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An improved high-lift aerodynamic prediction method for transport aircraft

Pierluigi Della Vecchia[1] · Fabrizio Nicolosi[1] · Manuela Ruocco[1] · Luca Stingo[1] · Agostino De Marco[1]

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Abstract
The aim of this work is the development of a methodology to predict lift characteristics for transport aircraft in the whole flight envelope, useful in the preliminary aircraft design stage. The purpose is an attempt to improve the classical methodologies for wing load distribution and lift prediction, applicable to both clean and flapped configuration. This has been obtained considering the airfoils' aerodynamic characteristics until stall and post-stall conditions during the process, and modifying 2D characteristics in the case of high-lift devices to take into account 3D effects introduced by the devices themselves. The method is a modification of standard vortex-lattice procedures which are capable of predicting wing aerodynamic characteristics. As regards the clean configuration, the enhanced method works by integrating airfoil characteristics, whereas as far as the high-lift devices' effect is concerned, the improved method works by substituting clean airfoil aerodynamic characteristics for the flapped aerodynamics ones, and introducing a correction to evaluate the 3D effects induced by the high-lift devices' geometrical discontinuities. The methodology is explained separately for these two configurations. The results of the developed method have been compared with CFD and experimental data showing good agreement, making available a fast and reliable method useful in preliminary aircraft design phase.

Keywords Aircraft design · High-lift aerodynamics · Transport aircraft · Span lift coefficient distribution · Extended lifting-line theory

List of symbols

2D	Two-dimensional
3D	Three-dimensional
AGILE	Aircraft third-Generation MDO for Innovative Collaboration of Heterogeneous Teams of Experts
AR	Wing aspect ratio
b	Wing span
CFD	Computational fluid dynamics
C_l	Two-dimensional lift coefficient
C_l^{clean}	Two-dimensional lift coefficient in clean configuration
C_l^{hl}	Two-dimensional lift coefficient in high-lift configuration (high-lift devices deployed)
$C_{l_{\mathrm{MAX}}}$	Two-dimensional maximum lift coefficient
C_L	Three-dimensional lift coefficient
$C_{L_{\mathrm{MAX}}}$	Three-dimensional maximum lift coefficient
C_{r}	Wing root chord
C_{t}	Wing tip chord
DAF	Design of aircraft and flight technologies research group
F	Downwash influence function
h	Altitude
HiLiftPW	High-lift prediction workshop
JPAD	Java program tool chain for aircraft design
M	Mach number
N	One-half of total number vortex points
MDO	Multidisciplinary design optimization
S	Wing area
V	Free-stream velocity
X_{LE}	Wing sections leading-edge coordinates along x-axis
y	Wing station along span (y-axis)
α	Geometric angle of attack
α_{0l}	Angle of attack which produces a 2D zero-lift condition
α_{e}	Effective angle of attack
α_{s}	Angle of attack at stall condition
α_{w}	Wing angle of attack

✉ Pierluigi Della Vecchia
pierluigi.dellavecchia@unina.it

[1] Department of Industrial Engineering (DII), University of Naples Federico II, Naples, Italy

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