Trends in computational failure mechanics: multiple scales, multi-physics and discontinuities

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Improved experimental measurement techniques and facilities have made it possible to quantify material properties at ever smaller length scales. This has major implications for numerical modeling of materials and structures. In particular, multi-scale concepts in computational analysis have gained importance. In them, it is attempted to explain, or predict, traditional engineering properties like strength, or ductility, from one, or several scales below the scale of observation.
Typically, this scaling down of analysis is accompanied by the necessity to model (evolving) discontinuities, such as cracks, shear bands, grain boundaries, or solid-solid phase boundaries. This poses major challenges to traditional numerical methods such as finite element or finite difference methods, which classically have been devised to solve *continuum* problems in an approximate sense. Methods that have the potential to successfully treat *discontinuities* will be discussed and some examples will be given. Finally, it is not only the vastly different *length scales* that govern contemporary (computational) mechanics, but also vastly different *time scales.* This, for instance, becomes manifest in multi-field problems. Examples are interface-coupled problems, such as fluid-structure interaction, or body-coupled problems, like water and ion transport in such different materials as concrete and the human skin.