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A comprehensive review of vertical tail design

Abstract

Purpose – This work deals with a comprehensive review of design methods for aircraft directional stability and vertical tail sizing. The focus on aircraft directional stability is due to the significant discrepancies that classical semi-empirical methods, as USAF DATCOM and ESDU, provide for some configurations, since they are based on NACA wind tunnel tests about models not representative of an actual transport airplane.

Design/methodology/approach – The authors performed viscous numerical simulations to calculate the aerodynamic interference among aircraft parts on hundreds configurations of a generic regional turboprop aircraft, providing useful results that have been collected in a new vertical tail preliminary design method, named VeDSC.

Findings – The reviewed methods have been applied on a regional turboprop aircraft. The VeDSC method shows the closest agreement with numerical results. A wind tunnel test campaign involving more than 180 configurations has validated the numerical approach.

Practical implications – The investigation has covered both the linear and the non-linear range of the aerodynamic coefficients, including the mutual aerodynamic interference between the fuselage and the vertical stabilizer. Also, a preliminary investigation about rudder effectiveness, related to aircraft directional control, is presented.

Originality/value – In the final part of the paper, critical issues in vertical tail design are reviewed, highlighting the significance of a good estimation of aircraft directional stability and control derivatives.

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Introduction

The aircraft vertical tail is the aerodynamic surface that must provide sufficient directional equilibrium, stability, and control. Preliminary sizing is determined by critical conditions as minimum control speed with one engine inoperative (for multi-engine airplanes) and landing in strong crosswinds.

The **airborne minimum control** speed V_{MC} is the calibrated airspeed at which, when the critical engine is suddenly made inoperative, it is possible to maintain control of the airplane with that engine still inoperative and maintain straight flight with an angle of bank of not more than 5° (EASA, 2015). The airborne minimum control speed may not exceed 1.13 the reference stall speed. Thus, this parameter affects the take-off field length, which must be kept as low as possible otherwise the payload could be reduced when the aircraft is operating on short runways. The V_{MC} involves large rudder angles δ_r to keep a small angle of sideslip β. See Figure 1 left. This requires a certain vertical tail area for a given rudder effectiveness τ, which must be the highest possible to keep control authority at 25° or more of rudder deflection.

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