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A level set approach for brittle damage

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In this paper, we present a model for damage evolution. It is well known that fracture mechanics alone, despite all the advances in numerical techniques to represent cracks, can not represent easily the initiation process or the changes of topology in the crack shape, like branching or merging of cracks. To model properly such phenomena, damage mechanics models are more adapted. But damage models have their own weaknesses. Damage models are usually written locally for a given material, which cause well known spurious numerical localization and force the use of complex techniques, be it averaging the local material law over a region or using second gradient model. Recently, new type of descriptions appeared, that we see as means to bridge the gap between damage and fracture mechanics. In Bourdin, Francfort and Marigo (1), brittle damage is regarded as a minimization problem on a crack field and the mechanical fields. The crack field represents the crack position by a continuous function over the full domain, whose value is 0 close to the crack and 1 far from it. The physics community (2) developed another model, the so called “phase field approach”. Here, the phase field, represents the damage and a global phase equation is coupled to the mechanical equations to describe the damage evolution. A level set technique was proposed by Salac (3), where a level set function is used to separate the fully damaged zone from the undamaged one. The damage front in this model advances, if a driving force reaches a critical value. The first two descriptions force to solve global equations on the full computation domain, in the last approach, only a front velocity needs to be computed and the level set advance can take advantage of narrow-band techniques to improve efficiency. Inspired by Nguyen (4) and Salac model, we propose a new model that might improve the previous one. In our model, a level set is used to separate the undamaged zone from the damaged one. The iso-zero of the level set is the damage front that moves according to a Kuhn Tucker type relation, on each point of the front :

$$v_n \geq 0 \quad f = e - \left(Y_c + \frac{\gamma_c}{\rho} \right) \leq 0 \quad f v_n = 0 \quad (1)$$

where v_n is the normal velocity of the damage front, e the free energy and ρ the radius of curvature of the front and f plays the role of the driving force that moves the front. Y_c and γ_c are parameters of the model, and respectively represent a critical bulk energy and a critical surface energy. Note that, $\gamma_c/Y_c = l_c$ introduces a natural length scale in the model, length scale that should prevent spurious localisation and allow for size effect in the model.

The algorithm to compute new position of the front verifying the above Kuhn Tucker relation will be described and some results in the framework of planar linear elasticity for the undamaged zone, including branching and merging of cracks will be discussed (figure 1).

References

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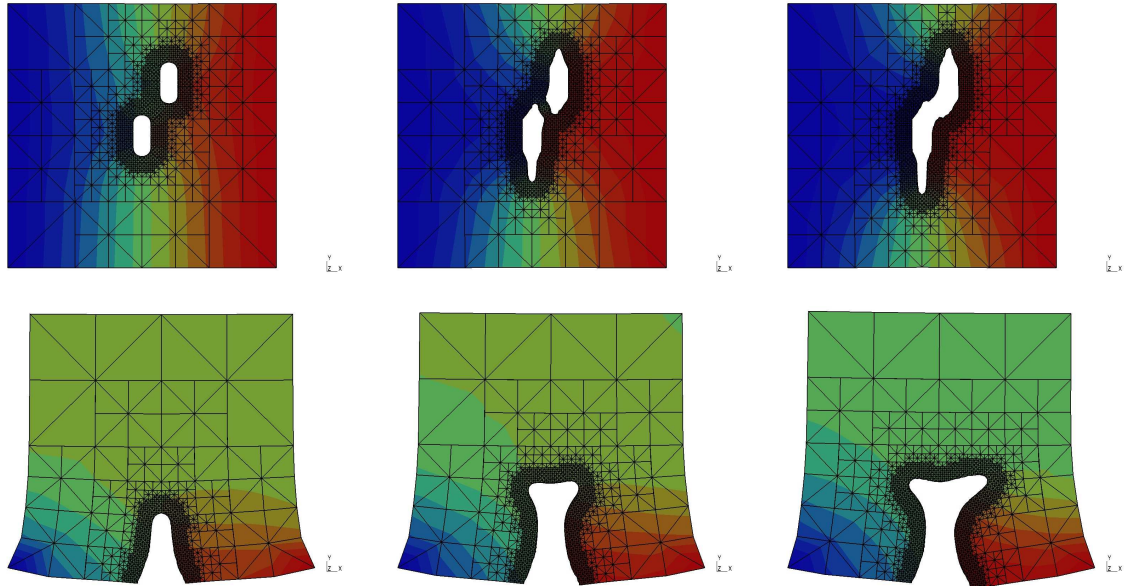


Figure 1: Top : Merging of two damaged zone, Bottom: Branching of a crack encountering a stiffer material.

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