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Analysis of a Sound Source Mechanism in an Axial Fan

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The prediction of the turbulent flow field in the tip clearance region of axial fans is of great technical interest for the determination of aerodynamic losses and the generation of fluid mechanically generated noise. Especially the tip-gap width has a substantial influence on the emitted acoustic pressure level. For the analysis of the unsteady turbulent flow field in the tip area of the axial fan blades, a newly developed flow solver for viscous, compressible flows, which is based on hierarchical Cartesian grids [1] is used. A major advantage of Cartesian-based solvers is the possibility to automatically generate the computational grid with arbitrary boundary refinement in parallel [3]. Predictions of the turbulent flow field are performed in a rotating axial fan at a Reynolds number of 9.36x105 based on the outer casing diameter. In order to handle complex boundaries the finite-volume method uses a fully conservative cut-cell method with a flux-redistribution technique for the treatment of small cells [2]. Furthermore, a parallel, rotationally periodic boundary condition for arbitrary refined Cartesian meshes was implemented. A mesh resolution study for a 72° segment of the fan was conducted with a number of mesh cells ranging from 50 to 1600 million cells where used. The operating point of the fan is defined by a volume flow rate of 0.65 m3/s and a rotational speed of 3000 rpm. The computation was performed with up to 90000 CPU Cores on the CRAY System Hornet and Hazel Hen at the High Performance Computing Center in Stuttgart (HLRS). In the present study the Navier-Stokes equations are solved in a rotating frame of reference, with a rotating outer casing wall and non-moving blades. At the inlet boundary the mass flow rate is prescribed. Adiabatic no-slip boundary conditions are applied along all walls and a fixed pressure is prescribed at the exit boundary. Sponge-layers are used to damp the reflecting waves at the inlet and outlet boundaries. A periodic boundary condition is applied in the circumferential direction. In order to apply the periodic boundary condition an overlapping region is used, in which at least two cell layers are used to maintain the second-order spatial accuracy. Since the grid itself is not periodic all primitive variables of the overlapping cells are reconstructed from the internal region using non-linear least squares interpolation. Simulations are performed for different tip gap widths where the results of the analysis as well as a comparison with RANS results will be included in the presentation of the paper. In particular, it will be shown that the turbulent flow field in the tip gap region represents a dominant noise source.

References

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