DEVELOPMENT AND TESTING OF A NEW PROJECTION SCHEME FOR COMPRESSIBLE IDEAL MHD

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Accurate simulations of space weather are important to protect satellites and electronic equipment at high latitudes, when solar storms erupt. Violent events, such as coronal mass ejections, may instead cross the interplanetary space and interact with the earth's magnetosphere; reliable forecast would help to reduce the damage that can follow from this.

Predictions of space weather require to solve the equations of the ideal magnetohydrodynamics. The MHD equations contain the implicit constraint that $\vec{\nabla} \cdot \vec{B} = 0$ (where $\vec{B}$ represents the magnetic field) which is not satisfied up to machine accuracy when the ideal MHD equations are discretized. The errors tend to accumulate and generally lead to divergence as the iterative process continues. There exist several approaches to overcome this problem.

A first approach is due to Powell, which proposed a scheme which adds a source term proportional to $\vec{\nabla} \cdot \vec{B}$ to the original set of MHD equations, in order to stabilize and correct for errors due to nonzero $\vec{\nabla} \cdot \vec{B}$.

A second approach is the projection method, which in the context of MHD, was first suggested by Brackbill and Barnes. The idea is to project the numerical solution provided by the scheme onto the subspace of divergence-free discrete solutions by means of a linear operator. This projected solution is then used in the next time step. The projection method typically involves the solution of a costly additional Poisson equation.

We have implemented a new projection scheme for the ideal MHD equations, using residual distribution methods. Unlike for the classical projection approach, no Poisson problems need to be solved. The implementation is done within the COOLFluiD framework, developed at VKI. We found that:
1) Divergence-free solutions can be obtained and appear to be (nearly) as accurate as similar results obtained using Powell's method.
2) Very fast convergence is achieved for most test cases. This is a clear improvement over earlier finite volume implementations.

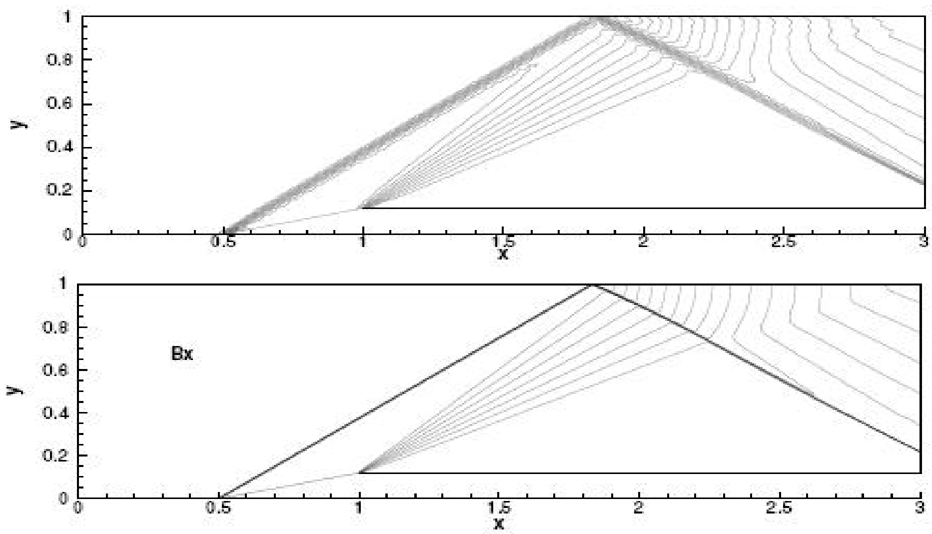

Figure 1: Magnetic field isolines for a field-aligned wedge flow. Upper: projection scheme. Lower: reference solution using Powell's source term scheme (RDS B-scheme)