Gust load alleviation with a Coanda-type flow actuator

Numerical simulation of time-varying active flow control for gust load alleviation on an aircraft wing

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In Short

- RANS and unsteady RANS simulations of gust interactions on an aircraft wing
- Coanda-type flow actuator and surface jet actuator for alleviation of gust induced loads
- Actuator implementation on medium range aircraft
- Improvement of spanwise actuator distribution and activation profile
- Determination of aerodynamic loads for structural sizing of the aircraft's wing box

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 in CO_2 emissions per passenger-kilometer is defined by the year 2050 [1]. Together with a continuing increase in air transport volume by about 3–4 % annually, this goal can only be reached through application of new technologies that allow for substantial reductions of structural weight, aircraft drag, and fuel consumption.

This research project is part of the Cluster of Excellence SE²A (Sustainable and Energy Efficient Aviation, EXC 2163/1) and investigates technologies for actively alleviating gust and maneuver loads encountered by transport aircraft during flight. Today, conventional control surfaces such as flaps or ailerons on aircraft wings are used to reduce dynamic gust and maneuver loads. Further reduction in wing weight, and therefore CO_2 emissions, appear feasible if a dedicated load alleviation system is applied with fast-acting flow control devices distributed along the span. New technologies such as fluidic flow actuators have the potential to provide fast, efficient, and highly adaptive lift redistribution to alleviate these loads.

A previous HLRN compute project (nii00166) involved low cost 2D Reynolds-Averaged Navier–Stokes (RANS) simulations of various potential flow actuation concepts for both sub- and transonic flight conditions [2]. Through that project, two different fluidic control devices - a Coanda-type actuator and a surface jet actuator - were identified as the most

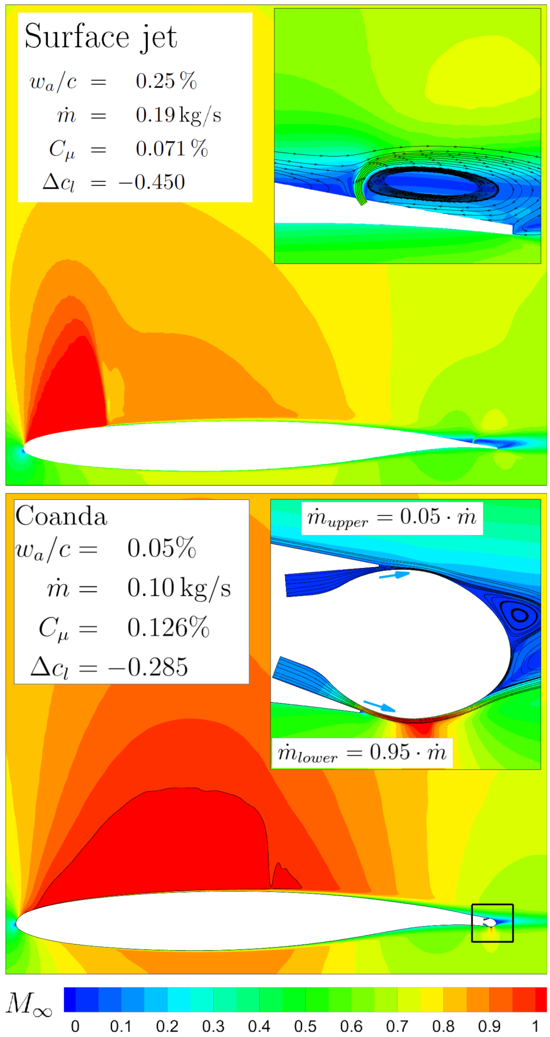

Figure 1: *Flow field around an airfoil with two types of actuators: Surface jet (top) and Coanda actuator (bottom).*

promising systems for fast and efficient load alleviation. Both actuator principles are shown in Figure 1 during actuation at design cruise flight conditions. The surface jet actuator generally shows strong effectiveness at the cost of very high mass flow rates. The Coanda actuator is superior in terms of mass flow efficiency but faces limitations on the load reduction capabilities under transonic operating conditions. Both actuator types were further improved and optimized during the previous project phase regarding actuator geometry and temporal activation profile.

Based on this previous work, the current phase of the project focuses on the implementation of an optimized actuator configuration on the 3D wing of a generic medium range aircraft and investigations of its load alleviation performance and optimal span-

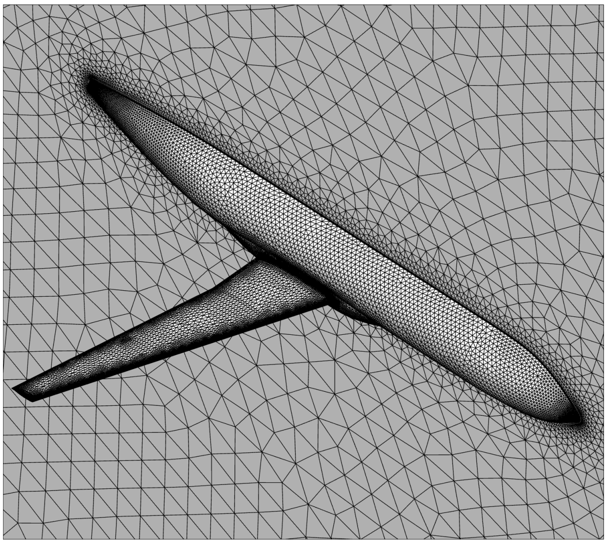

Figure 2: *Example grid of the medium range aircraft that serves as testbed within the SE^{2}A cluster.*

wise activation profile. Figure 2 shows the medium range aircraft that was designed within the Cluster of Excellence SE^{2}A and serves as a testbed for the development of revolutionary technologies such as fluidic load alleviation. In this project, time-resolved RANS computations of gust encounters at different operating conditions will be conducted to develop an optimal spanwise actuator distribution with reduced mass flow requirements. Time-varying flow control with different activation profiles along the span will be studied for both actuator types to improve actuator control authority and efficiency, as well as to investigate mutual interactions of spanwise adjacent actuation systems. These computations will be conducted for a range of operating conditions such as altitude and flight Mach number to identify critical load cases as well as flight conditions where the capabilities of the actuators are potentially limited.

Additionally, multiple critical load cases will be studied for the unactuated clean-wing configuration to establish the baseline aircraft performance and create a database of aerodynamic loads. The resulting aerodynamic loads will be used by the structural design team within the Cluster of Excellence SE^{2}A for structural sizing of the aircraft's wing box and serve as a starting point for coupled aerodynamic/structural simulations in the future. The development of a hybrid load alleviation system combining fluidic actuation with smart structural design exploiting structural non-linearities is envisioned here. This project therefore substantiates understanding of fluidic load alleviation on a generic transport aircraft configuration, answers key questions regarding the actuator integration on 3D wings and serves as a basis for later combination of passive and active load control techniques.

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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