Accepted Manuscript

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PII: S1270-9638(17)30240-7
DOI: https://doi.org/10.1016/j.ast.2017.10.031
Reference: AESCTE 4264

To appear in: *Aerospace Science and Technology*

Received date: 7 February 2017
Revised date: 5 July 2017
Accepted date: 23 October 2017

Please cite this article in press as: J. Enconniere et al., Mission Optimisation for a Conceptual Coaxial Rotorcraft for Taxi Applications, *Aerosp. Sci. Technol.* (2017), https://doi.org/10.1016/j.ast.2017.10.031

Mission Optimisation for a Conceptual Coaxial Rotorcraft for Taxi Applications

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Abstract

This paper presents the development and an application of a multidisciplinary methodology for the preliminary design assessment of compound coaxial rotorcraft with a counter-rotating rotor system and a rear-mounted propeller. A comprehensive optimisation strategy is deployed to evaluate the environmental and operational benefits of the aforementioned rotorcraft architecture. The code is validated against experimental data prior to the application of the methodology to the evaluation of a conceptual vehicle for intercity taxi applications. Response Surface Models (RSMs) are generated to mimic the rotorcraft performance in order to accelerate the optimisation process. The effects of the defined mission input parameters such as cruise speed, altitude, climb rate or mission length are evaluated. Pareto fronts for fuel burn, NO_x emissions and mission duration are obtained. The method was applied to a hypothetical scenario of mission length ranging from 50 to 300 km. Best estimate mission scenario are selected from the Pareto fronts, providing on average 23%, 20%, and 13% simultaneous reductions in mission duration, fuel burn, and NO_x emissions when compared to a conventional flight procedure. The picked scenarios coincide with the fuel optimised mission scenarios for each mission length, thus the multi-disciplinary environment was not required. Besides, an "improved" mission procedure is outlined, defining the mission characteristics independently of the mission's length. This procedure yields on average 22%, 14%, and 8% reductions in mission duration, fuel burn, and NO_x emissions, respectively.

Keywords: compound rotorcraft, coaxial rotor, performance simulation, mission analysis, gaseous emissions, optimisation

1. Introduction

1.1. General Context

The integration of innovative technologies in modern aircraft is strewn with obstacles. Not only any new system must fit with the safety and regulation standards, but also it must be proven to be serviceable and efficient in the highly competitive aerospace industry. Indeed, the cost of introducing any innovation is extremely high and time-demanding. Therefore, robust and cost effective multidisciplinary design and assessment tools are of prior importance for manufacturers in order to decide on the integration of any considered system or architecture on a preliminary design stage.

The attention of design engineers when it comes to deciding upon a technology is drawn toward: (i) the continuous rise in global energy demand, resulting inevitably in an increase in fuel price and the potential depletion of fossil fuel reserves, (ii) the growing concern for environmental impact, including chemical and noise emissions, and (iii) the sharp growth of rotorcraft operations expected in the future. Coming back to (i) and (ii), aerospace activities are currently a relatively small contributor to the global carbon dioxide (CO_2) footprint, with an estimated 2% share of the worldwide emissions [1]. However, the aircraft industry

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