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PROPOSITION DE SUJET DE THESE

Intitulé : Implementation Of Advanced Aeroelastic Coupling Simulations For Helicopters At Very High Speed

Référence : **MAS-DAAA-2025-14**
(à rappeler dans toute correspondance)

Début de la thèse : October 2025	**Date limite de candidature :** May 2025

Mots clés

Aeroelasticity, CFD/CSM coupling simulation, mesh deformation, helicopter rotor flow, high advance ratio

Profile and expected competencies

Enrolled in the last year of a Research Master or Engineering School, you have notions in structural mechanics and fluid mechanics and ideally in aerodynamics. You show an interest in aeronautics, research and innovation. You have a taste for programming and have skills in Python programming language. With excellent interpersonal skills, you will not hesitate to communicate with experts within ONERA. You demonstrate a good sense of critical analysis and an autonomy allowing you to adapt quickly to a technically demanding work environment.

Due to external constrains only **EU, UK and Swiss** candidates are eligible.

Context

Over the last decades, aeroelastic simulations of helicopter rotor using high-fidelity methods based on Computational Fluid Dynamics (CFD) were developed and implemented. The improvement of this numerical approach was possible thanks to the growth of the computational resources that were essential to capture the complex aerodynamic phenomena encountered around helicopter rotors. The aeroelastic coupling tool chain of ONERA has demonstrated its ability to predict accurately the rotor behavior in forward flights (Ref. [1][2]) and has permitted to better understand the aerodynamic mechanisms that lead to large amplitude blade deformations (Ref. [3][4][5]) at the limit of the flight domain of conventional helicopters (Figures 1 et 2).

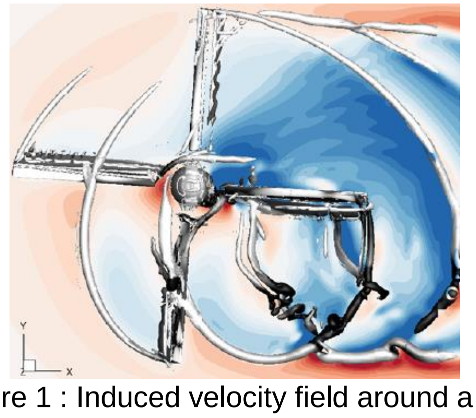

Figure 1 : Induced velocity field around a rotor at 280 km/h flight speed (Ref. [5]).

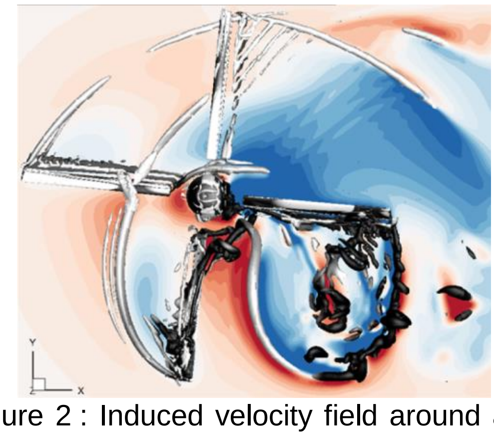

Figure 2 : Induced velocity field around a rotor at 320 km/h flight speed (Ref. [5]).

In recent years, the armies and the helicopter companies have increased the effort to propose new rotorcraft concepts that could significantly increase the maximum speed and range of conventional helicopters. A first kind of concepts for high speed is based on tilt-rotors such as the V-280 of Bell company and the AW609 of Leonardo Helicopters. A second kind of architectures consists in a main rotor to produce lift (possibly associated with small wings) and one or several propellers for the propulsion. The RAIDER coaxial compound helicopter of Sikorsky and the RACER compound helicopter proposed by Airbus Helicopters are two demonstrators that belong to this second kind of concepts dedicated to high speed. At such high operating speeds, the aeroelastic behavior of the main rotor significantly differs from conventional helicopters. The few articles devoted to this subject in the literature (Ref. [6][7][8]) show complex flow features such as dynamic stall, reverse flow

region, shock waves, negative lift and blade vortex interaction. Therefore, high-fidelity numerical simulations are needed to analyze these aerodynamic phenomena and better understand the aeroelastic coupling mechanisms that lead to unusual high-amplitude blade dynamics.
However, the current simulation tools showed some limits in terms of robustness and accuracy for these non-conventional flight conditions. Some improvements of the methods are thus required to perform and analyze very-high-speed rotor simulations with high-fidelity tools.

Objectives of the PhD

Therefore, the main objective of the PhD is to study the behavior of helicopter blades at high advance ratio forward flight condition based on aeroelastic coupling numerical simulations.
The student will first have to carry out a review of the existing literature in order to understand the theoretical bases of fluid/structure coupling and get familiar with high-speed helicopter rotor behavior. The student will also perform reference simulations based on existing simulation tools and validate his results with respect to wind-tunnel test data.
Then, the student will be in charge of developing a new aeroelastic coupling simulation module based on new tools recently developed at ONERA. This new coupling simulation method will be first validated with respect to the reference simulations and then implemented for very-high-speed conditions.
At these very-high-speed conditions, the torsion, the flap and the bending responses of the blade are known to show very high amplitude. However, the aerodynamic origins of this unusual blade dynamics are not clearly identified at the current state of knowledge. The numerical results provided in the framework of this PhD will be used in order to characterize these aero-elastic phenomena.

References

[1] Ortun, B., Potsdam, M., Yeo, H., Van Truong, K., “Rotor Loads Prediction on the ONERA 7A Rotor Using Loose Fluid/Structure Coupling”, Journal of the American Helicopter Society, Vol. 62(3), pp. 1-13, 2017
[2] Richez, F., “Analysis of Dynamic Stall Mechanisms in Helicopter Rotor Environment,” Journal of the American Helicopter Society, Vol. 63, No. 2, April 2018, pp. 1-11, DOI: 10.4050/JAHS.63.022006
[3] Castells, C., Richez, F. and Costes, M., “A Numerical Analysis of the Dynamic Stall Mechanisms on a Helicopter Rotor from Light to Deep Stall”, Journal of the American Helicopter Society, Vol. 65, No. 3, July 2020, pp. 1-17, DOI: 10.4050/JAHS.65.032005
[4] Castells, C., Richez, F. and Costes, M., “A Numerical Investigation of the Influence of the Blade–Vortex Interaction on the Dynamic Stall Onset”, Journal of the American Helicopter Society, Vol. 66, 032001, Mai 2021, DOI: 10.4050/JAHS.66.032001
[5] Casells, C., "Étude phénoménologique du décrochage dynamique sur un rotor d’hélicoptère en vol d’avancement", thèse de doctorat à Sorbonne Université, décembre 2020.
[6] Potsdam, M., Datta, A., and Jayaraman, B., “Computational Investigation and Fundamental Understanding of a Slowed UH-60A Rotor at High Advance Ratios”, Journal of the American Helicopter Society, Vol. 61(2), pp. 1-17, 2016
[7] Letzgus, J., Keßler, M. and Krämer, E., “Simulation of Dynamic Stall on an Elastic Rotor in High-Speed Turn Flight,” Journal of the American Helicopter Society, Vol. 65, No. 2, April 2020, pp. 1-12(12).
[8] Balmaseda Aguirre, M., Yeo, H., Richez, F. Jayaraman, B. and Ortun B., “High-fidelity aerodynamic loads of the double-swept ERATO rotor”, 50th European Rotorcraft Forum, September 10-12, 2024

Collaborations envisagées : Airbus Helicopters, DLR

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