Abstract

State of the art aircraft are highly optimized for cruise conditions as well as low speed flight. Especially the aerodynamic performance during take-off and landing is a key aspect in early design studies.
In times of increasing engine fan diameters, with the purpose of improving the propulsive efficiency, the optimization of the high-lift wing becomes constraint by geometric challenges, when integrating those engines below the wing. In order to prevent clashes of leading edge high-lift devices with the engine, span-wise cutbacks can become necessary, which take their toll on the maximum achievable lift during landing.

Localized installation of flow control was studied and evaluated as a suitable candidate to overcome those shortfalls.

This thesis is build up in sequential chronological steps on the way to a first localized flow control application inboard of the engine pylon. The topic is introduced with a historical analysis of once flying flow control aircraft with a focus on leading installations, followed by an analysis of previous tests and computations. Subsequently, the aerodynamic flow topology was analyzed and the problem of an early flow break up at the leading edge was defined.

The postulated improvement by means of a small span wise flow control method was confirmed by a low- speed wind tunnel test campaign. The analysis of the campaign, based on force measurements, oilflow visualizations and massflow quantifications, was used to derive a simplified vortex flow model of the stall initiation, yielding to an improved understanding of the local aerodynamic effects.

In order to assess overall interactions and dependencies on aircraft-level, a multidisciplinary aircraft-design study was conducted. The goal of this study was to evaluate the block-fuel effect of an exemplary airplane with different geometric wing high-lift-constraints.

In conclusion, flow control at the wing-pylon intersection was able to delay the stall significantly.
Supported by wind tunnel studies and analysis, the multidisciplinary evaluation showed that the required energy levels are in a realistic range to be installed on state of the art aircraft.

The comparison of optimized preliminary aircraft design configurations showed that the benefits of a flow control integration have a clear potential of outweighing the penalties associated to the installation.