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Discrete Element Simulations of Composite Ceramic Powders

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Abstract : Alumina refractories are commonly used in steel and foundry industries. These refractories are prepared through a powder metallurgy route. They are a mixture of hard alumina particles and graphite platelets embedded into a soft carbonic matrix (binder). The powder can be cold pressed isostatically or uniaxially, depending on the application. The compact is then fired to obtain the final product. The quality of the product is governed by the microstructure of the composite and by the process parameters. The compaction behavior and the mechanical properties of the fired product depend greatly on the amount of each phase, on their morphology and on the initial microstructure. In order to better understand the link between these parameters and the macroscopic behavior, we use the Discrete Element Method (DEM) to simulate the compaction process and the fracture behavior of the fired composite. These simulations are coupled with well-designed experiments. Four mixes with various amounts of Al_2O_3 and binder were tested both experimentally and numerically. In DEM, each particle is modelled and the interactions between particles are taken into account through appropriate contact or bonding laws. Here, we model a bimodal mixture of large Al_2O_3 and small Al_2O_3 covered with a soft binder. This composite is itself mixed with graphite platelets. X-ray tomography images are used to analyze the morphologies of the different components. Large Al_2O_3 particles and graphite platelets are modelled in DEM as sets of particles bonded together. The binder is modelled as a soft shell that covers both large and small Al_2O_3 particles. When two particles with binder indent each other, they first interact through this soft shell. Once a critical indentation is reached (towards the end of compaction), hard Al_2O_3 - Al_2O_3 contacts appear. In accordance with experimental data, DEM simulations show that the amount of Al_2O_3 and the amount of binder play a major role for the compaction behavior. The graphite platelets bend and break during the compaction, also contributing to the macroscopic stress. Firing step is modeled in DEM by ascribing bonds to particles which contact each other after compaction. The fracture behavior of the compacted mixture is also simulated and compared with experimental data. Both diametrical tests (Brazilian tests) and triaxial tests are carried out. Again, the link between the amount of Al_2O_3 particles and the fracture behavior is investigated. The methodology described here can be generalized to other particulate materials that are used in the ceramic industry.

Keywords : cold compaction, composites, discrete element method, refractory materials, x-ray tomography
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