Quasi 1-D Simulations of Nonclassical Steady Nozzle Flows

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Abstract

Most shock-capturing methods for the computation of steady quasi-one-dimensional compressible flows rely on time marching towards the steady condition, in which nonzero flux gradients are balanced by the source term. In general, standard numerical schemes for conservation laws, coupled with a conventional treatment of the source term, fail to attain this balance. A relatively simple approach resulting in a balanced scheme is the f-wave propagation method, in which the source term is used to modify the flux difference before performing the wave decomposition. In this work we focus on the numerical difficulties in the computation of nonclassical waves by means of the aforementioned scheme. We present numerical results for nonclassical steady flows in a convergent-divergent nozzle. The working fluid is modeled as a mono-component single-phase van der Waals gas, having a value of the isochoric specific heat large enough to generate a finite region of negative nonlinearity in the vapor phase. Flows evolving in the regime of mixed nonlinearity include nonclassical waves such as rarefaction shock waves and shock waves having upstream or downstream sonic state. It is shown that the Roe decomposition based on the computation of the standard intermediate state (Roe average) may not be sufficient to adequately capture the structure of sonic shock waves. In addition, the standard entropy fix techniques used to prevent non-physical shock waves are found to deteriorate the delicate steady state numerical balance. A further problem is the onset of oscillations near slowly moving shocks, which necessarily occur when the solutions is close to the steady state. Such oscillations may cause slow convergence or even prevent the convergence, especially when the steady state solution includes sonic shocks, near which numerical dissipation becomes small.

References

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