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Session:

Improvement of CFD-Wind Tunnel Correlation near Buffet Onset by Using Scale Resolving Simulations

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Introduction

This paper is dedicated to the assessment of turbulence modeling for CFD – Wind Tunnel correlation at transonic speedon a wide range of incidence angles, including near buffet onset.The reference geometry for validation is the CAE–AVM (Chinese Aeronautical Establishment – Aerodynamic Validation Model) [1]. CAE–AVMrepresents along-haul business jetwitha narrow fuselage, slender backswept high aspect ratio wings with fuselage mounted engines. The configuration has a cruise Mach number of 0.85 and a lift coefficient of 0.5.The model was tested in the DNW-HST, one of the pressurized transonic facilities of the German-Dutch Wind tunnels, located in Amsterdam, the Netherlands. The wind tunnel model has a wing span of 1.37m. The model was designed for measuring the aerodynamic loads and wing pressure distribution at six span-wise location (η = 0.20, 0.35, 0.45, 0.55, 0.65 and 0.75)witha total of 180 orifices. The model was mounted on a ventral Z-sting and or a dorsal sting, which both allow for longitudinal investigation.Results from the wind tunnel are used for comparison with CFD simulation by INCAS. These CFD results were obtained using RANS SST k-ω turbulence model [2] on two geometries: the first is the free flying Aerodynamic Validation Model with 1g wing shape, AVM; the second is with the deformed wing measured at wind tunnel cruise condition (Mach number = 0.85, CL =0.5) and the Z-sting support mounted, called AVM-DZ. Both CFD and tunnel data were presented and compared at the 2016, CAE-DNW Workshop on CFD-Wind Tunnel Correlation Study [3]. The RANS simulation were compared against wind tunnel results for AVM and AVM-DZ geometries and showed good agreement until buffet onset incidences with the better agreement for the AVM-DZgeometry, see Fig. 1. An extension beyond theRANS simulation for improving predictions at buffet onset (AoA$\geq$ 3 deg.) is considered with two approaches. Both of these approaches considered must use the same grid as for the RANS method in order to exclude discrepancies and grid influence on the results. Therefore the models used for improvement must be based on the SST. The first extension is to use the Unsteady-RANS (URANS) k-ω SST model at those incidences. The second approach is to use the Scale Resolving Simulation (SRS) extension for the SST turbulence model in an unsteady computation. This leads us to the use of Scale Adaptive Simulation (SAS) [4] based on the k-ω SST turbulence model. The advantage of using SST-SAS is that it is the only SRS model that allows to keep the same grid (unlike LES and DES that are strongly mesh dependent) and in addition,if the grid is too coarse or the time step too large the solution reverts to a steady RANS.As expected for the linear part of the CL–AoA curve (AoA< 3 deg.) the AVM-DZ was in closer agreement with the experimental results for CL, CD and CM since it takes into account the wing deformation and the support influence. Due to this, the SST-SAS and URANS k-ω SST computations will be performed only on the AVM-DZ geometry.The SST-SAS model is seen as the most affordable hybrid RANS-LES model and has the advantage of requiring a RANS-like resolution mesh.

Simulation methodology

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All the CFD results are obtained using the Ansys Fluent v16commercial software, and the density-based solver. For all the computations the CAE generated Workshop meshesare kept that consist of multi-block structured grid for both AVM and AVM-DZ geometries [3]. The numerical boundary layer has a target $y^+ \approx 1$, a growth factor of 1.2 and 45 layers. For the AVM geometry the mesh has 907 blocks and 28.6 million hexahedral cells; for the AVM-DZ geometry the mesh has 1195 blocks and 39.7 million hexahedral cells, both for the half model. The surface mesh and numerical boundary layer is kept the same for both meshes. Gradients are reconstructed using the Least Square Method;high order is achieved through Second-Order Upwind reconstruction for both flow and turbulence variables [5]. Time advancement is achieved using Second Order Implicit formulation.

First results using RANS

Overall the RANS k-ω SST turbulence model reproduces the CL, CD and CM very well up to the buffet onset, see Fig. 1a. The same trend for agreement of CFD and wind tunnel results can be seen also in Cp plots, see Fig. 1b, at the six span-wise locations and for oil-flow visualizations (to be included in the final paper).

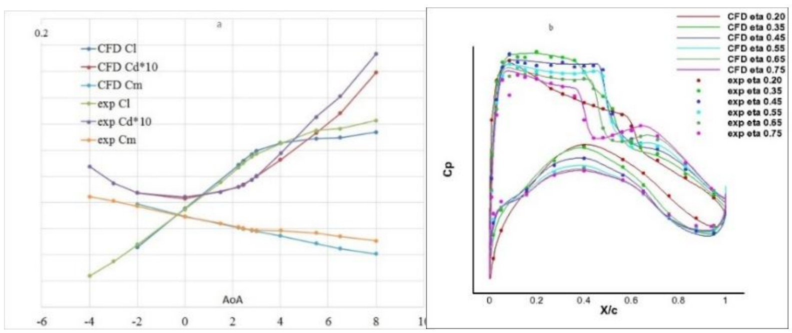

Fig. 1 k-ω SST RANS for AVM-DZ vs experimental results. Aerodynamic coefficients (a) and Cp plots for AoA = 2.45 deg.(b).

Conclusions and way forward.

At the buffet onset(AoA≥ 3 deg.at M=0.85) the steady state computations (RANS) under-predict the aerodynamic coefficients for CL and CD while keeping the same trend as the experiments, although the Cm shows a bigger discrepancy. This leads to the expectation that an unsteady simulation will be better suited for capturing the buffet phenomenon and will give a better agreement. Therefore the first step for improving the results is to use directly URANS based on the k-ω SST model. A second step is to use a better suited model for unsteady flows like the SST–SAS. These results will be included in the final paper.

References

[1] J. HUA, S. ZHENG, M. ZHONG, G. WANG, L. CHU, F. LIU & J. BAI: "Design and Verification Study of an Aerodynamic Validation Model".7th Asia-Pacific International Symposium on Aerospace Technology, 25 – 27 November 2015, Cairns

[2] F. R. Menter. "Two-Equation Eddy-Viscosity Turbulence Models for Engineering Applications". AIAAJournal. 32(8). 1598–1605. August 1994.

[3] "CAE-DNW Workshop on CFD-Wind Tunnel Correlation Study - 2016", Beijing, China. http://cae-dnw-workshop.dnw.aero/

[4] F. R.Menter and Y. Egorov. "The Scale-Adaptive Simulation Method for Unsteady Turbulent Flow Predictions.Part 1: Theory and Model Description", Journal Flow Turbulence and Combustion. 85. 113–138. 2010.

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[5] F. R. Menter. Best Practice: Scale Resolving Simulations in Ansys CFD v2.0, 2015.