Analysis of Dynamics of Spiral Jet Mills by Coupled CFD-DEM Simulations

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The spiral jet mill has a simple design and operation procedure, but has a very complex gas and particle flow fields, making it challenging to predict the milled particle size distribution without an empirical knowledge of the system. The particles are in a fast shearing dense phase near the wall, and as their size is reduced, the gas drag entrains them eventually out of the mill. The gas flow pattern changes from forced vortex near the wall to free vortex mid-way in the mill approaching the classifier region. Therefore, there exists a dynamic relationship between particle hold-up and the gas flow, as well as an interdependence between breakage and classification, all occurring in the same chamber. To provide a predictive capability, the dynamics of spiral jet mills has been analysed by coupled CFD-DEM. The role of particle hold-up and how it affects both particle dynamics and gas behaviour are addressed. The kinetic energy transfer from the gas to particles, grinding jet penetration, coarse graining methodology and size reduction simulations are presented.

The dynamics of the jets has been analysed as a function of the grinding gas pressure and particle hold-up. As the grinding gas pressure is reduced, the jets can no longer penetrate through the densely packed bed. This inhibits particles reaching the highest velocities needed to cause fragmentation and chipping.

The greatest challenge posed to CFD-DEM method is the number of particles in the system. The coarse graining method is applied to explore its capability to circumvent the challenge. This method replaces groups of smaller particles by a single larger one. Both the kinetic energy and dissipated energy are modelled successfully for the lowest scaling values of four or fewer particles per group. The predicted behaviour of the particles in the bed agrees with the base case. However, particle velocity in the lean region differs from the original simulation due to the scarcity of particles present in this region.

Finally, the breakage model of Ghadiri and Zhang has been implemented to allow for size reduction by chipping. By recording the mass of fines produced as a result of chipping as a function of time at various gas pressures, the total fluid expended work leading to breakage has been estimated. The methodology developed here provides a capability of predictive milling for various applications based on the mechanical and physical properties of single particles.