Time Spectral Method for Incompressible, Time-Periodic Fluid Flows

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One part of the daily tasks at the component development at Volkswagen Salzgitter is modelling the flow phenomenon within fluid pumps. While steady simulations to evaluate the performance of pumps are already state of the art, unsteady simulations are still the exception, because in general huge computational resources and memory are required. In this work an alternative solver to regular Unsteady Reynolds Averaged Navier-Stokes (URANS) is investigated and applied to common engineering problems.

The fluid flow in water pumps is time-periodic. To reach a converged periodic state with regular time-marching solvers several periods are necessary resulting in long computation times. A spectral solver is an interesting alternative to regular time-marching solvers. With the time spectral solver (TSM) the periodic steady state is directly computed without the need of a long transient phase. For the TSM the unsteady Navier-Stokes equations are transformed by Fourier transformation to a coupled system of steady equations. Thus discretization schemes for steady-state solvers can be applied. Besides the speed up of computational time, the TSM also allows an additional degree of freedom for parallelization. Domain decomposition as well as parallelization of different time levels can be employed.

Known from compressible solvers \([1,2,3,5,6]\) to compute turbomachinery flows, flutter of wing or compressor stages the TSM is adapted to incompressible flows using a pressure correction algorithm and implemented into the open source framework OpenFOAM\(^\circledR\). To increase stability of the coupled equation system the solution matrix is ordered by times instead of nodes. Thus the different time levels are closer to one another and convergence is reached faster than using an explicit treatment of the coupled equations. The momentum equation is solved in a coupled framework.

In the presentation the TSM within the OpenFOAM\(^\circledR\) framework is introduced and validated. The lift and drag coefficient of a simple airfoil test case are computed using URANS and TSM and compared to one another. Moreover, examples for more complex fluid flow problems are discussed.
References:


