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Large-Scale DES around Complex Geometries using an Unstructured Compressible Flow Solver

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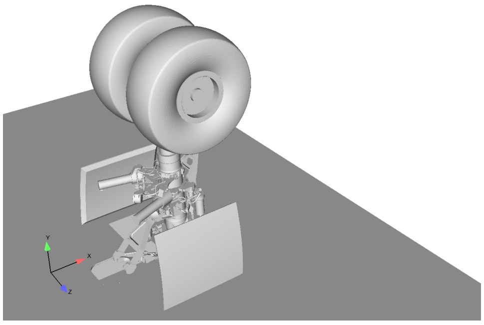
ABSTRACT

This work reports on unsteady turbulent flow simulations around complex geometries. For this purpose, a parallel implicit compressible flow solver on unstructured tetrahedral meshes has been developed. In order to capture the flow physics properly, a special care has been devoted to the spatial discretization as well as to modeling aspects.

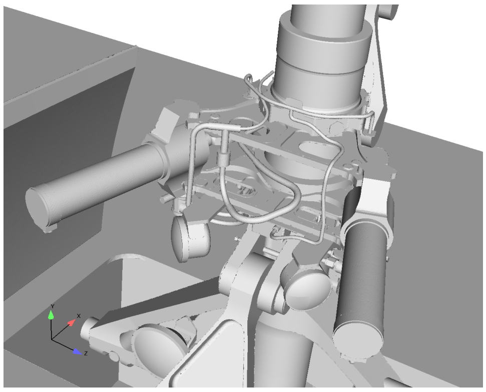
The second-order accurate numerical scheme blends a finite volume approach for the convection fluxes based on a piecewise linear reconstruction of the variables in each control volume with a P1 finite element Galerkin approximation of the diffusion fluxes. Yet robust, standard upwind schemes are not compatible with unsteady turbulent flow simulations. This is due to the significant amount of artificial dissipation that is used to stabilize the convective term discretization and that interacts strongly or overwhelms the subgrid scale model action. In fact, a relevant part of the kinetic energy of the well-resolved (and dynamically important) scales of the flow is removed through this artifical dissipation process. The solution followed in the present work is to resort to non-dissipative central schemes [1] which conserve the kinetic energy at the discrete level. In order to validate further the accuracy and stability of the present approach, the case of a very complex geometry is here considered.

The LES grid resolution near the wall is known to be much too expensive for high-Reynolds applications, typically encountered in industrial problems. A RANS-LES approach is thus here considered where the near-wall region is treated in RANS mode. This leads to grid requirements similar to the ones used in pure RANS simulations. The selected RANS-LES method is the well-known DES approach based on the one-equation Spalart-Allmaras model. It was recently proved that the initial formulation of DES, called DES97 in Spalart et al. [2], presents an incorrect behavior in thick boundary layers if the grid spacing parallel to the wall becomes inappropriate because the switch between RANS and LES is only determined by the grid. To overcome this deficiency the technique of delayed DES (DDES) has been developed [2]. The switch between models then depends also on turbulent flow properties. The spatial discretization has to be adapted to RANS-LES. A standard upwind scheme is used in the RANS region while the kinetic energy central scheme is active in the LES region. In this way, the proper discretization is used in accordance with the flow physics and the modeling strategy.

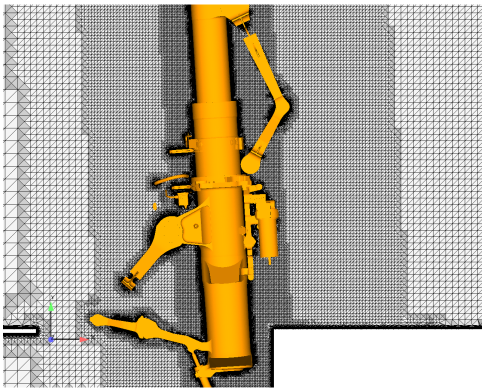
The present methodology has been applied to the unsteady flow past a landing gear. It is a very complex geometry since all the landing gear elements are represented, as depicted in Figs.1(a) and 1(b). The



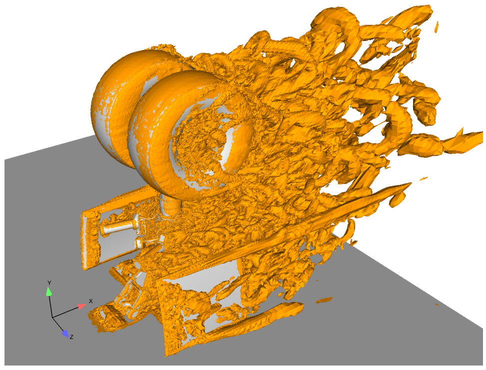
(a) CAD geometry



(b) CAD geometry close-up



(c) Volume mesh close-up



(d) λ_2 iso-surfaces

Figure 1: DDES of the flow around a nose landing gear

Reynolds number based on the landing gear height is 10^7, which is far beyond the scope of wall-resolved LES so that a RANS-LES approach is required. The Mach number is equal to 0.18. A relevant part of the work has been devoted to generate a mesh that represents the geometry correctly and that captures the relevant part of the flow physics. The mesh contains 12 millions nodes and 70 millions tetrahedra. A DDES has been performed in parallel on 100 processors. The time integration is fully implicit and uses a three-point backward differencing scheme. Preliminary results show that the simulation gives encouraging results since flow statistics are in a good agreement with existing data. Furthermore, the flow presents a large range of structure sizes as depicted in Fig. 1(d). The simulation has remained stable even though some grid elements are highly irregular and distorted. This highlights that the present kinetic-energy discretization is stable, robust and accurate even for very complex geometry leading possibly to highly irregular meshes. A detailed analysis of the flow will presented at the conference.

REFERENCES

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