Architecture, handling qualities and control laws of a distributed propulsion electric aircraft.

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1. Thesis Objective

This thesis proposes to study the optimization and co-design of the architecture of the control and stabilization systems for a distributed propulsion electric aircraft. The redundancy of the actuators, the combined management of the engines and the control surfaces, requires a multidisciplinary optimization approach both for the design and the architecture of the control systems (dimensioning of the engines vs. dimensioning of the airfoils and control surfaces) and for the definition of the control laws and the allocation of the actuators. The choices made on the definition of these laws have a direct impact on the dimensioning of systems and actuators as well as on the attainable performance and handling qualities. All of these constraints and criteria must be treated as a whole by a multidisciplinary co-design approach.

The objective is thus to study more particularly the impact on the handling qualities and aircraft performances of different architectures and strategies for allocation and control, and then to propose a multidisciplinary design methodology in order to design the different actuators and engines at the same time as the control laws.

This thesis will also be a contribution to the Aircraft design framework developed by ONERA and ISAE-SUPAERO called FAST.

2. Scientific context and related works

This thesis follows the works of Eric Nguyen Van's thesis [1, 2] on the design of an electric airplane and lateral control by the engines. We propose to go further in the study of the control laws and control architectures of a distributed propulsion airplane and their impacts on the preliminary design of the airplane.

The Radio-controlled model DECOL designed and built at ISAE-SUPAERO will serve as an experimental platform to test the performance of the proposed control architectures and laws.

Figure 1 : DECOL - RC model for distributed propulsion study

This work is also in line with the research carried out at ONERA on new distributed propulsion aircraft configurations (AMPERE [3], DRAGON [4] and industrial study contracts).

3. Innovations

Distributed electric propulsion (DEP) is an alternative to current conventional propulsion for both light and transport aircraft. It presents a field of exploration in terms of propulsion but also aerodynamics and structure that requires a global rethinking of aircraft design and operation [5, 6]. It could thus prove to offer performance advantages by exploiting certain multidisciplinary interactions, such as the Propeller/Wing interaction (see NASA's X57 project) [7] and other aero-propulsive synergy effects (see [3, 4])

The control of this type of aircraft is new and requires the consideration of these interactions. The development of accurate models for performances and handling qualities, that can be integrated into a design loop for the evaluation of different control architectures is the main contribution expected from this study.

4. References

[1] Towards an Aircraft with Reduced Lateral Static Stability Using Differential Thrust, Eric Nguyen Van, Daniel Alazard, Philippe Pastor, and Carsten Döll. AIAA Aviation Technology, Integration, and Operations Conference. Atlanta, Georgia, USA, 2018.

[2] Co-design of aircraft vertical tail and control laws using distributed electric propulsion, E. Nguyen Van, D. Alazard, C. Döll, P. Pastor, IFAC-PapersOnLine, Volume 52, Issue 12, 2019, Pages 514-519, ISSN 2405-8963.

[3] Handling qualities of ONERA's small business concept plane with Distributed Electric Propulsion, E. Dillinger, C. Döll, R. Liaboeuf, C. Toussaint, J. Hermetz, C. Verbeke, and M. Ridel. 31st ICAS Conference. Belo Horizonte, Minas Gerais, Brazil, 2018.

[4] Multidisciplinary Design and performance of the ONERA Hybrid Electric Distributed Propulsion concept (DRAGON), P. Schmollgruber, D. Donjat, M. Ridel, I. Cafarelli, O. Atinault, C. François, B. Paluch, AIAA SciTech Conference. Orlando, Florida, USA, 2020.

[5] Exploring the design space for a hybrid-electric regional aircraft with multidisciplinary design optimization methods. Thauvin, Jérôme (2018). PhD thesis, Toulouse, INPT.

[6] Enhancement of the conceptual aircraft design process through certification constraints management and full mission simulations, Peter Schmollgruber (2018), PhD thesis, ONERA / DTIS, University of Toulouse.

[7] Conceptual Design of High-Lift Propeller Systems for Small Electric Aircraft. M. D. Patterson, (2016). PhD thesis, Georgia Institute of Technology.

5. Candidate profile and application

Applicants should be graduated master (or/and engineer) students. A strong background in flight physics is required since the research assignment requires tools from aerodynamics, electrical propulsion and flight dynamics. Basics in control engineering are also required. Good communication skills in English are necessary (written and spoken), as well as good development skills (Python, Matlab, ...). Applications from candidates familiar with Aeronautical Engineering, Aircraft design and Multidisciplinary optimisation are particularly encouraged.

- Applications (CV, cover letter, academic records) are to be addressed to: philippe.pastor@isae.fr; carsten.doll@onera.fr
- Dates and duration: Late 2020 till late 2023 (36 months)
- Application deadline: open until June 15th, 2020.