Computational Particle Mechanics manuscript No.
(will be inserted by the editor)

Fragmentation and Abrasion in Granular Matter Systems

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Last edited: April 30, 2021/ Received: date / Accepted: date

Fragmentation and abrasion are fundamental particle-level processes that underlie many macroscopic properties and processes in granular media, from the particle size distribution of the fine fraction to stress-strain relationships and wear of equipment. Therefore, fragmentation and abrasion are relevant in many fields, including geotechnical engineering, mining, pharmaceutical, and chemical industries.

Fragmentation and abrasion in granular systems can be described on at least two complementary scales. On the sub-particular scale, the fracture of a single particle is modeled. Such fractures are affected by the material properties and structure of the particles. Properties such as the pore structure, pre-cracks, material plasticity, and the particles' geometric shape determine the particles' fracture behavior. The results of modeling on the sub-particular scale allow characterizing fragmentation of granules on a macroscopic scale. In many cases, such fracture models are based on a statistical analysis of the sub-particular scale; thus, they describe the average fracture behavior of a particle. Fracture models derived in this way can then be used to understand the macroscopic behavior of the bulk material.

Various numerical approaches have been used to simulate particle fragmentation and abrasion. At the sub-particle scale, peridynamics is often used, while the discrete element method (DEM) is more common for macro-scale simulations. However, DEM models are also used at the sub-particle scale, where particles are modeled as bound agglomerates. As with all numerical models, experimental calibration and

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validation are absolutely necessary to develop a practical and predictive simulation method. Several articles in this issue address this issue.

For the present issues, we have asked several experts in the field of simulation of fragmentation and abrasion in granular systems to contribute. The topics of these contributions are very broad, ranging from calibration and validation to the development of sub-particle and particle scale models and the prediction of bulk scale behavior. The first three articles deal with modeling at the sub-molecular scale: Silling *et al.* [1] present a new peridynamics model for modeling molecular crystal particles. Blanc *et al.* [2] discuss the effects of pre-cracks in the internal structure of the particles on the fracture behavior using peridynamics. Huang *et al.* [6] apply a constrained DEM model to predict the effect of pore size distribution on fracture behavior. Other contributions deal with macro-scale models: Gilvari *et al.* [4] show that a calibrated DEM bond model can be used to predict stress-strain relationships and dust formation in a bulk sample. Izard *et al.* [5] show how a DEM model can be used to predict the abrasive wear of an impeller in a tumbler. Zhao *et al.* [6] analyze experimental data of gravel rock particles that can be used to calibrate fracture models. Finally, Zhu *et al.* [7] use a coupled peridynamics-contact dynamics model, to predict the particle size and shape distribution in a granular sample.

The articles compiled in this special issue highlight many open challenges in this field: The breakage and abrasion behavior of a granular material depend strongly on the individual particles' characteristics and structure. A careful calibration and model selection are essential to obtain reliable predictions from numerical simulations. We hope that the scientific articles presented in this issue will motivate scientists working in this field.

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