Increasing the Flexibility of the High Order DGSEM Framework FLEXI towards Large Scale Industrial Applications

Project "hpcdg"

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Zonal LES of a Compressible Turbulent Boundary Layer

Goal: An efficient LES of compressible wall-bounded flows

A wall resolved LES with a turbulent inflow method is performed. The use of the recycling rescaling technique and the anisotropic linear forcing according to Kuhn et al. [3] gives accurate turbulent statistics and guarantees long-term stability. A comparison with the DNS from [4] shows a good agreement (Fig. 1 right) of the characteristic quantities.

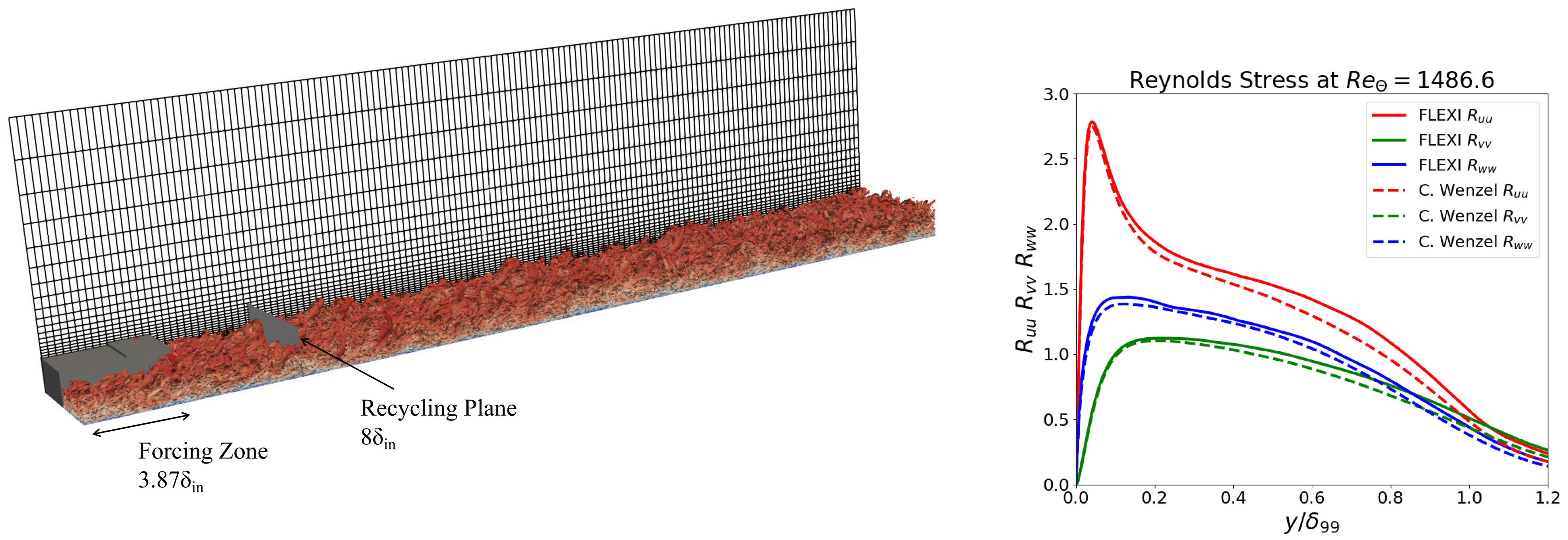

Figure 1: Left: Computational domain of the flat plate simulation (inflow: $Ma = 2$, $Re_\theta = 1100$) with 4.3×10^6 degrees of freedom, 6^{th} order method. Q-criterion visualization of turbulent structures colored by velocity magnitude. In the inflow region the forcing zone and the recycling plane are shown half in spanwise direction. Right: Morkovin's density scaled Reynolds stress profile compared to the DNS results from [4].

Implicit Time Discretization for the DGSEM

Goal: Extend the applicability of FLEXI towards stiff problems, e.g. low Mach number flows

An implicit time discretization for the split form DGSEM [2] has been introduced based on implicit Runge-Kutta methods and a Jacobian-free Newton-GMRES method. To accelerate the computation, a block-Jacobi preconditioner has been derived.

The influence of using large timesteps is illustrated with the flow over a cavity, see Fig. 2. One can observe that the implicit time discretization remains stable in under-resolved situations and gives consistent results.

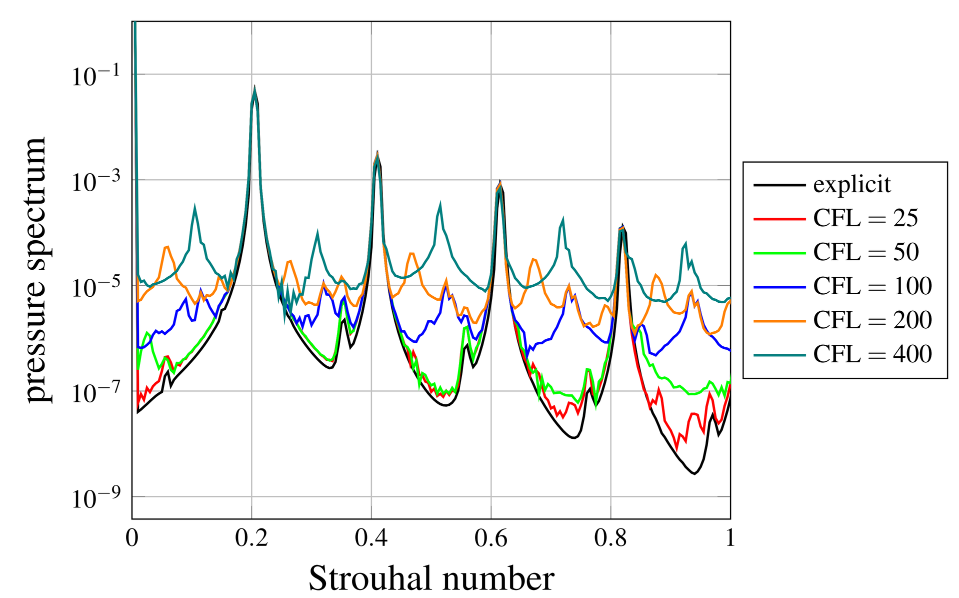

Figure 2: Pressure spectrum of flow over cavity with different CFL numbers, using the implicit-in-time split DG formulation and a temporal resolved explicit-in-time formulation as a comparison.

Large Eddy Simulation (LES) of Multi-Stage Turbomachinery using a Sliding Mesh Method

Goal: Enabling simulations of turbomachinery applications

A sliding mesh approach [1] is used to enable the simulation of typical applications in turbomachinery. The performance of modern turbomachines is strongly dependent on accurate prediction of the transition location. While the wall models for equilibrium boundary layers provide generally satisfactory results, the case of non-equilibrium multiscale flows remains more challenging. Thus, a wall-resolved LES of the mean line geometry of the Aachen 1.5 stage axial flow turbine featuring a stator-rotor-stator configuration is performed.

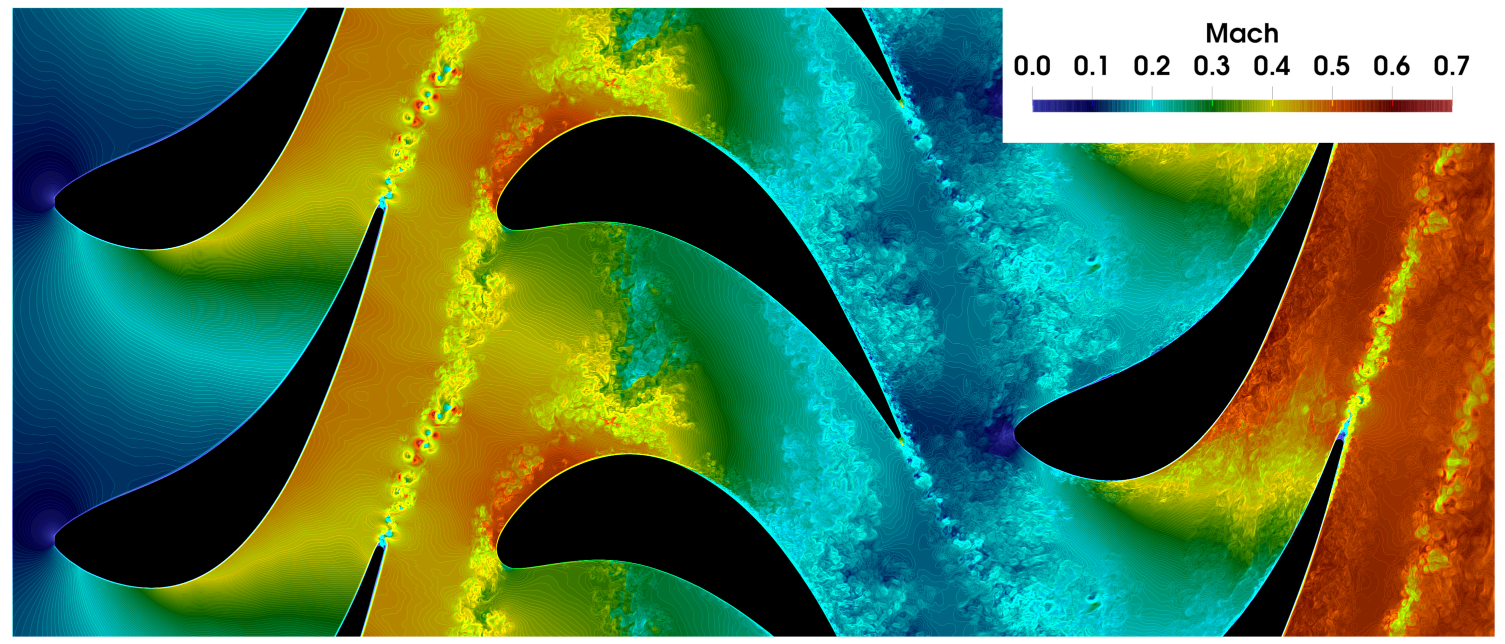

Figure 3: Instantaneous Mach number at the end of the simulation with $Re_C = 8 \times 10^5$ using $\approx 2 \times 10^8$ degrees of freedom of the 6^{th} order method.

The parallel performance of the baseline method is only decreased by $\approx 20\%$, see Fig. 4. For small loads, the parallel efficiency is influenced due to imbalance at the interface which cannot be hidden effectively for small loads.

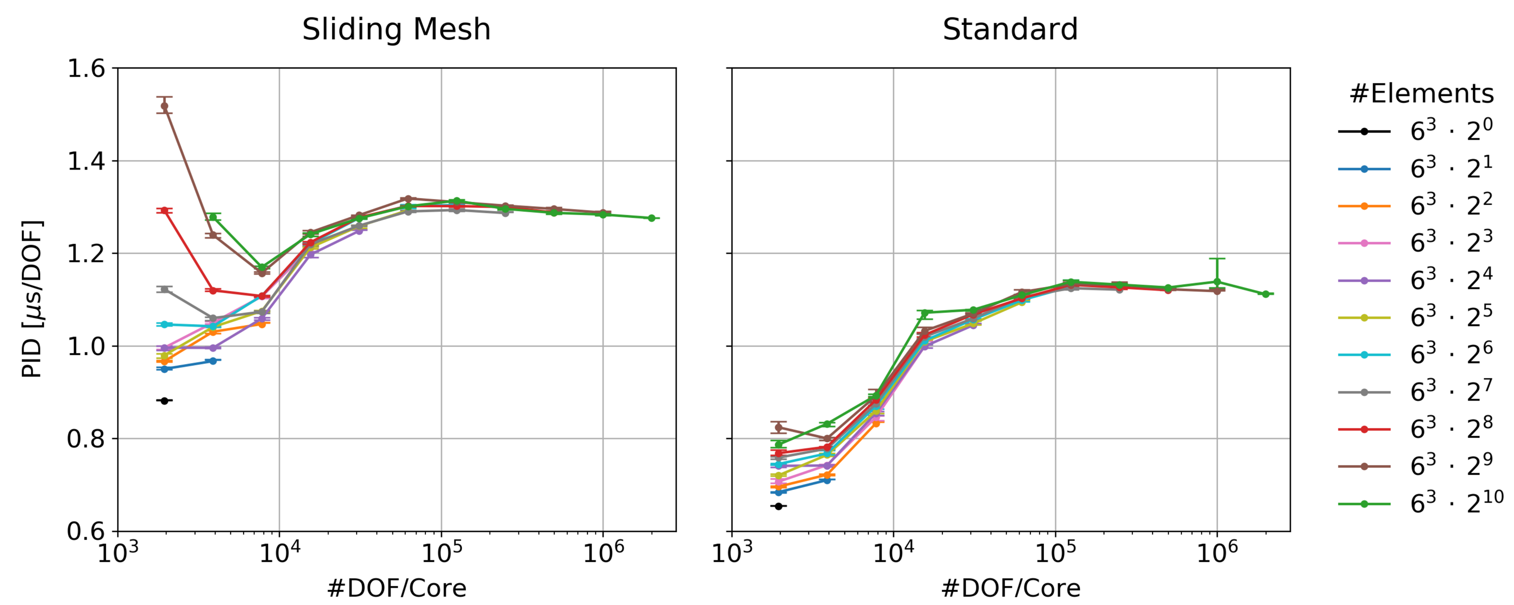

Figure 4: Results of the scaling test. Shown is the PID for several amounts of processor cores and mesh sizes. For every data point the mean of five runs is given with the maximum and minimum given as errorbars. The results of the sliding mesh implementation are shown on the left and the results of the baseline code on the right.

References

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