High-Speed Compressible Flow and Gas Dynamics

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Discretization schemes suitable for gas dynamics are reviewed and applied to the declarative concepts of Modelica. Here, a suitable connector definition is introduced to enable both robust simulation and higher-order schemes, which require larger stencils than typically available on established thermo-fluid dynamics connectors.

Summary

Certain applications involve a *high-speed compressible flow* (also called "gas dynamics"). Kinetic terms and dynamic pressure may not be neglected and have to be included in compressible formulations. Density variation is encountered with respect to flow phenomena, in particular dynamic conservation of momentum is relevant and also shock waves may be part of the solution. The Mach number may be larger than 0.3 (including the supersonic regime).

The key theoretical area to enable applications involving high-speed compressible flow is the discretization method for the governing equations. The foundations of numerical solution methods in thermo-fluid dynamics are well understood [3, 2]. However, in the framework of equation-based, object-oriented modeling languages, mostly methods suitable for low-speed compressible flow only have been applied. An exception is the work of López [1], who proposed an approach to model and simulate gas dynamics. Due to robustness issues, which are certainly linked to deficiencies in the connector definition used in [1], the approach was not widely adopted. In an attempt to finally extend the applicability of Modelica also to high-speed compressible flow and gas dynamics, this paper makes the following contributions.

- Relevant concepts of the theory in numerical solution methods for high-speed compressible flow are reviewed and translated from the algorithmic perspective taken in literature to the acausal concepts of Modelica.
- The elements of discretization schemes are decomposed in an object-oriented fashion and implemented in a generic library.

References

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[3] E. F. Toro. *Riemann Solvers and Numerical Methods for Fluid Dynamics: A Practical Introduction*. Springer, 1997.