Numerical Simulation of Detonation in Condensed Porous Explosives

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ABSTRACT

The present paper addresses a method for numerical modeling of deflagration and detonation processes in condensed porous reactive materials. The physical model is developed that takes into account such important factors as velocity and temperature nonequilibrium between non-reacted explosives (the solid phase) and products of reactions (the gas phase) and elasto-plastic properties of the solid phase. The solid volume fraction is assumed to change due to combustion and interphase deformation processes that force the pore linear size to change. The mathematical model is derived on the base of the Bayer-Nunziato description of two-phase heterogeneous medium. We modify this model to account for elasto-plastic properties of the condensed phase by implementing a modification of the Prandtl-Reus approach. Nonequilibrium processes include the velocity relaxation by the interface drag (Ergun correlations), the interphase mass exchange (the model of Lee-Tarver), the temperature relaxation by the convective and radiative heat transfer, and the interphase deformation (the model of Kiselev).

The system of governing equations of the model is hyperbolical, but has nonconservative form because of "nozzle effects" terms and source terms of the interphase interaction. To solve these equations numerically we develop a Godunov-type discretization on a moving eulerian grid. First, we split the system into two subsystems. One describes pure hydrodynamics of the nonequilibrium two-phase flow with no interphase interaction. Only gas dynamics in porous solid medium and deformation of the solid skeleton are treated at this stage. We extend the Rusanov flux approximation considered in [1] for the non-conservative Euler equations with fixed porosity to the case of variable in time porosity. The well-balancing property is formulated and proved for the numerical flux proposed. The solid phase equations are solved with a Godunov-type method proposed in [2]. At the second stage, the obtained numerical solutions are corrected by the stress model and the interphase interaction terms.

Finally, we show numerical results that verify the proposed method. We demonstrate that the method exactly reproduces steady-state solutions and warranties the well-balancing property on any arbitrary moving Eulerian grids. Comparisons are done for the Sod tests of [1] reformulated for moving porosity. Interphase models are tested on a plane shock/detonation wave propagation in elasto-plastic porous reacted material. Applications concern 2D simulation of detonation in a porous condensed medium.

References

[1] S. Clain and D. Rochette, "First- and second-order finite volume methods for the one-dimensional nonconservative Euler system", *Journal of Computational Physics*, 228, pp. 8214-8248, 2009.

[2] I. Menshov and A. Serezhkin, "Modelling non-equilibrium two-phase flow in elastic-plastic porous solids", *11thWorld Congress on Computational Mechanics (WCCM XI) 5th European Conference on Computational Mechanics (ECCM V) 6th European Conference on Computational Fluid Dynamics (ECFD VI).*