Applying the generalized Orowan criterion, to model cleavage fracture of High-Strength Low-Alloy steels (HSLA) – CFRAC 2019

Langenberg, J.*, Lenz, D. † Könemann, M. † Münstermann, S. †

* Steel Institute (IEHK)
RWTH Aachen University
Intzestraße 1, 52072 Aachen, Germany
e-mail: julius.langenberg@iehk.rwth-aachen.de, web page: http://www.iehk.rwth-aachen.de

† Steel Institute (IEHK)
RWTH Aachen University
Intzestraße 1, 52072 Aachen, Germany
e-mail: sebastian.muenstermann@iehk.rwth-aachen.de, web page: http://www.iehk.rwth-aachen.de

ABSTRACT

Perhibitting cleavage fracture is a crucial safety factor in the design of multiaxial loaded components. Damage mechanical simulations are utilized for the design of those components yielding to a better understanding of the mechanical properties. In this research, a modified version of the Gurson-Tvergaard-Needleman (GTN) model is used [1] for the prediction of cleavage fracture events. Cleavage fracture in Gurson models is mostly simulated by a combination with a Beremin model as a post-processor [2]. Unfortunately, the Beremin model is not able to take stress triaxialities and the Lode-angle into account, two parameters which are critical to adequately depict cleavage fracture.

The generalized Orowan cleavage fracture criterion, defines fracture in dependence of critical stress- and strain states for every element of the FEA calculation [3]. The study aims for the evaluation and implementation of the cleavage fracture criterion into the GTN model. Charpy impact tests in the lower shelf are used to demonstrate the applicability of the model. Thus, the generalized Orowan criterion given by [3] will be implemented into the underlying GTN formulation and a summary of the implementation technique will be given. The generalized Orowan criterion uses a combined damage criterion, taking into account both the technical cleavage fracture stress as well as the critical equivalent plastic strain. The equivalent plastic strain, at which crack initiation occurs in the material, will be evaluated and shall be coupled to the numerical model. This enhances the predictability of cleavage fracture. The evaluation uses fractographic analysis of both fracture surfaces and cuts of the cross section from different sample geometries. The examined steel shows different ductile resources at cryogenic temperatures, in dependence of triaxiality and Lode-angle. The local plastic strain, needed to trigger cleavage fracture in the material, thus has to be taken into consideration. Furthermore, different experiments show a huge variety in fracture strains which are taken into account by the use of a Weibull-distribution function. Combining both features yields to a damage plane as an important failure criterion for the numerical description of cleavage fracture.

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