ALE-based ductile damage and fracture

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Abstract

Mixed methods have been used with success in finite strain elasto-plastic with damage for decades. The subsequent stage is now dealt with enrichment methods, either local such as SDA or global such as XFEM. These are only suitable for academic fracture problems. Modeling of multiple crack intersection and coalescence can more directly done by remeshing techniques. Disadvantages of these are lower mesh quality (even blade and dagger-shaped finite elements), deteriorated crack path prediction and cumbersome coding. In order to overcome these difficulties, an approach fully capable of dealing with multiple advancing cracks and self-contact is presented. This approach uses the Arbitrary Lagrangian-Eulerian method (ALE) and localized remeshing at the tips (simpler than a full remeshing) and therefore mesh quality is better during crack evolution. Our nonlocal pressure-gradient element is used with full anisotropic finite strain elasto-plasticity based on smooth Mangasarian replacement functions (without return mapping). The critical crack front is identified and propagated when Strong Ellipticity is lost at each single Gauss point. The general form, given the Eulerian tangent D_{ijmn} and the Kirchhoff stress T_{ij}, is

$$\lambda_i \lambda_m v_j v_n G_{ijmn} < 0$$

with:

$$G_{ijmn} = D_{ijmn} + \delta_{im} T_{jn}$$

Our discrete constitutive system is smooth (the complementarity conditions are replaced) and consists of the following equations:

- Complementarity conditions
- Integrated flow law (which is implicit in the right plastic stretch, contrary to what is usually stated)
- Integrated back stress evolution using the Lie derivative
- Damage evolution law

Due to tight radius of the origin at the complementarity graph, a trust region method is used with excellent results (e.g. 14 uniform steps suffice in the Norris tension test).