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## **The Thick Level Set Model: a Non-Local Damage Model Allowing Automatic Crack Placement Inside Localization Zones**

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When dealing with damage models in order to initiate and grow cracks, two issues at least must be taken into account. The first one is to avoid spurious strain localization (zero dissipation produced although damage has reached its maximum value). The second one, is to allow displacements to be discontinuous when the material stiffness is totally lost.

The first issue is usually taken into account by introducing a length scale in the model and rendering the model non-local. Regarding the second issue, crack placement is so far in the literature a numerical issue and not related to the non-local damage model.

In this paper, we improve the current state of affairs regarding the issues described above. The Thick Level Set (TLS) model ties damage to a level set and was initially introduced in [1,2]. An important advantage of this model is that the model is non-local only where needed in the domain (close to localization) allowing the major part of the domain to be dealt with purely local constitutive law. Somehow, local and non-local zones are different entities separated by a moving surface treated in the spirit of [3].

Regarding the second issue, the TLS models offers an automatic way to place cracks inside localized zone. The crack location is simply all points beyond the level set  $l_c$  (iso- $l_c$ ). There is thus no limitations on the crack shape. Merging and branching is also carried out automatically due to the topological flexibility of the level set representation.

The first numerical implementation of the TLS was performed in [1,4]. It relies on the use of the X-FEM [5] to allow finite element support cut by the crack to be enriched with a Heaviside function thus modeling crack displacement discontinuity. In the presentation, we will introduce a further refinement in the numerical implementation. Both crack lips (iso- $l_c$  of the level set) will be allowed to cut the

same finite element. This permits a crack placement rather insensitive to the mesh size (provided it is of course below the characteristic length scale of the material).

Numerical simulations will target 2D and 3D application in quasi-static analysis of quasi-brittle materials. Disymmetric tension-compression constitutive models will be used. CPU time and numerical robustness of the TLS will be discussed.

### **References**

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