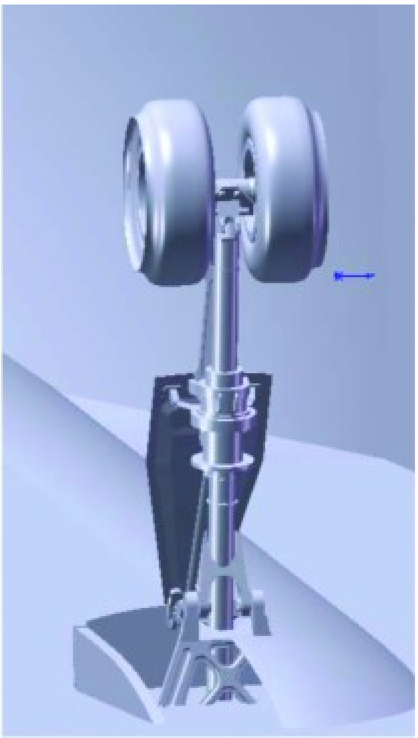
Aeroacoustics Simulations for the Aerospace Industry



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Case Studies

Sources of flow-induced noise are varied. Typically, for commercial aircraft, they are mainly associated with high-lift devices, landing gear, jet nozzles, and cabin and cockpit climate control devices. For military air-vehicles, structural and aerodynamic instabilities of weapons and weapons bays are additional issues that need to be addressed.

This article describes two case studies, namely the airframe noise simulation of a complex nose landing gear, and the aeroacoustics analysis of an avionic cooling rack in an Airbus cockpit.

Case Study #1: Aeroacoustics of a Complex Nose Landing Gear

This case was implemented as part of the Problem 4 of the First AIAA Workshop on Benchmark problems for Airframe Noise Computations (BANC-I), which was held in Stockholm, Sweden, on June 10-11, 2010. The geometry is a simplification of the Gulfstream G550 nose landing gear, configured as Partially-Dressed Cavity-Closed (PDCC). Experiments on a quarter-scale model were performed in the NASA-BART acoustic tunnel and at the University of Florida.

The computational model contained complete component details and resolved the geometry down into the laminar sub-layer (nominally y+ < 1). The mesh comprised trimmed hexahedra with extruded prisms in the normal-to-wall direction, totaling 39 million cells. In the vicinity of all the landing gear components and wheel, uniform cubic cells of 0.75 mm were used.

In addition, a mesh coarsening exercise was performed. Two coarse meshes were successively run, in which the cell size in the core flow region was increased from 0.75mm (fine) to 1.00 mm (medium mesh resulting in 22 million cells) and 1.25 mm (coarse mesh, 13 million cells), respectively.

First a steady-state simulation was performed in order to determine where volume mesh refinements were needed, as well as calculate the mesh frequency cut-off measure to size the cells. The applied mesh was well able to capture frequencies up to 5 kHz in the vicinity of the landing gear components, as shown on accompanying images.

The results from the transient compressible simulation, using DES and applying non-reflective treatments at the inflow and outflow boundaries, delivered a high level of confidence that both the mean and fluctuating flow fields were well predicted.

The total computational time for 0.25 seconds of simulated time on the fine mesh took approximately 16000 CPU-hours on a modern 3.0 GHz Linux platform. This corresponds to just over 5 days on 128 CPUs. Likewise, the coarse 13 million cell case took just under 2 days.

Case Study #2: Noise Signature from an Airbus Cockpit Avionics Cooling Rack

In this case study, we demonstrated the up-front use of the steady-state turbulence synthesization method to improve the noise signature of an avionics cooling rack. The electronics sit on shelves which are actively cooled by air channels within the shelving, supplied by ducts which are fed from the Environmental Control System (ECS).

Debatin?s technique was used to modify the original designs of plenum and shelf flow restrictor. The effects of the modifications were then assessed by quantifying the noise reduction through CFD simulation and comparing the results with the measured noise reduction. A DES simulation was used for the transient flow-field predictions. Microphones were placed in arbitrary location in the plenum and in the shelf restrictor.

It was found that the modified plenum design significantly reduces the volume of flow recirculation, and consequently the shear-noise generating mechanisms.
The result was a reduction of noise levels across the full range of the human hearing spectrum. The DES simulation succeeded in predicting the level of noise reduction correctly (approximately 3dB in the range 300-10,000 H z), but over-predicted the improvement in the lower frequency range.

The flow turbulence through the shelf restrictor was found to be greatly reduced, resulting in a 2-5 dB reduction is noise levels between 100 and 10,000
Hz. The predicted levels of noise reduction were excellent across this full range.

The total model size was approximately 1.5million cells. Calculations in steadystate and transient (DES) were performed by a graduate intern student and completed within a period of three months, using computer resources limited to 8 CPUs maximum.

Conclusion

By working closely with the transport industry, CD-adapco provides validated tools to predict and design against aeroacoustical effects early in the design process. Two industrial aeroacoustics case studies, among a multitude of other possible applications in the aerospace industry, have been briefly described in this article. The results proved to be accurate and the study helped illustrate how a deeper understanding of acoustical phenomena can be gained through the use of STAR-CCM+, thereby enabling a higher degree of engineering value to be added while reducing costs and timescales in the CAE process.

Aeroacoustics best practices are now included in the STAR-CCM+ online documentation. For more information about methodologies and best practices for
aeroacoustics simulations in the automotive and aerospace sectors, please refer to .

References

?Chasing Noise with Simulation?, Debatin, ECOMAS CFD 2006, The Netherlands, September 5-8, 2006.
?Efficient CFD Simulation Process for Aeroacoustic Driven Design?, Mendonça et al., presented at the II SAE Brazil International Noise and Vibration Congress, October 17-19, 2010, Florianopolis, Brazil, SAE-2010-36-0545.

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