STABLE CRACK GROWTH OF AN ELLIPTICAL SURFACE CRACK: NUMERICAL SIMULATION AND COMPARISON WITH THE EXPERIMENT

E. Keim*, D. Siegele**

INTRODUCTION

The evaluation of stable crack growth in the three dimensions (3D) is not a common task when applying numerical tools. Therefore a numerical round robin was conducted by Takahashi (1) who also performed the corresponding experiments. By means of a 3D finite element analysis a plate under tension containing a half-elliptical part through crack was analysed assuming elastic-plastic material behaviour. According to a given J-resistance curve stable crack growth was simulated.

NUMERICAL ANALYSIS

For the numerical analysis a rectangular section of the plate was examined. The geometry of the specimen and the mesh layout of the layers 1 to 4 are given in Figure 1. The mesh consisted of a total number of 383 isoparametric 20 noded elements and 2125 nodal points. No special crack tip elements were used.

The investigated plate was made of Japanese carbon steel JIS STS 42. Stress-strain curves were measured by the uniaxial tension test. A J-resistance curve which was obtained from CT-specimens of the original material was taken for further material characterization and a J_{IC}-value of 750 N/mm was determined. In the calculation the "Material-Nonlinear-Only (MNO)"-formulation and the engineering stress-strain law were applied.

The plate was loaded by an increasing displacement normal to the crack plane. For calculation of J-integral and simulation of stable crack growth the routine IWM-CRACK (2) in connection with FE code ADINA was used. Crack growth was automatically simulated by local node-shifting of the crack front during the analysis using the J-resistance curve as controlling parameter. J was calculated by the virtual crack extension method. In Figure 2 the results are plotted: With increasing dis-

* Siemens AG, UB KWU, Erlangen, FRG
** Fraunhofer Inst. für Werkstoffmechanik, Freiburg,FRG

placement the J-values increase and the highest values are obtained always at the deepest point. At 65 % of the final load the plate is fully plastified and the beginning of crack growth is calculated. At higher loads the crack grows continuously according to the material J-Δ a curve up to a maximum amount of 2 mm. Then the calculation was interrupted.

COMPARISON OF CALCULATION AND EXPERIMENT

A total number of four plates in tension with identical crack depths were tested. Each specimen was loaded quasi-statically at room temperature up to different amounts of tensile displacements and then unloaded.

In Figure 3 the load versus the near-crack displacement is plotted for all four plates and in addition the numerical results are shown. The global behaviour of the four plates is similar i.e. the initial crack depths and the geometries are in agreement. Numerical and experimental results of displacements agree which is also observed for other locations on the plates. From complete plastification up to final load the calculated loads are higher than the experimental ones due to the MNO option, that is no necking is considered.

The results of the stable crack growth are given in Figure 4. Our solution is in relatively good agreement with the experimental data. Contrary to all other solutions the crack shape was modified by locally displacing the crack front without the assumption of a semi-elliptical shape.

It could be shown that by means of numerical methods stable crack growth could be simulated even for complicated threedimensional crack geometries like half-elliptical cracks.

REFERENCES

(1) Takahashi, Y. et al" Round Robin Study on Ductile Growth of Part Through Crack in Carbon Steel Plate" to be published.

(2) Siegele, D. and Schmitt, W. "Determination and Simulation of Stable Crack Growth in ADINA", Computers & Structures Vol.17, No.5-6, pp.697-703, 1983

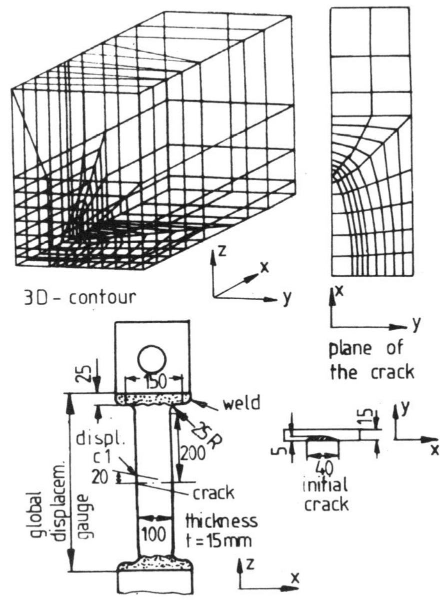

Figure 1 Geometry and mesh layout

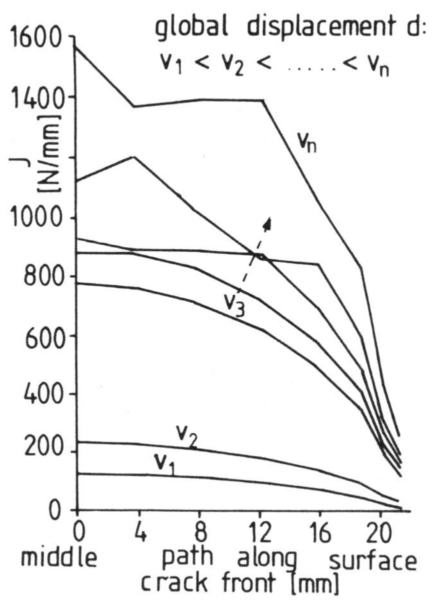

Figure 2 J-Integral values with increasing displacement

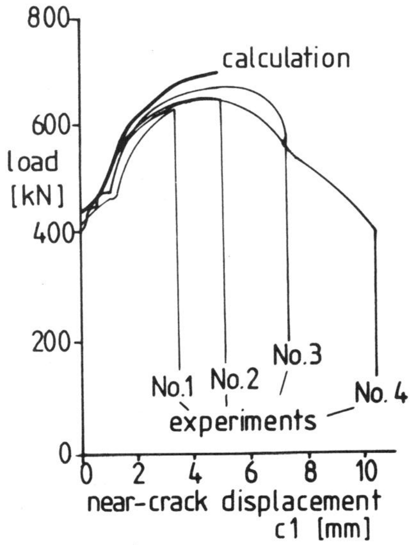

Figure 3 Comparison of global behaviour

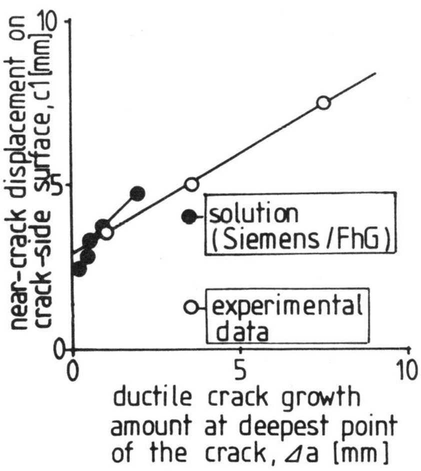

Figure 4 Comparison of local behaviour