A Fail-Safe Design Approach Based on the Fracture Mechanical Analysis and Epistemic Uncertainty Quantification

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Keywords: *Fail-Safe Design; Optimization; Uncertainty Model Fuzziness; Fracture Mechanics.*

Abstract

The developed method for a fail-safe optimal design of structures is based on a coupled approach of optimization involving a genetic algorithm, the fracture mechanical analysis, and uncertainty analysis enabling the quantification of epistemic uncertainty in the fracture process. The fail-safe structures are intended to retain their functionality even if subjected to certain damage conditions, e.g. a local failure of structural members. In the proposed approach, the failure process is modeled by means of the finite element analysis, employing the concept of discrete fracturing as well as the configurational mechanics based criteria, as shown in Özenç and Kaliske (2014). The application of the configurational mechanics, especially the material force approach, enables to properly characterize singularities related to imperfections, defects and dislocations in the structure.

The aim of the proposed approach is the identification of an optimal structural design, which under the damage conditions fails in a safe manner, following the prescribed fail scenario. Thus, the influence of uncertainties needs to be quantified. The uncertainties arising in the failure process of structures are not only related to variability and randomness. Exemplary, in a structure designed as a system of coupled substructures, the crack initiation position is uncertain but not random, since it results from the boundary conditions change initiated by the occurrence of a certain failure scenario and damage of particular neighbouring structural members. For the modeling of this type of uncertainty, the uncertainty model fuzziness is applied, which is discussed in Möller and Beer (2004) and Möller et al. (2000). By means of the proposed method, the uncertain crack propagation is optimized permitting a local failure within a structure only, and preventing from the total structural collapse.

References

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