Fluidic gust load alleviation

Numerical simulation of time-varying active flow control for gust load alleviation

K. Khalid, A. Bauknecht, *Institut für Strömungsmechanik, TU Braunschweig*

In Short

- RANS and hybrid RANS/LES simulations
- Unsteady computations at sub- and transonic conditions with time-varying actuator control parameters
- Interaction of discrete vertical gusts with actuated 2.5D wing section
- Scale-resolving simulations for capturing unsteady interactions between boundary layer, surface jets, and flow separation over curved airfoil geometry.

Future air transport systems will need to fulfill much stricter environmental requirements, as e.g. outlined by the strategic European Aviation Roadmap described in the European Commission's Flightpath 2050 report, where a goal of 75% reduction of CO_2 emissions per passenger-kilometer is defined by the year 2050 1. Together with a consistent increase in air transport volume by about 4–5% annually 2, this goal can only be reached through application of new technologies that allow for substantial reductions of structural weight, aircraft drag, and carbon fuel consumption.

This research project is part of the Cluster of Excellence SE^{2}A (Sustainable and Energy Efficient Aviation, EXC 2163/1). The research project investigates technologies for actively alleviating dynamic wing loads induced by gusts and maneuvers encountered during flight. If these peak aerodynamic wing loads can be suppressed, a safe reduction of wing weight – and consequently fuel and CO_2 emissions – becomes feasible. New technologies in the form of fluidic flow actuators have the potential to provide fast, efficient, and highly adaptive lift redistribution that alleviates these loads.

The initial phase of the project involved low cost 2D Reynolds-Averaged Navier–Stokes (RANS) simulations of various potential flow actuation concepts for both sub- and transonic flight conditions 3. This preliminary study was essential to identify candidate actuation concepts that fulfill the requirements of medium range passenger aircraft at both cruise and low-altitude conditions. A fluidic actuation concept based on a Coanda-type trailing edge jet was found to offer high control authority over the sectional wing lift at moderate system requirements. Figure 1 depicts an example Mach contour plot of transonic flow

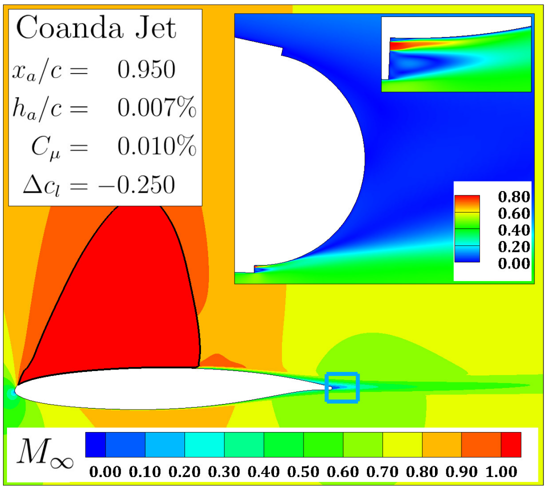

Figure 1: *Mach contour plot of transonic flow over airfoil with active Coanda jet at 95% chord position*

$(M_\infty = 0.78)$ over an airfoil with active Coanda-type trailing edge jet actuator at 95% chord. The actuator effectively reduces airfoil lift by $\Delta c_l = -0.25$ at low mass flow requirements, indicated by the momentum coefficient $C_\mu = 0.01\%$. The actuator's high control authority at low mass flow requirements warrants further investigation at higher modeling fidelity.

The current second phase of the project involves a more detailed investigation of the identified most promising actuation concept. The internal and external actuator geometry has been optimized in terms of actuator control authority over airfoil lift, while maximizing airfoil performance without blowing. Further potential for increasing the actuator efficiency lies in time-varying jet actuation. To this end, the present HLRN-proposal focuses on the investigation of the temporal behavior of optimized actuator configurations on 2.5D wing sections. As an example, Fig. 2 shows the lift history of an impulsively started Coanda jet actuator computed with unsteady RANS simulations using the Spalart-Allmaras turbulence model. In these initial simulations it was found that jet attachment was not correctly modeled and that higher-fidelity methods are required to capture the interaction between the boundary layer, time-varying surface jet, and curved airfoil surface.

Time-resolved, RANS simulations with a Reynolds-Stress Model (RSM), as well as limited hybrid RANS/LES simulations are to be conducted for a) unsteady gust interactions with the unactuated wing section to establish the baseline airfoil performance, b) time-varying flow control with different primary control functions to improve actuator control

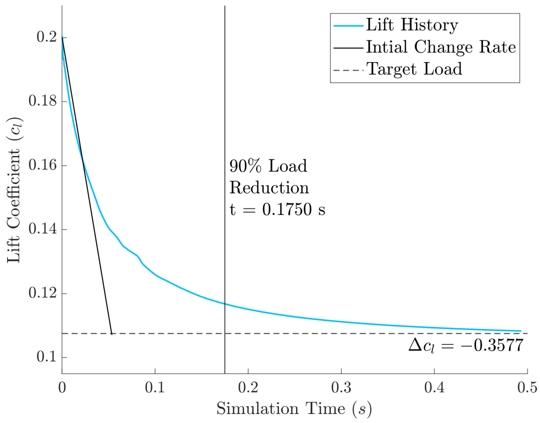

Figure 2: *Lift history of impulsively started Coanda jet actuator*

authority and efficiency and to investigated mutual interactions of spanwise adjacent actuation systems, and c) combination of unsteady flow control and gust interaction to demonstrate gust load alleviation under realistic operating conditions. The obtained database further serves as the basis for derivation of a Reduced Order Model that enables consideration of active flow control in the design process of gust load alleviation control systems and for implementation into preliminary aircraft design, as planned in linked projects within the Cluster of Excellence SE^{2}A.

WWW

https://www.tu-braunschweig.de/ism/forschung-und-arbeitsgruppen/flow-physics-of-load-reduction

More Information

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Project Partners

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