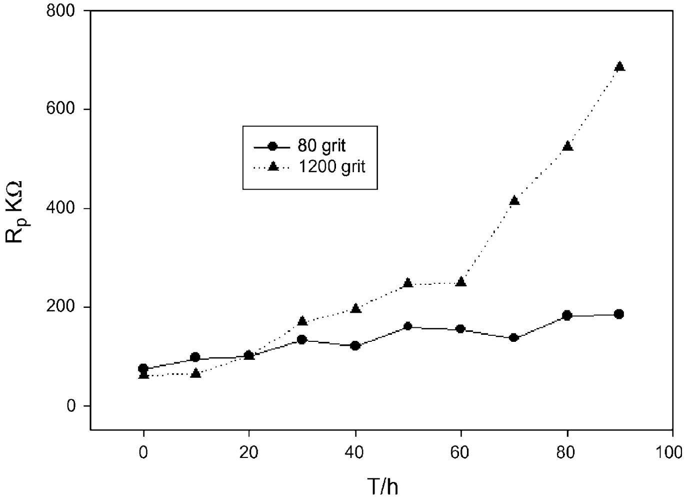

Fig. 7. Evolution with time of exposure of the noise resistance (R_n) of samples of alloy AA 5083 in 3.5% NaCl, with different degrees of surface finish.

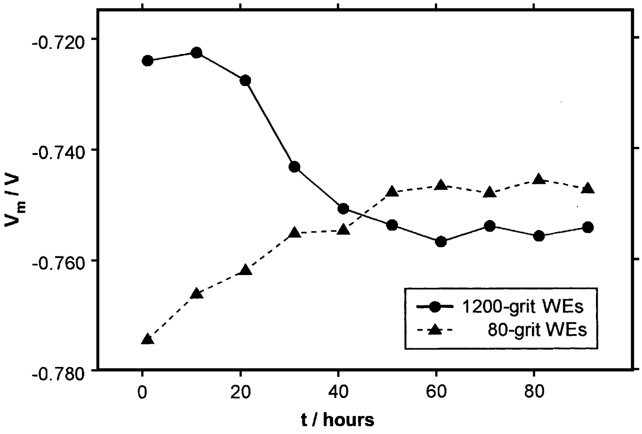

Fig. 8. Evolution with time of exposure of the mean potential of corrosion (V_m) of samples of alloy AA 5083 in 3.5% NaCl, with different degrees of surface finish.

takes place, that is, on the number of Al(Mn,Fe,Cr) precipitates exposed. In Fig. 8, it can be observed that, during the two first days of exposure, the values of V_m for the samples polished to 80 grit stay considerably below those obtained for the samples polished to 1200 grit. This would indicate that the number of precipitates exposed initially in the samples polished to 80 grit is considerably less than those exposed in the samples polished to 1200 grit. The increase in the values of V_m with time, for the samples polished to 80 grit, would be related to the slow formation of a layer of alumina on the matrix of the alloy [23]. Following the model proposed, the value of the initial potential in the samples polished to 1200 grit is related to the high activity as a consequence of the larger number of precipitates exposed. Hence a process of intense LAC would take place in the first hours of exposure. This causes the rapid loss of contact between the Al(Mn,Fe,Cr) precipitates and the matrix. The effect of the loss of the cathodic precipitates is reflected in the decrease of the values of V_m during the first hours of exposure, Fig. 8. From then, the potentials of the two samples follow a similar evolution.

As has previously been commented, the samples polished to 80 grit are characterised by presenting a low number of Al(Mn,Fe,Cr) particles exposed. This would cause the LAC process in these samples to have a relatively low intensity, and therefore the number of particles exposed would not change significantly with time. This would explain why, as may be deduced from the evolution of the values of R_n, the activity remains almost constant during the entire period studied. In contrast, the activity of the samples polished to 1200 undergoes considerable variation with time, and at the end of the period of exposure, reaches a level considerably lower than in the samples polished to 80 grit. This evolution can be explained as being the result of two effects. On the one hand, as has previously been commented, the LAC process causes a loss of the cathodic activity. However, the high activity taking place in the first hours of exposure results in the rapid growth of a protective layer in the anodic zones. This layer would be the second cause of the loss of activity of the system, for periods of prolonged exposure.

4. Conclusions

This paper describes a study conducted of the influence of the degree of surface finish of alloy AA 5083 samples on their behaviour against corrosion in aerated solutions of NaCl at 3.5%.

The results obtained by tests of weight loss, linear polarisation and microscopy demonstrate, first, that the degree of surface finish does not have an influence on the morphology of the attack. In the samples polished to 1200 grit, the damage by localised alkaline corrosion is more severe than that observed when the samples are polished to 80 grit. This increase in the activity can be related to the higher density of intermetallic particles of cathodic character exposed on the surface.

Second, the technique of electrochemical noise measurement has been employed to monitor the evolution of the systems studied, with the length of immersion time. The results of the ENM indicate that each system evolves differently. Thus, the values of noise resistance and corrosion potential show that the activity in the samples polished to 80 grit remains almost constant during the entire period of time studied, whereas the activity in the samples polished to 1200 gradually diminishes. Both tendencies can be explained by the difference in the density of cathodic precipitates existing on the surface.

In summary, in this type of sample, the degree of surface finish determines the density of intermetallic particles exposed. It is this parameter that finally conditions both the intensity of the attack and its evolution with time of exposure. Finally, the set of data obtained, making use of different experimental techniques, can be interpreted coherently with reference to the model of behaviour proposed.

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