STS-03

Scale-resolved simulations of the deployment and retraction of a Krueger high-lift device

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Laminar wing technology for reducing the fuel consumption and environmental impact requires new leading-edge high-lift devices. One solution is to introduce a Krüger device deployed from the lower wing surface leaving the upper surface undisturbed. The movement of the Krüger device is particularly complex with a two-hinge arrangement allowing the device to be folded in contracted position. During the deployment the aerodynamic performance becomes critical with large unsteady separation behind the device. The deployment is sufficiently rapid for substantial dynamic effects, which makes URANS approaches less reliable. The deployment is, though, slow in comparison with the turbulence scales, which makes scale-resolved approaches computationally expensive due to excessive time-resolution requirements in comparison with the deployment speed.

The setup for scale-resolved simulations is, hence, critical and must be carefully optimized to be affordable. In the first part of the study, the meshing strategy was carefully selected. In particular, the LES region is critical concerning the resolution, and a uniform structured mesh is superior concerning CPU cost vs. resolution (blue zone in Figure 1). The dynamic Krüger device is automatically meshed by boundary-layer mesh and triangles (red zone in Figure 1), which also is used for the upper part and far field. The 2D mesh is extruded in the spanwise direction. Moreover, the Spalart-Allmaras DDES hybrid model, multi grid and line implicit treatment were chosen as a good compromise for reducing CPU cost. For selected intermediate positions of the partially extended Krüger device, a set of grids was created manually, with the structured regions in the wake regions, see Figure 2. The time resolved simulations were carried out to evaluate the influence of the dynamic effects induced by the Krüger device motion.

The experimental ONERA L1 wind-tunnel setup was used for the second part of the study both for far-field conditions and with wind-tunnel walls. The inclusion of wind-tunnel walls in this setup with symmetry spanwise conditions was verified by full 3D computations. Moreover, the true measured flap movement was implemented in the CFD. The major results are shown in Figure 3. There is a clear influence of the wind-tunnel wall, with a much deeper lift deficit during deployment and a larger asymmetry between deployment and retraction phases. Also, the fully retracted and deployed states are affected. The 2D URANS computations are surprisingly well capturing the behavior of the DDES simulations. The largest differences are found during the retraction.

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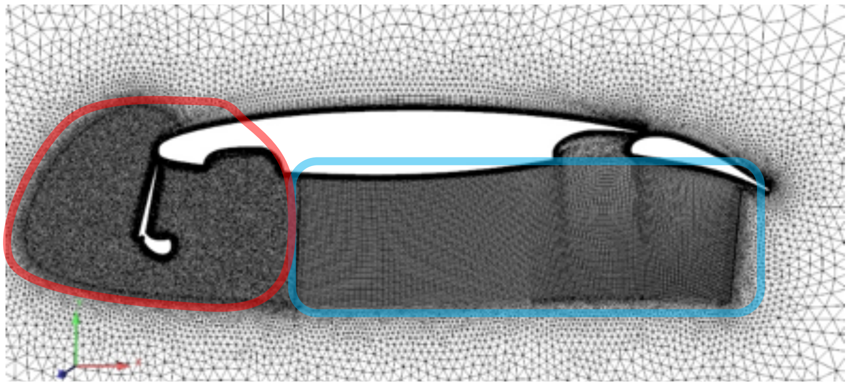

Figure 1. Automatic meshing using Pointwise. Red: Dynamic zone with mesh deformation and remeshing. Blue: Uniform structured zone optimized for LES.

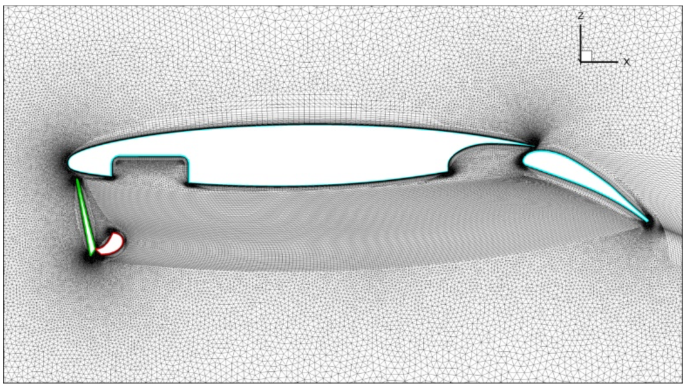

Figure 2. Manual Pointwise mesh for static Kruger position with structured hexa blocks in the wake regions.

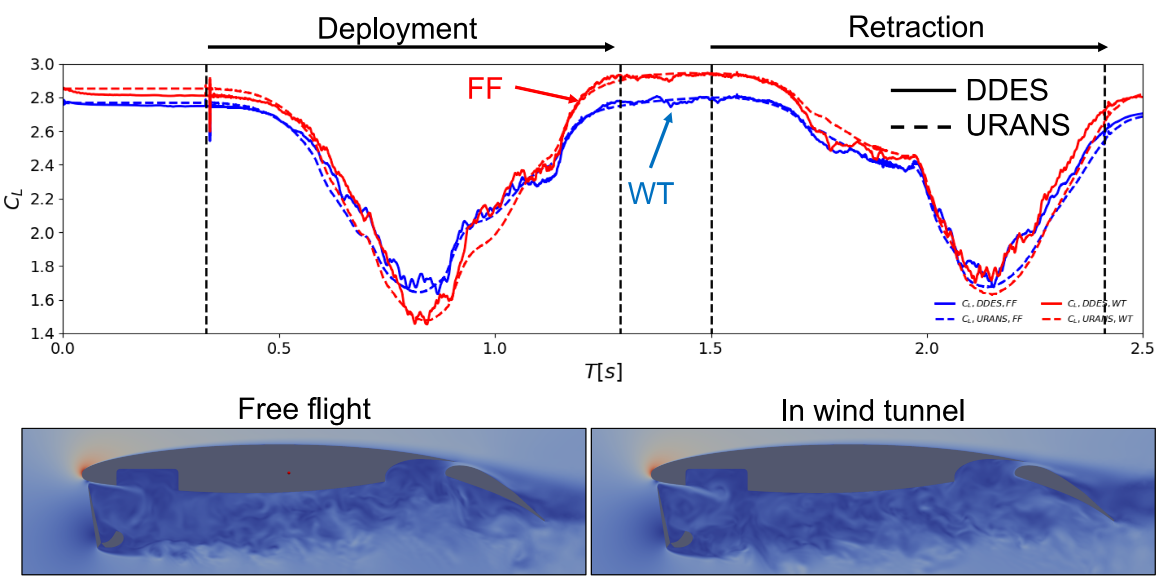

Figure 3. Full deployment and retraction cycle. Comparison between S-A DDES (—) and URANS (--) in free flight (FF) and with wind-tunnel walls (WT).