ADVANTAGES OF NOTCHED SPECIMENS IN SSR TESTS

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The effect of the electrochemical potential in the stress corrosion resistance of AA7017-T651 has been studied by Slow-Strain-Rate (SSR) tests and the rating of this effect has been done by means of the fracture load. Low susceptibility to a 3.5% NaCl aqueous solution was detected for most of the potentials using smooth specimens. However apreciable stress corrosion cracks are developed in the tested samples. This shortcoming is surpassed by the use of notched specimens.

The effect of the cross head speed for the notched specimens at two selected potentials was ascertained. From these results a net load threshold for the nucleation and a crack growth rate for the propagation has been obtained for each potential. The agreement of this calculated values with the available experimental results is very good.

INTRODUCTION

The Slow-Strain-Rate Test (SSRT) proposed by Parkins et al. (1) is widely used in Stress Corrosion Cracking (SCC) research. However it is not yet clear which are the best specimen type and fracture parameter for the sensitive rating of SCC materials susceptibility. Stoltz (2) has checked the influence of the specimen geometry on the reduction in area of a low susceptibility material and found the better sensitivity for a plain strain specimen. Holroyd and Scamans (2) have reviewed the use of SSRT in aluminium alloys and they point out that ductility parameters, like elongation, reduction in area or fracture energy, are being the more sensitive ones. Nevertheless fracture load seems to be a more attractive parameter because it is easier to measure and has a closer relation with the stress corrosion crack size. However fracture load is a low sensitivity parameter for detecting small cracks in plain specimens.

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In the present work, the authors show that the fracture load sensitivity can be increased upto an operative level with a proper selection of the specimen geometry. Round notched specimens of a low susceptibility alloy were selected. The aim of this choice is to shift the fracture conditions to a linear elastic like situation. Another shortcoming affects the SSRT results: they give a SCC ranking that it is strain rate dependent. Then it could be inverted by testing at other rate. For the authors, this ambiguity arises from the two steps nature of SCC, namely nucleation and propagation, as shown below.

MATERIAL AND EXPERIMENTAL METHODS

A 30 mm thick plate of commercial AA 7017-T651 aluminium alloy was used. The composition and the mechanical properties in the ST direction have been reported previously by García-Cordovilla et al. (4). The samples for SSRT were plain cylindrical specimens (12.5 mm gauge length and 5.0 mm diameter) or notched cilindrical specimens (12.5 mm gauge length, 7.2 mm diameter with a 45° V-notch of 1.1 mm depth and 0.38 mm tip radius). Both of them have threaded endings. DCB specimens (25x25x135 mm) were used in a wedge-loaded condition for crack growth rate measurements. All the specimens were stressed in the ST direction and the crack growth in the DCB ones was in the rolling direction. The SCC susceptibility was evaluated in aqueous solutions of 3.5 % NaCl. Potentiostatic control was provided by electronic potentiostats in a three electrode arrangement, when necessary. A saturated calomel electrode (SCE) was used as reference electrode. The fracture load values obtained in agresive media are normalized to the fracture load of specimens tested in air dried with magnesium perchlorate. The actual crack size of the DCB specimens was optically measured and the K_I values was calculated by the Hyatt's expression (5).

RESULTS AND DISCUSSION

The influence of electrochemical potential upon the resistance to SCC has been studied by SSRT at a 5×10^{-9} m.s^{-1} cross head rate. The results for notched specimens can be seen in figure 1. The plain specimens curve is shown as reference. A sustantial increase in the failure load sensitivity is obtained by the use of the notched specimens. In particular, this has allowed to resolve the -1000 to -800 mV zone like a susceptibility small peak.

Because the rating parameter values and the fracture load ones in particular depend on strain rate, this influence has been studied at cross head rate in the 10^{-9} to 10^{-7} m.s^{-1} range and at -1200 mV and free corrosion potentials. Only the notched specimens were used here and the results are presented at figure 2. Also the theoretical predictions, according to a proposed model, are shown. For the two potentials, the fracture load decreases with the stressing rate being faster in the -1200 mV case.

All notched specimen fracture surfaces showed a external ring of intergranular cracking surrounding a transgranular dimpled area. The relation between the fracture load P_c and the mean crack size a_c was found to be approximately linear and it can be written as

$$P_c = P_o + B\, a_c \qquad (1)$$

The least-squares fit of the experimental results give P_o = 13.0 KN, B = -7420 KN/m and a - 0.9898 correlation coefficient. During the SSR tests, the load P versus elongation (cross head rate $\dot{e}$ x time t) evolution was found to be also linear. This behaviour can be written with a single equation because the slope was similar in all tests. Hence:

$$P = C\,\dot{e}\,t \qquad (2)$$

with the best estimated C = 13.1 ± 0.2, GN/m. The tests performed in dry air also follow the equations (1) and (2).

For modeling the SSRT of AA 7017 - T651 notched specimens, we assume: 1) The stress corrosion cracks are characterized by a initiation load P_i and a growth rate v, as it is sketched in figure 3. 2) Both of them are potential-dependent but strain-rate-independent. Then, obtaining the critical crack size a_c from figure 3 and equation (2) and introducing it into the equation (1), one arrives at:

$$P_c = \frac{P_o\,C\,\dot{e} - P_i\,B\,v}{C\,\dot{e} - B\,v} \qquad (3)$$

This sigmoid type relation give us the fracture load value for any strain rate.

Equation (3) was plotted in figure 2, for both experiments. The parameters v and P_i were obtained by learn-squares fitting of experimental values; they correspond to $v = 2.7 \times 10^{-9}$ $m.s^{-1}$ and $P_i = 0.27\ P_o$ for the -1200 mV curve and to $v = 1.6 \times 10^{-9}$ $m.s^{-1}$ and $P_i = 0.51\ P_o$ for the free corrosion potential curve. The experimental crack growth rates measured with DCB specimens were 3.7×10^{-9} $m.s^{-1}$ at -1200 mV and 1.9×10^{-9} $m.s^{-1}$ at the free corrosion potential. They are very similar to the calculated one. Constant load tests have been carried out because the initiation load and the load threshold are conceptually similar. The results are not yet completed but the available values for the -1200 mV potential can be seen in figure 4. The load threshold, if any exist, could be around the 0.10 P_o.

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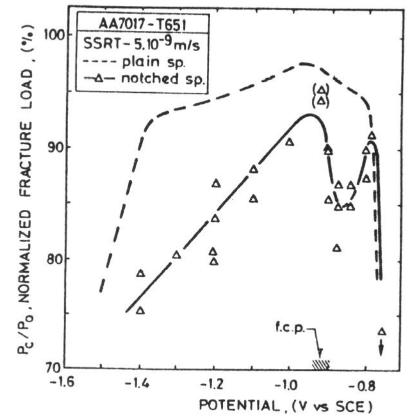

Figure 1. Effect of the potential on normalized fracture load.

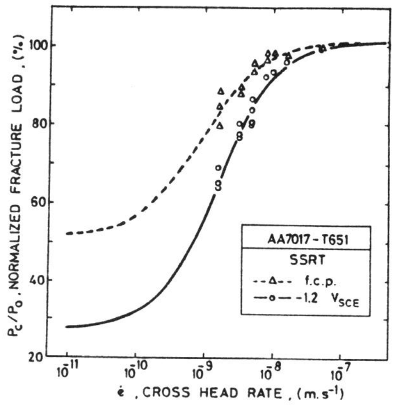

Figure 2. Strain Rate dependence of normalized fracture load.

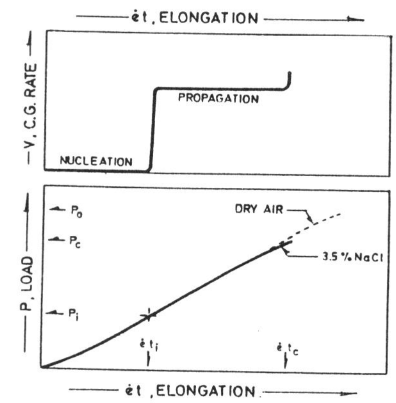

Figure 3. Schematic picture of crack growth an load evolution versus calculated elongation.

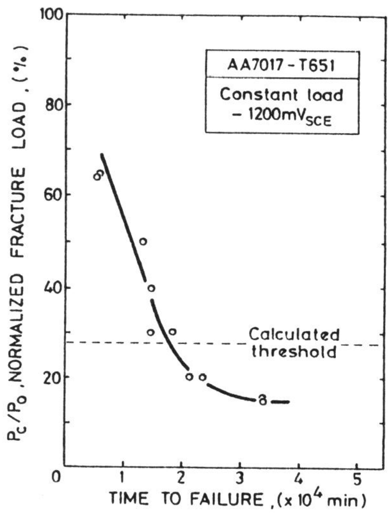

Figure 4. Imposed constant load versus time to failure for the -1200 mV potential.