Determination of UAV loads based on flight simulation results

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Abstract:

A typical approach to define loads for manned civil aircraft consist in calculations of load envelope, which is described in regulations appropriate for the aircraft type. In case of a small UAV, the regulations do not specify mathematical model to calculate the load envelope. In the military domain, for a UAV heavier than 150kg, NATO standards are recommended [4] but those regulations are based on manned EASA Certification Specification CS23. If a small UAV is going to be designed in classical configurations, adaptation of manned regulations can be a feasible solution. But, this approach might rise issues if an unconventional UAV is designed, especially one that is flying with a relatively high speed. This paper addresses this problem by the use of flight simulation, to define the limit loads. This study was conducted for a small rocket UAV designed in a tailless configuration. The layout of the rocket plane is presented in Figure 1. The control of pitch is ensured by deflection of the elevons. Alternatively, a symmetrical deflection of ruder on the left and right side plates also result in change of the rocket plane pitch angle. Analysis presented in this paper are restricted to the longitudinal motion which is only controlled by elevons.

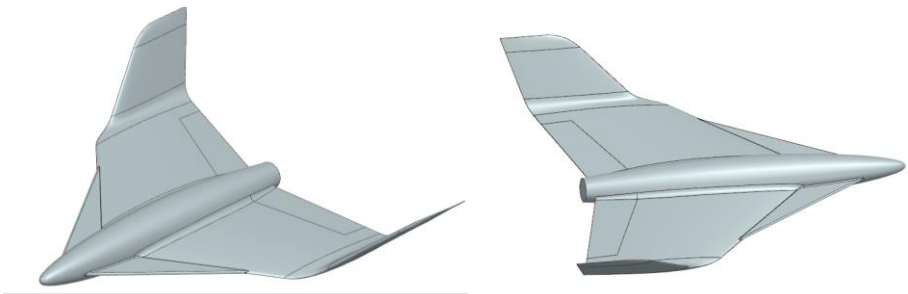

Figure 1 Layout of the rocket plane

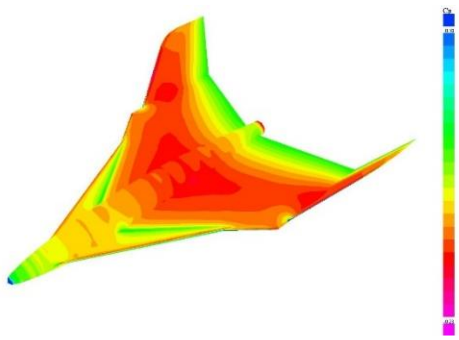

Figure 2 Cp distribution computed by MGAERO software in case of Ma=0.1 and AoA=0 deg.

Aerodynamic analyses were carried out with the use of MGAERO [3], an exemplary pressure distribution is presented in Figure 2. Obtained characteristics were used in creation of the simulation model. The rocket plane flight simulations were performed with the use of the SDSA package [1][2], which can simulate the aircraft as a rigid body with 6 degrees of freedom. To collect the data a few manoeuvres were tested, each of them were commanded by a step or doublet elevons deflection. A plot with an exemplary elevator deflection for selected cases is presented in Figure 3. The exemplary case showing dynamic response of the UAV in a sudden pull-up manoeuvre is presented in Figure 4. Initially the lift coefficient drops due to the negative elevator deflection, but resulting positive pitching moment allows for achieving an angle of attack in excess of that in the equilibrium condition with equal dH. The preliminary results revealed that the use of a classic aircraft regulation would overestimate the maximum loads.

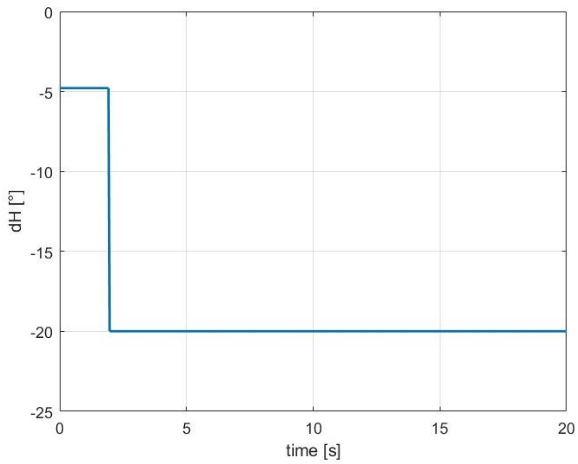

Figure 3 exemplary elevator deflection step-profile

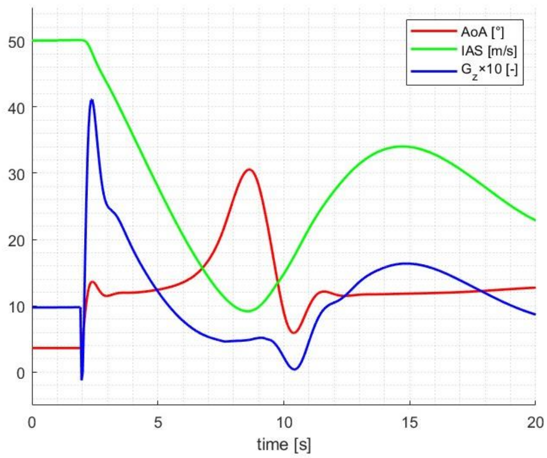

Figure 4 time history of selected variables in resulting manoeuvre

References

[1] Goetzendorf-Grabowski T., Mieszalski D., and Marcinkiewicz E. Stability analysis using sdsa tool. Progress in Aerospace Sciences, 47(8):636–646, November 2011.

[2] Goetzendorf-Grabowski T. SDSA - Simulation and Dynamic Stability Analysis application. https://www.meil.pw.edu.pl/add/ADD/Teaching/Software/SDSA , 2020. (Accessed on 08/07/2024)

[3] MGAERO A Cartesian Multigrid Euler Code for flow Around Arbitrary Configurations - User's Manual Version 3.1.4, 2001.

[4] NATO STANDARD AEP-4671 UNMANNED AIRCRAFT SYSTEMS AIRWORTHINES REQUIREMENTS (USAR) EDITION B VERSION 1 APRIL 2019