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Geometrical and numerical aspect of the Thick Level Set (TLS) Damage and fracture model

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In the TLS model for damage and fracture, first presented in [1], the spatial evolution of the damage is regularized by limiting the gradient of d (the damage parameter). This limiting is done by computing d as a function of another field variable ϕ for which the constraint $\|\nabla\phi\| \leq 1$ must be fulfilled everywhere. The material domain Ω is therefore divided into two sub-domains, one for which $\|\nabla\phi\| < 1$ and one for which $\|\nabla\phi\| = 1$. In the first zone the damage is diffuse and is said to be local: its evolution depends only on the local stress or strain fields. In the second sub-domain the damage is regularized by limiting the spatial variation of ϕ and therefore avoiding spurious localization of the damage. This second sub-domain is said to be non local, and the damage evolution on this zone is driven by a non-local law which can be computed by enforcing the constraint on ϕ on the local evolution law. This approach has several advantages : (i) The non local computation can be done only on the relevant part of the domain. (ii) The damage evolution in the non local zone is completely driven by the motion of the boundary Γ between the local and non local sub-domains.

The function that link d to ϕ is defined as a monotonous function of ϕ , which saturate to 1, where the material is fully damaged, beyond a certain value of ϕ , corresponding to an internal length scale l_c . This mean that the fully damaged zone is bounded by an iso-value of ϕ . This fully damaged zone is interpreted as being the crack. The model permits to describe a full failure scenario : starting from diffuse damage, using classical local damage model. When damage start to localize, the constraint on ϕ impose a non local behavior, introducing a length scale in the problem. When damage reach 1 somewhere, a crack is automatically defined and can continue to evolve. It is geometrically described by the iso- l_c surface of ϕ . With this model we were able to cover different interesting failure scenario, including damage initiation, crack apparition, crack coalescence and crack bifurcation [2], [5]. Nice features of the model include a natural link with Griffith theory for fully developed cracks as well as an equivalence with cohesive cracks [3]. The model was also recently compared with phase-field approach [4], for the brittle and quasi-brittle cases.

In this presentation we will set the focus on the implementation of some geometrical aspects of the TLS. We will in particular show how the fast marching method can be used to enforce $\|\nabla\phi\| = 1$ in the non local zone, to construct the discrete space on top of the finite element mesh, that is used to compute the damage evolution, and to construct a good approximation of the skeleton of the non-local zone, where the damage gradient is not continuous. In particular this skeleton extraction can enhance a lot the precision of the TLS Method by giving a better way to extract the iso- l_c . It also permits to improve the discretization of the fields, since the skeleton is also the locus of discontinuities of the gradient of d .

References

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