Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX (to be filled by the organizers)
Preferred Topics: SUSTAV
Corresponding author: Valerio Mosca
e-mail of corresponding author: v.mosca@tu-braunschweig.de
Type: Oral
Status of corresponding author: Student

Potentials investigation of active flow control on retrofit of commercial aircraft

Valerio Mosca 1, Stanislav Karpuk 2, Ali Elham 3*

** Corresponding author*
1 Phd candidate, IFL TU Braunschweig, Braunschweig 38108, Germany, v.mosca@tu-braunschweig.de
2 Researcher, IFL TU Braunschweig, Braunschweig 38108, Germany, s.karpuk@tu-braunschweig.de
3 Professor, University of Southampton, Southampton SO16 7QF, United Kingdom, a.elham@soton.ac.uk

Abstract

Hybrid Laminar Flow Control (HLFC) remains one of the most promising airframe technologies that can substantially improve overall aircraft efficiency [1]. Although many numerical and experimental studies investigated the capabilities of HLFC, it is still challenging to consider the technology at a conceptual aircraft design phase due to a need for more information. The present work focuses on investigating several existing aircraft retrofitted with the HLFC technology to obtain generic correlations useful for early conceptual aircraft design. The work will also suggest potential limits of HLFC applied for current airplanes with present regulations. The work focuses on at least three standard aircraft with various payloads and ranges and suggests the initial limits of HLFC. A series of studies are performed for each aircraft to achieve the provided goals. An aerostructural optimization framework has been developed to redesign the wing for a given aircraft with the presence of HLFC. The framework comprises medium-fidelity physics-based analysis tools and includes different modules: aerodynamics, structures, suction system analysis, and performance evaluation. The aerodynamic module is characterized by a Quasi-Three-Dimensional (Q3D) model that combines the use of Vortex Lattice Method (VLM) AVL, an Euler equations solver (MSES), and Linear Stability Analysis for wing study. The methodology adopts a conical transformation, representing a 2.75D approximation, able to take into account wing sweep angle and taper ratio for better treatment of three-dimensional effects. Structural analysis is performed with the tool EMWET [2], which couples physics-based wingbox sizing techniques with empirical models. The remaining modules are given by semi-empirical formulations. For each of the three aircraft, several retrofit studies are presented. First, each aircraft considered in the work is digitized using the SUAVE [3] aircraft design environment and available resources. An initial fully turbulent wing optimization of the digitized airplane is performed to estimate the airfoils of the reference wing. The design variables are given by airfoil shape parameters at different sections from root to tip and twist angles. Then, the reference wing is retrofitted with the leading edge suction system to investigate the current capabilities of a benchmark wing with the technology. After that, the optimization of the wing with HLFC is performed to estimate a limit of possible retrofit and the maximum benefits of the technology. Suction scale coefficients are applied for HLFC to control the suction distribution. Hence, each aircraft is optimised for full turbulent wing and for HLFC application. Data are then compared with the use of suction on the first optimised version, looking for potential relationship between airfoil, wing parameters and suction system capabilities. It will be arranged in a series of correlations that can be used for early estimations of aircraft wing aerodynamics with the presence of HLFC. This way, the work shall help designers reduce high uncertainties related to the technology at early design stages for various commercial aircraft and recommend practical aerodynamic limits of its applicability.

References

[1] Beck, N., Landa, T., Seitz, A., Boermans, L., Liu, Y., and Radespiel, R., “Drag reduction by laminar flow control,” Energies, Vol. 11, No. 252, 2018. https://doi.org/10.3390/en11010252
[2] Elham, A., La Rocca, G. and van Tooren,M.J.L. Development and implementation of an advanced, design-sensitive method for wing weight estimation, Aerospace Sci. Technol., 2013, 29, (1), pp 100–113, doi: 10.1016/j.ast.2013.01.012.
[3] Lukaczyk, T.; Wendroff, A.; Colonno, M.; Economon, T.; Alonso, J.; Orra, T.; Ilario, C. SUAVE: An Open-Source Environment for Multi-Fidelity Conceptual Vehicle Design. In Proceedings of the 16th AIAA ISSMO Multidisciplinary Analysis and Optimization Conference, Dallas, TX, USA, 22–26 June 2015.