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PRECONDITIONED VMS FOR COMPRESSIBLE FLOW II: TRANSIENT PROBLEMS

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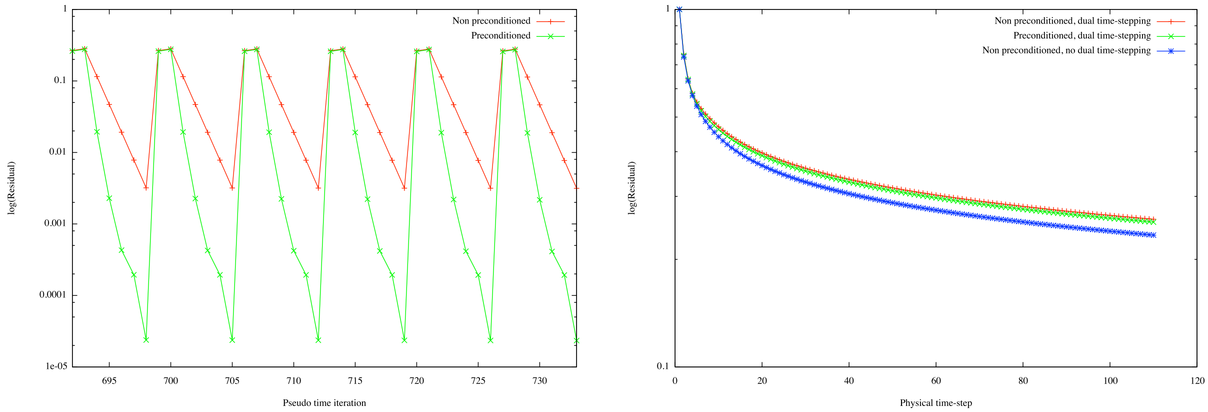
Local preconditioning is here applied to solve the Euler and Navier-Stokes equations for transient compressible flow. *Choi-Merkle*'s steady preconditioner [1] is adapted for transient problems in [2, 3, 4] and used in this work. Space is discretized by means of the finite element method. Low Mach, transonic and supersonic regimes are solved.
When a local preconditioner is used, the preconditioned system and the original one have only the steady-state solution in common. In order to keep temporal accuracy for transient problems, the dual time-stepping technique is needed. Other than the physical time, this technique uses a pseudo or artificial time to converge the solution at each physical time-step. The physical and the pseudo time are discretized using finite differences. The variational multiscale stabilization (VMS) term for the preconditioned dual time Navier-Stokes equations is computed in this work.
The goal of local preconditioning is the uniformization of the characteristic propagation speeds of the system which entails a gain in convergence speed. The preconditioner is here applied to accelerate the convergence of the pseudo time to a pseudo steady state at each physical time-step. For low Mach number problems where the pseudo time-step is mainly determined by the acoustic speed, the convergence acceleration when preconditioning is especially significant. This is shown in figure 1(a) representing the convergence in pseudo time of the inviscid shock tube test case at Mach number 0.00184. The agreement of the preconditioned and the non preconditioned cases is shown in figure 1(b). A lineout of the density corresponding to the preconditioned case is given in figure 2. No many differences are seen between the solution of the preconditioned and the non preconditioned case for this value of the Mach number.



(a) (b)

Figure 1: 1(a) Convergence history within pseudo time of the inviscid shock tube test case at Mach number 0.00184. Non preconditioned and preconditioned convergences both using 6 iterations of pseudo time are plotted together. 1(b) Convergence history within physical time of the same problem. The solution without preconditioning and without dual time is added on this plot, showing the agreement of the solution on the three cases.

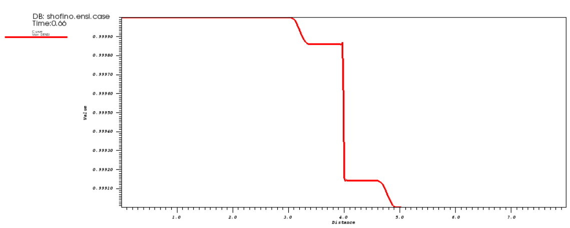


Figure 2: Density lineout at 0.66 seconds of the inviscid shock tube test case at Mach number 0.00184. Preconditioning and 6 iterations of pseudo time-step are used.

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