Local Approaches to Fracture Assessment: Material, Geometry and Load History Effects

Local approach methods are becoming increasingly popular in assessments of crack behaviour where the classical fracture mechanics cannot provide predictions. Some guidance on the use of a selected number of local approach methods is already included in the British R6 procedure "Assessment of the integrity of structures containing defects". In this seminar I will discuss my experience with several such methods going beyond the R6 provision. The seminar will be split into two parts dealing separately with cleavage and ductile fracture.

Part 1: Is the weakest link argument not the weakest link in the argument?
In this part, I will discuss the assumptions and the corresponding differences in most of the existing local approach methods for cleavage fracture predictions, including one microstructurally-informed method developed recently by me. I will illustrate the application of the current methods for predicting the effects of irradiation and crack geometry on the cleavage fracture toughness. The results will show that the methods have limited predictive capability with physically realistic parameters. I will discuss this outcome and will demonstrate that the improvements over the years have been focused on what I call 'local' or 'individual' failure probability. The common feature of these methods is the strategy to calculate the 'global' or 'cumulative' failure probability which is based on the weakest-link argument. I will support my view that this argument is the weakest point in the development of a successful local approach. I will finally discuss possible routes for furthering our understanding on the interactions between micro-cracks which is crucial for developing a more realistic methodology for 'global' failure probability from 'individual' probabilities.

Part 2: Load history effects on ductile initiation fracture toughness
In this part, I will focus on the most widely used local approach method for ductile fracture - the one based on the Gurson-Tvergaard-Needlemen (GTN) porous plasticity model. I will use the model to consider the effect of load history on ductile fracture initiation in a typical fracture mechanics test specimen. The aim is to investigate the benefits of applying such a model to situations where events in the plant loading history can have a significant effect on crack driving force for typical defects that subsequently develop during service. The results will show how the initial detrimental effect of residual stresses can be assessed and that in certain circumstances load excursions on the specimen can have a beneficial effect on global load carrying capacity. It will be thus shown that in principle load history effects can be captured by adopting the local approach for the assessment of ductile fracture. It will be also noted that the trends observed in other local parameters, e.g. J and CTOD, must be treated with caution, probably due to near crack-tip softening associated with the implementation of the GTN model in a region of high stress concentration. I will discuss some issues with the implementation of the GTN model and will offer some necessary steps for further development.

I will conclude with emphasising our need to make progress on both types of models, cleavage and ductile, in order to make any progress on more "engineer-friendly" approaches, such as the J-Q approach for toughness assessments.