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Aerodynamic guidelines in the design and optimization of new regional turboprop aircraft

Pierluigi Della Vecchia *,[1], Fabrizio Nicolosi [2]

University of Naples "Federico II", Via Claudio 21, 80125 Naples, Italy

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ABSTRACT

This paper aims to provide some guidelines in the aerodynamic design and optimization of future regional turboprop aircraft with about 90 passengers. Currently there are no configurations on the market of this type, thus a typical 70 passengers turboprop aircraft is taken as reference starting point. The most critical aircraft components in terms of aerodynamic drag contribution and possible improvement are highlighted and an automatic procedure manageable trough MATLab® is described. This interfacing procedure allows importing and modifying geometries using interpolating curves and surfaces via NURBS. Within the optimization loop, any new geometry is analyzed trough the panel code solver until optimized shapes are found. Wing–fuselage junction (also called "Karman"), undercarriage pod, fuselage nose and wing-tip device have been investigated and estimation of performance advantages has been computed. Design of the winglet is presented highlighting performance improvements during the entire mission profile. Finally two different turboprop configurations are proposed: the first with a 4-abreast fuselage arrangement and the second with 5-abreast, highlighting pros and cons of each configuration.

1. Introduction

Nowadays the increase in oil price, the huge growth of air transport traffic and the increasing attention to the aircraft environmental footprint led to considerable interest of specialists in new configurations of regional transport aircraft. As highlighted by the ATR Senior Vice President of Operations, Luigi Lombardi, during EWADE 2011 conference, the airlines will need about 3000 new turboprops in the next 20 years [22]. The 42% of the new turboprop deliveries expected to be 70 seats. The new 90+ seat segment is a strong percentage of the total, i.e. the 39% as shown in Fig. 1. Also Bombardier Commercial Aircraft Vice President Marketing, Philippe Poutissou, has expressed optimism about the future and he sees strong demand for this size aircraft in the market in the next two decades [45]. In particular, in its latest forecast of new aircraft deliveries in the 20–149 seat market segment over the next 20 years, Bombardier forecasts that 5800 aircraft will be delivered in the 60–99 seat segment and 6300 (only 500 more) in the 100–149 seat category [45,6]. This work aims to provide some guidelines in the aerodynamic design of future regional turboprop aircraft with about 90 or more passengers.

The aerodynamic design of an airplane has been constantly improved since its introduction in the 1920s. The design of a new flight vehicle was soon accompanied by theoretical research and wind tunnel testing. These new design techniques required not only sophisticated design tools, but also high capabilities to realize the designed geometries and to sustain the costs. Past research activities on aircraft design aimed to drag reduction and usually they were focused on wing and lifting surface design, and especially on airfoil design. However, especially at high speed conditions (low lift coefficient and then low induced drag), an accurate fuselage design is crucial to reduce the total drag of an aircraft and improve flight performance.

One of the most important items on the fuselage aerodynamic design is the junction between wing and body. With the junction term is identified the connection of bodies with different aircraft components, in this special case the wing and the free-form shaped body of the aircraft. In particular, this junction induces interactions between the components, especially the combined boundary layers causes a flow phenomenon very difficult to describe and simulate as well explained in Simpson [43], Hoerner [18] and Schlichting and Truckenbrodt [39].

Simpson shows that the flow around a junction is characterized by a three-dimensional separation with horseshoe vortices

* Corresponding author.
E-mail addresses: pierluigi.dellavecchia@unina.it (P. Della Vecchia), fabrizio.nicolosi@unina.it (F. Nicolosi).

[1] PhD.

[2] Assistant Professor.

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