SEMI-AKTIVE FLUTTER SUPRESSION USING CONTROL SURFACE DEFLECTIONS

2026 ABSTRACT

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STEADY/UNSTEADY AERODYNAMICS – ABSTRACT

Introduction

To maximize aerodynamic efficiency, the wings of modern commercial aircraft exhibit an increase in span, thereby increasing their aspect ratio. This results in a decrease in the induced drag coefficient, leading to lower fuel consumption. However, the larger span of the wing also reduces its bending stiffness.

The transonic flow, combined with the increasingly flexible wings, is subject to the impact of disturbances, such as an increase in flight velocity, an increase in angle of attack, or a gust impact, to trigger a critical condition known as flutter. The interaction of unsteady aerodynamic forces due to the vibrations of the aircraft wing in its elastic eigenmodes with elastic forces and inertia forces can result in a self-excited oscillating system. Reinforcing the wing structure counteracts this effect but also leads to an increased structural weight. Thus, numerous investigations regarding the influence of flow control methods for flutter suppression have been proposed. Examples are the use of shock control bumps (Nitzsche, Otte, Kaiser, Hennings, 2022) and spoiler deflections (Schmalz & Quero, 2022). These modifications in the geometrical outline are used to modulate the pressure distribution along the airfoil, aiming for an improvement on the flutter boundary.

Concept Description

This work focuses on investigating flutter suppression measures using existing control surfaces on the basis of an advanced dropped hinge flap (ADHF). The measure is used to influence the shock characteristics on the wing by independently controlling spoilers and flaps, thereby shifting the flutter boundary to larger values for off-design conditions of the cruise flight compared to a reference configuration.

Simulation Setup

A modified OAT-15A airfoil is investigated by applying ANSYS Fluent. Unsteady RANS simulations are closed by the $k - \omega$ SST turbulence model. A two-dimensional case is studied for a variation of the angle of attack α and the Mach number Ma. Different control surface deflections are investigated and compared with a clean (unmodified) OAT-15A profile.

Results and Analysis

First, multiple adjustment angles of the ADHF are compared to the clean configuration. Figure 1 displays the influence of three different control surface deflection settings on the pitching moment coefficient derivative $C_{m\alpha,25\%c}$ and the lift coefficient derivative $C_{L\alpha}$ with respect to a clean profile. According to the findings of Schmalz et. al., it is aimed to reach a reduction of the $C_{m\alpha}$ values and the $C_{L\alpha}$ values respectively with respect to the clean OAT-15A profile for a frequency of $k = 0$ (rigid case) to identify regions of interest for flutter suppression.

It is evident that for a given lift coefficient C_L, the ADHF deflection settings - including the spoiler and the flap deflection angle - have to be carefully adjusted to reach a reduction with

respect to the clean configuration. A C_L range of $C_L = [0.3 - 0.7]$ can be identified as a region of interest for flutter suppression. A simultaneous deflection of the spoiler and the flap by 10° delivers the largest improvement.
Figure 2 shows the according influence of the control surface deflections on the flow field for a lift coefficient of $C_L = 0.68$ ($\alpha = 1°$). Hereby, the spoiler and the flap are each deployed by an angle of 10°. The upwards deflection of the spoiler leads to an upwind shift of the supersonic region on the upper wing surface. The following lift loss of the main profile is counteracted by the deployed flap.

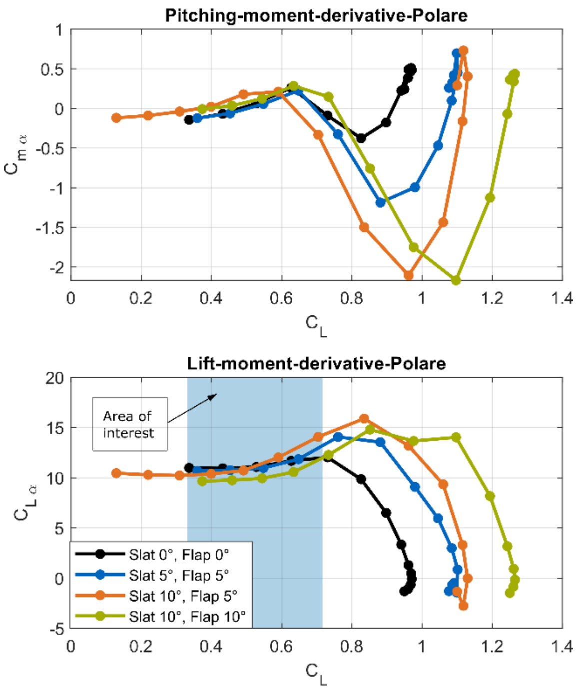

Figure 1: $C_{m\alpha}$ plot for multiple ADHF-settings

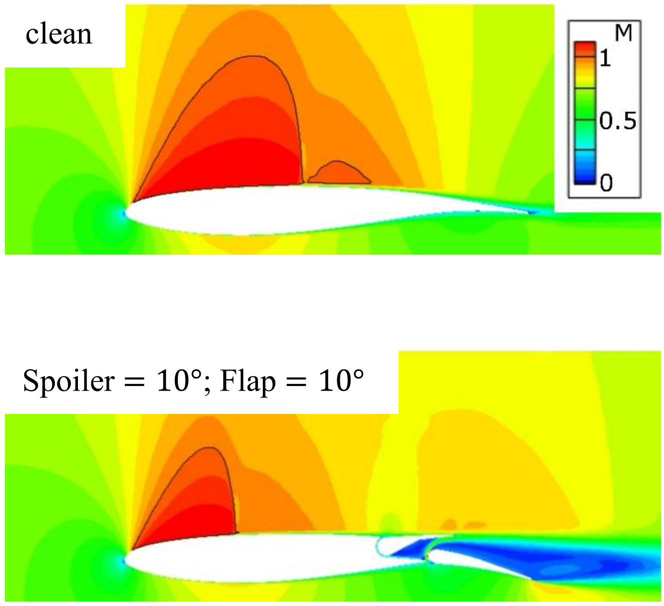

Figure 2: Mach field plot for $\alpha = 1°$ and $M_\infty = 0.73$

Conclusion and Outlook

This work shows a proof of concept for a modified ADHF system to influence the flutter boundary. Insights from the non-oscillating profile are used to project to the actual elastic behavior. To verify this, an additional comparison between the flutter boundary of the clean and the modified profile is conducted enabling a free two-degree rigid body motion of each profile.

Literature

Nitzsche, J., Otte, J., Kaiser, C. and Hennings, H., The Effect of Shock Control Bumps On The Transonic Flutter and Buffeting Characteristics of a Typical Wing Section, IFASD-2022-049, 2022.

Schmalz, M., & Quero, D., Numerical Investigation of a Spoiler Effect on the Transonic Flutter Boundary, 23rd STAB/DGLR Symposium, NNFM 154, pp. 14-23, Berlin, 2024.