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Session:

Investigation of structured and unstructured grid topology and resolution dependence for scale-resolving simulations of axisymmetric detaching-reattaching shear layers

Jan-Erik Schumann, Volker Hannemann, Klaus Hannemann

German Aerospace Center (DLR), Spacecraft Department, Bunsenstr. 10, 37073 Göttingen, Germany

Introduction

Grid optimization is still a major concern for scale-resolving simulations. Even though a lot of effort has been put into predicting optimal grid topology and resolution a priori, in most cases this is not trivial. This is especially true for high Reynolds number flows for which Direct Numerical Simulations are not available as comparison.

Hence for the case of a detaching-reattaching turbulent shear layer at $Re=1.2\cdot10^{7}\ m^{-1}$ and transonic conditions a comprehensive grid study is presented and the influence of resolution and topology on both first and second order statistical moments as well as spectral content of the flow solution is systematically investigated. In combination with this investigation two LES grid sensors are also tested for their applicability to hybrid RANS-LES computations of this type of flow.

Grid topology & resolution investigation

Hybrid grids are used to enable a fine circumferential resolution in the focus region, but still allow for a coarser circumferential resolution at the axis and for a coarser general resolution outside the focus region. From theoretical considerations structured grids should lead to higher accuracy for similar grid spacing compared to unstructured grids. The exact significance of the effect, however, has not been sufficiently and systematically investigated. For this reason a grid topology is used that enables the focus region, i.e. the region where turbulent structures of interest develop, to be discretized either with hexahedral (structured) or prismatic (unstructured) elements while also enabling a coarsening of the resolution away from the focus region.

On the one hand, the in-plane (i.e. axial and radial) resolution of the grid is changed and the sensitivity of the solution to these changes is

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investigated. Experimental and numerical data for observed mean and root-mean-square wall pressures and the spectral content of the wall pressure are available for comparison [1][3][4].

Two grid sensors are used to guide the grid refinement. The first one [8] gives an indication of the resolved scales compared to the unresolved ones and thus of regions where refinement is necessary. A second sensor [7] is used indicate the preferred direction of refinement. Both sensors, to the authors' knowledge, have not been used for this type of transonic, high Reynolds number flows in the hybrid RANS-LES context and thus the results are also used to observe their suitability for this kind of application.

On the other hand, the circumferential resolution is refined to also investigate the sensitivity of the solution to this parameter. The coarsest resolution is taken to be about 1.8° which is below the maximum recommended 2.5° [4], but still higher than the usually used 1° [3][5] enabling a more precise analysis and determination of the necessary resolution. Additionally, results from structured and unstructured grids with comparable resolutions and grid size are directly compared.

The goal is to find the effects of changing the grid resolution and/ or topology in different parts of the focus region on all aspects of the solution. The further goal is to assess how well these effects are represented in the different grid sensors and thus if these sensors are able to provide insights into optimal grid creation without the need for full investigations of statistical moments and spectral content.

References

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