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PRECONDITIONED VMS FOR COMPRESSIBLE FLOW I: STEADY PROBLEMS

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Local preconditioning is here applied to the Euler and Navier-Stokes equations to solve steady compressible flow problems. We test *van Leer-Lee-Roe*'s [1] and *Choi-Merkle*'s [2] preconditioners for the solution of inviscid and viscous steady problems, respectively. Low Mach, transonic and supersonic regimes are solved.
Based on the idea of Chorin [3], local preconditioning was firstly set up by Turkel [4] for incompressible and low speed compressible flow and it has traditionally been applied together with the finite volume method. Finite element spatial discretization and explicit time integration with a local time step is used in this work. The variational multiscale stabilization (VMS) term is adapted to solve the preconditioned equations.
The goal of local preconditioning is the uniformization of the characteristic propagation speeds of the system. This entails a gain in convergence speed and accuracy of the solution. Additionally, the preconditioned system is better suited for the computation of the VMS. Local preconditioning adds no extra computational cost. It is applied to the set of equations before any discretization is done. It consists of transforming the original convective jacobians and the diffusion matrices into the preconditioned ones. For low Mach number problems where the time step is mainly determined by the acoustic speed, the convergence acceleration when preconditioning is especially significant. This is shown in figure 1 representing the convergence of the Naca 0012 airfoil at Mach number 0.01 for both the inviscid and viscous cases. Local preconditioner also gives a better stability to the solution as it is seen in figure 2 corresponding to the inviscid case.

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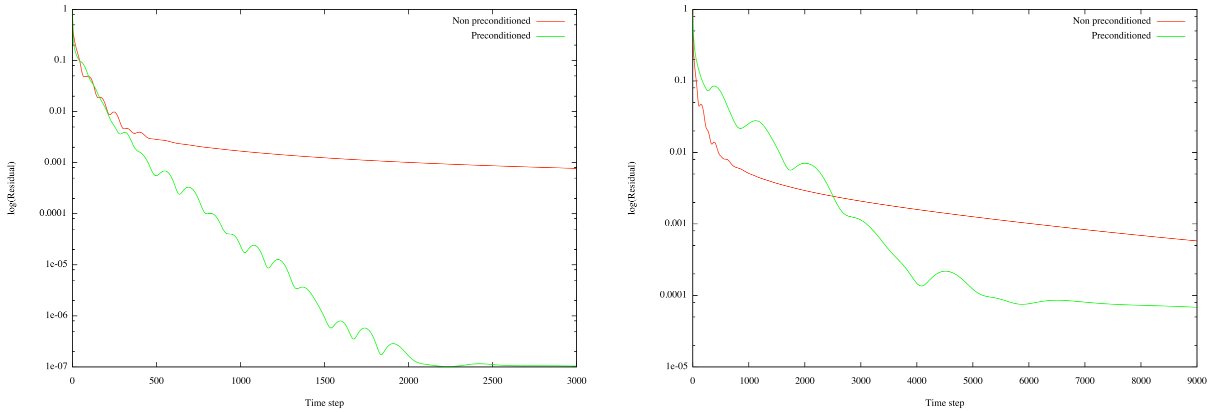
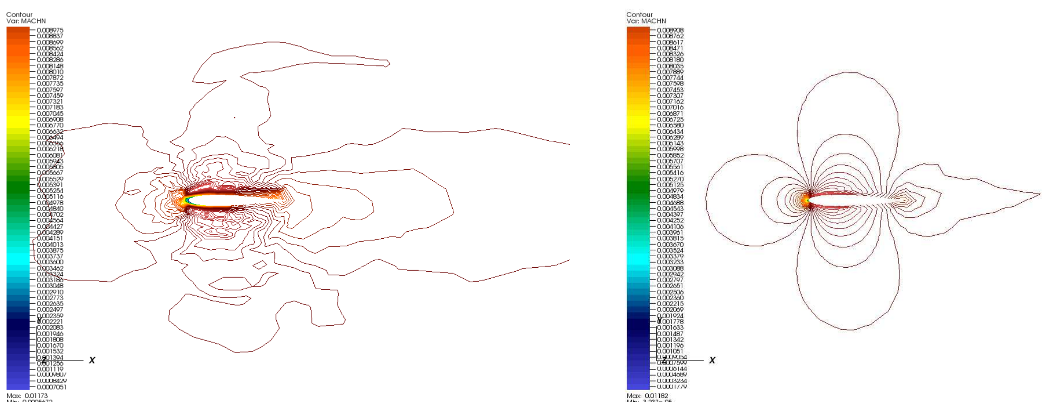


(a) Inviscid case (b) Viscous case at Re=100

Figure 1: Convergence history of the solution of the Naca 0012 test case with zero angle of attack at Mach number 0.01 for both the inviscid and viscous case. Non preconditioned and preconditioned convergences are plotted together. The same grid of 4522 tetrahedra on a domain of $30 \times 30\,\mathrm{m}$ is used for the inviscid and viscous case. The CFL number is set to 0.3 for the inviscid case and to 0.2 for the viscous case.



(a) Non preconditioned case (b) Preconditioned case

Figure 2: Mach contours after 6000 time steps of the Naca 0012 test case with zero angle of attack at Mach number 0.01. A grid of 4522 tetrahedra on a domain of $30 \times 30\,\mathrm{m}$ is used. The CFL number is set to 0.3.

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