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LESSONS LEARNT FROM GAP-TURBULENCE CASE IN FP7 VALIANT PROJECT

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This talk is devoted to the simulation of the ‘gap-turbulence interaction’ test case which was one out of four generic test cases on aerodynamic noise studied both experimentally and numerically in the framework of the EU FP7 project VALIANT – VALidation and Improvement of Airframe Noise prediction Tools.

The experimental study of the low Mach number and high Reynolds number flow around the gap configuration was carried out at TsAGI (Central Aerohydrodynamic Institute, Moscow). Both boundary-layer measurements and acoustic farfield measurements have been made in the experiment. It was found that the farfield acoustic spectra were characterized by a pronounced discrete mode along with the broadband noise.

Numerical simulations were performed by two teams: Keldysh Institute of Applied Mathematics (KIAM) and Technical University of Berlin (TUB). Although both KIAM and TUB used similar hybrid RANS/LES turbulence treatment in their nearfield simulations and farfield extrapolations based on the acoustic analogy of Ffowcs-Williams and Hawkings, the numerical methods employed were fundamentally different.

At the initial stage of the study, both numerical teams found a significant discrepancy between the peak frequencies obtained experimentally and numerically, although the simulations were in rather good agreement with each other. It took some time to reveal the reason and, thereby, to learn the lessons of the case.

- Gap-turbulence interaction can be characterized by two basic lengths, namely the gap width and the plate thickness. Depending on the choice of these parameters the turbulent flow over the gap can exhibit complicated unstable behavior. Small deviations of constitutive variables can cause two different flow states around the gap. The first state is mostly determined by the gap leading edge and its character length is the plate thickness. The resulting flow in this case looks like a wake flow past a blunt trailing edge. The second state is mostly determined by the gap trailing edge and its characteristic length is the gap width. In this case the resulting flow looks close to the flow over a cavity.

- The turbulent flow in the gap region is very sensitive to the incoming turbulent boundary layer and “unstable”. Even within each different flow state, the coherent peak frequency can fluctuate depending on the condition of the upstream boundary layer. For instance, within the wake-type state, the displacement thickness of the boundary layer effectively changes the thickness of the plate and the frequency corresponding to the blunt trailing-edge vortex shedding noise may fluctuate.

- The aeroacoustics of the first, wake-type, regime of gap-turbulence interaction corresponds to the trailing-edge bluntness noise while that of the second type – to the cavity noise. Under the first flow regime, the peak frequency appears significantly lower than the peak frequency in the second case. As a result, depending on the case conditions (ratio between the plate thickness and gap width, upstream BL thickness, intensity and structure of incoming turbulent boundary layer) the aeroacoustics of the gap-turbulence interaction can exhibit several narrowband humps in a relatively wide band of frequencies.

The investigation of the gap-turbulence case within the EU FP7 VALIANT project has revealed several important numerical issues including the known ones which have been additionally confirmed. Some lessons learned are the following:

- Although the computation of broadband noise from separated flows at low Mach number and high Reynolds number is nowadays possible by means of numerical simulation and state-of-the-art hybrid CFD/CAA & RANS/LES methods, its quantitative prediction is not straightforward and may not always be possible with acceptable accuracy. In particular, the quantitative prediction appeared impossible in the gap-turbulence case considered in VALIANT when the turbulent flow admits switching from one state to another under the strong influence of broadband turbulence. However, even if accurate predictions for such cases may be out of range, the simulation results still offer a possibility to investigate the aeroacoustic phenomena in quality and to find ranges of possible dispersion in flow parameters and acoustic data.

- Since complete DNS and LES of real aerodynamic problems at high-Reynolds numbers, are still out of reach, further improvements of hybrid RANS/LES models are of great demand. It is confirmed once more that an adequate emulation of unsteady turbulent inflow conditions in turbulence resolving numerical simulations is very important. Virtual obstacles described by immersed boundary method were used within VALIANT to turbulize the boundary layer flow, but this method still needs further investigations and appears to require a careful adjustment to the specific problem at hand. Synthetic turbulence inflow models therefore remain of high importance, especially for the application of hybrid RANS/LES methods to weakly separated flows, in order to provide a proper transition between modeled and resolved turbulence in the so called “grey” areas.

REFERENCES

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