CRACK CLOSURE BEHAVIOR OF IRON IN AIR AND VACUUM

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INTRODUCTION

The fatigue crack growth rate, da/dN, in vacuum is usually much lower than in air. There are two reasons for this behavior:

- A change of the relation between the effective stress intensity range, ΔK_{eff}, and da/dN (caused by rewelding or a greater reversibility of the plastic deformation on the crack tip and so on)
- or a change of the crack closure behavior.

Mostly, these two groups of effects are not separated for the crack growth experiments in vacuum. The purpose of this work was to investigate the difference in the crack closure behavior between air and ultra high vacuum condition in the near threshold region.

EXPERIMENTAL PROCEDURE

The material used was ARMCO iron with a grain size of 70 µm, a 0.2%-offset yield stress of 150 MPa and a ultimate tensile strength of 280 MPa. The fatigue crack growth behavior in air is described by Pippan et al. (1). CT specimens with a width w = 50 mm, thickness B = 12 mm, notch depth ≈ 15 mm, in the LT-orientation are used.

The pre-cracks were produced in cyclic compression ΔK = 15 MPa$\sqrt{m}$, R = 20) as described by Suresh (2) and Pippan (3). Then a constant load fatigue test was performed. da/dN and the crack closure level at R = 0.1 was measured in air and vacuum ($p < 1 \cdot 10^{-10}$ bar). The crack closure was measured with crack tip strain (CTS) technique. Furthermore these results were compared with the results of a direct current potential drop (DCPD) technique.

RESULTS AND DISCUSSION

Fig. 1 shows da/dN, the change of the minimum and maximum stress intensity (K_{min} and K_{max}) and the closure stress intensity K_{cl} as a function of the change of the crack length Δl for the constant load tests (R = 0.1, initial stress intensity ΔK_i = 10 MPa$\sqrt{m}$) in air and vacuum. At the start of the tension fati-

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gue tests no crack closure occurs since the pre-crack was produced in cyclic compression (2,3). With an increase of the crack length K_{cl} increases in air and vacuum. Therefore da/dN decreases. After Δl = 1.5 mm the da/dN values agree with the long crack results (1). The difference of K_{cl} (measured with CTS-technique) between the experiments in air and vacuum is not significant. Thus the difference of da/dN between vacuum and air is caused mainly by a change of the da/dN-ΔK_{eff} relation.

In air the DCPD-technique has shown no change of the potential V when the crack closes. This effect is caused by the oxide layer on the fracture surface. In ultra high vacuum no oxide layer develops and therefore a change of the potential (DCPD-technique) indicates a change of contact points or areas on the fracture surface. Figs. 2 and 3 show typical results of the DCPD- and the CTS-technique. The change of V is very great at the part of the amplitude where the CTS-technique indicates a closed crack. But at the part of the amplitude where the CTS-technique seems to show an open crack the DCPD-technique indicates also a change of contact points on the fracture surface. Near $(P_{max} + P_{min})/2$ there are a minimum of contacts. For greater loads again the area of contacts increases. Such results were observed also by Petit (4). The reason for this effect may be caused by frictional contacts at the part of the amplitude where the crack seems to be open from the CTS-measurements.

REFERENCES

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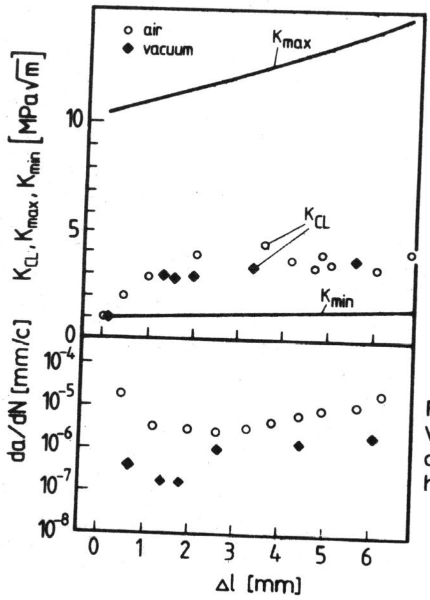

Figure 1 K_{cl}, K_{max}, K_{min} and da/dN as a function of the change of the crack length Δl in a constant load amplitude test, the pre-crack was produced in cyclic compression

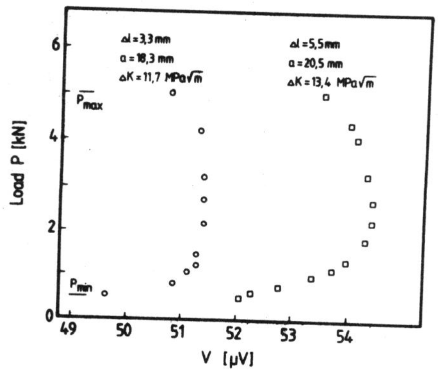

Figure 2 Change of the potential V as a function of the load, for different crack length in ultra high vacuum

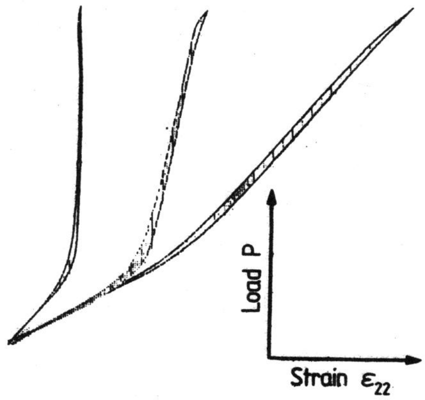

Figure 3 Typical load vs. crack-tip-strain curves (ΔK about 12 MPa√mm, R = 0.1)