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NUMERICAL TREATMENT OF TURBULENT LOW-MACH-FLOW FOR TURBINE COOLING APPLICATIONS

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A typical way to increase cooling efficiency in turbine cooling channels is to use ribs that cause flow separations. In order to optimize these channels a quick, robust and accurate process is required to simulate the fluid flow in cooling channels. Ribs lead to highly unsteady and three-dimensional flow separation. This type of flow is a challenging task for RANS solvers.

In this work the performance of the DLR inhouse solver TRACE is examined in simulating flow separations with heated walls compared to LES and Experiments. The backward facing step has been chosen as a representative case for separated boundary layers. The inflow Mach number is about 0.1 and the Reynolds number based on step height is 28.000. The sidewall downstream of the step is heated with a constant wall heat flux.

The purpose of the study is twofold. On the one hand, a procedure is applied to increase the convergence rate of the flow solution. On the other hand, a combination of turbulence models is identified that delivers accurate results for the turbulent eddy viscosity and conductivity.

The incompressible nature of this testcase leads to long convergence time. Numerical experiments prove that Low-Mach preconditioning accelerates the convergence rate. In this study it has been shown that Mach preconditioning increases the convergence rate up to factor of 4.

Furthermore mesh studies have been conducted starting from y^+=1 to even finer y^+ values. It has been shown that the thermal field reaches mesh convergence for smaller y^+ values compared to the flow solution.

Four turbulence models have been examined: one-equation Spalart-Allmaras, two equation Wilcox $k\omega$ and Menter SST and the anisotropy resolving Hellsten EARSM. These models have been combined with three different models to calculate turbulent eddy conductivity, a constant turbulent Prandtl number, an algebraic model for the turbulent Prandtl number and a two-equation $k_\theta\omega_\theta$-model for the turbulent heat flux. The model combination that performs best is the Wilcox $k\omega$ or Menter SST with algebraic Pr_T-modification. Here reattachment point and heat flux in the reattached region are in good agreement with measurements and LES. Differences occur in the recirculation region.

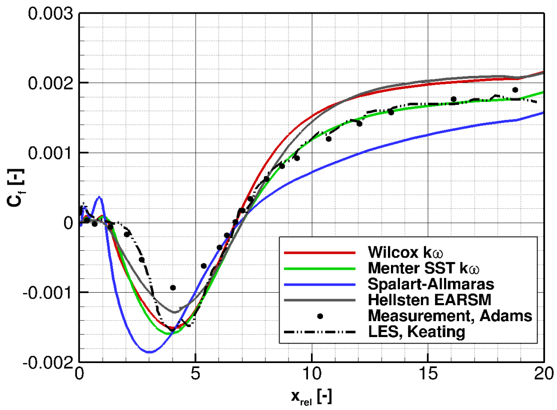

Figure 1: C_f-distribution

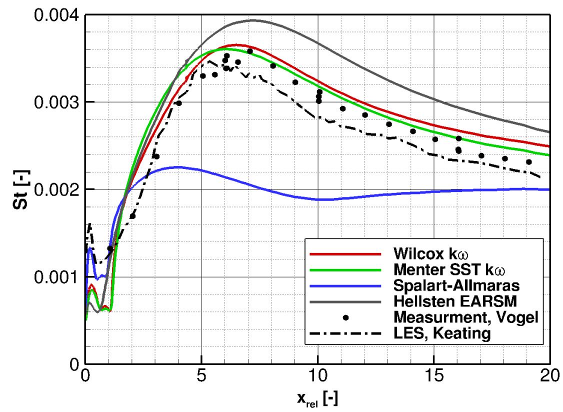

Figure 2: St-distribution

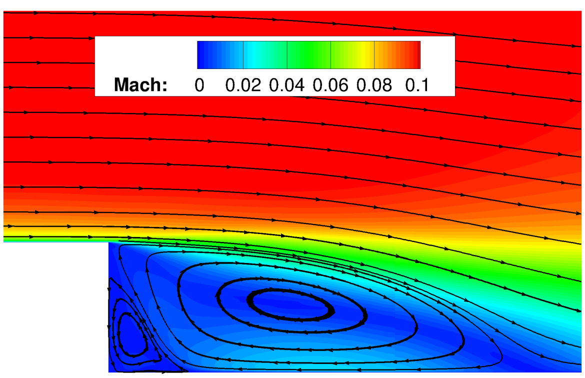

Figure 3: Mach number distribution

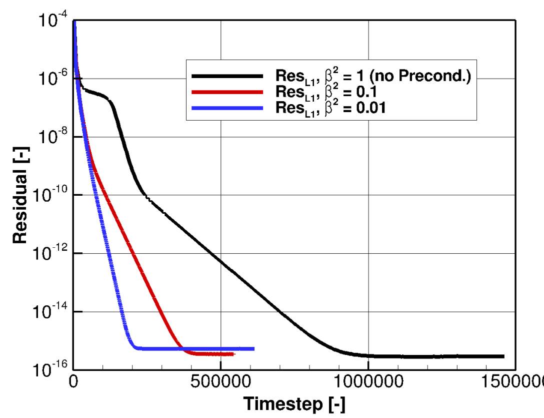

Figure 4: Convergence

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