COMPRESSIBLE FLOW SIMULATION ON UNSTRUCTURED GRIDS WITH MULTIDIMENSIONAL UPWIND SCHEMES

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Unstructured grid CFD methods are of increasing interest for solving complex flow problems because unstructured grids can be generated with less user input than structured grids and are by nature well suited for solution adaptation. Unstructured grids require however more accurate discretization schemes which are much less dependent on grid orientation than the classical upwind finite volume schemes. A valid answer is the multidimensional upwind Residual Distribution (RD) method, which is being developed at the VKI since the past decade. The objective of the current PhD project is to further improve the accuracy and efficiency of this method for the simulation of compressible inviscid and viscous flows in the subsonic to supersonic regimes.

In past year extensive verification and validation computations have been carried out with the THOR unstructured grid code developed as part of this project. This confirmed the expected order of convergence of the multi-D upwind RD method and compared its accuracy to state of the art finite volume methods, on structured and unstructured grids, such as the FLOWER and TAU codes developed by the DLR. A higher level of accuracy of the RD method was demonstrated on typical problems such as the subsonic and transonic flow over a wing and complete aircraft configurations, such as shown in Figure°1. Figure°2 shows the turbulent transonic flow over the ONERA M6 wing, computed using the Spalart-Allmaras turbulence model[1]. The multi-D upwind RD method has a clear advantage over the finite volume methods in achieving a perfectly monotone shock capturing, thanks to a well-defined positivity property.

Despite this advantage, the multi-D upwind schemes also have some flaws in common with certain flux difference splitting finite volume schemes, most notably unphysical "expansion shocks", violating the second law of thermodynamics. To address this problem a multi-dimensional entropy fix has been developed for the RD schemes, which introduces a model for a continuous sonic expansion, so that the entropy condition is respected, i.e. the occurence of unphysical expansion shocks is avoided[2].

In order to extend the applicability of the THOR solver to low Reynolds number flows, of interest to UAV applications for example, a 2D boundary layer transition prediction code was developed, based on the e^N linear stability method. Our present approach starts from using directly the boundary layer profiles interpolated from the Navier-Stokes solution, as opposed to the more usual, but also less general, approach of using a separate boundary layer code.

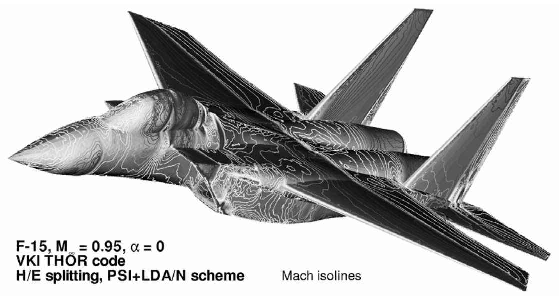

Figure 1: Euler computation. Grid courtesy of EADS Military, Munich

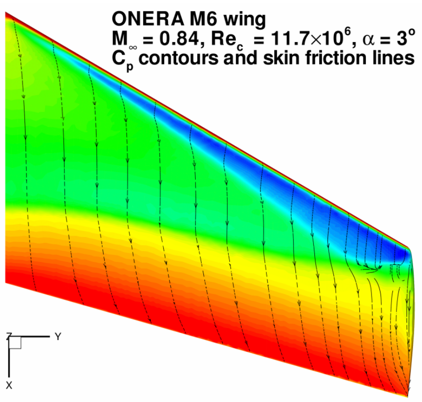

Figure 2: RANS computation on ONERA M6 wing with S-A turbulence model

[1] K. Sermeus and H. Deconinck, "Drag prediction validation of a multi-dimensional upwind solver", in CFD based aircraft drag prediction and reduction, VKI Lecture Series 2003-03, February 3–7 2003.
[2]K. Sermeus and H. Deconinck, "An entropy fix for the multidimensional upwind residual distribution schemes", To appear in Computers and Fluids.