MICROSTRUCTURE AND STRESS CORROSION SUSCEPTIBILITY OF THE HEAT AFFECTED ZONE IN Al-Zn-Mg WELDMENTS

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The microstructure and susceptibility to stress corrosion cracking (SCC) of the white zone in AA 7017 weldments, prior to (WZ) and after (WZP) a postweld heat treatment, are investigated and compared to those of the commercial tempers T4 and T651. The microstructure was studied by means of optical microscopy and differential scanning calorimetry, whereas the susceptibility to SCC was evaluated by means of slow strain rate tests and measurements of the crack growth rate in aggressive environments.

INTRODUCTION

Nowadays technology allows to considerably improve the resistance to stress corrosion cracking (SCC) of weldable Al-Zn-Mg alloys series, without appreciable loss in other properties of technological relevance (1). However, welding promotes significant microstructural changes in a region known as the heat affected zone, which seems to be the origin of the important increase in the susceptibility to SCC observed in weldments of these alloys (2,3). In particular an important role in the process of crack propagation in aggressive environments has been ascribed to the zone adjacent to the weld bead, commonly called white zone due to its response to etching in nitric acid (4,5).

Schmiedel and Gruhl (6) were first in investigating the macroscopic properties of a region as small as the white zone. They focused their investigation on the study of the influence of the thermal cycle (used to reproduce the microstructure of the WZ) on its susceptibility to SCC, evaluated by means of standard constant load tests. More recently the present authors have studied the resistance to SCC of the white zone in the weldable Al-Zn-Mg alloy AA 7017 by means of the slow strain rate test and measurements of the crack growth rate (7).

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The purpose of the present work is to pursue the investigations initiated in ref. (7) and, in particular, to compare the microstructure and susceptibility to SCC of the white zone with those of the commercial tempers T4 and T651.

MATERIALS AND EXPERIMENTAL PROCEDURES

The material used in this investigation was supplied in the form of 10 and 30 mm thick plates in the T651 temper. Atomic absorption gave the following composition in weight percent: Zn 5.01, Mg 2.44, Cu 0.12, Cr 0.17, Zr 0.13, Mn 0.29, Fe 0.23, Si 0.11 and Ti 0.05. In order to reproduce the microstructure of the white zone, we followed a procedure similar to that of Schmiedel and Gruhl (6); its main features are described in ref. (7). As post-weld heat treatment we have chosen the same used to obtain the T651 temper, that is, 7 days at room temperature after the solution heat treatment, followed by ageing at 150°C for 8 h (WZP), the effect of a longer treatment (48 h) was also investigated (WZP1). On the other hand, natural ageing (T4 and WZ) lasted at least 30 days. The susceptibility to SCC aqueous solutions of Na Cl (3,5%) was evaluated by means of the slow strain rate test (SSRT), whereas crack growth rates were measured on double beam wedge-loaded (DBWL) specimens in the free corrosion potential; details of the procedures concerning these techniques can be found in ref. (7). The microstructure was examined by means of optical microscopy and differential scanning calorimetry (DSC). Fracture surfaces were examined by means of scanning electron microscopy (SEM).

RESULTS AND DISCUSSION

In a previous work (7), the main characteristics of the microstructure of the white zone produced through the method mentioned above were discussed and compared to those of the white zone in weldments. The main conclusion was that this procedure adequately reproduces the significant features of the actual white zone. In this work we compare WZ and WZP samples with the commercial tempers T4 and T651. Optical microscopy revealed the following features: i) Whereas the two commercial tempers show an unrecrystallized grain structure with elongated grains, both WZ and WZP samples show a recrystallized microstructure with large and equiaxed grains. ii) Particles in the T4 and T651 tempers are uniformly distributed, while in the white zone samples they are mainly located along the grain boundaries and very few of them lie inside the grains. This analysis was supplemented by DSC measurements; the following points are worth comment: i) The thermograms for WZ and T4 samples are very similar, in particular the first endothermic peaks, which are related to the dissolution of the particles forming the microstructure of the samples, do almost overlap; this indicates that the type (likely G.P. zones) size and density of particles in the two materials are very similar. ii) More noticeable differences are observed in the artificially aged samples (T651 and WZP); although the first endothermic peaks are relatively similar, the differences in the first exothermic reaction are remarkable. As the latter reaction is mainly related to the formation of the stable phase, we can conclude that the amount of this phase in the microstructure of T651 samples is appreciably higher than in the WZP material. Longer post-weld heat treatments (WZP1) considerably reduce these differences.

The results of the SSR testing are illustrated in fig.1. We note that the T651 material shows the highest resistance to SCC; the two naturally aged (T4 and WZ) samples come next, having a very similar susceptibility, whereas the lowest resistance to SCC corresponds to the WZP samples. The results of the DBWL testing are illustrated in Fig.2, where crack growth rates are plotted as a function of the stress intensity factor. The following SCC susceptibility ranking can be drawn from these results: T651 << WZP1 < T4 < WZP <WZ; actual values of crack growth rates range from 2 x 10^{-9} m/s (T651) to 2 x 10^{-6} m/s (WZ). We also note that the K_{ISCC} is higher for the naturally aged samples (T4 and WZ) than for the artificially aged ones (T651, WZP and WZP1).

The following features of the results presented above are worth to comment: i) Naturally aged materials have a high susceptibility to SCC, no matter what grain structure they have (T4 and WZ samples). ii) However, artificially aged samples show a very strong dependence of their resistance to SCC on the grain structure and spatial distribution of particles. Particularly revealing are the results for WZP1; this material has an amount and type of particles similar to the T651 temper and its susceptibility to SCC is, nonetheless, much higher. iii) The present results for the crack growth rate in white zone samples indicate that, as already pointed out in ref.7, crack propagation might in fact be the relevant factor in determining the SSC resistance of AA 7017 weldments. iv) The combination of the SSR results and the crack growth rates for WZP samples, indicates that crack initiation does also play an important role. In fact, although this material shows the highest susceptibility to SCC in the SSR test, its crack growth rate is lower than that observed in the untreated material (WZ); this suggests that, crack initiation, crucial in SSR experiments, is much faster in WZP samples than in WZ samples.

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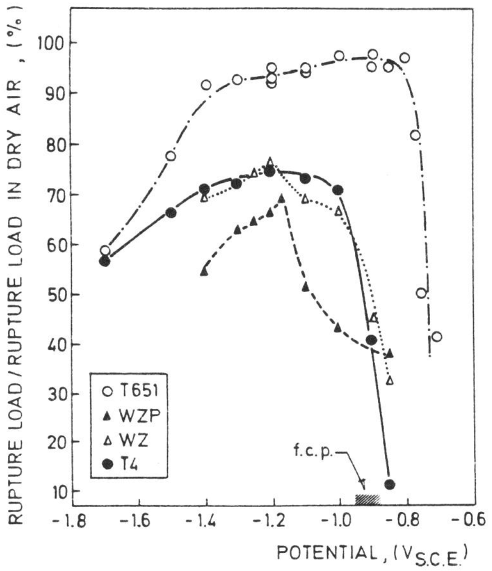

FIGURE 1- Influence of potential upon fracture load for 0.3 μm/min strain rate tests.

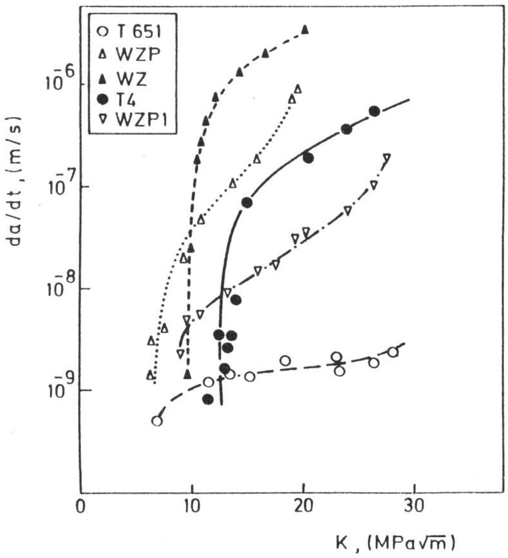

FIGURE 2- Crack growth rate - K curves for DBWL tests.