AERO-MECHANICAL OPTIMIZATION OF A CONTRA-ROTATING OPEN ROTOR

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ABSTRACT

The present contribution fits into the frame of the ongoing 7th Framework European Project DREAM, whose first objective is to design, integrate and validate new engine concepts to reduce fuel consumption and CO2 emissions 7% beyond the ACARE 2020 objectives while its second major objective is a 3dB noise emission reduction per operation point. One of the main themes targets the development of contra-rotating rotors with variable pitch blades which are known to provide 10 to 15% fuel burn reduction but are noisier than high by-pass turbofans.

The work to be presented has been carried out in the frame of SP3 Direct-Drive Pusher Open Rotor lead by Snecma and more specifically in the concept studies carried out along the WP 3.2. Partners include Airbus, CIAM, Cenaero, DLR, Dowty and ONERA while the aero-acoustic tests are to be conducted in the TsAGI facilities, Russia. The design studies have essentially been structured in two phases. A preliminary aero-acoustic optimization phase aimed at identifying the most relevant parameters and providing a first quantitative assessment of trades, in terms of noise versus aerodynamic performance benefits. A second phase, starting with the definition by Snecma of a new baseline geometry combining test concepts highlighted in the first phase and integrating new manufacturing and mechanical constraints, was then dedicated to the detailed design. The objective was to maximize the propellers efficiency at top-of-climb conditions and to minimize the noise emission at take-off focusing on interaction noise while fulfilling the thrust and torque split specifications at both operating points.

These objectives were successfully met by the development and exploitation of an efficient multi-objective surrogate-assisted optimization strategy based on 3D RANS evaluations. The setup of the aero-mechanical optimization chain implemented by Cenaero, targetting major contra-rotating open rotor challenges, will be described along with the design methodology. Both 2D profiles shape and 3D modifications of the propellers, with variable pitch adjustment at both operating points, were carried out leading to a conception space counting over 100 design parameters. Besides the aerodynamic performances in terms of thrust, torque and efficiency based on mixing plane evaluations, an acoustic criterion aiming at decreasing the rotor/rotor interaction noise at take-off by minimizing the front rotor wake harmonic content up to the height of the clipped aft rotor was exploited to drive the optimization process. Selected optimized geometries will be presented, analyzed and compared. Although the acoustic criterion driving the optimization process did not lead to an improvement of the noise characteristics over the whole directivity range, it will be shown that this objective function may be regarded as a cost-effective (in terms of computational investment) and efficient way to integrate noise-related aspects during the design phase. Improvement of the acoustic formulation and relevant mechanics to be incorporated into the design intent is the subject of ongoing work. Experimental testing of the selected geometries is scheduled at Tsagi premises end of 2010.