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Discussion of fracture paper #18 - A crack tip energy release rate caused by T-stress

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A T-stress is generally not expected to contribute to the stress intensity factor because its contribution to the free energy is the same before and after crack growth. Nothing lost, nothing gained. Some time ago I came across a situation when a T-stress, violates this statement. The scene is the atomic level. As the crack is producing new crack surfaces the elastic stiffness in the few atomic layers closest to the crack plane are modified. This changes the elastic energy which could provide, contribute to or at least modify the energy release rate. If the energy is sufficient depends on the magnitude of the T-stress, the change of the elastic modulus and how many atomic layers that are involved.

If I should make an estimate it would be that the energy release rate is the change of the T-stress times the fraction of change of the elastic modulus times the square root of the thickness on the affected layer. Assuming that the T-stress is a couple of GPa, the change of the fraction of change of the elastic modulus is 10% and the affected layer is around ten atomic layers one ends up with 100kPa m^(1/2). Fairly small and the stress and its change are taken at its upper limits but still it is there. The only crystalline material I could find is ice with a toughness of the same level. Other materials are affected but require some additional remote load.

Interestingly enough I came across a paper describing a different mechanism leading to a T-stress contribution to the energy release rate. The paper is:

Zi-Cheng Jiang, Guo-Jin Tang, Xian-Fang Li, Effect of initial T-stress on stress intensity factor for a crack in a thin pre-stressed layer, Engineering Fracture Mechanics, pp. 19-27.

This is a really read worthy paper. The reasons for the coupling between the T-stress and the stress intensity factor is made clear by their analysis. The authors have an admirable taste for simple but accurate solutions. The paper describes a crack with a layer of residual stress, that gives a T-stress in the crack tip vicinity. As the crack advances increasing more material end up behind the crack tip rather than in front of it. The elastic energy density caused by the T-stress is larger in front of the tip than it is behind it. The energy released on the way and can only disappear at the singular crack tip, not anywhere else in the elastic material. The reason for the energy release is the assumed buckling in the

direction perpendicular to the crack plane. An Euler-Bernoulli beam theory is used to calculate the contribution to the energy release rate. Having read the paper I realise that in a thin sheet buckling out of its own plane in the presence of a crack and a compressive T-stress there will be energy released that should contribute to crack growth. The buckling will give a more seriously distorted stress state around the crack tip, but never the less. In this case the buckling area would be proportional to the squared crack length in stead of crack length times the height of the layer as in the Jiang et al. paper. The consequence is that the contribution to the stress intensity factor should scale with the T-stress times square root of the crack length.
Suddenly I feel that it would be very interesting to hear if anyone, maybe the authors themselves, know of other mechanisms that could lead to this kind of surprising addition to the energy release rate caused by T-stresses. It would be great if we could add more to the picture. Anyone with information is cordially invited to contribute.

Per Ståhle