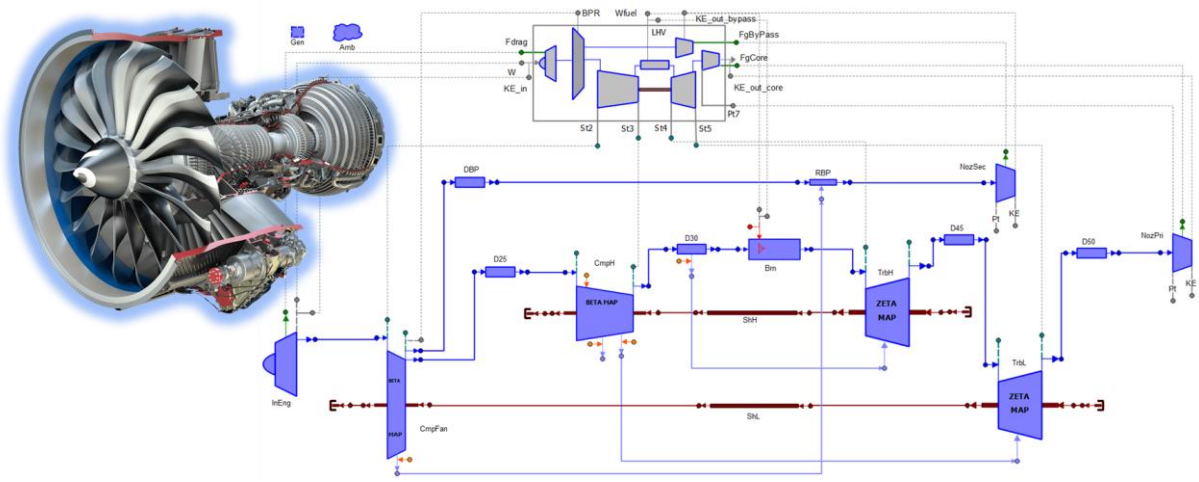
Multidisciplinary Modelling of Gas Turbine Engines

Description

The turbomachinery and propulsion research group at ISAE-SUPAERO's Department of Aerodynamics, Energetics and Propulsion (DAEP) has extensive experience with industry-standard software for jet engine system architecture sizing and performance modelling software called ***PROOSIS***™[1]. The software employs object-oriented modelling paradigm to enable the system designer to compose any propulsive system architecture of interest, to construct a mathematical model around it and finally to use it for simulating system performance at whatever calculation cases of interest: single- or multi-point ***sizing***, steady state ***off-design performance***, transient performance, optimisation, etc.



A generic turbofan engine architecture (CFM56 engine to the left used for illustration here) representation in PROOSIS.

Saying "any architecture of interest" naturally works only within the validity domain of the models available in PROOSIS. In our particular case, the validity envelope is bound by the default PROOSIS library called ***TURBO***, which collects ***thermodynamic and mechanical models*** of a wide variety of components (compressors, turbines, shafts, etc.) necessary to model performance of various gas turbine engine cycles – e.g. turbofans, turbojets or turboprops. In a broader framework (outside of the immediate scope of the current project) of modelling a much more elaborate propulsive system design space tightly integrated with the airframe and other onboard systems – efforts have been put in place to ***extend the default engine modelling capabilities***[2] in PROOSIS enabled by the default TURBO-library based paradigm. The current project picks up on these works.

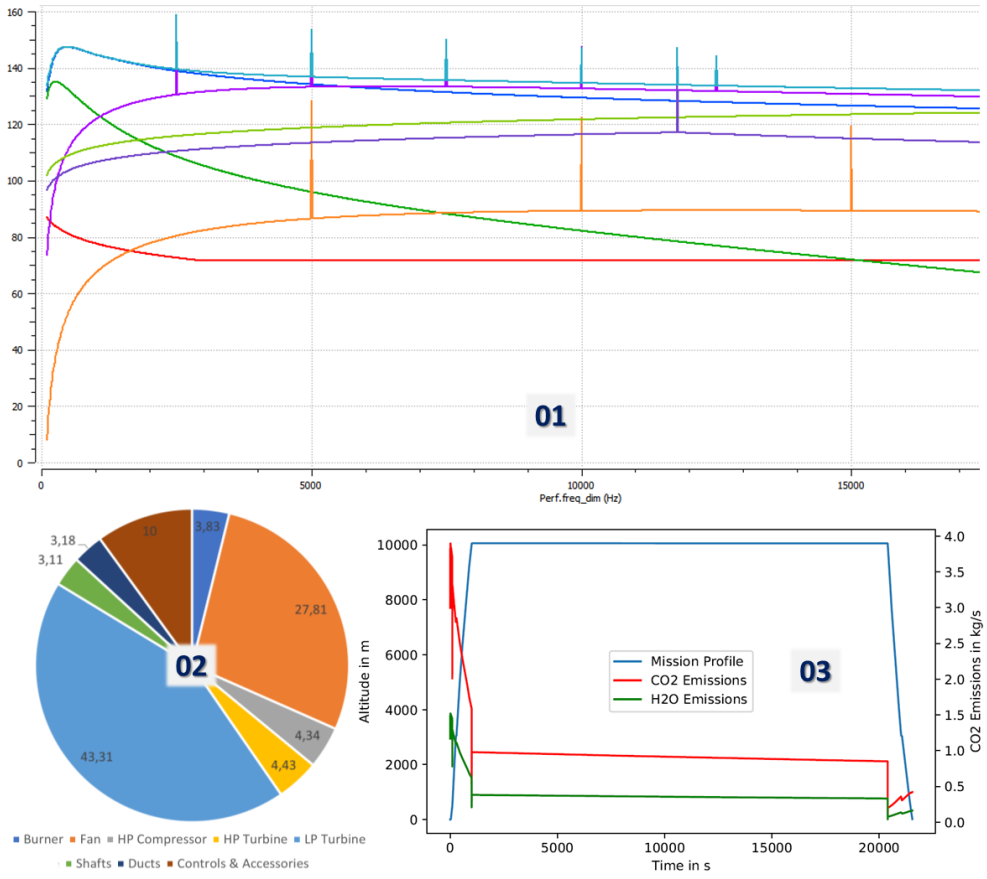
The previous developments, which will be made available to the intern at the start of the current project, concern the following disciplines, whose models have been coded manually inside respective customised versions of TURBO libraries:

- ***Aeroacoustics***: using simple analytical models for turbomachinery, combustion chamber and nozzle sound power levels, allowing preliminary estimation of noise sources and distribution;
- ***Weight***: using simple empirical models for component weight estimation (with non-negligible epistemological uncertainty);

[1] https://www.ecosimpro.com/products/proosis/

[2] PROOSIS allows the users to introduce custom functions, tables, equations, etc. through a user-friendly interface.

- ***Polluting emissions***: simple empirical correlations for the combustion chamber components allowing (likewise with non-negligible uncertainty) to estimate emissions of various polluting species throughout the flight profile.



Sample of results obtained by the respective disciplinary models coded in dedicated customised PROOSIS libraries, for a generic turbofan model: 01) Noise emissions at 50° directivity angle; 02) Weight breakdown; 03) CO2 & H20 emissions along a typical mission.

The respective rudimentary models have been developed separately i.e. an integral multi-disciplinary model leveraging all the above capabilities is <u>not</u> available at the moment.

It is worthwhile to remember that the application scope of such models is ***preliminary sizing and design***, which is associated with ***correct orders of magnitude*** of modelled phenomena, along with correct ***tendencies and functional sensitivities***. That way, a multitude of solutions (a so-called 'trade space') can be explored at low computational cost in order to discriminate relevant solutions from the rest, sufficiently early in the system design process.

Project objectives

The objectives for the candidate embarking on the project at hand will therefore be:

1. Assembling a ***complete custom MD TURBO library*** and verifying its functioning on a ***turbofan model***.
2. If time, ***testing the flexibility*** thereof by applying it to a scope of engine architectures beyond a simple turbofan, e.g. a turboprop or a hybrid-electric architecture[3].

[3] Currently under development in a separate project, due to be finalised before the current internship kicks off.

3. Carrying out **trade studies** on different application cases to assess applicability scope of the library, i.e. verify the capability of evaluating how different disciplines trade against one another (e.g. fuel performance versus acoustic signature).

Depending on the state attained by the associated projects prior to this project start, as well as on the candidate affinities and rate of progress later on, the objectives can be re-evaluated and adjusted prior to the project start and/or along the way.

Requirements

Compulsory: thermodynamics and propulsion; affinity towards multi-disciplinary work.

Optional: familiarity with *C/C++*[4]; familiarity with MatLab.

Number of candidates: 1

Language: English and/or French (not compulsory)

Contact

Aleksandar Joksimović, Researcher, DAEP: aleksandar.joksimovic@isae-supaero.fr

[4] PROOSIS is written in a high level language derived from *C++*, normally very accessible to uninitiated users with minimal coding background; Pacelab APD is written in *C#*..