New Preliminary Sizing Methodology for a Short-Medium Range Airplane with BLI Propulsion

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Abstract

Current environmental issues necessitate rethinking of aircraft propulsion in order to reduce the fuel burn, polluting emissions and the airplane noise footprint. To that purpose, significant effort is dedicated to development of innovative propulsive concepts. One of notable solutions is Boundary Layer Ingestion (BLI), characterised by a potential for fuel burn reduction, achieved by improving efficiency at the aircraft level. Well known aircraft design methodologies such as the ones outlined by Roskam and Raymer are not applicable to highly integrated airframe-engine systems such as BLI; they need to be adapted to be usable on such configurations.

The goal of this article is to detail a new approach to aircraft design methodologies. While taking existing methodologies as starting point, it is adapted to airplane architectures with partial or complete BLI propulsion. The methodology focuses on aircraft preliminary sizing: the first design step, which consists in determining the macroscopic characteristics of the airplane. It takes up methods from Roskam's and Raymer's methodologies for preliminary sizing but also includes three additional parameters which enable the user to take into account the effect of BLI on: airplane lift-to-drag ratio, fuel burn and the engine weight. The impact is evaluated as a function of the new parameter α, which is introduced to describe the ratio of BLI thrust to the total thrust of the airplane at cruise. In order to perform this extended mass-performance loop within the scope of the preliminary sizing, a typical mission is introduced, equivalent for both the reference aircraft and the new targeted aircraft. An iterative procedure based on aircraft characteristic weights is firstly used to converge on a take-off weight value. The further procedure and the results are detailed further in the paper.

The methodology development is accompanied by an application case: preliminary sizing of a B737-type aircraft with BLI engines. This application has shed light on difficulties in assessing the impact of previously introduced BLI parameters, due to scarce availability of reference data on BLI architectures. To compensate for this lack of reference, a sensitivity study of those BLI parameters has been carried out. The study shows that the fuel burn change due to introduction of BLI has the most dominant influence on aircraft characteristics; it is followed by impact on the engine weight and on the aircraft lift-to-drag ratio. Finally, a validation of the introduced methodology has been performed.

Keywords: Boundary Layer Ingestion, Aircraft design methodology, Preliminary sizing

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New Preliminary Sizing Methodology for a Commuter Airplane with Hybrid-Electric Distributed Propulsion

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Abstract

Following the latest aggressive emissions and external noise reduction targets, there now exists an increasing amount of research and emphasis on the hybridisation of the propulsion and power systems of aircraft. With the aim of expanding upon the current repository of studies focusing on tightly-coupled and integrated hybrid-electric propulsion systems, a new approach to the preliminary design of such systems is introduced herein.

The purpose of this approach is to establish a novel methodology for the fully integrated preliminary design of hybrid-electric aircraft. While conventional airplanes may be designed by taking the propulsive and non-propulsive systems into account separately at a basic level, a greater level of detail is necessary early on in the process for integrated platforms. In the overall development of this methodology, both current and projected future state of technologies are used. The specificity of the established methodology is its ability to cover a variety of implementations on different hybrid-electric aircraft. Furthermore, a sensitivity study is performed on the major driving parameters of the methodology. And finally, in order to assess the accuracy and validity of the methodology, a comparison was made with the results obtained when applied to a pre-existing aircraft model.

The resulting methodology takes into account the specificities of such dual energy aircraft that lead to highly non-linear, tightly coupled parametric expressions. A generic hybrid architecture is proposed containing a hybridised, dual-energy propulsor associated with a conventional, single-energy propulsor. With a judicious choice of efficiencies and the declaration of two non-dimensional variables (hybridisation ratio and dual energy/single energy ratio), this architecture can model multiple conceptual configurations at a high-level. After establishing the power requirements for flight in multiple mission segments, the power and energy split can then be computed and used to size the propulsion system. A new coupled range equation is also derived, taking into account the combined use of two energy sources and their differing impact on fuel weight consumption during flight.

Practically, this methodology is intended to be used in the early stages of aircraft design to provide first order estimates of major sizing parameters (aircraft weight, power and energy usage, range) as well as to create high level trade studies, independently of any specific aircraft configuration. Further work is needed to precisely and objectively compare the numerous configurations made possible by such hybrid-electric aircraft.

Keywords: hybrid-electric, dual-energy, aircraft design, preliminary sizing, integrated aircraft, batteries, propulsion systems

Development of a Decision Tool for Identification of Optimal Hybrid-Electric Architectures for Airplane Propulsion

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Abstract

Due to the exponential growth of the commercial air traffic, and despite the continuous effort invested in making conventional airliners more respectful of the environment, aviation environmental impact is expected to grow in the near future. Such circumstances led to ambitious targets with quantitative environmental objectives in terms of fuel burn, noise and CO2/NOx emissions, such as the NASA N+3 or ACARE FlightPath 2050 programs. In order to reach these objectives, not just an incremental development is required, but also a technological breakthrough and a multidisciplinary design approach. Such changes in the aircraft industry should allow a response to sustainably meeting the increasing air transportation demand.

The presented work focuses on hybridization of aircraft propulsion systems for the next generation of airliners. A feasibility study and an assessment of different hybrid-electric configurations and technologies conceivable for year 2035 are carried out. This literature-based decision methodology is developed in order to evaluate each configuration regarding technology maturity and performance potentials for a given technological horizon. The analysis shows that the Parallel Hybrid distributed propulsion configuration, among the hybrid-electric configurations, exhibits the highest potential for a 2035 entry into service commercial application, more particularly for regional aircrafts. A second calculation method is developed to quantify the preliminary performance and improvements, compared to non-hybrid aircraft, this preferable hybrid configuration can provide on conventional ATR72-500 regional missions. Using data from the literature-based analysis of 2035 technological horizon, the results demonstrate that gains in fuel burn of about 27% and substantial gains in emissions and noise can be reached with the parallel hybrid configuration, leading to a reduction of 14% in the cost of the mission.

Following these results, the presented methodology can be employed by any user wishing to take into account different hybrid solutions. Optimum mission profile as well as battery usage and power needs can be found and used in a modelling and simulation software in order to assess the performances of hybrid aircraft solutions.

Keywords: hybrid-electric propulsion, decision tool, technology maturity, mission analysis, performance assesment