RÉPUBLIQUE FRANÇAISE
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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAADA-2025-22**
(à rappeler dans toute correspondance)

Lieu : Châtillon

Département/Dir./Serv. : DAAA / MSAE

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DESCRIPTION DU STAGE

Thématique(s) : Optimisation multi-fidélité pour l'aérodynamique, l'aéroacoustique et l'aéroélasticité

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

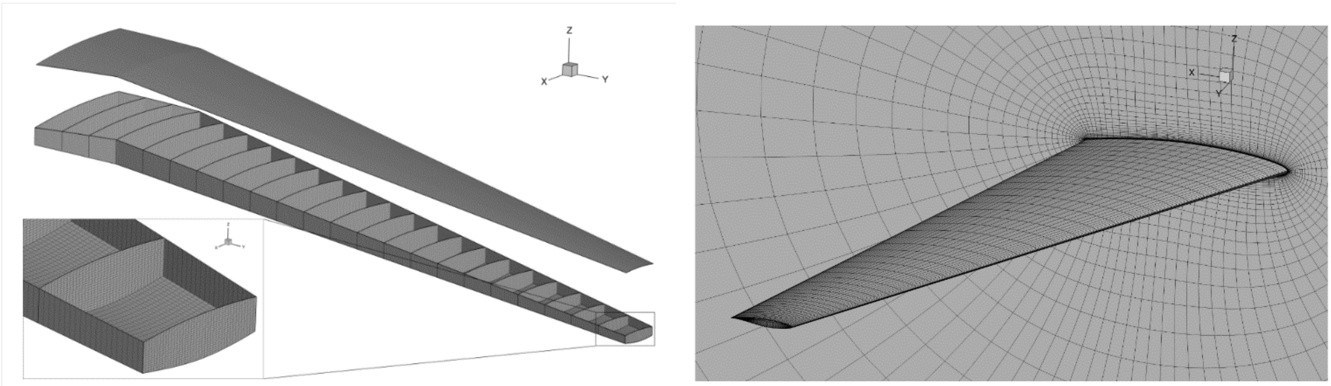
Intitulé : Efficient High-fidelity Aero-Structural Optimization of a Civil Transport Aircraft Wing

Sujet :

The end-goal of the aircraft development process is to design the aircraft which boasts the highest possible performance for a given mission, while satisfying a large number of requirements emerging from operational, manufacturability, and safety constraints. This can be translated into a problem of mathematical optimization, where the objective function (the quantity to be improved) is the overall aircraft performance, and the various requirements appear as constraints.

Multidisciplinary Design Optimization (MDO) leverages modern optimization algorithms to guide the design process efficiently, considering the relevant engineering disciplines (aerodynamics, structures, propulsion, control, …) – as well as their interactions – to systematically resolve trade-offs.

This approach has been demonstrated with success [1] in aero-structural optimizations of aircraft wings and airframes, where the design variables are the structural sizing parameters (in other words, thicknesses and cross-sections of various structural components) and the external shape of the wing.



Example of structural and aerodynamic computational models for the proposed optimization benchmark.

Such applications are characterized by large numbers of design variables as well as constraints. Moreover, the evaluation of the objective and constraint functions for each new design are computationally expensive when high-fidelity computational fluid dynamics (CFD) and structural mechanics (CSM) are involved.

For these reasons, gradient-based algorithms are used to solve the overall optimization problem, and explore the design space efficiently. However, such methods require not only the value of the objective function and constraints, but also their derivatives with respect to each of the design variables.

The efficient calculation of these derivatives, called the *sensitivity analysis*, is challenging. The computational cost is proportional to the number of outputs of interest (the constraint and objective functions). To overcome this, it is common practice to introduce *constraint aggregation* in order to significantly reduce the total number of constraint functions. However, a drawback of this approach is that the aggregation functions must be tuned correctly, and may lead to sub-optimal designs if many constraints are active at the same time [2].

The goal of this internship is to assess the impact of constraint aggregation methods on the structural sizing of a representative model of a civil aircraft wing [3]. For this, the work is broken down in three main steps.

1. A first series of structural sizing optimizations will be carried out, both with constraint aggregation and without, considering a fixed distribution of loads on the wing surface representative of realistic flight conditions. This will allow you to become acquainted with the structural analysis and design software NASTRAN, and to make a first comparisons between these initial results.
2. The same optimizations will be performed once more, with and without aggregation, considering this time the variation of the aerodynamic forces acting on the wing due to changes in the in-flight shape. These will be obtained using a simplified aero-elastic analysis based on the Vortex-Lattice Method. The comparison of results will be extended further in order to validate – or invalidate – the claim that constraint aggregation techniques may deteriorate the quality of the sizing optimization results.
3. The final stage of the internship will be dedicated to reproducing the above comparisons using a high-fidelity aero-elastic analysis based on the in-house computational fluid dynamics (CFD) solver *elsA*. To mitigate the high computational cost of the un-aggregated sensitivity analysis, the comparison will be limited to the sub-set of the constraints which are found to be most critical to the structural design.

By the end of this internship, you will have gained hands-on experience with a variety of computational tools and methods for structural and aerodynamic analysis, as well as deeper insight into their application in aircraft structure design. You will be encouraged to use this practical knowledge in order to contribute meaningfully to answer ongoing research questions.

Références :

[1] Achard, T, Blondeau, C., Ohayon, R. (2018) High-Fidelity Aerostructural Gradient Computation Techniques with Application to a Realistic Wing Sizing. AIAA Journal, vol. 56

[2] Poon, N. M. K., Martins, J. R. R. A. (2007) An Adaptive Approach to Constraint Aggregation Using Adjoint Sensitivity Analysis. Structural and Multidisciplinary Optimization 34(1), p. 61-73.

[3] Gray, A. C., Martins, J. R. R. A. (2024) A Proposed Benchmark Model for Practical Aeroelastic Optimization of Aircraft Wings. In AIAA SCITECH 2024 Forum, p. 2775.

Est-il possible d'envisager un travail en binôme ? Non

Méthodes à mettre en œuvre :

☐ Recherche théorique	☐ Travail de synthèse
☒ Recherche appliquée	☒ Travail de documentation
☐ Recherche expérimentale	☒ Participation à une réalisation

Possibilité de prolongation en thèse : A renseigner

Durée du stage : Minimum : 5 months Maximum : 5 months

Période souhaitée :

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
computational structural mechanics, aircraft design, optimization, programming skills (ideally Python) would be appreciated	