PhD thesis at
Département Aérodynamique, Energétique et Propulsion
ISAE-Supaero, Toulouse, France

# Numerical simulations of rotorcraft aeroacoustics

Small and medium size unmanned rotorcraft generate noise through complex aerodynamic phenomena, such as blade-wake interactions, laminar separation, transition to turbulence and interaction between turbulent boundary layer and blade trailing edge, for example. While these mechanisms of noise generation are understood in some specific cases, they remain unclear for a wide range of operating conditions. These includes, for example, low Reynolds number regimes typical of small size, stealth rotorcraft used in military operations, strongly interacting rotor wakes regimes in multi-rotor vehicles typical of Urban Air Mobility concepts, vortex ring state encountered by helicopters in descending flight and transsonic low Reynolds number flows in low density environment (e.g. high altitude, Mars planet). In these cases, understanding noise sources is crucial as it may help reduce the aeroacoustic footprint for acoustic stealth and public acceptability purposes, detect and prevent vortex ring state-induced crashes and study atmospheric properties on the Mars planet, for example.

In this context, the present PhD thesis aims at conducting high-fidelity numerical simulations using an in-house LES/DNS code solving the compressible Navier-Stokes equations to compute the flow and acoustic fields past isolated and tandem rotors in various flight conditions and analyze the physical mechanisms that drive noise generation in such configurations. Specifically, the work will focus on transitional regimes where the laminar flow is prone to separation, transition and reattachment, leading to the development of a so-called laminar separation bubble. Operating conditions from subsonic to transsonic regimes and in both hovering and forward (or ascending/descending) flight will be considered The detailed analysis of the velocity and acoustic fields will rely on state of the art post-processing methods (e.g. space-time modal decomposition like SPOD, BMD and DMD) and the results will be assessed against experimental data obtained in the framework of a companion study.

This PhD thesis is the continuation of a previous PhD thesis, ending April 2023, where the aeroacoustics of an isolated rotor in hovering flight conditions has been investigated. (see figure 1) This thesis demonstrated the ability of the present approach (numerical simulations and post-processing) to unravel the fundamental physics behind noise generation in this context. Specifically, blade-wake interactions, laminar separation and transition to turbulence were found to be key mechanisms in acoustic radiation in the near and far field around the rotor. The goal of the present thesis is hence to extend previous work to various operating conditions typical of urban air mobility concepts (multiple rotors), rotorcraft descending flight (vortex ring state regime) and flight in low density environment (low Reynolds number transsonic flows).

Toward this end, the PhD candidate will perform high-fidelity numerical simulations using an in-house code. This includes meshing (ICEM and/or GMSH), high performance computing (on local and national clusters) and data processing (manipulating large datasets). In addition, advanced post-processing will be performed using in-house and/or available research codes (Python and/or Matlab) from the literature. In this regard, the candidate should have a good background in fluid mechanics and be familiar with programming languages. Knowledge in aeroacoustics and a first experience in computational fluid mechanics

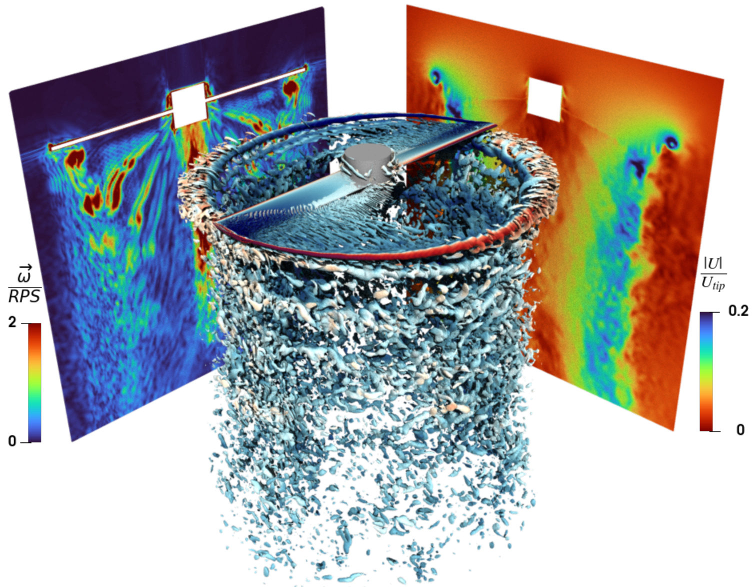


Figure 1: Flow past a rotor in hovering flight. Q-criterion iso-surfaces reveal the presence of flow separation at the blade surface and strong tip vortices that rapidly burst into small scale structures and interact with the following blade.

is a plus. Furthermore, the candidate should be highly rigorous and demonstrate ability to work both in autonomy and in close collaboration with other researchers.

The candidate will be hosted at ISAE-Supaero in Toulouse, France. The PhD program is fully funded by the French ministry of research for three years. It is supervised by R. Gojon and T. Jardin at the Département Aérodynamique, Energétique et Propulsion (DAEP), a laboratory comprising approximately 60 people working on aerodynamics and propulsion for aeronautics and astronautics.

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