Prediction of cleavage fracture in fracture mechanical tests (SENB) using an modified version of the Gurson-Tvergaard-Needleman model (GTN) – COMPLAS 2019

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ABSTRACT

Fracture mechanical safety analyses have been used for several decades to carry out safety-relevant designs of components. In particular, it is important to exclude cleavage fracture as a possible form of rupture. Fracture mechanical analyses make simplified, partly empirical assumptions for the treatment of stress and strain fields in front of the crack tip. In order to verify the conservative estimations of these assumptions, damage mechanical simulations of fracture mechanics specimens are performed. This allows a detailed description of the stress fields in front of the crack tip.

Therefore, a modified version of the Gurson-Tvergaard-Needleman (GTN) model is used to predict cleavage fracture events in SENB samples [1]. This can be enabled, by implementing the generalized Orowan cleavage fracture model to the GTN model [2]. This model defines fracture in dependence of critical stress- and strain states for every element of the FEA calculation. Taking into account both the technical cleavage fracture stress as well as the critical equivalent plastic strain, cleavage fracture can be defined more precisely compared to older models. The equivalent plastic strain, is thereby dependent on the lode angle and stress triaxiality. This enhances the predictability of cleavage fracture.

A difficulty in the simulation of fracture mechanics specimens with sharp cracks thereby lies in the mesh dependence of the stress field in front of the crack tip, as well as in the mesh dependence of the crack path [3]. Especially for low temperatures at which only very low local plastic strains occur, an adequate meshing of the crack tip and the possible crack path is of particular importance. For this reason the generalized Orowan model uses local values for an initiation of the brittle crack. To solve this problem, the study intends to illustrate a detailed parameter study on different meshing methods in front of the crack tip. At first, simulations are conducted on simplified models with crack initiation in order to minimize the computational effort. Subsequently, the most promising approaches are transferred to simulations of SENB samples. The simulated results will be compared with experimental results of a structural HSLA steel.

REFERENCES

[1] Brinnel, V., 2017, Improved Limit State Definitions for Pressure Vessels by a Scalebridging Application of Damage Mechanics, Aachen

[2] He, J.; Lian, J.; Golisch, G.; Jie, X.; Münstermann, S., 2017, A generalized Orowan model for cleavage fracture, Engineering Fracture Machanics, 186: 105-118

[3] Kuna, M., 2013, Finite Elements in Fracture Mechanics: Theory - Numerics – Applications, Springer Netherlands