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Application of a coupled DEM–CFD approach to engineering problems

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The paper deals with the application of a fully coupled DEM/CFD approach (discrete element method combined with computational fluid dynamics) for investigating some different combined mechanical-hydraulic-thermal problems at the meso-scale in frictional-cohesive materials (rocks, granulates and concrete). As compared with usual continuum mechanics methodologies in most existing numerical studies, discontinuous meso-scale models at the grain level (such as the discrete element method (DEM)) are more realistic since they allow for a direct simulation of meso-structure and are thus useful for studies the mechanism of the initiation, growth and formation of cracks and shear zones at the meso-level. DEM allows for a better understanding of local meso-structural phenomena that evidently affect global material behaviour [1]. We used DEM which takes advantage of the so-called soft-particle approach [1–3]. A linear contact under compression was assumed. Normal and tangential contact forces satisfied the cohesive-frictional Mohr-Coulomb condition. CFD was used to describe the laminar viscous two-phase liquid/gas flow in pores between discrete elements by employing channels.

Innovative elements of our approach with respect to other existing DEM/CFD models in the literature are the following [2, 3]: 1) co-existence of two domains (a discrete and continuous one) in one physical system (the sum of domain geometries creates a complete physical system), 2) precise determination of the geometry and topology change of voids and fractures, 3) remeshing method of voids and fractures, 4) transformation schema of computation results from the old grid (before remeshing) to the new grid (after remeshing) and 5) detailed tracking of the fluid volume fraction in voids and fractures (material voids can be fully or partially filled with the fluid). Every single pore is discretized by a number of elements. Thus, the pressure field in a single pore is spatially variable while in existing DEM/CFD models, the pressure field in a single pore is constant. The flow path may be reproduced in a single pore in contrast to existing DEM/CFD models. In addition, huge pressure gradients in a single pore are captured while in existing DEM/CFD models the pressure gradient in a single pore is equal to zero. Two phases were considered in fluid flow: liquid phase and gas phase. Some engineering coupled DEM/CFD problems were discussed such as e.g. hydraulic fracturing in rocks [2–4] and capillary pressure-driven water flow in concretes [5].

References

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