Development of the local approach to fracture over the past 25 years: theory and application

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ABSTRACT

This review paper is devoted to the local approach to fracture (LAF) for the prediction of the fracture toughness of structural materials, essentially metallic materials. The bases of this relatively newly developed methodology are first presented. The LAF has been considerably developed over the past two decades, not only to provide a better understanding of the fracture behaviour of materials, in particular the failure micromechanisms, but also to deal with loading conditions which cannot easily handled with the conventional LEFM and EPFM global approaches. Both ductile rupture and brittle cleavage fracture micromechanisms are considered. The ductile-to-brittle transition observed in ferritic steels is also adressed. Two types of LAF methods are presented : (i) those assuming that the material behaviour is not affected by damage (eg. Brittle fracture), (ii) those using a coupling effect between damage and constitutive equations (eg. Ductile fracture).

The micromechanisms of brittle and ductile fracture investigated in elementary volume elements are briefly presented. The emphasis is laid on cleavage fracture in ferritic steels. The role of second phase particles (carbides or inclusions) and grain boundaries are more thoroughly discussed. The distinction between nucleation and growth controlled fracture is made. Recent developments in the theory of cleavage fracture incorporating both the effect of stress state and that of plastic strain are presented. These theoretical results are applied to the crack tip situation to predict the fracture toughness. It will be shown that the ductile-to-brittle transition curve can reasonably be well predicted using this approach. The LAF methodology requires the indentification of a number of material parameters. The numerical results may also be dependent of the mesh sizes used in the finite element calculations. Some indications on identification procedures and mesh size effects are given.

Additional applications of the LAF approach methods are also shown, including: (i) the effect of loading rate and prestressing; (ii) the influence of residual stresses in welds; (iii) the mismatch effects in welds and interfaces; (iv) the warm-prestressing effect; (v) the irradiation embrittlement. An attempt is also made to clearly delineate research areas where large improvements should be made for a better understanding of the failure behaviour of structural materials.