ON OBJECTIVE DYNAMIC FAILURE PREDICTIONS USING LOCAL CONSTITUTIVE MODELS

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1. Context: the modelling and simulation of damage and failure

Today, realistic simulations of complex industrial problems including all their technological complexity require using legacy codes. In the case of the simulation of failure, two main difficulties arise. The first one concerns only quasi-static or slow dynamic problems. In this case, implicit schemes should be the dominant approaches. However the numerous instabilities associated with damage and cracking make the convergence problematic and sometimes impossible. Here, path following techniques are mandatory and are often used in combination with viscosity. In order to ensure convergence, explicit algorithms are therefore mainly used by industrials. In this case, mass and time scaling techniques allow for the increase of the critical time step to allow for quasi-static simulation. It is unclear though how the use of these techniques affects the prediction of failure.

The second difficulty is the occurrence of spurious mesh dependence in the failure prediction. A huge literature has been devoted to non-local model with variants from non-local integral approaches to explicit and implicit gradient approaches or Cosserat models [1-2]. Despite of all this studies the development of these approaches in an industrial context is still seldom. The main reason is probably the fact that non-locality implies many and non-obvious code developments, identification practices are also an issue.

2. Rate dependent model and localization

That is why we have sought for another, even if maybe less general, possibility, to overcome the difficulty, the use of rate dependent models. Needleman was possibly the first to discuss how, in statics, the use of viscosity can allows to conserve the elliptic property of a plastic negative hardening model and, thus should eliminate pathological mesh-sensitivity [3]. Several models have been proposed in order to control localization by viscosity, particularly for ductile materials with negative hardening [4]. Nevertheless, it has been observed that the crack growth behavior predicted by simulations based on a visco-plastic version of the GTN model is mesh sensitive [5]. Other experiences were also deceptive showing that spurious localization is not automatically circumvent when using viscous model.

3. Bounded rate model

That is why we have proposed in the concept of bounded damage rate model, which has been used, for dynamic loading as impact, to predict the failure of composite materials but also the one of metallic material in the case of ductile failure [5]. A physical interpretation of the model is that a continuous damage variable results from a complex averaging process of micro flaws each of which having a finite propagation velocity, leading thus to a bounded damage rate. The main limitation of such approaches, has can be seen so far, is that such model should be used in combination with dynamic analyses.

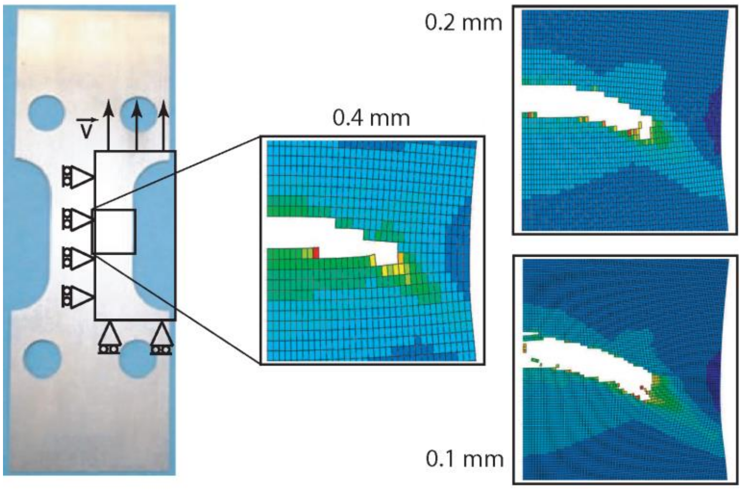

Figure 1: Mesh independent prediction in dynamics using a bounded rate ductile damage model [5]

4. Toward objective quasi-static failure prediction with bounded rate model

Recently we have tried to make use of such model for the quasi-static failure prediction of metallic materials. The proposed path is the combination of explicit simulations and bounded rate models using adapted scaling techniques aiming at performing mesh independent quasi-static simulations [6].
After an overview concerning the basis of bounded rate model illustrated on several examples the presentation explores its extension to quasi-static situations on examples relevant for turbo-machinery disks.

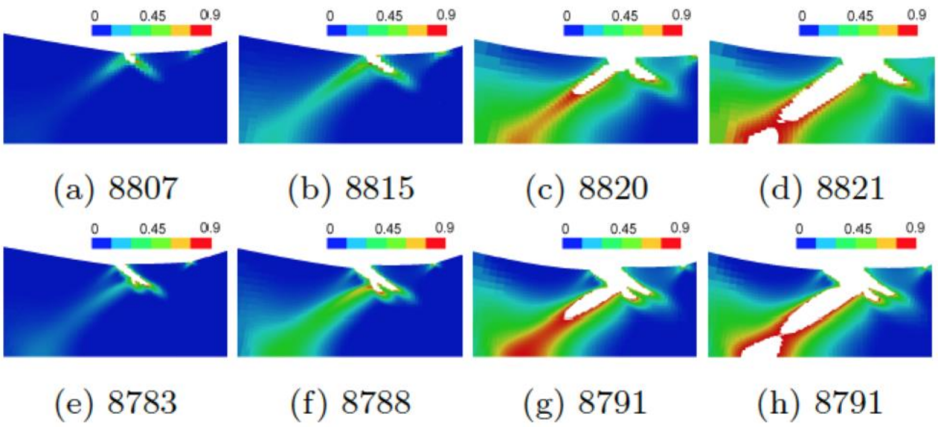

Figure 2: Comparison of the crack pattern of a 2D rotating disk at four (close) instants for two different meshes and different time scales for a scaled dependant damage rate model of Lemaitre type [6]

5. References

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