Crack tip modelling - Discussion of fracture paper #9

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Discussion of fracture paper #9 - Crack tip modelling

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Dear Reader,
I recently took over as the ESIS blog editor. Being the second in this baton relay, I will do my best to live up to the good reader expectations that has been established by my precursor, who is also one of the instigators of the blog, Wolfgang Brock.
I did not follow the blog in the past. That I regret now that I go through the previous blogs. Here I discover many sharp observations of new methods and concepts paired with a great ability to extract both the essential merits and to spot weaknesses. Much deserve additional studies to bring things to a common view. We are reminded that common views, often rightfully, but not always, are perishable items.
Paper 9 in this series of reviews concerns phenomena that occur when a crack penetrates an interface between two materials with dissimilar material properties. In the purely elastic case it is known that a variation of Young's modulus along the intended path of a crack may improve the fracture resistance of inherently brittle materials. If the variation is discontinuous and the crack is about to enter a stiffer material the stress intensity factor becomes unlimited with the result that fracture will never happen. At least if the non-linear region at the crack tip is treated as a point. To resolve the problem the extent of the non-linear region has to be considered.
The selected paper is: Effect of a single soft interlayer on the crack driving force, M. Sistaninia and O. Kolednik, Engineering Fracture Mechanics Vol. 130, 2014, pp. 21–41.
The authors show that spatial variations also of the yield stress alone can improve the fracture resistance. They find that the crack tip driving force of a crack that crosses a soft interlayer experiences a strong dip. The study is justified and the motivation is that the crack should be trapped in the interlayer. The concept of configurational forces (a paper on configurational forces was the subject of ESIS review no. 7) is employed to derive design rules for an optimal interlayer configuration. For a given matrix material and load, the thickness and the yield stress of a softer interlayer are determined so that the crack tip driving force is minimised. Such an optimum configuration can be used for a sophisticated design of fracture resistant components.
The authors discuss the most important limitations of the analysis of which one is that a series of stationary cracks are considered instead of a

growing crack. The discussion of growing versus stationary cracks is supported by an earlier publication from the group. Further the analysis is limited to elastic-ideally plastic materials. A warning is promulgated by them for directly using the results for hardening materials.

The paper is a well written and a technically detailed study that makes the reading a good investment.

The object of my discussion is the role of the fracture process region in analogy with the discussion above of the elastic case. The process region is the region where the stresses decay with increasing straining. When the process region is sufficiently small it may be treated as a point but this may not be the case when a crack penetrates an interface. The process region cannot be small compared to the distance to the interface during the entire process. In the elastic case the simplification leads to a paradoxical result. The main difference as compared with the elastic case is that the ideally plastic fields surrounding a crack tip at some short distance from the interface have the same characteristics as the crack that has the tip at the interface, i.e. in the vicinity of the crack tip the stress is constant and the strain is inversely proportional to the distance to the crack tip. This means that the distance between the crack tip and the interface do not play the same role as in the elastic case. A couple of questions arise that perhaps could be objects of future studies. One is: What happens when the extent of the process region is larger than or of the order of the distance to the interface? If the crack is growing, obviously that has to happen and at some point the fracture processes will probably be active simultaneously in both materials. The way to extend the model could be to introduce a cohesive zone of Barenblatt type, that covers the fracture process region. The surrounding continuum may still be an elastic plastic material as in the present paper.

A problem with growing cracks is that the weaker crack tip fields does not provide any energy release rate at a point shaped crack tip. Would that limitation also be removed if the finite extent of the process region is considered?

With these open questions I hope to trigger those who are interested in the subject to comment or contribute with personal reflections regarding the paper under consideration.

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