ELASTIC-PLASTIC FINITE ELEMENT ANALYSES OF WELDED STRUCTURES CONTAINING CRACKS AND COMPARISON WITH EXPERIMENTS

R. Twickler and W. Dahl*

INTRODUCTION

In the case of a welded structure the influence of inhomogeneities of the material on the deformation and fracture behaviour has to be taken into account for a failure assessment as it is described in detail by Dahl et al. (1). If the method outlined in (1) should be extended to welded constructions, that means also using fracture mechanics concepts (J-integral or CTOD) and FE-calculations and thus avoiding the disadvantages of approximation methods, a lot of experiments (tensile tests and fracture mechanics tests for different zones of a welded joint (WJ)) and a more complicated FE-computation compared to a pure base material (BM) one are necessary (see Heuser et al. (2)).

The purpose of this paper is to make a contribution to the entire problem of assessing the failure behaviour of a welded structural component. This is done by presenting results of 2- and 3-dimensional FE-calculations of welded structures containing cracks including comparisons with measurements and a failure prediction for a series of wide plate tests. The computations were carried out by using the FE-program ABAQUS (3).

DESCRIPTION OF GEOMETRIES AND MATERIALS

Two different geometries (thicknesses B = 30 mm) machined from two different materials (20 MnMoNi 5 5, 15 MnNi 6 3) were investigated: a single edge notched bend specimen containing a fatigue crack a = 33 mm loaded in 3-point bending (SENB3), see Figure 1, and a wide plate of CNT-type (centre notched tension) with width 2W = 350 mm and a saw cutted flaw of 2a = 20 mm, see Figure 2. In contrast to an earlier investigation (2) the whole welded joints were modelled by finite elements, that means in both cases the material distribution represented by different stress-strain curves across the welded joint was taken into account (see e.g. Figure 1). In the SENB3-case the yield strengths of base material and weld metal (WM) were determined to 492 MPa and 618 MPa, respectively. For the heat affected zone (HAZ) only one stress-strain curve with a yield strength of 591 MPa was available. In the CNT-case 400 MPa was used for base material, 424 MPa for the 20 mm wide weld metal region and 492 MPa for the coarse grained zone of the HAZ directly at the fusion boundary (HAZ1). The total 16 mm wide HAZ was modelled with 6 different stress-strain curves across its width.

* Institut für Eisenhüttenkunde der Rheinisch-Westfälischen Technischen Hochschule Aachen, Intzestraße 1, D-5100 Aachen.

RESULTS

Concerning the global behaviour of the SENB3-specimen (Figure 1) it can be observed that the plane strain curve is the stiffest one, as expected, because this approach doesn't allow a lateral contraction of the geometry. Up to crack initiation (i) a quite good agreement can be established between the experiment and the 3-dimensional computation not allowing for crack growth, whereas the plane stress solution leads to loads which are much too low. Also for the CNT wide plate a quite good agreement between numerical and experimental results especially in the small scale yielding region and for the limit load can be observed (Figure 2). In this case the 3-dimensional solution is only somewhat stiffer than the plane stress result in the fully plastic range. Comparing the thickness of the wide plate with the other dimensions this correspondence could also be expected.

In Figure 3 results from J-integral caclulations belonging to different orientations of cracks in welded joints and for comparison in pure BM- and WM-models are summarized. By this means the path (in)dependence of J-integral is demonstrated. If the crack orientation is perpendicular to the different material zones the deviation of single J-values from mean J-value J_m grows continually. Consequently a meaningful J-value cannot be specified. In the other cases the deviation is limited to about ± 5%, which means J-integral is path independent within this range.

In Figure 4 experimentally obtained data are compared with a failure prediction using J-integral concept and FE-computations. A conservative prediction of the failure behaviour of a series of welded CNT wide plates can be established. The very distinct conservatism at lower temperatures is mostly due to the fracture mechanics material properties, which were obtained by testing prefatigued specimens characterized by higher local stresses in the small scale yielding range compared to saw cutted ones.

REFERENCES

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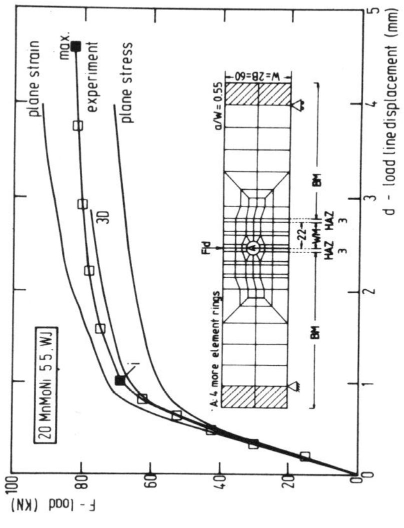

Figure 1. Global behaviour of a welded SENB3-specimen, FE-model

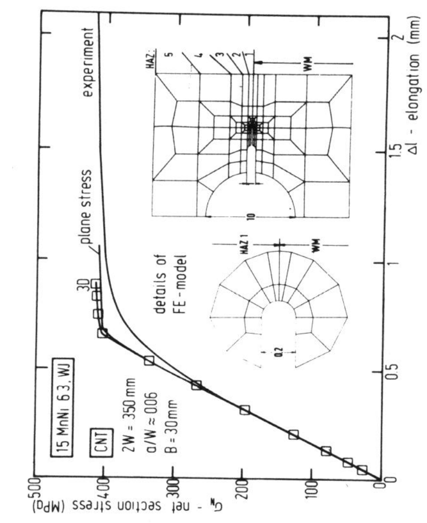

Figure 2. Global behaviour of a welded CNT wide plate, FE-model

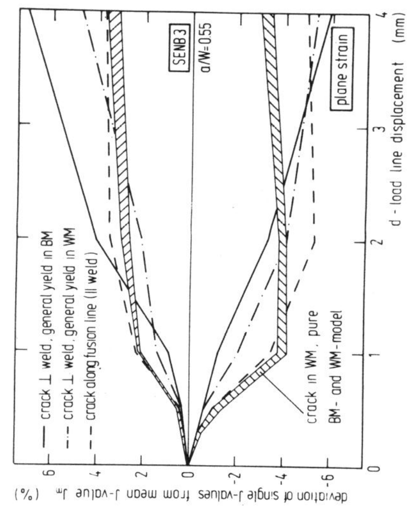

Figure 3. Path (in)dependence of J-integral in welded joints

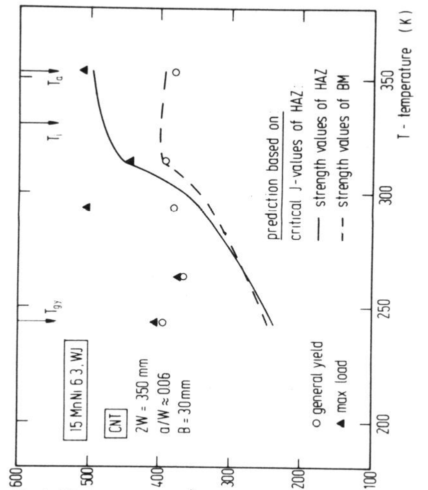

Figure 4. Failure prediction of welded CNT wide plates using J