DNS and ILES of transitional flows around a SD7003 using a high order Discontinuous Galerkin Method

C. Carton de Wiart[1,2] and K. Hillewaert[1,2]
[1] Cenaero
Rue des Frères Wright 29, B-6041 Gosselies, Belgium
[2] iMMC, Université catholique de Louvain
e-mails: *corentin.carton@cenaero.be*, *koen.hillewaert@cenaero.be*

The simulation of turbulent flows by Direct Numerical Simulation (DNS) and Large-Eddy Simulation (LES) approaches requires extremely low numerical dispersion and dissipation. For fundamental flow problems one can use structured high-resolution finite differences (FDM) or spectral methods. These are only applicable to simple geometries since they require high-quality structured meshes. For industrial flows and complex geometries, currently the only viable option consists of classical second order Finite Volume (FVM) codes, preferably adapted to conserve kinetic energy. The low accuracy requires very fine meshes, in practice prohibiting adequate resolution. Finite Element-like high-order methods such as discontinuous Galerkin (DGM) [1], residual distribution, spectral element methods, ... have attracted considerable interest lately since they bridge the gap between accuracy and geometric flexibility. DGM has the additional advantages of computational efficiency and a simple way of checking grid resolution. Combined with those advantages, the interesting properties of DGM in terms of dissipation and dispertion errors make DGM a powerful tool to perform high fidelity DNS of transitional and turbulent flows.

The present study focuses on the simulation of the 3D flow around a SD7003 airfoil at a Reynolds number equal to 60000 with an angle of attack of $\alpha = 4$. At this Reynolds number, the flow is known to go from laminar to turbulent through a laminar separation of the boundary layer, leading to a transitional shear layer followed by turbulent reattachment (figure 2). This

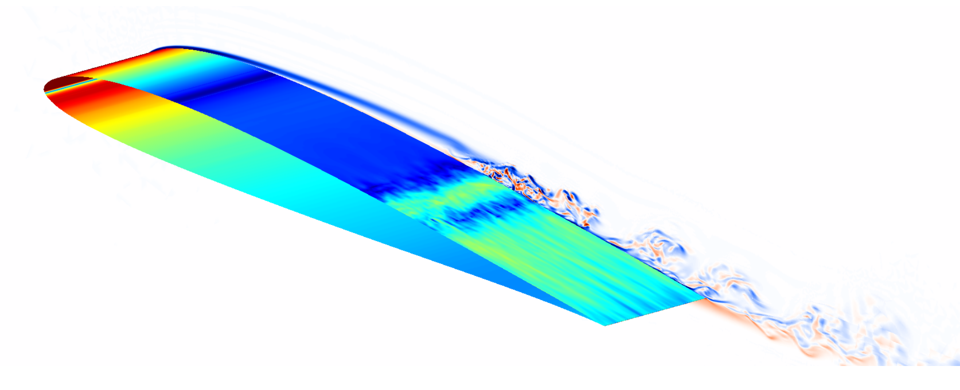

Figure 1: Instantaneous vorticity field on the periodic plane and skin friction on the surface of the airfoil.

benchmark has been already studied in several publications [2, 3]. The ability of DGM to perform accurate DNS is shown and the interesting properties of the discretisation in the presence of underresolved features are studied. Indeed, DGM only dissipates the scales that the model is not able to capture correctly, thus acting like a subgrid scale model. This property makes DGM an good candidate for implicit large eddy simulation (ILES). In the first part of the study, an accurate DNS is performed and compared to the litterature. On the second part, several ILES are done on a mesh similar to the one of the DNS but with progressive coarsening in the turbulent region of the flow. A preliminary computation has been done within the frame of the "2012 International Workshop on High-Order CFD Methods" and already shows good agreement with literature. The extrusion length in the spanwise direction is set in agreement with the recommandation of the workshop and is equal to 20% of the chord length. Lift and drag coefficients are presented in figure 2. In order to attain a statistically converged state, 10

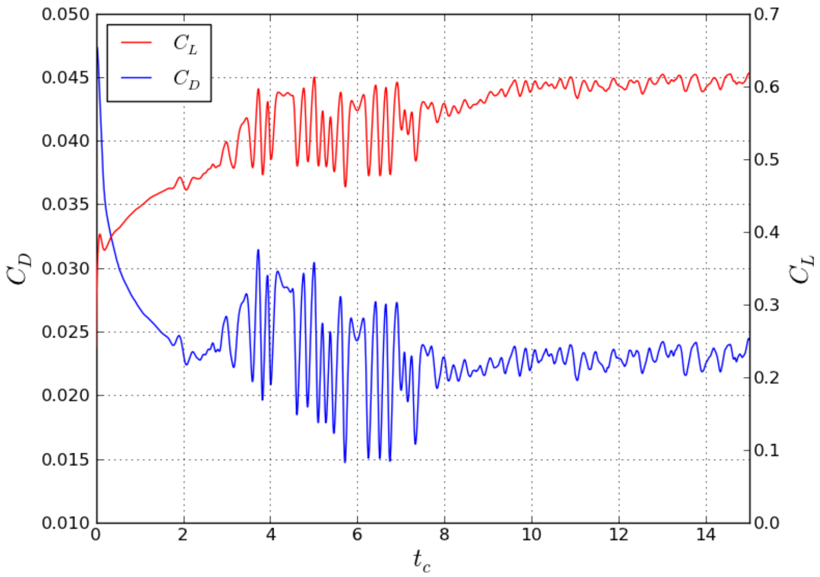

Figure 2: Temporal evolution of lift and drag coefficients.

convective times are needed. Figure 1 shows the vorticity on the periodic plane and the skin friction on the surface of the airfoil at $t = 15t_c$.

References

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