Energy based cleavage criterion (Gp approach) applied to the problem of shallow crack effect

C. Jacquemoud*, S. Jules†, S. Géniaut†

* DEN-Service d'études mécaniques et thermiques (SEMT),
CEA, Université Paris-Saclay
F-91191 Gif-sur-Yvette, France
e-mail: clementine.jacquemoud@cea.fr

†EDF Lab Paris-Saclay
7, boulevard Gaspard Monge
91120 Palaiseau, France

ABSTRACT

An energy-based criterion has been developed at EDF by Wadier [1] to predict cleavage fracture under non-proportional loading. The objective is to provide the engineers with a tool of common and practical use, being a simple extension of the classical J-integral approach.

This approach, called Gp approach, consists in modelling the crack by a notch of finite thickness and in minimizing the total energy of the structure with respect to the length of the virtual propagation of this notch. An energy parameter, representing the mean stored elastic energy, is defined taking into account the constraint effect. It might be used in any situations of cleavage fracture where the J-integral is too conservative and/or is not valid such as unloading conditions.

Validation of the proposed criterion has been conducted through a benchmark aiming at predicting the shallow crack effect on the two finite element codes: code_aster [2] and Cast3M (developed at CEA [3]). Initially developed in code_aster, the Gp approach has been implemented in Cast3M via a post-treatment subroutine. This application aims at verifying the situations where the approach is valid and evaluating the Gp sensitivity to different parameters such as mesh, temperature, notch high, strain hardening, etc…

Experimental data on SEN(B) tests made of ferritic steel and containing shallow and deep cracks were available at different temperatures in the ductile-to-brittle transition range. 2D simulations of the deep crack tests enable to identify the critical energy release rate for fracture, by comparison to experimental results. The Gp approach has then been applied to predict the toughness increase due to the presence of a shallow crack. Results are compared to predictions obtained with the classical J-integral approach to evaluate the efficiency of the Gp approach.

REFERENCES

[1] Y. Wadier, "An energy approach to predict cleavage fracture under non-proportional loading", *Engineering Fracture Mechanics*, Vol. **97**, pp. 30–51, (2013).

[2] code_aster, http://www.code-aster.org/

[3] Cast3M, http://www-cast3m.cea.fr