Navier-Stokes Calculations of Multielement Airfoil Flows

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Abstract

Navier-Stokes calculations have been performed to predict and optimize the flow around various two-element airfoil configurations with optional Gurney flaps. Structured multiblock grids were used for discretization of the fluid domain, turbulence was modeled using the Wilcox k-ω model. Initial investigations included the influence of flap chord length, flap deflection and gap settings, in a second step maximum lift optimization was extended also regarding airfoil thickness and camber. The computed parameters for flap chord length and flap location correspond well with reference data, further numerical optimization significantly improved high-lift characteristics.

Keywords: Multielement Airfoils; Gurney flap; Navier-Stokes Calculations

1 Introduction

Common high-lift devices as they are discussed in this article provide the possibility to adapt and improve the aerodynamic characteristics of airfoil wings in a much wider range than in the case of single-element airfoil sections. Efficient layout of external airfoil flaps yet implies detailed knowledge of all influencing geometric parameters. To reduce wind tunnel time for testing and development numerical methods have been used for many years. Coupled boundary layer and inviscid calculations however cannot model all encountered flow features due to the complexity of multielement high-lift flows. Hence stationary Navier-Stokes calculations have been performed using the Wilcox k-ω model to investigate the influence of major geometric parameters considering multiple separated regions and confluent boundary layers.

2 Grid-generation

The projected simulations comprise several hundred flow-field calculations, thus grid-generation was fully automated. To ensure efficient utilization of computing resources two-dimensional structured multiblock grids were used for discretization of the fluid domain. The surrounding of the airfoil sections is discretized by two C-grids, see Fig. 1, far-field discretization is done by four H-grids reaching up to a distance of ten chord lengths. Due to identical grid topologies the resolution for each geometry setup is constant by a total number of 41910 elements.

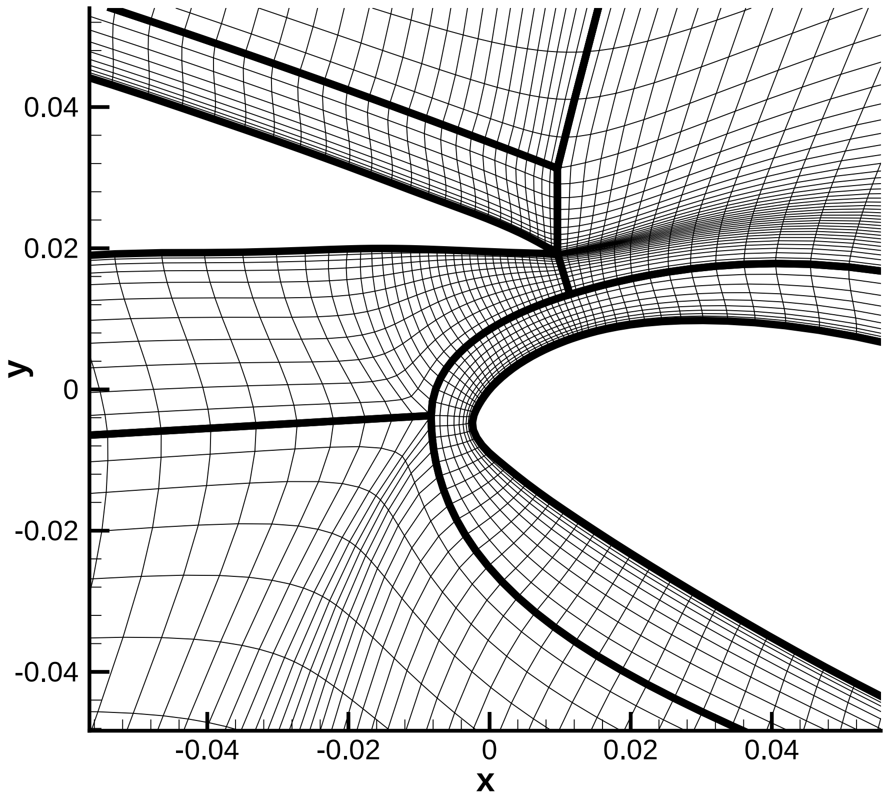

Figure 1: Computational grid and block boundaries in vicinity of flap nose

3 Navier-Stokes calculations

Evolving from the DLR CEVCATS code the applied Navier-Stokes code FLOWer solves the compressible Reynolds-averaged Navier-Stokes equations in integral form. For spatial discretization a central cell-vertex finite volume formulation of second order accuracy is used , time integration is carried out by an explicit hybrid multistage Runge-Kutta scheme. Calculations were accelerated by local time stepping, enthalpy damping, implicit residual smoothing and a four-level multigrid algorithm. Due to the high computational requirements of the aforementioned simulations the LRZ VPP700 was chosen for calculation. The applied solver is already optimized for use on a Fujitsu VPP platform so further adaptation was not necessary. As a result of the two-dimensional grid layout memory requirements were less than 300 MByte, one geometry setup took about 1200 seconds of total CPU time.

4 Results and Discussion

Computations were performed for $Re = 2.5 \cdot 10^6$ and $M = 0.2$. Considering flap chord length and flap location good agreement with reference data [1] could be achieved which indicates that especially the zone of confluent boundary layers on the upper flap side near the slat is realistically calculated by the k-ω turbulence model, see Fig. 2. For large separation bubbles at high angles of attack unsteady flow and slower convergence occurred, in most cases L1-density residuals lay below $1 \cdot 10^{-5}$.

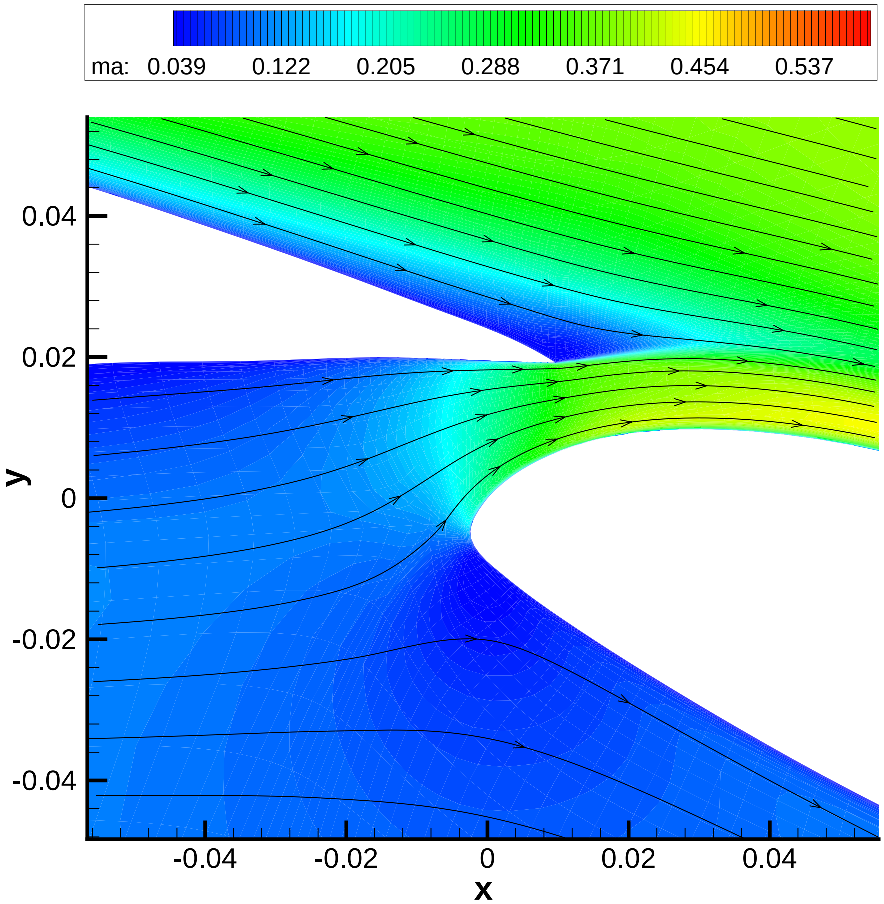

Figure 2: mach number and streamtraces in vicinity of flap nose

Based on a conventional two-element airfoil further improvement of maximum lift resulted from changing thickness and camber of main airfoil and external flap, highest lift coefficients were reached by an additional Gurney flap. Due to the promising computational results experimental evaluation of the described numerical simulations is currently being prepared for a basic two-element airfoil and a high-lift configuration with optimized parameter setting and Gurney flap.

Bibliography

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