Presented by

Burkhard Gölling, Airbus

Prepared by

Burkhard Gölling, Airbus

Heribert Bieler, Airbus

German R&T Activities for Active Flow Control for High lift / Low Speed

Active Flow Control Technologies for Low Speed

Agenda

- Objectives of active flow control (AFC)
- CFD tool for development & design
- Experimental results
- Conclusions & Outlook

Active Flow Control Technologies for Low Speed Objectives

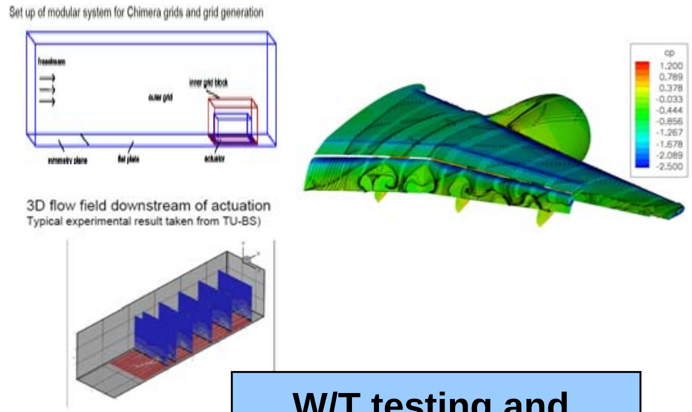
Objectives

- **Improved performance for high lift**
  - Integration of efficient active flow control (AFC) systems
  - Efficient and high reliable flow control systems

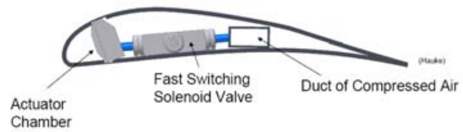
- **Reduced Weight**
  - Less complexity of high lift systems (i.e. simple slotted flap with AFC in comparison with double slotted flap or slatless configurations)
  - Smaller lifting surfaces towards more lean structures

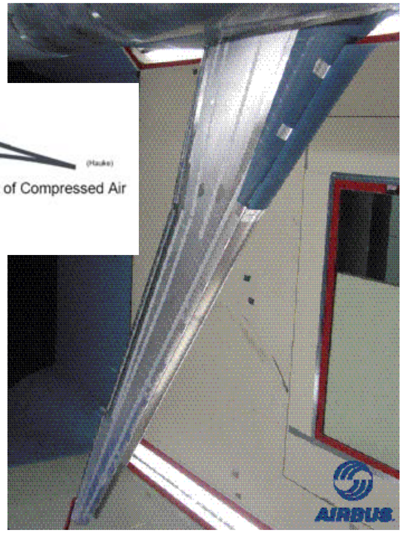
- **Reduced Airframe Noise**
  - Noise source reduction by AFC for less noise emission
  - Improved control of steep flight procedures for less noise imission

CFD Tool development and design



W/T testing and system development





Active Flow Control Technologies for Low Speed R&T Activities & Integration of German Activities

In Search of the Best Ideas ...

Germany:
DLR, Techn. Univ. / Univ.
Fraunhofer Institutes

List of main German R&T activities:

- LuFo (German Civil Aircraft Research Program)
- Transfer projects between Universities & Industry
- Patenship program between Airbus and DLR

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R&T investigations for active flow control (AFC)

CFD Tool application for design and development

CFD for design purposes

Tau applications for design:

- Passive obstacles like VGs will be indirectly simulated.
  Application of innovative direct methods like volume method approach is ongoing.
- Steady RANS application for continuous / steady flow control applications.
- Active flow control is not yet delivered to design.

Passive design by:

- shape changing materials
  (i.e. by smart material)

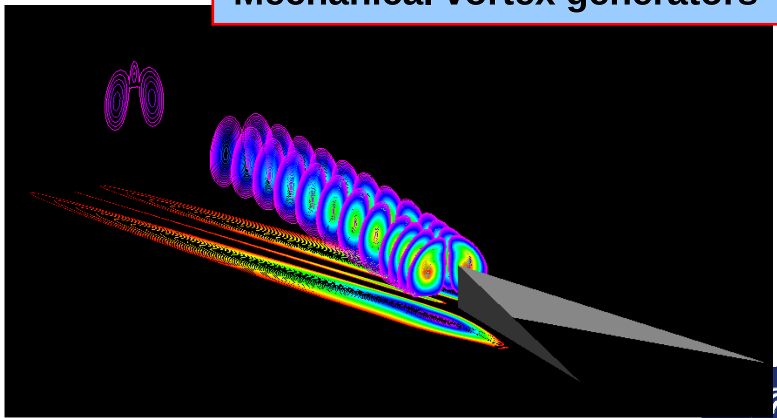
*Figure about smart materials concept
will be shown here.*

Application of passive flow control:

For generation of streamwise oriented vortices in the separating shear and/or boundary layer using of

- vortex generators (VG) and
- subboundary layer vortex generators (SBVG)

Mechanical vortex generators

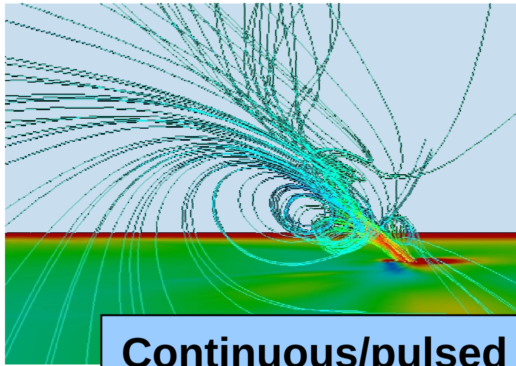


CFD for active flow control means

Verification and validation (V&V) of Tau

for applications of flow control techniques
starting at flat plate towards
more complex geometries:

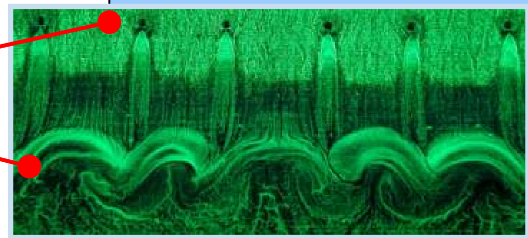
- Steady / unsteady jets with mass transfer through holes or spanwise slots:
  - Source of compressed air for blowing jets needed.
  - Allow steady and unsteady actuation.
  - Electro-mechanical principle available and proved efficiency.
- Steady / unsteady synthetic jets through holes or spanwise slots:
  - No net mass flow, no piping
  - Powerful system and moving parts needed
  - Performance has to be proved next.



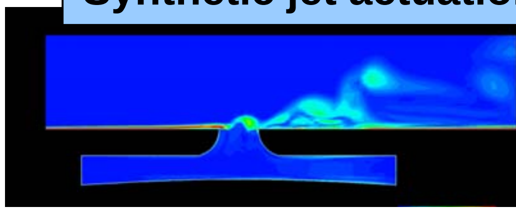
Continuous/pulsed jet

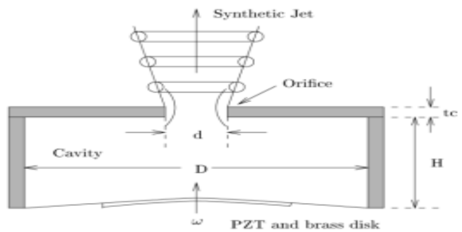
Row of Orifices

Separation Line

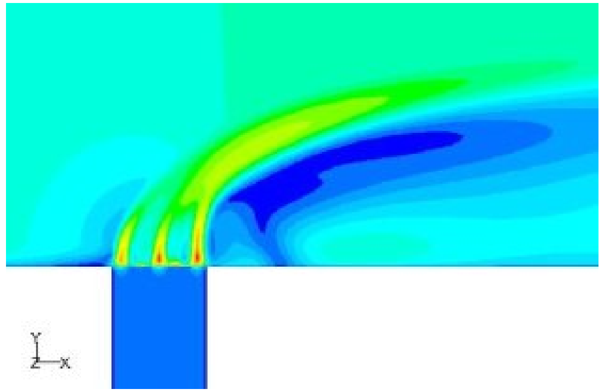


Synthetic jet actuation





CFD direct Models for low Speed Flow Control
R&T cooperation of Airbus

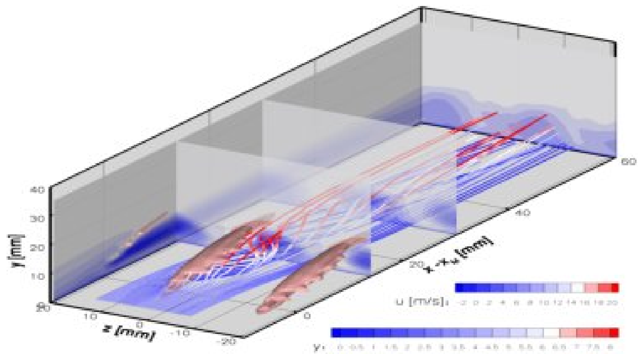


DLR: Qualification of TAU

- Qualification of DLR TAU code for high-lift flow control

TU BS: DES & Chimera studies

- Assess DES for flow control on chimera grids
- Numerical simulation of high lift relevant configuration



IAG Stuttgart:
Simulation of continuous jet actuation

- DNS-simulations of slotted actuators in turbulent BL flow.
- 3-D-Actuator- and BL-flow simulation by LES and RANS
- Coupling of actuator simulation and BL simulation.

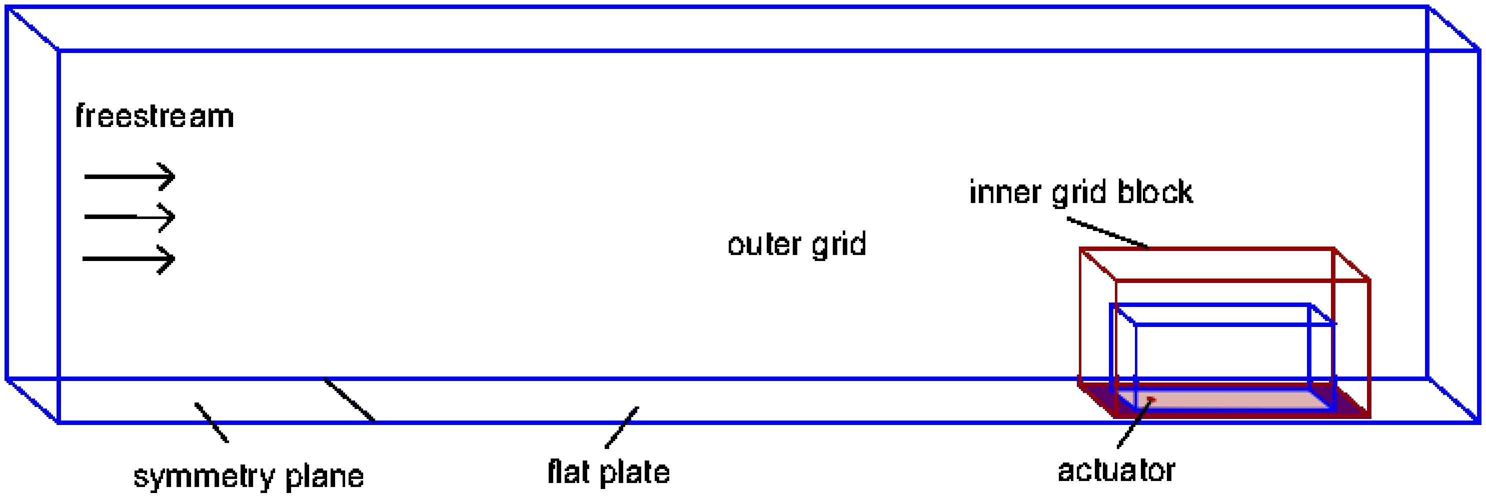
Jet actuator principle integrated in CFD applications

CFD direct Models for low Speed Flow Control
Chimera studies for AFC on flat plate

Topic:

Set up of modular system for Chimera grids and grid generation

Modular system essential for actuator arrays on curved surfaces



Modelling of actuator arrays by joining several inner grids with 1 outer grid

Status quo of development and V&V:

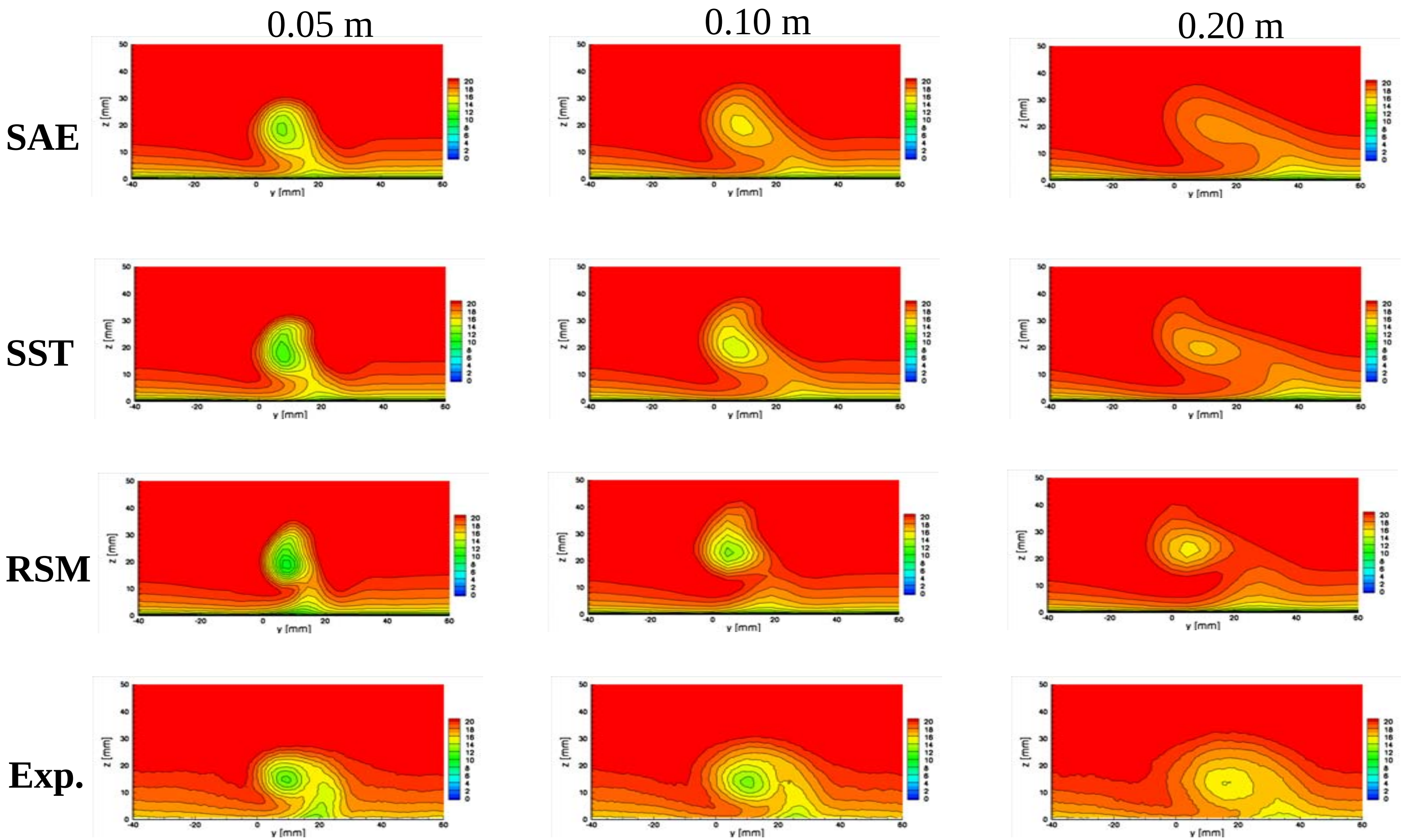
- Grid concept set up and
- Grids generated for 2D cases

CFD direct Models for low Speed Flow Control
TAU prediction vs experiment: Flat Plate

Steady jet blowing, TAU in RANS mode

Influence of Turbulence Models

hole D=6.4 mm, α=45°, β=90°, λ=2.5



U-velocity

Proof of active flow control concepts in wind tunnels

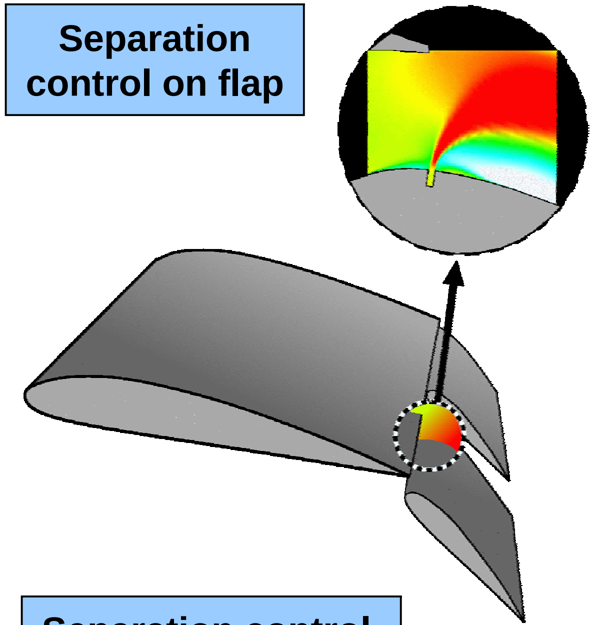
Active Flow Control Technologies / Techniques

- **Objective**
  - ➢ Control Aerodynamic Forces and Moments

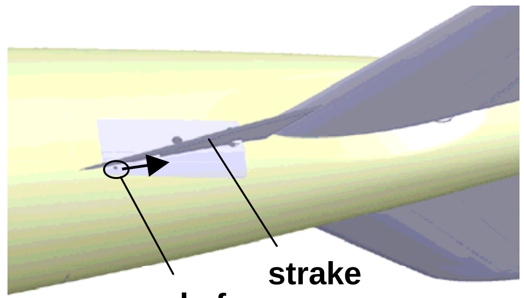
- **Fluid mechanism**
  - ➢ Detachment of the flow from the surface due to the momentum deficit in the boundary layer close to the surface

- **Means of active flow control**
  - ➢ Momentum transfer via AFC
    - – Pulsed tangential jet flows
    - – Continuous or pulsed jets
    - – Pneumatic solutions on streamwise geometry kinks and on TE
  - ➢ Introduction of vorticity to enhance mixing.
    - ➢ Mass-less jet actuators

Separation control on flap



Separation control at empennage



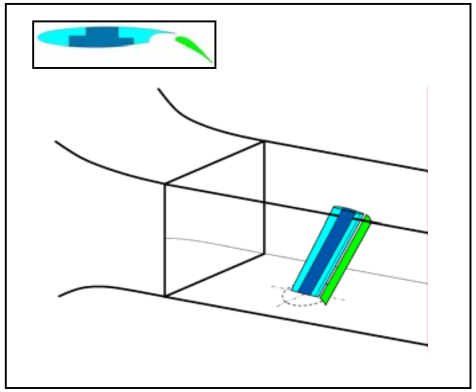
Wind tunnel tests for active flow control
Way of progress

Continuous work on active flow control technology:

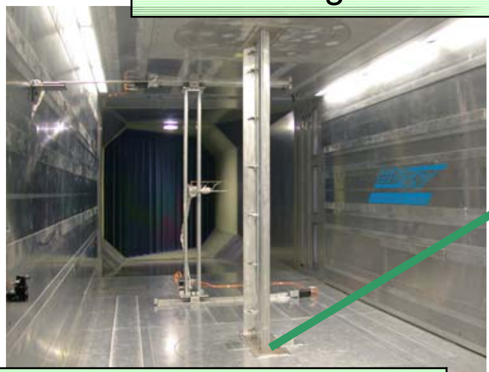
- Starting with 2D high lift configurations at low Re via
- more complex 3D configurations achieving proof of active flow control concepts on high Re
- towards qualification of flow control subsystems like actuators on aircraft level.

2.5D W/T tests with
Large scale model
at DNW-LLF
Optimised
Active flap investigations
with integrated systems

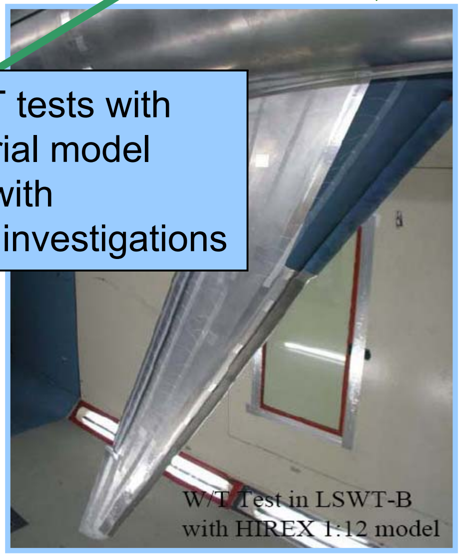
Increased scale level,
Re number and
maturity



2D W/T tests at
high Re numbers
Enhanced Active flap
investigations



3D W/T tests with
industrial model
with
active flap investigations



2D W/T tests
Active flap investigations
on 2-element configuration

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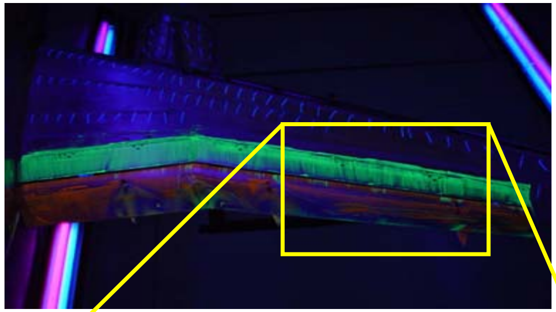
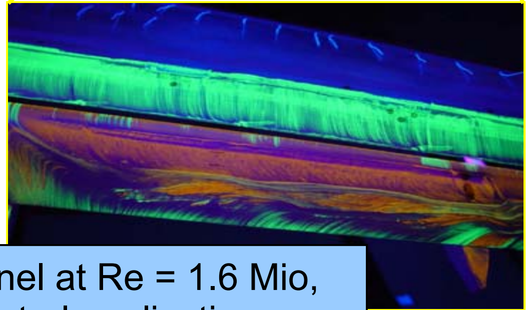
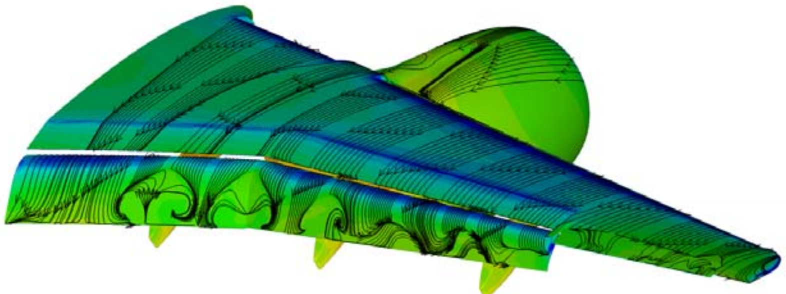
Wind tunnel test on flap – basic flow (without FC)

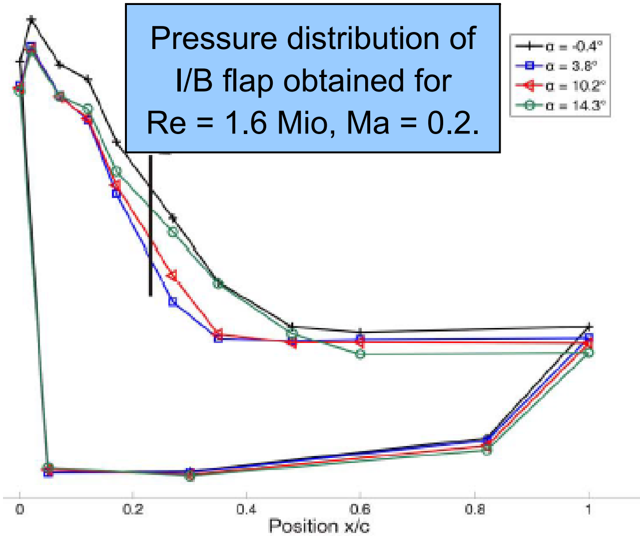




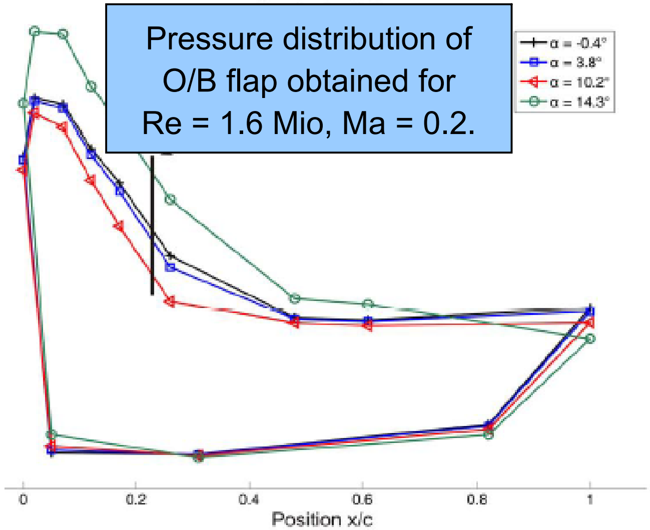
3D industrial model in wind tunnel at Re = 1.6 Mio, Ma = 0.2 design for flow control applications
Left: wind tunnel model; Right: Oil flow visualisations.



Comparable CFD simulations:
Re = 1.6 Mio, Ma = 0.2 , SAO Tu-model:
unsteady calculation, snapshot.



Pressure distribution of I/B flap obtained for Re = 1.6 Mio, Ma = 0.2.



Pressure distribution of O/B flap obtained for Re = 1.6 Mio, Ma = 0.2.

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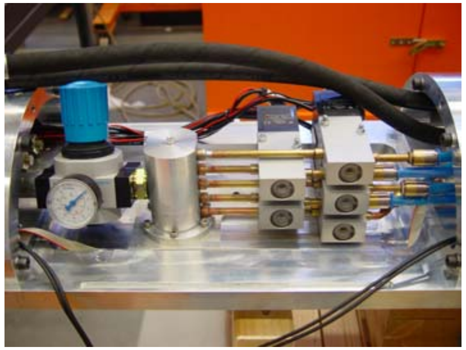
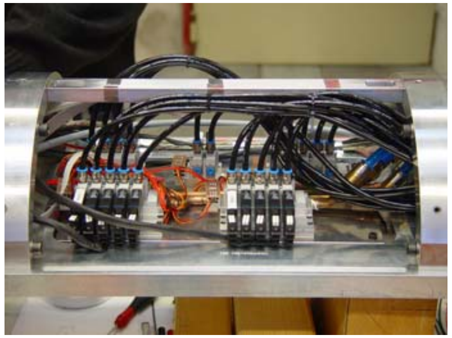
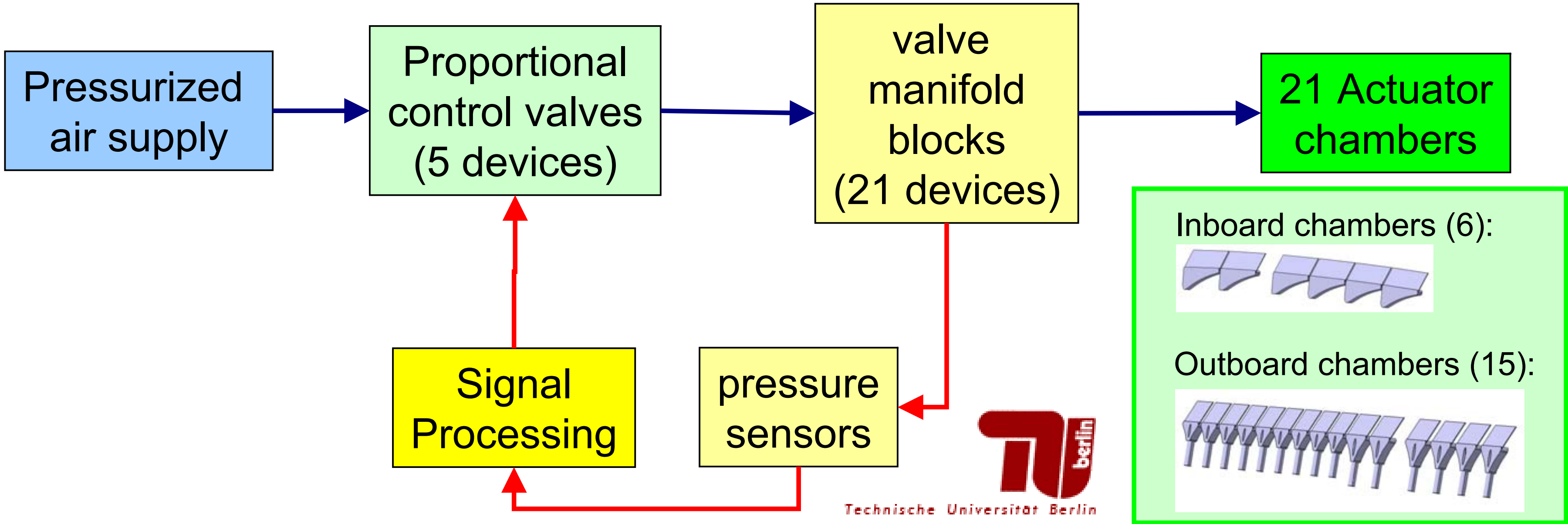
Wind tunnel test – flow control actuator set-up

- Active flow control system scheme







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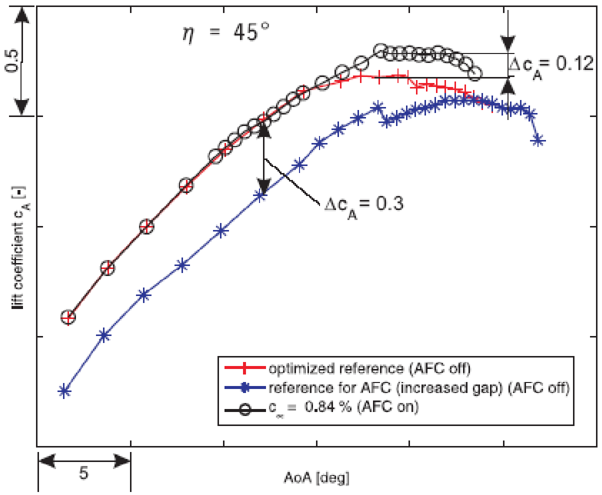
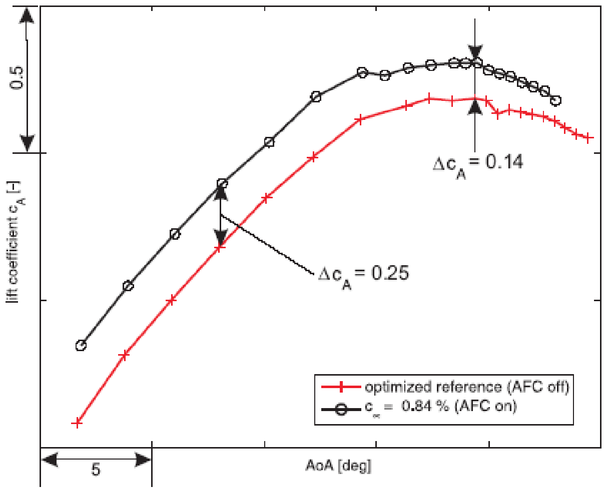
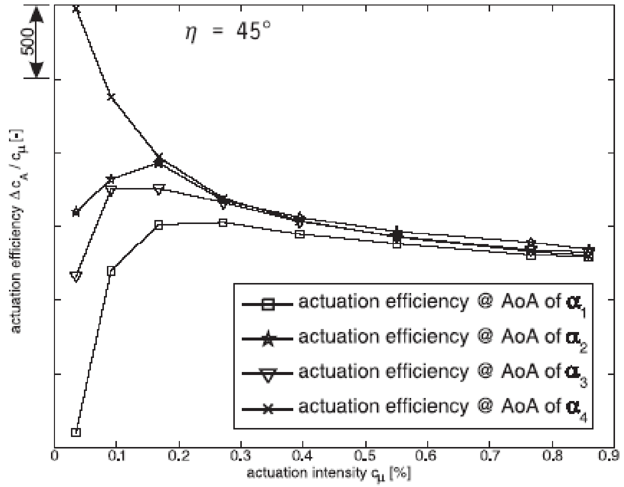
Wind tunnel test on flap with active flow control
Main results

The application of pulsed active flow control on trailing edge device leads to:

- a reattachment of separated flap flow was obtained leads to a significant increase of lift moment.
- an efficient actuation of separated flap flow was achieved also at low mass flow rates, Cμ.
- a defined high lift configuration with active flow control realized an improved performance than a optimised designed high lift configurations without flow control, esp. in the non-linear regime at CL,max.







Conclusions & Outlook

Conclusions

<u>Achieved tasks:</u>

Numerics in R&T:

- CFD Modelling how vorticity is created by control device, how is the interaction with mean flow is investigated.
- Simulation of existence and impact of device by various modelling levels was studied.

Experiments in R&T:

- Pulsed AFC on flap was very successful proved on industrial high lift wind tunnel model configuration
- AFC actuator system were working very efficiently wrt obtained increased aerodynamic performance.

Outlook

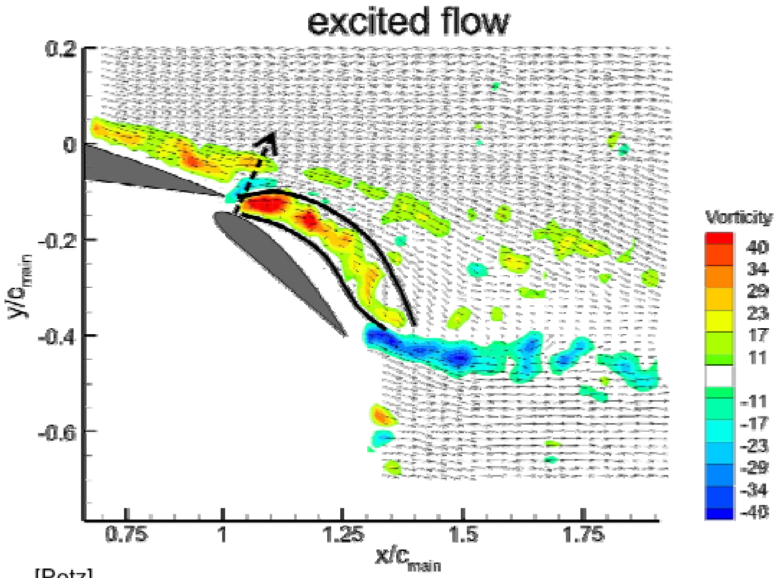
… for numeric in R&T:

- Efficient methods for unsteady flows, higher order methods in space and time.
- Impact of control device on grid generation and solver architecture (e.g. small scale devices have to be spatially, temporally resolved).
- Design oriented modelling of flow control concept via simple RANS based criteria derived from high resolution solutions (DES, LES, DNS) possible ?!

… for AFC experiments in R&T:

- Selection of efficient flow control techniques wrt performance, energy needs, integration, maintenance and flight certification issues.
- Proof of AFC system concepts towards higher maturity.
- Demonstration of AFC on large scale W/T model and towards flight Reynolds numbers.

Thanks
for
your attention!



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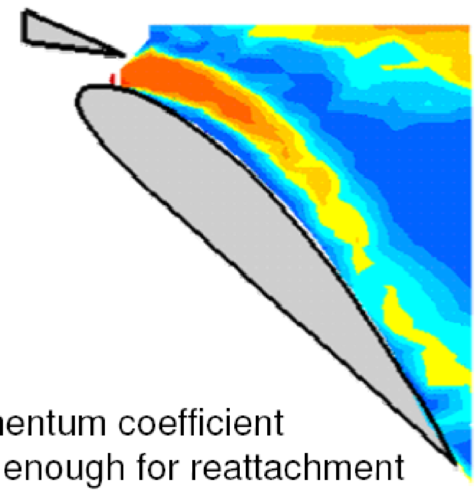

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Enhancement of simple flap systems by delaying flow separation or flow reattachment using periodic excitation from the flap shoulder

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Aerodynamics

Berlin University of Technology
Institute of Aero- and Astronautics
Department of Aerodynamics, Prof. Dr.-Ing. W. Nitsche

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CFD direct Models for low Speed Flow Control Qualification of TAU Tool for AFC on Flat Plate

Topic:

Influence of Turbulence Models

Status quo of development and V&V:

• Impact of turbulence modelling on TAU predictions studied

Momentum coefficient change for different turbulence models at z = const (measure of flow control efficiency)

vs distance from actuation