

Numerical simulation and experimental investigation of the damage behaviour of electron beam welded joints

Begin of the Project: 01.10.2007

End of the Project: 30.09.2011

Aim

The main goal of this project is to micromechanically analyze the fracture behaviour of a steel alloy butt joint using the finite element method. In this project, the Rousselier model is adopted to describe void growth and coalescence as well as crack growth for an S355 butt electron beam welded joint. Based on the experimental investigations, the Rousselier parameters can be fixed by numerical calibration. The same Rousselier model will be used to predict the ductile crack growth of C(T) specimens with different initial crack positions. The simulation results will be compared with the experimental results of C(T) specimens in order to confirm that the Rousselier model can predict the fracture behaviour of homogeneous structures as well as for inhomogeneous beam welded joints.

Approach

The project is divided into two parts. The first part is to determine necessary Rousselier parameters and model input data based on the experimental investigation and numerical calculation. Metallographic cross-sectional investigations are performed in different weld regions in order to obtain size, shape, volume fraction and distribution of non-metallic inclusions. The void volume fraction (f_0) and average distance between particles (l_c) can be obtained by comparing the calculated and experimental force-cross section reduction (ΔD) curves of notched round specimens. Based on hardness test results and microscopic investigations of electron beam welded specimens, three different weld regions are defined, i.e. the fusion zone (FZ), the heat affected zone (HAZ) and the base material (BM). Local mechanical properties are derived from tensile test results of unnotched round bars and flat specimens from these regions. These local mechanical properties and the Rousselier parameters are used as model input data.

The second objective is to predict ductile crack growth in compact tension (C(T)) specimens by applying the same Rousselier parameters obtained in the first part of the analysis. Ductile crack propagation in C(T) specimens is studied with an initial fatigue crack located in the BM, in the FZ and in the HAZ, respectively. After applying

the Rousselier model on the C(T) specimens, the numerical results are compared with the experiments in terms of force vs. Crack Opening Displacement (COD) as well as fracture resistance (J_R) curves.

The Rousselier model is first applied to the homogeneous S355 base material. Based on the information of optical microscope, the Rousselier parameters (l_c , f_0) are calibrated numerically. Notched round specimens extracted from the base material are used for the calibration. According to Fig. 1, the Rousselier parameters can be fixed for the BM. The same parameters are used to predict the crack propagation in C(T) specimens as shown in Fig. 2. It can be seen from Fig. 2 that the Rousselier model can predict the crack propagation in a homogenous C(T) specimen well (deviation < 5%). The Rousselier model is presently applied to predict the crack propagation for a C(T) specimen with the initial crack located in the FZ and HAZ.

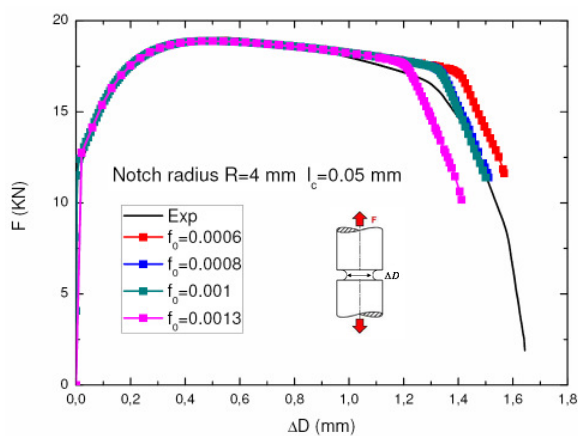


Fig. 1: Comparison between numerical and experimental F- ΔD curves of notched specimens with 4 mm notch radius.

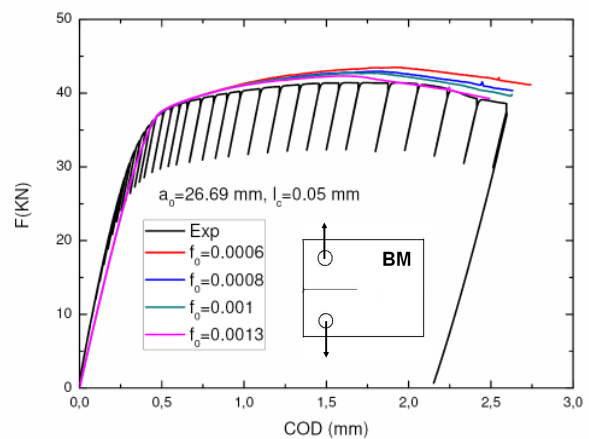


Fig. 2: Comparison between numerical and experimental F-COD curves of C(T) specimens obtained from the base metal.

Partners

Some of the experimental work is done in collaboration with “Neue Materialien Bayreuth GmbH” where the electron beam welded joints are made. Local mechanical properties of different weld regions, hardness tests as well as the chemical composition of the welded joint are also determined there.

Publication

H. Y. Tu, Y. Rudnik, S. Schmauder, U. Weber, V. Ploshikhin. Numerical simulation of crack propagation in electron beam welded joints. In: 18th Euro Conf on Fracture, ECF 18, Dresden, 2010.

Acknowledgment

The research has been financially supported by China Scholarship Council (CSC) and Prof. S. Schmauder. This financial support is gratefully acknowledged.

Contact Person

Mr. Haoyun Tu

Tel.: +49/711/685-63075

Fax: +49/711/685-62635

E-mail: haoyun.tu@imwf.uni-stuttgart.de

Prof. Dr. rer. nat. Siegfried Schmauder

Tel.: +49/711/685-62556

Fax: +49/711/685-62635

E-mail: siegfried.schmauder@imwf.uni-stuttgart.de

Dr.-Ing. Ulrich Weber

Tel.: +49 / 711 685-63055

Fax: +49 / 711 685-62635

E-mail: ulrich.weber@imwf.uni-stuttgart.de