Multiscale modeling of plasticity and fracture: A statistical and data science perspective

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ABSTRACT

Predicting mechanical failure represents a fantastic challenge as it depends on a myriad of factors related to material microstructure, specimen geometry and loading conditions. Fracture mechanics and plasticity theory provide the quantities that control plastic flow and failure at the continuum scale. But it does not give any hint on the microscopic quantities affecting the strength and toughness of materials. Micromechanical approaches try to bridge microstructural features of solids with their mechanical response, but they are confronted to the high level of complexity of microstructures and microscopic damage processes involved in materials. Recently, new approaches inspired from data science have emerged: the key microscale parameters that control fracture at large scale can be identified, and even learned, from the statistical analysis of a large amount of data. The objective of this symposium is to gather scientists from the Mechanical Engineering, Physics and Materials Science communities interested by data science approaches in failure and plasticity to discuss the recent advances in this rapidly growing field and promote inter-disciplinary interactions.

The proposed symposium is timely for several reasons. On one side, multiscale mechanics models integrate now more and more the stochastic nature of the fracture and plasticity processes that result from the microstructural disorder of materials [1,2]. This allows to go beyond the average response of solids and thus provides insights on the fluctuations and their statistical features. These fluctuations are evidenced on quantities like the rate of plastic flow or the crack speed, but also on the morphologies that result from fracture and plasticity [3-6]. In return, the improved understanding of these signals and patterns open perspectives for the development of new experimental techniques that consist in extracting meaningful, and often precious, information from the statistical treatments of fluctuations observed during fracture and plasticity. On the other side, tools borrowed to data science (like data mining or machine learning) have been increasingly used in the field of solid mechanics, very often in conjunction with multi-scale models of fracture and plasticity, building a real synergy between both approaches [7]. Currently, statistical predictions range in a wide gamut of applications, from indentation of composites [8] to neural networks for understanding of elastic and plastic [9, 10] features of deformation in crystals.

Overall, the interplay between data science and mechanics have provided new venues for the design of materials with improved properties and paved the way for new methods for the multi-scale characterization of the mechanical properties of materials that will be discussed during the symposium. The ambition of the proposed symposium is to identify, at this early stage of the development of these new approaches, the most promising research directions and encourage collaborations between the communities active in this emerging field. In that way, we envision that this workshop will contribute to create a new pluri-disciplinary community that will sustain the development of this rapidly growing research field.

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