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STATUS OF ONERA RESEARCH ON WAKE VORTEX EVOLUTION AND ALLEVIATION IN THE FRAMEWORK OF NATIONAL ACTIVITIES AND EUROPEAN COLLABORATION

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ABSTRACT

A lot of research on Wake Vortex characterization and alleviation has been conducted in the last decade by ONERA in the framework of either national activities or European partnership. The present paper will highlight the main results that have been obtained at ONERA for these last years, with emphasising on characterisation of wake vortex evolution, and, on the development of strategies for wake vortex alleviation. The above-cited research programmes dealt with both experimental and numerical investigations to characterise the wake flow field generated by either generic very large or standard four-engine large transport-type aircraft models.

Highly documented data bases were generated from various facilities up to full-scale flight trials; results from such trials will not be covered in the present paper, yet. Thus, the different stages of the wake evolution were identified from two complementary ONERA facilities, using their most appropriate measurement techniques: the F2 low speed Wind Tunnel and the Lille free-flight B10 & B20 catapult facilities.

Two main strategies, for minimising wake vortex intensity, have been considered: firstly, to act at the source, in the near-wake field, by either promoting small scale instabilities and increasing diffusion of vorticity or introducing new turbulence in the vortex core, resulting in a larger but less intense core, or secondly, to create in the far-wake field a multiple-vortex system to promote long-wave instabilities and/or to trigger perturbations to obtain a premature wake collapse. More research studies have been devoted to this second strategy, by considering either a passive concept leading to spanwise wing loading modification (via arrangement of flap deflections) or an active one (blowing device, for instance).

Thus, from extensive studies at the ONERA F2 wind tunnel, high-lift wing configurations were selected from specific flap arrangement, appropriate for wing loading variations, using a generic four-engine type aircraft model (Fig. 1). Such tests confirmed the generation of a rather powerful vortex in the inner part of the wing was generated, either co-rotating or counter-rotating with the ones generated at the outer part of the wing Tests conducted at the ONERA free-flight catapult facilities (B10 & later B20) allowed to show up the real potential of such a wing loading modification for altering vortex trajectories, by creating either closer or wider resulting vortices in the mid-wake field, inducing either

larger or weaker descent speed. PIV and Lidar measurements allowed tracking the wake vortex development in the B20 facility, getting a more precise description of the secondary flow field, as well as of the velocity profiles. Thus, an innovation design in the Lidar set-up was developed by ONERA in order to apply the triangulation method and thus, obtaining the vortex trajectory and a new PIV traverse system was designed to capture the evolution of the wake vortex during a single shot. PIV and Lidar instrumentations were complementary, since the first allowed a detailed characterisation of the wake flow to ~40 wing spans behind the model, and the second the tracking of vortices to ~100 spans.

Therefore, ONERA has considered several blowing devices (Fig. 1) as a means to trigger instabilities for wake vortex control. Potential of continuous or pulsed blowing was shown in the extended near-wake field using the same generic four-engine type aircraft model. Blowing using discrete holes at the wing tip was then selected to be tested at the catapult, in order to investigate the effect of continuous blowing on the mid-wake field up to about 100 wing spans. Combination of flap arrangement and suction was also considered.

Furthermore and in parallel to testing campaigns, numerical simulations of the wake-vortex development behind an aircraft in high-lift configuration, were performed from the near- to the mid-wake field. At first, LES validations were carried out, starting from extrapolated initial conditions from the recorded experimental near-wake field. More recently, the aerodynamic flow around a complete aircraft in high-lift configuration was computed using a RANS method, a cut-plane was extracted form the near-wake solution, and the numerical results were then used as the input for the LES computations (Fig. 2). First results will be discussed for a four-engine large aircraft type configuration.

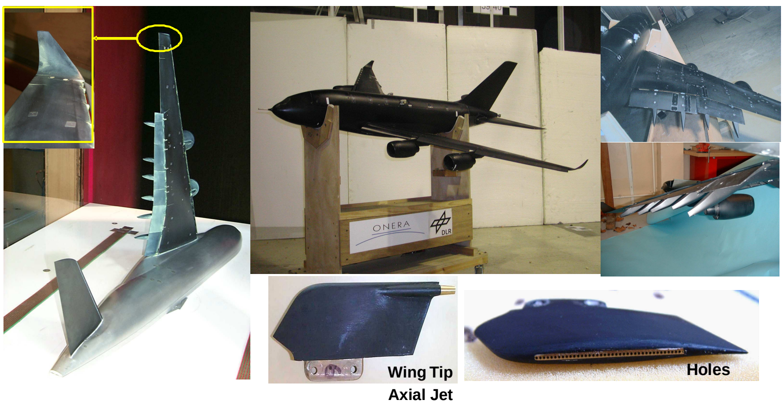

Figure 1 – Half- & Full-models of a generic Very Large Transport aircraft-type (with active & passive devices) tested at ONERA F2 WT, B10 & B20 catapult facilities.

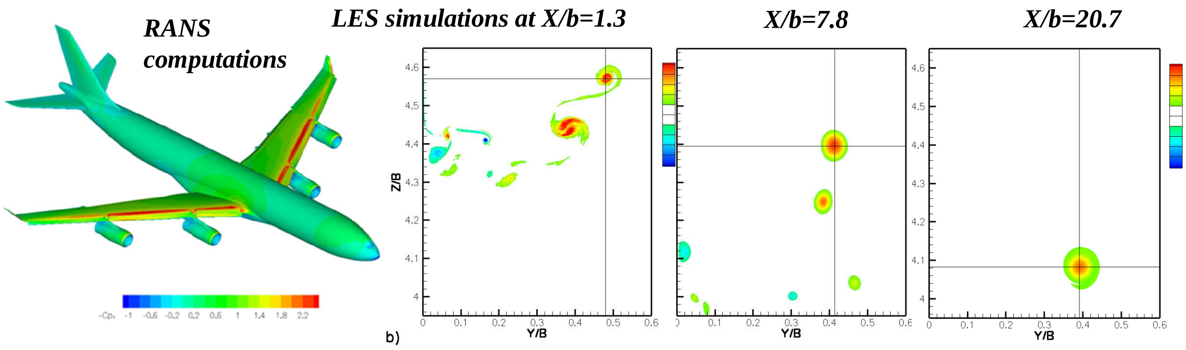

Figure 2 – RANS and then LES computations starting from initial conditions (RANS) at X/b=0.40.