PROPOSITION DE STAGE – MASTER 2 DET
Dynamique des fluides, Energétique et transferts
Université Toulouse 3 Paul Sabatier - Toulouse INP - INSA Toulouse - ISAE SUPAERO – IMT Mines Albi

Physical modelling and simulation of a distributed propulsion, propeller – wing interaction

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Location : IMFT, groupe ASI - Aerodynamics, wake, interactions

Period : 5 months, february –June, 2022

Application : send a CV, motivation letter, references to christophe.airiau@imft.f

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Background and objectives

The thrust power delivered by a jet engine of civil aircrafts using kerosen or bio-fuels is very much larger than the one provided by propeller engine powered by electrical energy. Today many projects are developed around the world using several (5 to 17) electrical propellers embedded on wing, see for instance the Maxwell X57 or the NASA Sceptor in USA and in France the Daher EcoPulse. The use of distributed propulsion leads to ask some new questions and to solve new scientific problems. Among all, the effects of the propellers on the wing and the existing model ever studied in the previous century have to be investigated again and probably improved taking into account of the new application, and under the light of 70 years of knowledge, efficiency of numerical solvers and optimization approaches.
Today some RANS simulations on simple to complex multi propeller configurations can be found in the literature. However, few results are finally available and the existing published methodologies must be better understood and possibly improved and validation domain has to be more pointed out. Actually we are at the beginning of this new research domain with large potential industrial application. The new various emerging projects proposed by ONERA, NASA, AIRBUS, DAHER, SAFRAN and other known companies ever confidential must be fed by open academic researches.


Sceptor, NASA


New NASA project

[1 page recto-verso max. : contexte, motivations, objectifs, programme de recherche, références, etc.]

The objectives of this project are centred on the physical modelling of the propeller effect on a wing flow and its local characteristics. RANS simulations will be performed later depending on the results given by the first work part.

Timeline

The major models related to propeller design are build from the disk rotor theory and the Blade Element Momentum Theory (BEMT) (with different variations) and the vortex line theory (Prandtl). A variation of the BEMT model has been implemented in OpenFoam – refered here as BEMT-OF. In addition, the propeller –wing interactions are based on two different approaches: one is to considerer the effect as a change in the dynamic pressure, the second one is to

consider a change of the induced angle of attack. At the end, the pressure coefficient, the pressure drag and the lift are modified. Skin friction drag is changed also it must be investigated independently.
The full BEMT and the lifting line theory models are ever implemented in in-house Python modules. A previous training has also initiated RANS simulations + rotor disk applications on a wing with OpenFoam inside the RTRA eAIRchitecture project. From these works, tools, knowledge and local experience, the timeline and steps of this project can be drawn:

1. bibliography : BEMT (all models), propeller- wing model interactions, existing simulations on the topic
2. training on existing tools
3. implementation, validation and comparisons of the different models not ever implemented
4. brain-storming on possible theoretical improvements, application to distributed propulsion
5. parametrical studies (definition of the input and outputs), database generation
6. definition of surrogate models
7. definition of an optimisation process for distributed propulsion, objectives, methodology, critical analysis of the results
8. comparison and validation with RANS simulation with the RotorDisk model (OpenFoam)

Skills
Initiative, ability to work in a team, good knowledge in **aerodynamics** (fluid mechanics), on CFD (OpenFoam), very good knowledge of UNIX and clean and efficient programming (**Python**). The capability to understand theories is a major criteria of selection.

Profile
Engineering student or Master 2 in fluid mechanics, aeronautics