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Damage process sensitivity analysis using an XFEM-Level Set framework

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Abstract

Designing efficient and lightweight structures is a key objective for many industrial applications such as in aerospace or the automotive industry. To this end, composite materials are appealing as they combine high stiffness and light weight. The main challenge slowing down the integration of such materials in real structures is their damage behavior. The latter should be considered in the design process of the structures. This work focuses on developing a systematic approach to designing structures that can sustain an acceptable amount of degradation or exhibit a low sensitivity to damage. An optimization approach is chosen to achieve this goal. To deal with complex geometries and to allow for large shape modifications in the optimization process, the extended finite element method (XFEM) is advantageously combined with a level set description of geometry. The degradation of materials is modeled by using a non-local damage model, motivated by the work of James and Waisman [1] on a density approach to topology optimization. To solve design problems with damage constraints by gradient-based optimization method, a sensitivity analysis of the damage process is developed. Damage propagation and growth is an irreversible process. Therefore, the path dependence of the structural response needs to be accounted for in the sensitivity analysis. In this paper, we present an analytical approach for efficiently and accurately evaluating the design sensitivities, considering both direct and adjoint formulations. Finally, the sensitivity analysis approach is studied with simple benchmark problems and compared with the results obtained by finite differences.

Keywords: damage, sensitivity analysis, XFEM, level set.