

Dynamic and Stability of Wake Vortices

PARTENAIRES



Keywords: turbulence, URANS, global stability analysis

Departement: Aérodynamique, Énergétique et Propulsion (DAEP)

Chapô: The proposed internship is part of a project called DESTINS, which aims to study the dynamics of vortices developing within aircraft wakes using direct numerical simulation and global stability tools. The numerical analysis will be compared to experiments on the towing tank of the department. This internship will be devoted to the theoretical and numerical aspects and therefore to the implementation of the numerical tools that will help the future experimental campaigns.

JOB DESCRIPTION:

Vortex dynamics has always been a subject of great interest to the scientific community because of its involvement in many engineering applications.

These vortices are an unavoidable by-product of lift generation on wings of finite span and contribute to the induced drag (see Figure 1a). Their presence can be very dangerous for following aircraft due to induced unsteady loadings on wings that can lead to a strong rolling moment. This aspect plays an important role in the configuration of UAVs in formation or swarms of UAVs, as well as in the imposition of limitations for take-off and landing frequencies between two consecutive aircraft, limitations which are essential for safety and air traffic control [1].

The interaction of wake vortices with the exhaust jets of the engines leads to the formation of contrails, which can persist over a long time period under certain atmospheric conditions (see Figure 1b) and eventually transform into cirrus clouds. In this case, the induced cirrus clouds contribute significantly to the radiative forcing of aviation and are assessed to be one of the main contributions to the climate impact of aviation [4, 5].

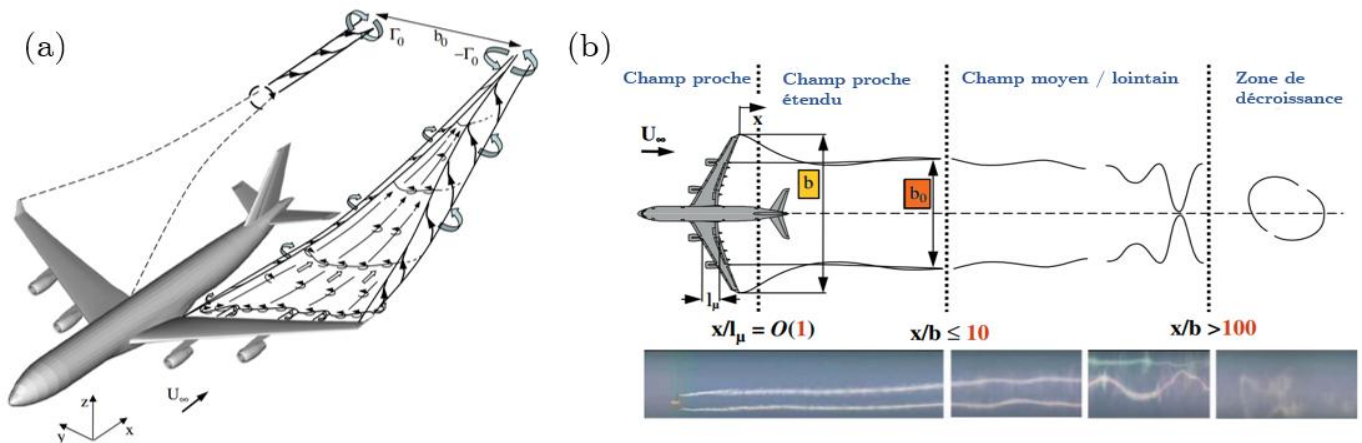


Figure 1: Evolution of the vortex sheet and winding process (a) [2]. Determination of the wake vortex evolution regions as a function of the downstream position (b), figure adapted from [3].

In addition to these critical issues, it should also be emphasized that these vortices are a main source of aero-acoustic noise. For example, in the aeronautical industry, in take-off/landing flight configurations, the vortices generated by the deployment of the trailing edge flap are a source of noise [6].

For all these reasons, a scientific effort to improve our understanding of their dynamics is necessary as a first step to design efficient control strategies. One of them relies on the excitation of three-dimensional instabilities [7, 8], which need to be studied using fully global approaches in order to gain a detailed understanding of the physical mechanisms.

MISSIONS:

The aim of this internship is to characterize the formation and near-field evolution of wing-tip vortices over a range of Reynolds and Mach numbers by means of Unsteady Reynolds-Averaged Navier–Stokes (URANS) simulations. In particular, we seek steady solutions of the URANS equations, i.e., RANS solutions corresponding to equilibrium states of the flow. These computed flows will constitute the base states of the global stability analyses, in which turbulence is accounted for through a linearized Spalart–Allmaras model [9, 10]. The quality of these base flows will directly determine the reliability of the stability predictions.

The first part of the internship will be devoted to getting to grips with generic URANS solvers on a reference wing-tip vortex configuration for which detailed experimental data are available [11]. Particular attention will be paid to

the meshing strategy, since the vortex core is a thin region of intense rotation that must be resolved over long downstream distances.

The second part will consist of a parametric study of wing configurations at several Reynolds and Mach numbers. Beyond computing the flows, the student will analyse the physics of the vortices: roll-up of the vortex sheet, downstream evolution of circulation, core radius and axial velocity, and sensitivity of the vortex core to turbulence modelling. The computed vortices will be compared to analytical models such as the Batchelor vortex [12], in order to extract the parameters governing their stability (swirl number, axial velocity deficit or excess) and to position each configuration with respect to known instability criteria from literature.

Looking ahead, at the end of the project, the resulting database of converged RANS equilibrium solutions will serve as base states for the first global stability analyses.

Therefore, the goals of this internship can be summarised as follows:

- Getting to grips with the URANS solvers and the CFD mesh generation software (ANSYS ICEM, Gmsh or similar).
- Validating the numerical set-up on a reference wing-tip vortex case against experimental and numerical data.
- Computing the flow around wings at several Reynolds and Mach numbers on dedicated meshes.
- Providing the RANS base flows for the global stability analysis tools.

REQUIRED PROFILE:

The candidate should be enrolled in a Master's (M2) or final-year engineering program in fluid mechanics or aerodynamics, and have prior experience with meshing software and the choice of mesh parameters, as well as with setting up CFD simulations and interpreting their results. Knowledge of C++ and Python would be appreciated.



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COMPENSATION: 4.35€ / h – 35 h / week

DURATION: 6 months

RYTHM: Full-time

LOCATION: TOULOUSE, ISAE-SUPAERO

RESPONSIBLE OF THE SUBJECT:

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APPLICATION PROCESS: Applications (CV and grades) must be sent to tommaso.talamucci@isae-supaero.fr; gabriele.nastro@isae-supaero.fr and jerome.fontane@isae-supaero.fr

APPLICATION DEADLINE: December 2026

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