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ON THE INTEGRATION OF HIGH-ORDER BOUNDARY ELEMENTS IN A 3D DISCONTINUOUS GALERKIN METHOD FOR TURBOMACHINERY FLOWS

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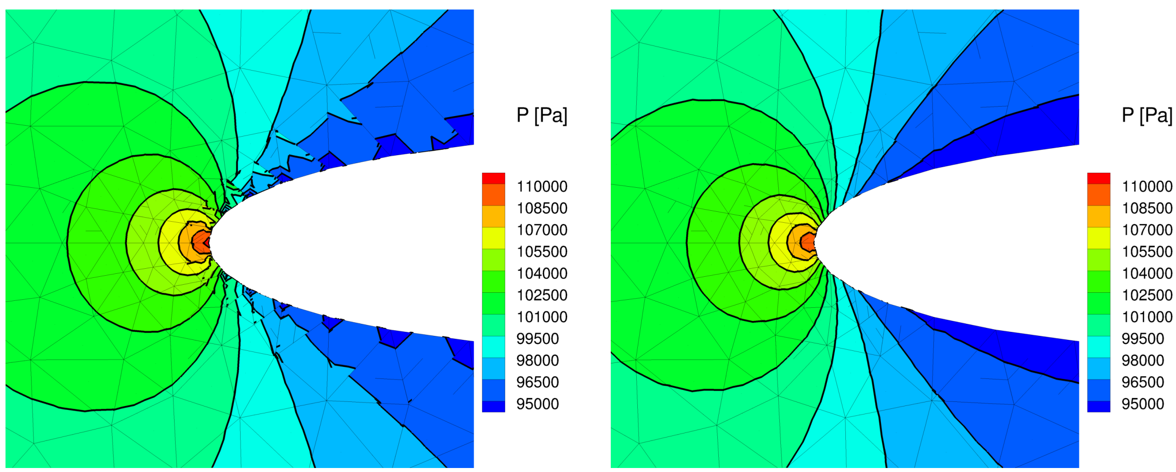
This paper describes the integration of a Discontinuous Galerkin (DG) solver into the DLR flow solver TRACE which solves the three-dimensional compressible Navier-Stokes equations on structured and unstructured grids [1]. Special emphasis is put on the integration of the DG approach into the process chain for turbomachinary applications which requires extension for the generation of curved elements near the boundary and visualization of high-order elements.

The DG solver employs up to fourth elements for the spatial discretization. However, the generation of appropriate meshes with high-order elements and visualization of solutions on these elements is not provided by commercial tools. Therefore, the pre- and post-processing [4] tools of the TRACE process chain, have been extended.

The importance of accurate approximation of geometric boundaries for DG has been pointed out by many authors, cf. [3, 2]. Since, the accuracy of the solution near boundaries is strong influenced by the geometric representation of boundary elements, it is mandatory to modify the discretisation schemes at curved solid walls in order to avoid oscillatory results and spurious entropy production. Therefore, for cells adjacent to curved solid wall boundaries the standard linear parametrisation is replaced with a polynomial representation ($q > 1$). The transformation from a reference element to the curved element is expressed in terms of Lagrange polynomials and is calculated from additional points on the curved boundary. The corresponding formulas for the Jacobians of 2D and 3D elements and the face normal vectors are adapted.

The application of the method to several academic problems has been used to validate the solver and estimate the efficiency of the high order ($p > 1$) accuracy discretizations. To demonstrate the importance of curved boundary treatments when dealing with complex geometries, the simulation results for the flow around a NACA0012 airfoil are presented in Fig. 1. The three-dimensional computational domain corresponds to a cascade of profiles and is resolved with tetrahedra. Here the pressure distributions are shown for the solutions employing cubic elements. Whereas the steady solutions obtained on the straight boundary elements (Fig. 1(a)) show spurious disturbances, the result of simulation with high-order geometrical representation of boundary elements (Fig. 1(b)) are of high quality.



(a) Straight boundary elements (b) Curved boundary elements

Figure 1: Comparison of contour plots computed by DG solver with the polynomial order $p = 3$.

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