A semi-automatic toolchain with Large Eddy Simulations accelerated on Graphics Processing Units for rapid modelling of jet installation noise

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Abstract

In unsteady Computational Fluid Dynamics (CFD) and especially Large Eddy Simulations (LES) used as a high-fidelity Computational Aero Acoustics (CAA) method, good mesh quality directly translates to good flow and acoustic solution. This also applies for many CFD methods, which require hex/prism-dominant meshes in sensitive flow regions such as in the vicinity of boundary and free-shear layers. Such quality meshes are typically structured block-by-block and generated manually by the user. However, the block-structured meshing procedure for any realistic industrial case is very laborious and can take up a few months for a complex geometry case. In application to nozzle exhaust flows, it is almost impossible to produce good quality hexahedral mesh for anything else than simple nozzles without either any external structures or any detailed modelling of the upstream geometry. This puts constraints on the numerical method used for solving the governing fluid dynamics equations too.

In this talk we present a semi-automatic toolchain we developed, where we use the hex-dominant meshing capabilities provided by the open-source OpenFOAM tool SnappyHexMesh, together with a highly optimized CAA hex-dominant solver utilising Graphics Processing Units (GPUs). The solver is based on the high-resolution CABARET method for Wall Modelled Large Eddy Simulations, which was developed by the authors in previous publications [1-5]. Advantages of the CABARET method include low dissipation and dispersion errors for optimum local Courant number (around 0.5) which is achieved using asynchronous time stepping. Together with the implementation on GPUs these properties allow solving realistic industrial cases (200+ million cells) within an industrially relevant time span (e.g. days and not months) using moderate computer resources.

To demonstrate our toolchain, we show the meshing and flow results of the DJINN platform 1 cases, which involves a dual stream nozzle with a pylon in an isolated and installed case. In the installed case, the geometry is complex with the presence of the wing, flaps, and fuselage. For both cases the meshing procedure is described, whilst discussing the local grid refinement options and their effect on the flow solution. Far-field noise results are obtained by coupling the LES solutions with the Ffowcs Williams – Hawkings method using a permeable formulation with multiple closing surfaces to filter out the pseudosound effect of vorticity waves. Comparison with the reference experimental data and other numerical results will be reported.
Noticeable is that the meshing procedure applied for the GPU CABARET solver results in hex-dominant meshes, while the mesh generation only takes several hours on 12 CPU cores. The LES flow solutions are obtained on mesh sizes 150 -220 million cells, and the calculations are performed using just two high-end GPUs fitted in one workstation. The total simulation time including pre- and post-processing is 2-3 weeks, whereas the same geometry and flow solution on a CPU cluster of several thousands of cores is likely to take a few months. This demonstrates the efficiency of the suggested tool-chain, which could be used as part of design optimisation study [6], as well as the economic return for industry.

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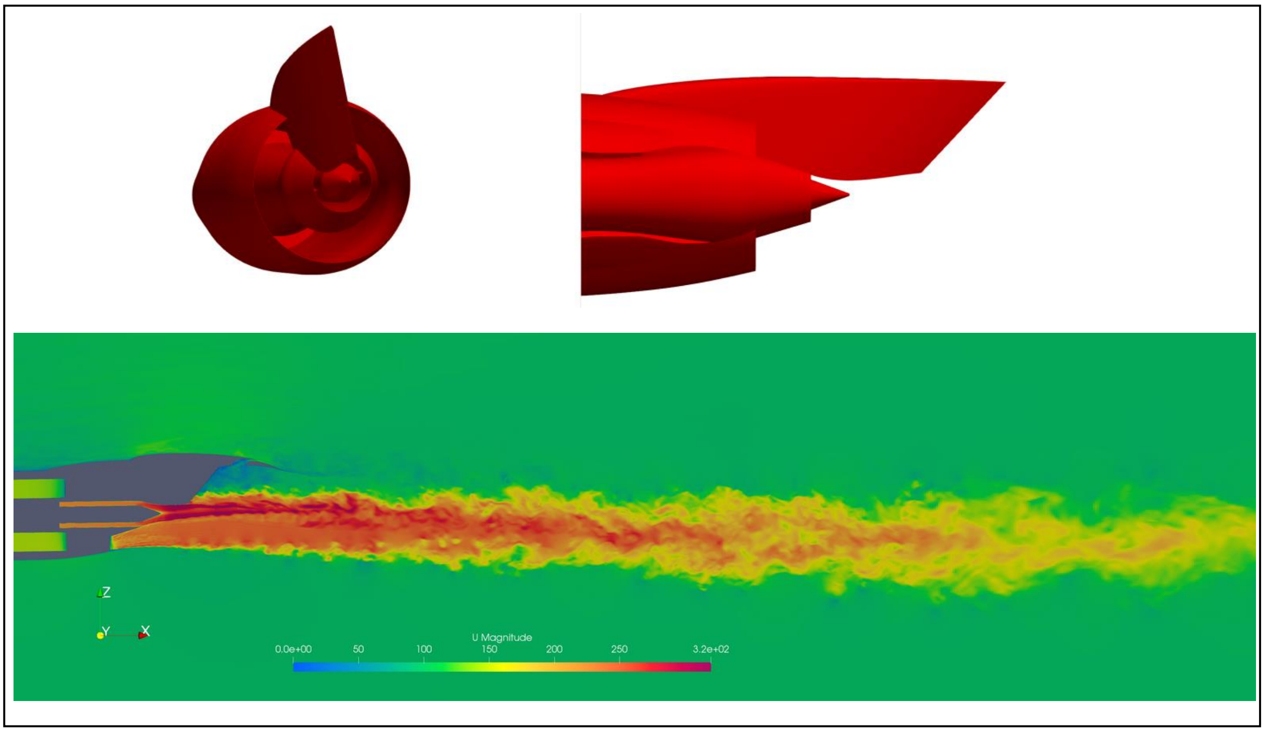

Fig. 1 Geometry and a snapshot of the flow solution for the isolated DJINN platform 1 case.

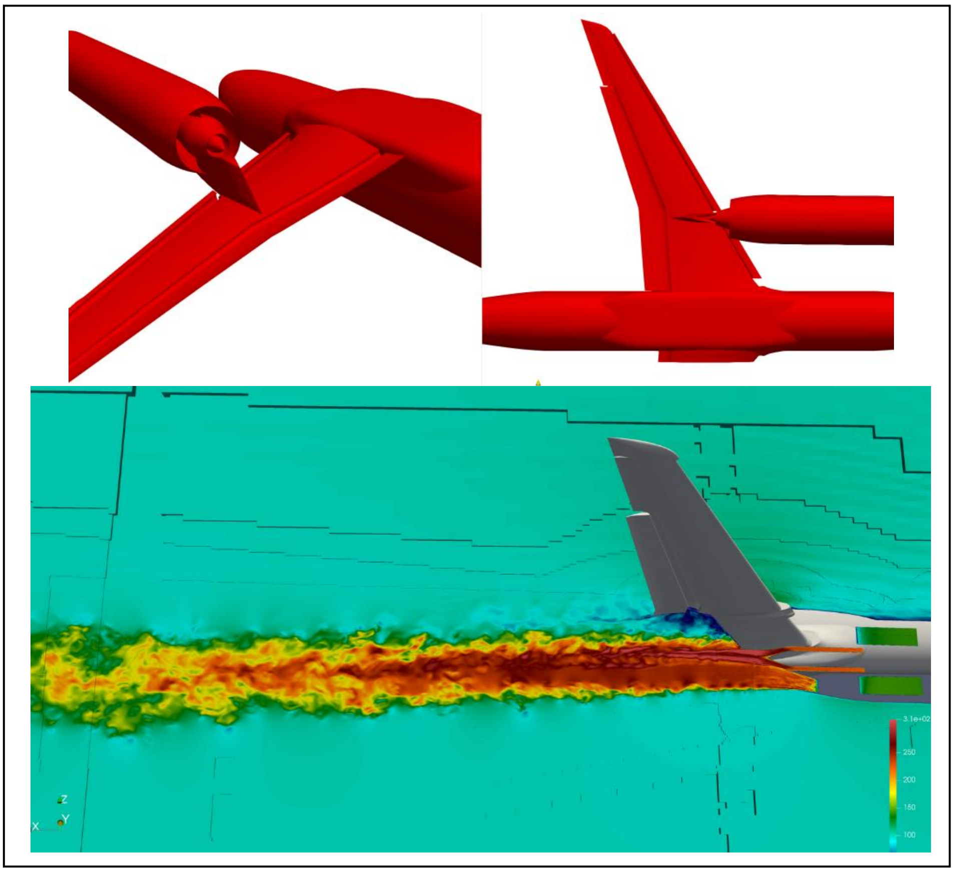

Fig. 2 Geometry and a snapshot of the flow solution for the installed DJINN platform 1 case.

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