A high order finite volume solver for simulation of heat transfer in compressible flow from very low to intermediate Mach numbers

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Abstract

This abstract presents the study of compressible flow around a cylinder with heat transfer. The numerical simulations are carried out using a high-order finite volume solver using moving least squares (MLS) reconstruction [1] for unstructured grids. It focuses on the determination of the global and local heat transfer coefficients and their dependances with Reynolds number, Mach number and the temperature ratio. An isothermal no-slip boundary condition is imposed on the cylinder surface. The simulations and post processing procedures are first validated using adiabatic conditions and compared with the available results of drag and lift coefficients. Then, Nusselt number is computed for several Reynolds numbers. The results are in good agreement with experimental correlations. Furthermore, the influence of Mach number on the heat transfer around the cylinder is compared with the existing literature results and analyzed with regards to viscosity and fluid thermal conductivity variations.

The main idea behind the higher-order formulation of the finite volume method (FVM) is the use of reconstructed variables of a given order of accuracy, into the numerical flux, to achieve the desired order of the scheme. In other terms, the FVM solver will deal with average values of the field variables, and the solution is assumed constant within each control volume. So, the underlying spatial representation would be that of a piecewise constant flow field. High order schemes are constructed by substituting the constant representation by a piecewise continuous reconstruction of the flow variables inside each cell, which will ensure the sought order. To improve the order of accuracy, the flux functional will be computed at the cell interfaces, rather than the use of centroid values, and a higher-order reconstruction of the flow variables will be used at the interfaces by a Taylor expansion at the vicinity of each cell.

The central difficulty in extrapolating variables from the centroid cell to the integration point at the interface cell is about estimating the high order derivatives of the Taylor expansion. The FV-MLS overcomes this difficulty by using moving least squares approximations to compute the derivatives based on the substitution of the constant representation by a piecewise continuous shape function reconstruction of the flow variables inside each cell, using cell-averaged values from neighbor centroids (which constitute the stencil of the active cell). In addition, the proposed method allows a reconstruction of the fluxes at the cell interfaces, by the use of compact stencils without introducing new degrees of freedom, which is a real advantage over the most popular existing high-order methods.

References

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