284d A Hybrid Lagrangian-Eulerian Approach in Simulating Gas-Solid Flows Consisting of Multiple Solid Phases

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Gas-solid flows have a wide variety of applications in the chemical industry involving, e.g., fluidized beds, spouted beds, and pneumatic transport. In the recent past, researchers have begun employing simulation techniques along with traditional experimental approach, to better understand the behavior of such flows. Simulations can aid and compliment the experiments, providing easy visualization as well as detailed information about local behavior. There has been extensive published work on the simulation of fluidized beds and spouted beds. These studies have employed the two basic approaches in simulating granular flows (i) the continuum approach (Gidaspow et al.) (ii) the discrete element simulation (DES) (Tsuji et al., Kuipers et al.) approach. In the continuum approach the solid phase is treated from an Eulerian view point as a continuum, using the kinetic theory of granular materials (KTGM) for the closure relations for averaged properties like viscosity; the gas and solid phases are treated as interpenetrating continua. In DES, the solid phase is treated from a Lagrangian view point and each particle is tracked individually accounting for its interactions with other solid particles as well as the surrounding gas flow. Both of the above approaches have their own advantages. Continuum approach requires less computation time and is often adequate to understand the overall behavior of the flow. On the other hand, DES does not need closure relations needed in the continuum approach; but it is computationally more intensive and stores information about each individual particle and hence provides more information about the details of the flow. Nevertheless, there are certain situations which seem naturally suited to one particular approach. In a dilute granular flow, the validity of continuum approximation becomes questionable, yet the particle-particle interactions may not be completely negligible, hence the DES approach seems preferable; in case of a packed bed the continuum approach is less expensive and hence preferred. Also, there are situations involving more than one particle type which require multiple solid phases. For example, in coal combustion or gasification, there is a carrier fluid flow and two general types of particles: relatively big sparsely distributed coal particles with low volume fraction, which can be treated as one solid phase, and a different second solid phase constituting of smaller char particles which occupy the entire gasifier. In such cases a hybridized treatment of the solid phases seems logical, i.e., simulate the dynamics of bigger coal particles flow using DES and the char flow using continuum KTGM. This would not only reduce the cost of using DES for both phases but also gives a more realistic description of the motion of the coal particles. Hence a hybrid approach that combines both the continuum and DES approaches is attractive to increase the accuracy and decrease the computational time.

In the present study, we propose the use of a hybrid approach as explained above, in simulating gas-solid flows consisting of multiple solid phases. To test this new modeling approach, a simple case fluidized bed case is presented with 2 solid phases – phase 1 consisting of fewer larger particles is simulated using DES; phase 2, with numerous smaller solid particles is simulated using the continuum approach. The results and discussion will be presented.