PROPOSITION DE SUJET DE THESE

Intitulé : Robust Optimisation of Aeronautical Structures under Aeroelastic Constraints

Référence : **MAS-DAAA-2022-023**
(à rappeler dans toute correspondance)

Début de la thèse : Fall 2022	**Date limite de candidature :**

Mots clés

Robust optimisation, Aeroelasticity, Uncertainty Quantification, Surrogate modelling

Profil et compétences recherchées

Master in Mechanics (Research) or Applied Mathematics
- basic knowledge in aeroelasticity, solid mechanics, fluid mechanics and/or uncertainty propagation
- python
- proficient in English

Présentation du projet doctoral, contexte et objectif

Aeroelasticity plays a significant role in the design of aeronautical structures and their certification. The coupling between the airplane aerodynamics and the dynamics of its structure may lead – for certain flight conditions – to uncontrolled oscillations and, eventually, structural failure. This phenomenon, called flutter, has to be predicted and taken into consideration by the structural design; composite materials are usually exploited to better distribute the structural stiffness and tailor the composite stack to enhance the coupled aeroelastic behaviour [e.g. 1]. These aeroelastic tailoring optimisations aim to push the critical flutter velocity – i.e. lowest velocity for which the instability appears – safely outside the flight envelope and, therefore, make the airplane safe to fly.

However, uncertainties linked to modelling and manufacturing could jeopardise the conceived structure and, hence, safety factors are nowadays used to prevent unpredicted instabilities at the expense of the optimality of the design. Robust optimisation technique can be exploited to take into account these sources of uncertainty and, therefore, reduce the need of safety margins. Preliminary studies in this direction can be found on simple academic cases [e.g. 2, 3]: composite materials are optimised to reduce both the critical velocity and its probability to be inside the flight envelope, by means of reliability-based optimisation algorithms. An accurate estimation of the probability for the flutter to appear leads to a large number of evaluations of the critical flutter velocity: these computations can be very expensive, even when a simple model of a simple geometry is used, making unfeasible a direct call to the computation during the optimisation process. This calls for adapted techniques that involve, on the one hand, the choice of a convenient design space for the composite properties [4] and, on the other hand, the extensive use of surrogate models.

The challenge of this thesis is to step up these techniques to realistic aeronautical cases. The effects of the uncertainties on the manufacturing process of the composite materials (i.e. the orientation of the composite plies) will be taken into account in the optimisation process, namely for the no-flutter constraint. Moreover going towards more realistic aeronautical applications will imply a larger number of optimisation variables and, thus, a larger design space: techniques of reduction of the dimensionality of the design space will be implemented to enable an effective exploration of the design domain. Finally, a finer description of the physical model will be necessary to describe the aerodynamics typical of the transonic regime: compressible models for the fluids will have to be considered when evaluating the aeroelastic performance and their integration in the design process addressed.

The candidate will initially acquire knowledges and skills in the domain of reliability-based optimisation and surrogate modelling aimed to the aeroelastic tailoring. Later, the candidate will integrate and develop tools and techniques to face (i) the large-scale optimisation linked to aerospace structures, (ii) the mid-fidelity computation of aeroelastic performance and stability, and (iii) the integration of different levels of physical modelling.

References

[1] JKS Dillinger, T Klimmek, MM Abdalla, Z Gürdal, “Stiffness optimization of composite wings with aeroelastic constraints,” Journal of Aircraft, 2013.

[2] C. Scarth, J.E. Cooper, P.M. Weaver, and G.H.C. Silva, "Uncertainty quantification of aeroelastic stability of composite plate wings using lamination parameters," Composite Structures, vol. 146, pp. 84-93, 2014.

[3] L. Coelho, N. Fabbiane, C. Fagiano, C. Julien, and D. Lucor, "Reliability-based design optimization of a composite plate through a dual design space," VIII Conference on Mechanical Response of Composites, vol. CT13 - Optimisation, 2021.

[4] S. W. Tsai and N. J. Pagano, "Invariant properties of composite materials," in Composite materials workshop, S.W. Tsai, J.C. Halpin, and N.J. Pagano, Eds. St. Louis, Missouri, Lancaster, Pennsylvania: Technomic Publishing Company, 1968, pp. 233–253.

Collaborations envisagées

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