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Corresponding author: GIANNAKAKIS Panagiotis
e-mail of corresponding author: panagiotis.giannakakis@safrangroup.com
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Title

A performance modelling approach to open fan propeller module

Authors

Nicolas Tantot [1], Panagiotis Giannakakis [2], Henri Yesilcimen [3], Anthony Binder [4]*
** Corresponding author*
[1] Safran Aircraft Engines, 77550 Moissy-Cramayel, France, nicolas.tantot@safrangroup.com
[2] Safran SA, 78772 Magny-Les-Hameaux, panagiotis.giannakakis@safrangroup.com
[3] Safran Aircraft Engines, 77550 Moissy-Cramayel, France, henri.yesilcimen@safrangroup.com
[4] Safran Aircraft Engines, 77550 Moissy-Cramayel, France, anthony.binder@safrangroup.com

Abstract

Unducted aeroengines architectures feature ultra high propulsive efficiency, and are adequate answers to the environmental challenge aviation propulsion is facing. During preliminary design and development of such complex architectures, a robust and flexible modeling of the propulsor energy behavior is mandatory. An innovative approach based on 1D induced velocity models combined with aerodynamic polars is proposed for an open fan configuration consisting of a variable pitch propeller rotor combined with a variable pitch stator.

This paper provides a detailed description of the modeling proposed for the performance calculation of the rotor and the stator behavior over their whole operating range, taking in consideration their mutual dependencies as well as external effects such as nacelle influence. The core of the approach consists in identifying each propulsor stage with lift and drag polars, and using a set of calibration factors associated to the main physical links of interaction between fluid and rotor/stator, enabling a comprehensive matching of any defined geometry. In order to create physically representative aerodynamic polars, the method first estimates the rotor incident flow-field using a simplified induced velocity calculation based on an ideal rotor wake assumption and the Goldstein/Theodorsen theory. At the same time, the velocities induced by the stator are modeled using an elliptic wing hypothesis, properly calibrated for the open fan configuration.

After describing the method logic and implementation, an assessment of the method accuracy and computational effort is provided, along with a set of use cases, covering propeller map generation, static and reverse performance assessment compared to CFD, and examples of design parametric studies varying diameter, clipping, and rotor blades count.

This scalable averaged approach aims at providing a relevant compromise between behavior prediction fidelity and numerical versatility so that it can be used in a cycle performance model, for both purposes of predesign parametric studies and assessment of off-design behavior of a given geometry.

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