The impact of winglet's geometry on aerodynamics and stability of tailless aircraft

Agnieszka Kwiek [1)], Dawid Biesiadecki-Dziuba[2)]

[1)] Warsaw University of Technology, Faculty of Power and Aeronautical Engineering, Institute of Aeronautics and Applied Mechanics, Aircraft Design Department

[2)] Warsaw University of Technology, Faculty of Power and Aeronautical Engineering

Abstract:

Winglets are a very popular way to improve aerodynamics characteristics of aircraft. But in case of the tailless aircraft, their geometry might be crucial to ensure a proper dynamic characteristics and handling qualities.

The aim of this paper is to investigate different designs of the winglets and the impact of their geometrical features on the aerodynamics and stability of the tailless aircraft. As an exemplary aircraft for this analysis a mother aircraft was selected. The aircraft is a part of the Modular Airplane System dedicated for suborbital tourist flights [1] and [2]. The role of the mother plane is to lift a rocket plane above the most denser part of the Earth's atmosphere. So to ensure capability to fly up to 15 kilometres a tailless configuration with a high aspect ratio wing equipped with winglets were selected for this mother airplane.

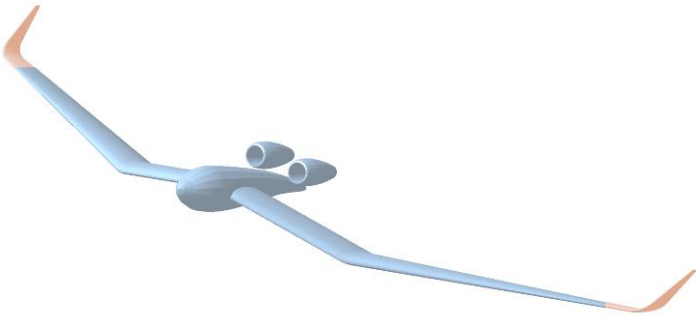

Figure 1 The mother plane layout. The geometry of the blue part if fixed for all considered model while the orange part represents exemplary winglet's geometry

The layout of the mother plane is presented in Figure 1. The geometry of the aircraft is fixed except the winglets which are highlighted in orange. Due to a preliminary stage of this study, the impact of the winglet's geometry on the change of centre of gravity and moments of inertia is neglected. The types of winglet's shapes considered in this study were proposed in [3].

Aerodynamic computations were performed with use of the PANUKL package which can be classified as a low order panel method tool [4]. The software has a good track of aerodynamic prediction including cases of unconventional configurations as tailless aircraft. The distribution of Cp, obtained with use of the PANUKL, for a selected design is presented in Figure 2. Analysis of the dynamic stability was conducted with use of the Simulation and Dynamic Stability Analysis (SDSA) package [5]. A standard mode of motion like short period, phugoid, roll, Dutch roll, and spiral were considered. The impact of the winglet hight on selected stability derivatives is presented in Figure 3.

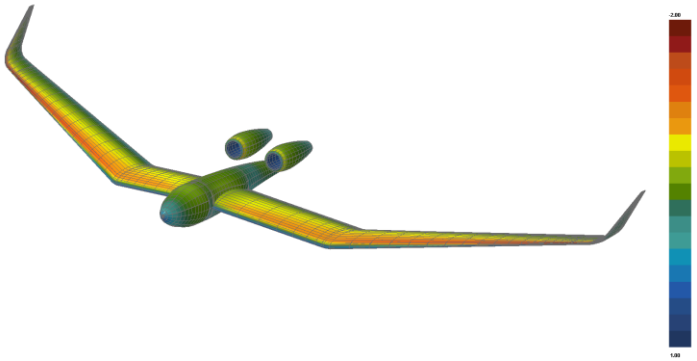

Figure 2 Pressure distribution obtained by the PANUKL for an exemplary winglet shape

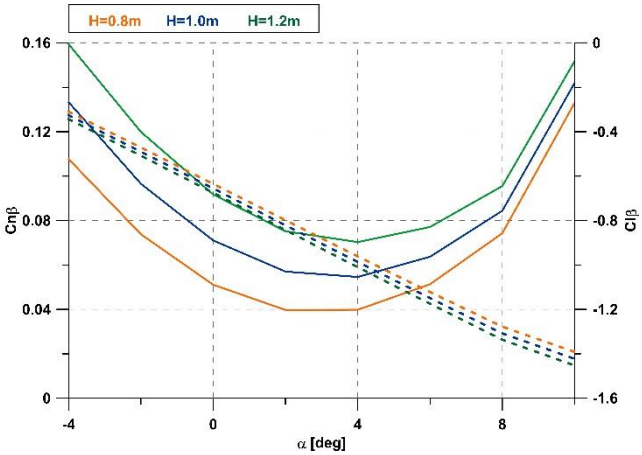

Figure 3 Impact of the winglet hight on yaw and roll moment derivative with respect to side slip angle. Those derivatives determine lateral-directional static stability as well as impact the Dutch roll damping and roll performance.

The outcome of this paper encompassed a sensitivity study of the winglets geometry on the aerodynamics and dynamics of the tailless aircraft. That create a benchmark for optimisation process which incorporate the dynamic stability as a constrain.

References

[1] Galiński C., Goetzendorf-Grabowski T., Mieszalski D., Stefanek Ł., (2007), A concept of two-staged spaceplane for suborbital tourism, Transactions of the Institute of Aviation, No. 4 (191), pp.33-42

[2] Figat M., Galiński C., Kwiek A., (2012), Modular Aeroplane System. A Concept and Initial Investigation, Proceeding of the 28th Congress of the International Council of the Aeronautical Sciences, Brisbane, Paper ICAS 2012-1.3.2

[3] Biesiadecki-Dziuba D. (2024), Aerodynamic optimization of a carrier plane in suborbital flights, BEng thesis, in polish.

[4] Goetzendorf-Grabowski T. PANUKL - Package to compute the aerodynamic characteristics of an aircraft using low order panel method. https://www.meil.pw.edu.pl/add/ADD/Teaching/Software/PANUKL, 2020. (Accessed on 19/08/2024)

[5] Goetzendorf-Grabowski T. SDSA - Simulation and Dynamic Stability Analysis application. https://www.meil.pw.edu.pl/add/ADD/Teaching/Software/SDSA , 2020. (Accessed on 19/08/2024)