MULTIDISCIPLINARY OPTIMIZATION OF AIRCRAFT PROPELLER BLADES

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In the search for greener aircraft, propellers have promising features such as their very high efficiency together with peculiar characteristics: high trust generation at low speed, long lifetime, low cost, high mechanical integrity and high environmental friendliness (including nowadays cabin and outbound noise) among many others. The purpose of the present project is to set-up and performs a multidisciplinary, multi-objective and multipoint optimization as the recent advances in computing capabilities have made this an affordable option. The optimization should aim at increased efficiency at cruise particularly, combined with low noise production while preserving the structural integrity of the blades and the take-off/landing performances. The method must be robust and as inexpensive as possible but with acceptable accuracy.

The core of the optimization process, which is developed at VKI, is a search engine in the form of an Evolutionary Algorithm that drives the search by mimicking evolution theories. Coupled with the search engine are a computationally inexpensive surrogate model which delivers approximates of the performance for new designs, and a database of known geometries with their respective performances. This database is regularly augmented with promising new designs so that the accuracy of the surrogate model is safeguarded by recursive training along the evolutionary process. Wrapped around the core are discipline related prediction tools:

- a prediction tool for aerodynamic performances (here, a steady RANS-solver),
- a prediction tool for stresses (here, a FEA-solver applied on composite blades with aerodynamic and centrifugal loading),
- a prediction tool for aeroacoustics (that computes tonal noise from steady CFD results through an implementation of the Ffowcs Williams – Hawkings acoustic analogy).

The design variables are the coordinates of points controlling the radial distributions of chord, thickness, sweep and twist as well as the airfoil shape. The allowable margins and the number of parameters are chosen such that very innovative designs are possible. The objectives are built upon several performance parameters reflecting various operating conditions.

Two optimization runs have been performed: one including the aerodynamic and aeroacoustic tools only, and the other including all three disciplines. This resulted respectively in 28 end 61 designs complying with all constraints. Some designs were analyzed in more details.

Both optimizations illustrate the feasibility and the capabilities of the method. It is proficient in exploring the search space and delivering designs with features that are worth further investigation. One of them is the humps on the blade obtained by smoothly increasing the chord of a specific region of the blade. Finally, general conclusions are drawn and improvements to the method are proposed.

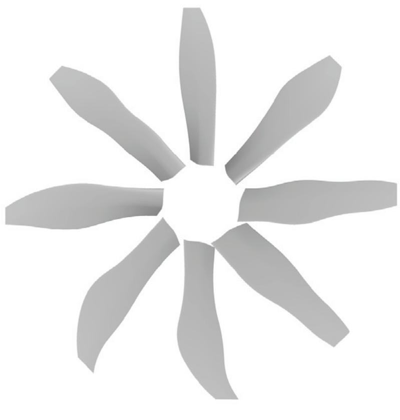

Figure 1: Composite image of 8 blade designs obtained in the present study