# STABLE CRACK GROWTH OF A SEMI-ELLIPTICAL OUTER SURFACE CRACK IN A PRESSURE VESSEL

W. Brocks*, G. Künecke*

## INTRODUCTION

J-dominance is usually assumed to describe the stable propagation of a crack in a ductile material. The corresponding material resistance curves are obtained from specimens of simple geometries as, e. g., compact specimens with a straight crack front under uniaxial external load. For large amounts of plastification and crack advance, the $J(\Delta a)$-curves become size and geometry dependent which contradicts the idea of a "material" parameter and, in addition, only a few investigations exist how to apply the $J_R$-curve to predict the local crack extension for a surface flaw in a pressure vessel.

## ANALYSIS

In order to study this problem, elastic-plastic finite element (FE) analyses of an experimentally investigated pressurized vessel (Fig. 1) with an outer surface flaw have been accomplished. The experiment had revealed a remarkable amount of stable crack growth in axial direction beneath the surface, see Aurich et al. (1) and Fig. 2. This phenomenon of "canoe" shaping cannot be explained by the distribution of J along the crack front, as $J(\Phi)$ has its maximum at the deepest point of the crack (Fig. 3). Taking the distributions $J(\Phi)$ from the FE calculations and $\Delta a(\Phi)$ from the experiment, local $J(\Delta a)$-curves can be obtained for different points of the crack front which differ between each other as well as from the "material" resistance curve which has been obtained from compact specimens (Fig. 4).

The elastic-plastic stress analysis of the vessel by FEM shows that, due to a higher "in-plane" constraint in the axial direction, the triaxiality of the stress state defined by the ratio of hydrostatic to effective stress,

$$\chi = \sigma_{hyd}/\sigma_{eff}, \qquad (1)$$

* Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, FR Germany.

is greater near the vessel surface rather than at the deepest point of the crack where the maximum of J is found (Fig. 3). Thus, a $J_R$-curve obtained from a specimen which does not account for the triaxiality of the stress state will not be able to successfully predict the local crack propagation for a semi-elliptical surface flaw (Fig. 5), see Steenkamp (2). Now, local resistance curves $J_R(\Phi)$ may be defined by assuming that the initiation value $J_i$ is a material parameter but that the slope $dJ_R/da$ depends on the triaxiality $\chi$ obtained from the stress analysis. In order to find $J_R(\chi)$ tests on different specimen geometries, i. e. side-grooved and non-side-grooved compact specimens (for high triaxiality), center cracked panels (for low triaxiality) etc., have to be determined. Using local resistance curves which account for the local triaxiality, a much better prediction of the local crack growth $\Delta a(\Phi)$ can be given (Fig. 6).

## REFERENCES

(1) Aurich et al., BAM-Forschungsbericht 137, Bundesanstalt für Materialforschung und -prüfung, Berlin, FR Germany, 1987.

(2) Steenkamp, P. A. J. M., Fracture Control of Engineering Structures - ECF6, Vol. I, edited by H. C. van Elst and A. Bakker, EMAS, Warley, UK, 1986, pp. 15 - 31.

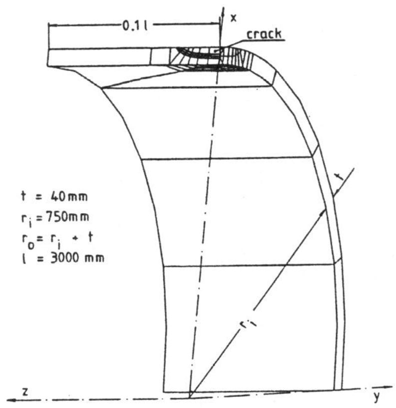


Figure 1 FE mesh of the vessel

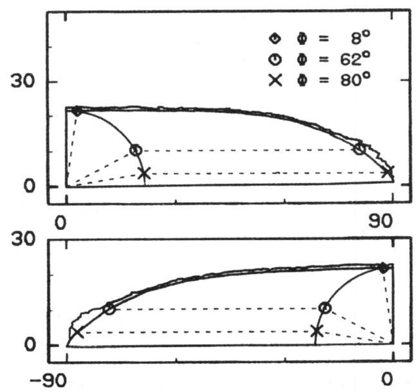


Figure 2 Fatigue crack and stable crack growth

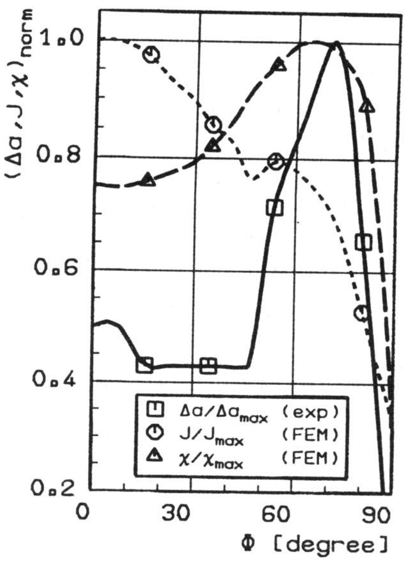


Figure 3 Variation of $\Delta$a, J, $\chi$ along the crack front

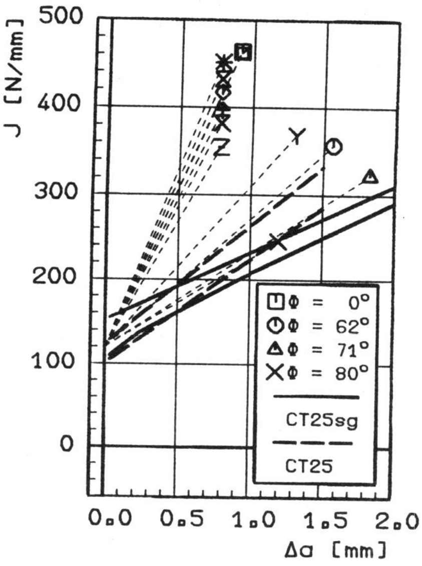


Figure 4 J-resistance curves for the vessel and compact specimens

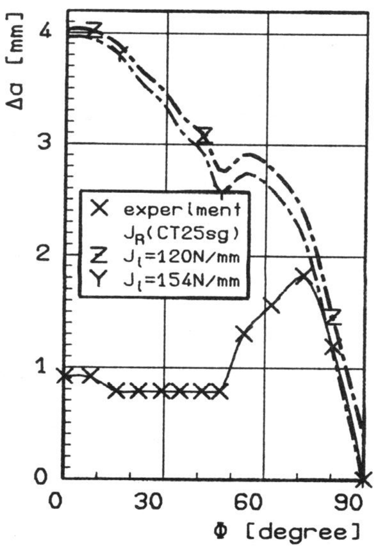


Figure 5 Prediction of $\Delta$a based on a unique $J_R$ curve

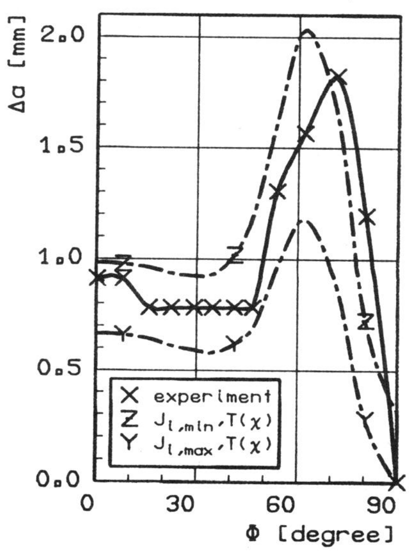


Figure 6 Prediction of $\Delta$a based on $\chi$ dependent local $J_R$ curves