**Flux preconditioning methods and fire events**

*P. Birken and A. Meister*

Standard compressible flow solvers produce unphysical results at low Mach numbers. Especially the pressure exhibits a wrong asymptotic behaviour if the Mach number tends to zero. Guillard and Viozat proposed a preconditioning procedure for the Roe flux that restores the correct pressure distribution and allows to compute unsteady flows. Commonly referred to as flux preconditioning methods, the idea is to replace the dissipation matrix $\mathbf{D}$ in the flux by $\mathbf{D}^P = \mathbf{P}^{-1}|\mathbf{PF}|$, where the Turkel preconditioner $\mathbf{P} = diag(\beta^2, 1, 1, 1)$ is used. Compared to other methods, this approach has several advantages: Given a compressible flow solver, it is trivial to implement a new flux function. Furthermore, the method does not require the solving of elliptic correction equations for the pressure, as for example the flux correction schemes, thus saving cost per timestep.

However, the flux preconditioning methods suffer from stability problems for both explicit and implicit time stepping schemes. Also the linear equations obtained in the implicit schemes are much more difficult to solve than for the respective unpreconditioned reference solver. For an explicit scheme, if the Mach number tends to zero, we have found that the timestep has to go to zero with $M^2$. Using a von Neumann stability analysis, it is possible to prove this. We will present the proof for the more general class of preconditioners:

$$\mathbf{P} = \begin{pmatrix} \beta^2 & 0 & 0 & 0 \\ -\frac{\alpha v_1}{\rho c^2} & 1 & 0 & 0 \\ -\frac{\alpha v_2}{\rho c^2} & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix},$$

as well as analyzing their asymptotic behaviour.

Finally we will apply the method to tunnel fire events. Recent incidents in european car tunnels have spawned interest in this kind of problems. They are characterized by a low Mach number and strong heat sources in the tunnel, which leads to flows which can no longer be modelled by the Boussinesque approximation and have to be solved using techniques for compressible flow.