An Eulerian Method for Computing Gas-Solid Two-Phase Flows

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ABSTRACT

In our presentation we address the development of a numerical method that solves the system of governing equations for dispersed solid-gas two-phase flows in non-equilibrium regimes when the phase velocities and temperatures are different enough. The mathematical model is described by conservation laws of mass, momentum, and energy for the solid and gas phases. The intergranular pressure is introduced in the solid phase, which depends on the solid volume fraction and vanishes as the volume fraction becomes less than a critical value of the close-packed structure. The solid phase equations degenerate in this case and are no longer strictly hyperbolic. Due to so-called nozzling terms in the right-hand side, the gas phase equations are not conservative. In the present paper, we discuss how to correctly take into account these two singularities of the governing equations at the discrete level.

We split the equations into two sub-systems one for the solid phase and another for the gas phase. The first sub-system (solid) is integrated with the Godunov method. With this aim, we state the appropriate Riemann problem that describes elementary solid-solid interactions. Under minor assumptions this problem can be solved analytically in the non-linear formulation; the solution provides the flux approximation that correctly works in the whole range of volume fraction. The linear approximation of the solution is shown to be insufficient and leads to incorrect numerical results.

The sub-system of the gas phase is referred to the class of non-conservative Euler equations (shallow water, quasi-1D gas dynamics, two-phase flow). These equations have intensively investigated during the last decade. Most results obtained concern a fixed in space function of volume fraction [1]. In our case this function varies both in space and in time. We develop the Rusanov method [2] to solve numerically the gas dynamics constrained by moving solid porous material. First, the Rusanov flux approximation is recast so that it could be applied to moving Eulerian grids. Then, we extend the Rusanov-type method for the non-conservative Euler equations with fixed in space volume fraction [1] to account for moving grids with maintaining the property of well-balancing. Finally, the Rusanov-type method is proposed to calculate gas dynamics in the moving skeleton of the solid phase. The method is proved to guarantee the well-balancing property.

References

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