Helicopter stabilizer optimization considering rotor downwash in forward-flight

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Abstract

Purpose – The paper aims to reduce the aerodynamic drag of a rotorcraft stabilizer in forward flight by taking into account downwash effects from the main rotor wake (power-on conditions).

Design/methodology/approach – A shape design methodology based on numerical optimization, CAD-in-the-loop (CAD: computer-aided design) approach and high-fidelity Computational Fluid Dynamics (CFD) tools was set-up and applied to modify the horizontal empennage of a rotorcraft configuration. This included the integration of both commercial and in-house computer-aided engineering tools for parametric geometry handling, adaptive mesh generation, CFD solution and evolutionary optimization within a robust evaluation chain for the aerodynamic simulation of the different design candidates generated during the automatic design loop. Geometrical modifications addressed both the stabilizer planform and sections, together with its setting angle in cruise configuration, accounting for impacts on the equilibrium, stability and control characteristics of the empennage.

Findings – An overall improvement of 11.1 per cent over the rotorcraft drag was estimated at the design condition (cruise flight; power-on) for the stabilizer configuration with optimized planform shape, which is increased to 11.4 per cent when combined with the redesigned airfoil to generate the stabilizer surface.

Research limitations/implications – Critical design considerations are introduced with regard to structural and systems integration issues, and a design candidate alternative is identified and proposed as a compromise solution, achieving 8.3 per cent reduction of the rotorcraft configuration drag in cruise conditions with limited increase in the empennage aspect ratio and leading edge sweep angle when compared to the pure aerodynamic optimal design obtained from genetic algorithm evolution.

Originality/value – The proposed methodology faces the empennage design problem by explicitly taking into account the effects of main rotor wake impinging the stabilizer surface in forward flight conditions and using an automated optimization approach which directly incorporates professional CAD tools in the design loop.

Keywords Optimization, Helicopter, CFD, CAD-in-the-loop, Forward flight, RotorCraft

Paper type Research paper

Nomenclature

Symbols

α = angle of attack, *deg.*
c = airfoil chord, *m*
C_l = lift coefficient (in 2D)
C_L = lift coefficient (in 3D)
C_d = drag coefficient (in 2D)
C_D = drag coefficient (in 3D)
$C_{D,f}$ = friction drag coefficient
C_M = pitching moment coefficient
M = Mach number
Re = Reynolds number
y^+ = dimensionless wall distance

Definitions, acronyms and abbreviations

AoA = Angle of Attack
CAD = Computer-Aided Design
CAE = Computer-Aided Engineering
CFD = Computational Fluid Dynamics
CIRA = Centro Italiano Ricerche Aerospaziali
d.c. = drag counts
EU = European Union
FPx = x^{th} Framework Program
GA = Genetic Algorithm
GRC2 = Green RotorCraft (subproject 2)
HPC = High-Performance Computing
IGES = Initial Graphics Exchange Specifications
ISA = International Standard Atmosphere
ITD = Integrated Technology Demonstrator
JTI = Joint Technology Initiative
l.e. = leading edge

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Aircraft Engineering and Aerospace Technology: An International Journal
88/6 (2016) 846–865

[DOI 10.1108/AEAT-03-2015-0082]

The present work has been funded by the European Union as part of the Clean Sky JTI FP7 Research Program (GRC2 sub-project of the Green RotorCraft ITD – Grant Agreement number: CSJU-GAM-GRC-2008-001). The fruitful collaboration between all project beneficiaries indeed contributed to the reported work.

Received 18 March 2015
Revised 15 June 2015
Accepted 19 June 2015