FINITE ELEMENT ANALYSIS OF A PIPE ELBOW WITH LONGITUDINAL THROUGH CRACK

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INTRODUCTION

One of the main topics of our present research work in the field of fracture mechanics is the analysis of cracked piping components with complex geometries, e.g. pipe bends, nozzles and pipe branches. Thereby our investigations are aimed to a realistic evaluation of leakage areas of through cracks under consideration of transient operational loads.

As a first step in the frame of this work a 90 degree pipe elbow without crack and also with a longitudinal through crack located at extrados position was considered. In the following some results of elastic-plastic finite element calculations of the cracked elbow will be presented, whereby the elbow is loaded either by internal pressure only or by superimposed internal pressure and in-plane outward bending moment.

FE-CALCULATIONS

For the calculations the finite element program ADINA was used, which in our version contains some fracture mechanical extensions. Especially the calculation of J-integral-values and the evaluation of stable crack growth are possible, according to proposals by DeLORENZI (1) and SIEGELE and SCHMITT (2).

The pipe elbow was studied experimentally by KASTNER et al. (3). The component was loaded by internal pressure in this case, and is made of the steel 20 MnMoNi 55. The experiment was performed at a temperature of about 50 °C and showed a burst pressure of the component of about 18,5 MPa.

The geometrical data and the 3D-FE-model of the elbow are shown in Fig. 1. In the case of the internal pressure loading two different crack lengths were considered with and without stable crack growth, respectively.

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In the case of the additional outward bending moment only the fixed crack length a = 375 mm was considered.

The internal pressure was increased up to 19 MPa, while the maximum moment was 1000 kNm (case 1) or 3000 kNm (case 2), respectively, and the moment was applied simultaneously, i.e. with the same time function as the pressure.

RESULTS

Some results of the calculations are shown in Figs. 1 to 3. Besides an example for the plastic zone size, leakage areas calculated by a post processor program from the FE-results and J-integral-values are presented.

The analyses of the crack opening behaviour of the elbow show:

a) The calculated structural behaviour (e.g. crack opening displacement) and instability pressure (about 17,2 MPa) are in good agreement with the experiment (18,5 MPa).

b) At higher stress loads the leak areas calculated by FE are remarkably higher than those gained by analytical estimation schemes ((3), (4)). This is due to bending effects caused by the large plastic zones neglected in the analytical approximations.

c) The addition of an in-plane outward bending moment results in a decrease of leak areas and J-integral-values.

REFERENCES

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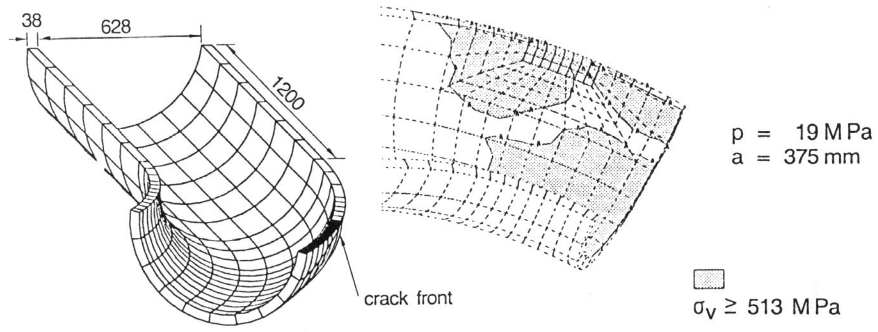

Fig. 1: FE-model of cracked pipe bend and plastic zone size at p = 19 MPa

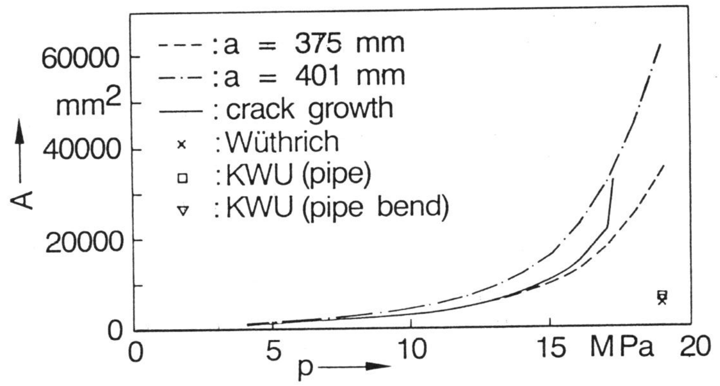

Fig. 2: Leckage areas as functions of internal pressure and analytical estimation values (3), (4)

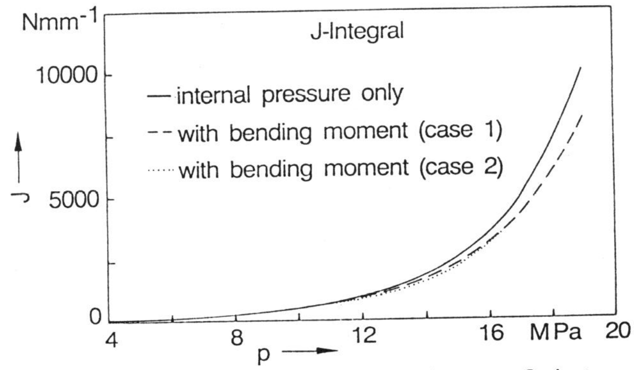

Fig. 3: J-integral values as functions of internal pressure without and with bending moment