On numerical instability of Godunov-type schemes for hypersonic shock waves in media with high heat capacity

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Godunov-type schemes with different Riemann solvers are widely used in computational physics. Some media, being compressed by strong shocks can have high thermal capacity due to heat of reaction or phase transition or due to excitation of internal degrees of freedom of molecules. In this work we show numerical instability for such shocks that is different from well-known carbuncle phenomenon [1]. Test initial boundary value problem is formulated and results of testing of several carbuncle-free numerical fluxes (rotated approximate Riemann solver [2], HLLE [3], Rusanov numerical flux [4] and the AUSM scheme [5]) are presented. The numerical fluxes are used in the framework of the finite volume scheme with TVD reconstruction of variables.

Ideal gas equation of state is used in the calculations. The shock waves in ideal gas are known to be stable with respect to multidimensional perturbations. However, if the adiabatic exponent close to 1, all tested Riemann solvers show absence of grid convergence and 2D instability pattern of the shock-wave surface. The calculations correspond to the hypersonic shock wave Mach number.

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