FATIGUE CRACK PROPAGATION IN Al-Zn-Mg SINGLE CRYSTALS AND ITS DEPENDENCE ON THE ENVIRONMENT

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INTRODUCTION

High cycle fatigue crack propagation has been studied in precipitation hardened Al-Zn-Mg specimens aged at 135°C for 10 (UA) and 1000 h (OA). For underaged (UA) and for overaged (OA) specimens a CRSS (τ_0) of about 100 ±5 MPa was obtained but the microstructures of the two kinds of specimen were quite different. In UA crystals tested in moist and dry atmospheres the crack propagated in a crystallographic manner (stage I). For OA specimen, however, cracks propagated predominantly in stage II in dry and wet atmospheres (1,2).

STAGE I CRACKS

In wet nitrogen the crack extension was influenced by the hydrogen atoms penetrating into the persistent slip band (PSB) which was formed in front of the crack tip. The crack growth rates (da/dN) versus ΔK for dry nitrogen and laboratory air are shown in Fig. 1. The broken line in Fig.1 represents crack growth rates in dry nitrogen (35 Pa), whereas full and open circles represent da/dN data in laboratory air (1.2 kPa). For laboratory air and crack growth rates smaller than $5 \cdot 10^{-8}$ m/c a plateau range was found at 100 Hz which is represented by the lower hatched area in the figure. For da/dN values higher than $5 \cdot 10^{-8}$ m/c (open circles) H-embrittlement vanishes and the crack propagates as fast as in dry nitrogen. For 5 Hz, however, embrittlement effects and the corresponding crack growth acceleration was observed up to 10^{-6} m/c. It can be concluded that the diffusion of hydrogen into the PSB must be the rate controlling step for hydrogen induced corrosion fatigue and it is assumed that the hydrogen atoms will be trapped by mobile dislocations. Model calculations (3) demonstrated that the diffusion of mobile hydrogen must be higher than 10^{-11} m^2/s. In this case the crack propagates always through hydrogen saturated material during each cycle.

STAGE II CRACKS

Fatigue tests undertaken with OA specimens in atmospheres containing water vapor pressures (1.2 kPa, 35 PA, $5 \cdot 10^{-4}$ Pa) respectively (Fig. 2) have shown that the crack propagated in stage- II.

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In that case the traces of water vapor found even in a nominally dry nitrogen atmosphere (p_{H2O}=35 Pa) are sufficient to affect corrosion enhanced crack extension and no difference in da/dN between dry and wet atmospheres was observed below $5 \cdot 10^{-10}$ m/c. For da/dN values greater than 10^{-9} m/c the crack behavior in dry nitrogen is similar to the crack propagation in vacuum. In vacuum corrosion fatigue was suppressed when no water vapor was present and the threshold value was about 2 times higher than in nominally dry and wet atmospheres. These results correspond quite well with tests undertaken on 7075 alloys in the T 7351(OA) condition by Petit(4).

CONCLUSIONS

Fatigue tests undertaken on UA and OA single crystals have shown that in wet nitrogen both, stage I and stage II crack extension rates are accelerated by the presence of water vapor. For stage I cracks it is the hydrogen penetrating the PSB which governs H-embrittlement and the transport of H-atoms is the rate controlling step. For stage II cracks the transport of water vapor and the adsorption of H-atoms is rate controlling and governs H-embrittlement.

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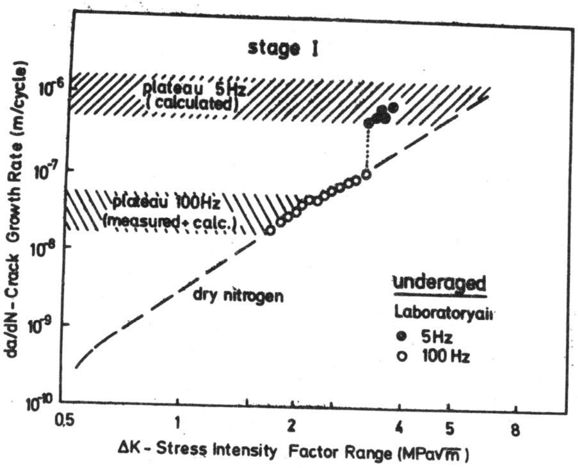

Fig. 1 Crack propagation rates da/dN versus ΔK for 100 Hz (open circles) and for 5 Hz (full circles).

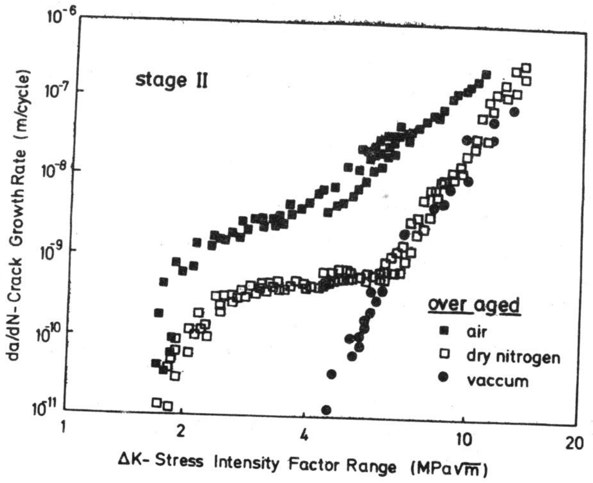

Fig. 2 Crack propagation rate da/dN for overaged specimen (100 Hz). The presented data result from 9 tests.