Sharp cracks in continuous damage models using the eXtreme Mesh deformation approach (X-Mesh) : a 1D study

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Abstract

Continuous damage models are widely used to model the propagation of cracks, since they can handle
complex cracking processes, from nucleation to coalescence and branching. However, these approaches
do not explicitely model cracks opening, which is necessary to avoid numerical issues when the damage
variable d tends to 1, or to model contact phenomenon between cracks lips for instance. In this work,
we will see how to use the eXtreme Mesh deformation approach (X-Mesh) introduced in (1) to insert
macro-cracks opening inside a continuous damage model. In particular, we will consider two continuous
approaches to fracture: the Phase-field approach which has been widely used to model the failure
of material since the last few years, and a more recent one, the Lip-field approach. Both formulate
the mechanical problem to be solved as the minimization problem of an incremental potential, and intro-
duce a characteristic length parameter c to avoid mesh dependency, the main difference being how this
parameter c is taken into account.

The main idea of X-Mesh as it is presented in (1) is to move the nodes of a finite element mesh to have a
time continuous, sharp representation of a moving front (for instance in (1), a phase-change front). These
nodes movements allow to model topological changes of the front, including coalescence and splitting.

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Note that only the position of the mesh element nodes changes, the topology of the mesh being fixed (that
is, the connectivity between the nodes), which is easier than full remeshing. For fronts where only
the derivative of the quantity of interest if discontinuous, having only a line/surface of nodes in 2D/3D
on the front is enough; however, in the case of cracks where the displacement field is discontinuous, the
key idea will be to move nodes to create zero measure elements at the cracks location.

Since both Phase-Field and Lip-field formulate the mechanical problem to be solved as an optimisation
problem, where the unknown are the displacement and damage fields, it is natural in the X-Mesh framework to consider the mesh nodes position as an additional unknown. In this work, we will show on a 1D
bar example that by optimising the mesh nodes position, zero measure elements appear when the damage
variable tends to 1, allowing jumps of the displacement solution.

(1) Moës, N. and Remacle, J.F. and Lambrechts, J. and Lé, B. and Chevaugeon, N. (2023). The eXtreme
Mesh deformation approach (X-MESH) for the Stefan phase change model. Journal of Computational Physics, 477: 111878.