

Structural Design of a Shock Control Bump for a Natural Laminar Flow Aircraft Wing

Sven Christian Künnecke, Markus Kintscher,
Johannes Riemenschneider

Institute of Composite Structures and Adaptive Systems
German Aerospace Center (DLR)
Brunswick, Germany

SMASIS 2020
15th September 2020



Knowledge for Tomorrow



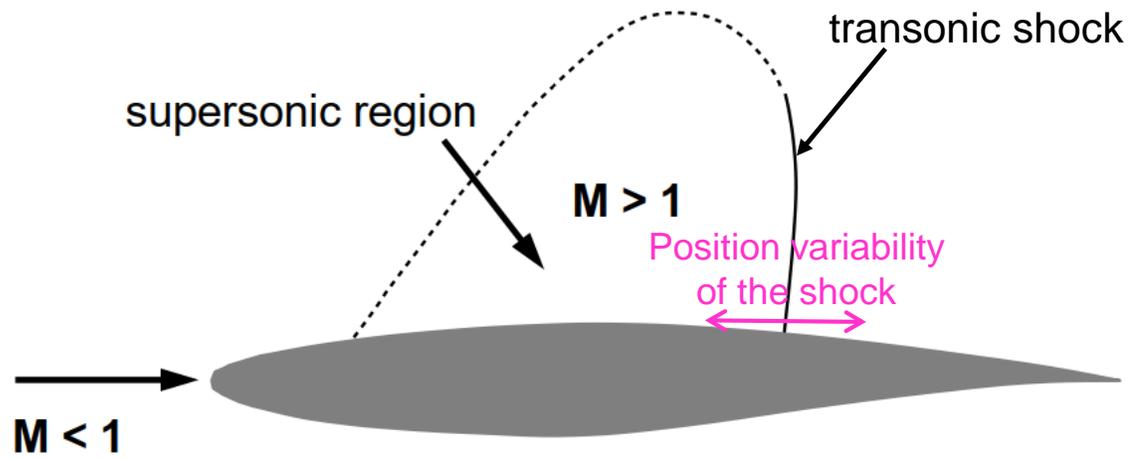
Overview

- Aerodynamic basics of shock control bumps
- Adaptive Spoiler
- Finite Element Simulation
- Conclusion & Outlook

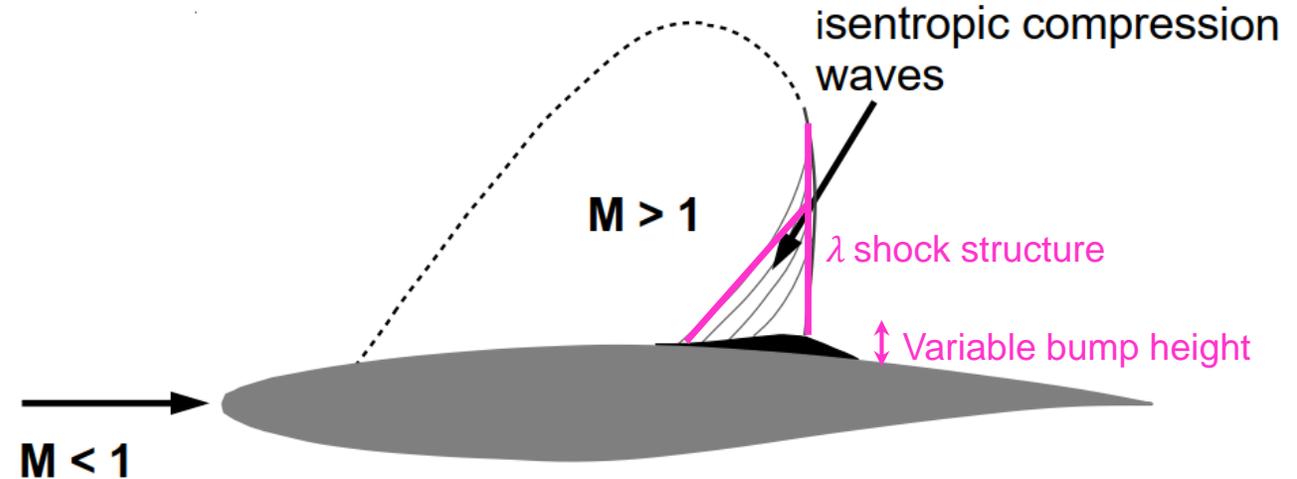


Aerodynamic Background of Shock Control Bumps (SCBs)

Uncontrolled
High wave drag



Controlled (SCB)
Wave drag reduction



→ Adaptive SCB on the spoiler

M: Mach number



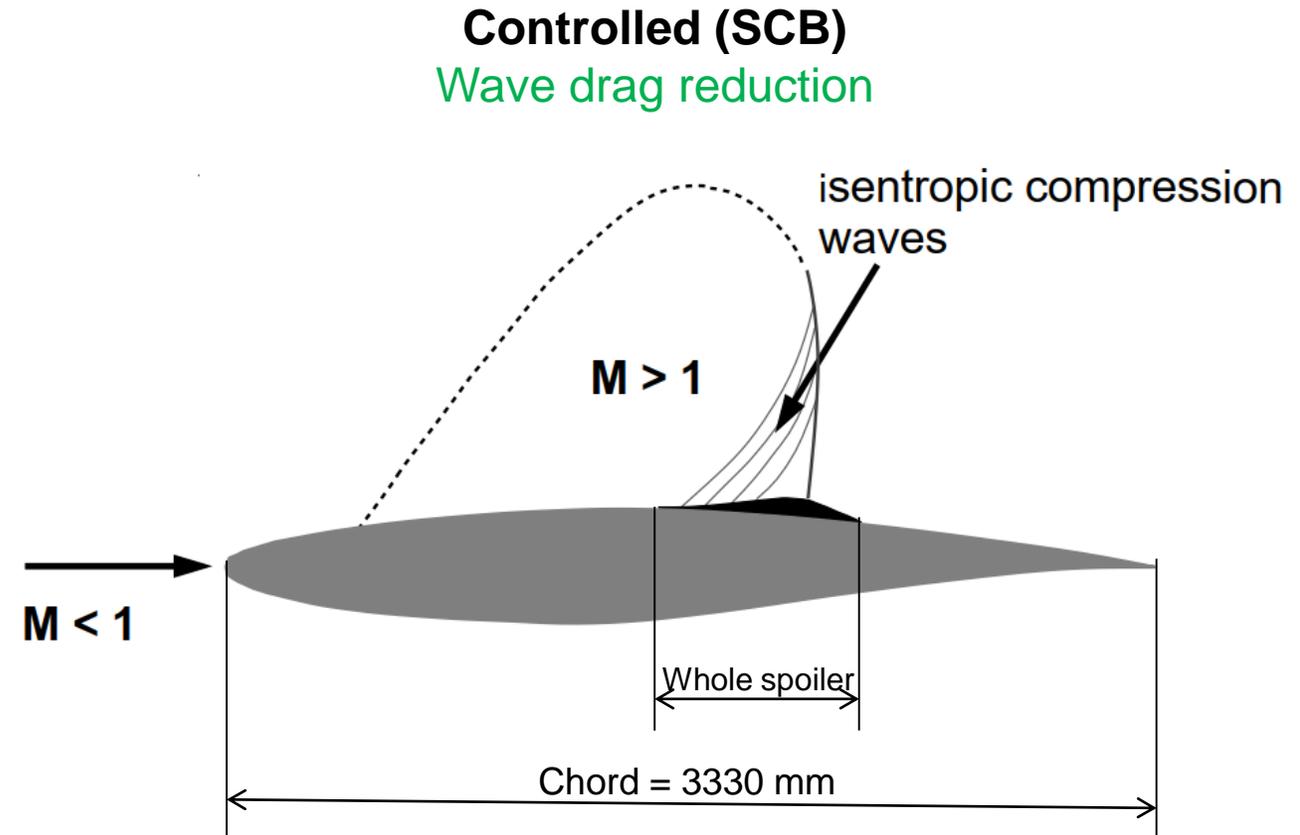
Design Space and Goals

Design of the model:

- Shock location: 60% - 70% chord length
- Spoiler length: 785 mm (~23.6% chord)
- Spoiler span: 1600 mm
- Spoiler skin material: from HexPly M21 prepreg
- Reinforcement core material: Rohacel foam

Goals:

- Bump crest position variation: 10% chord
- Bump height: 0.5% chord
- Contour deviation of max. ± 0.5 mm to clean shape

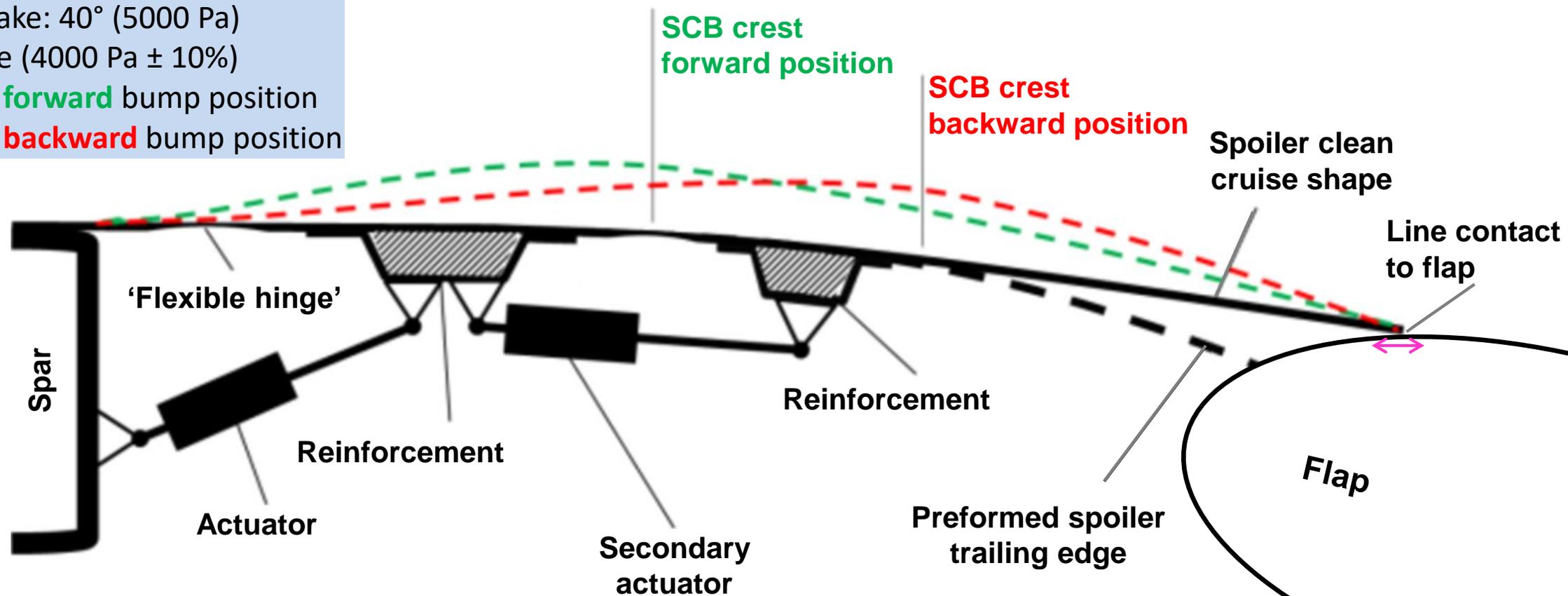


Adaptive Spoiler

Variable in SCB Height and Position

Load cases:

- Airbrake: 40° (5000 Pa)
- Cruise (4000 Pa ± 10%)
- Max. **forward** bump position
- Max. **backward** bump position

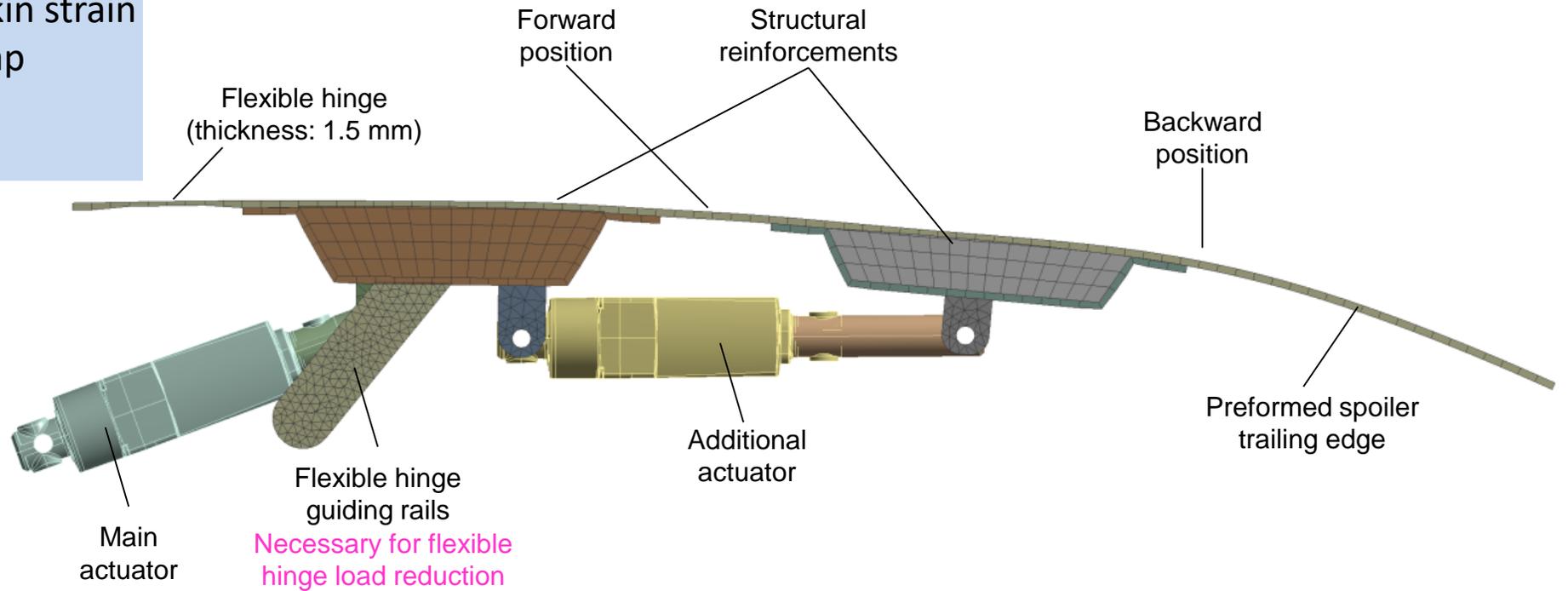


Adaptive Spoiler

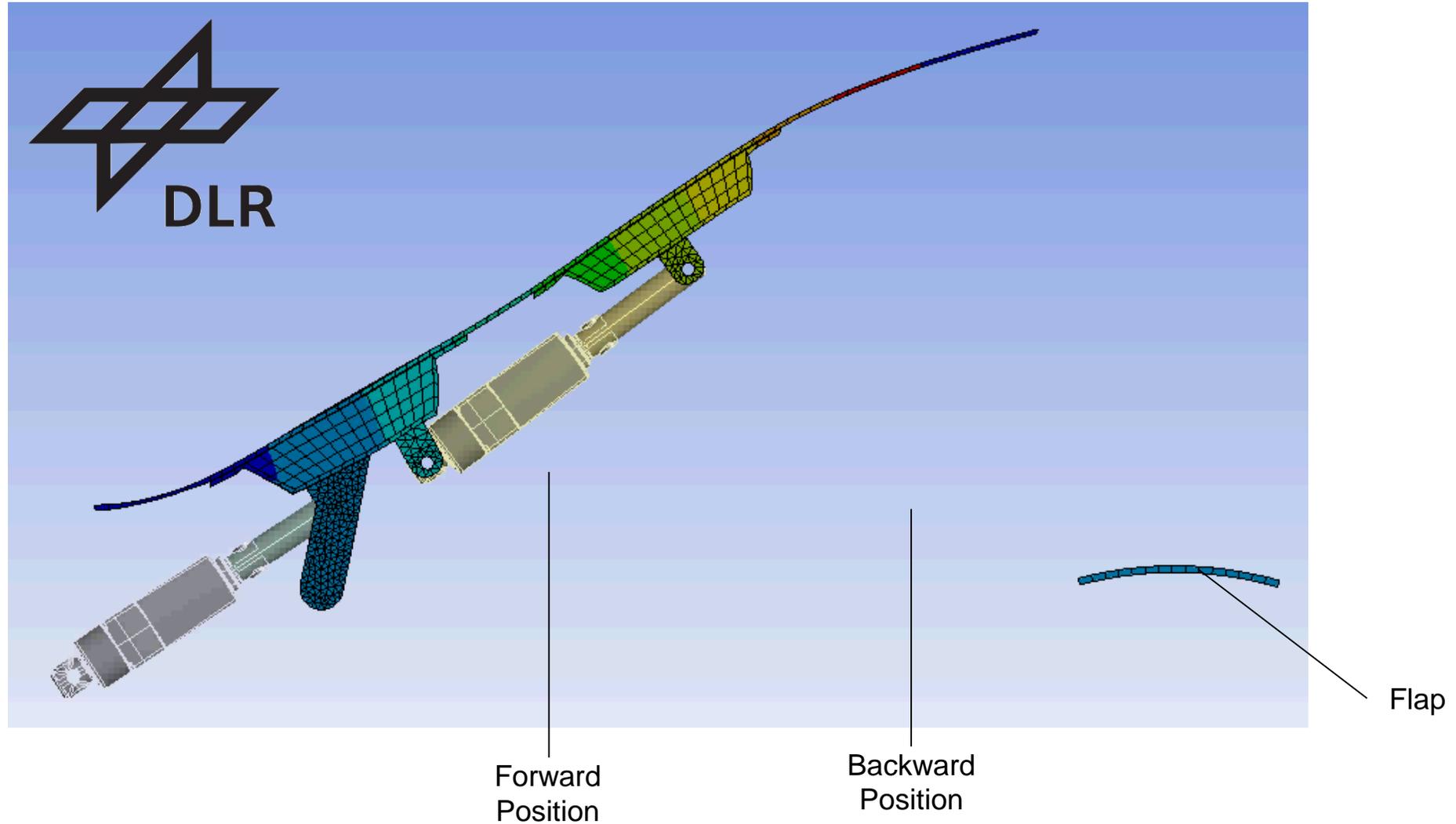
Finite Element (FE) Model

Design drivers:

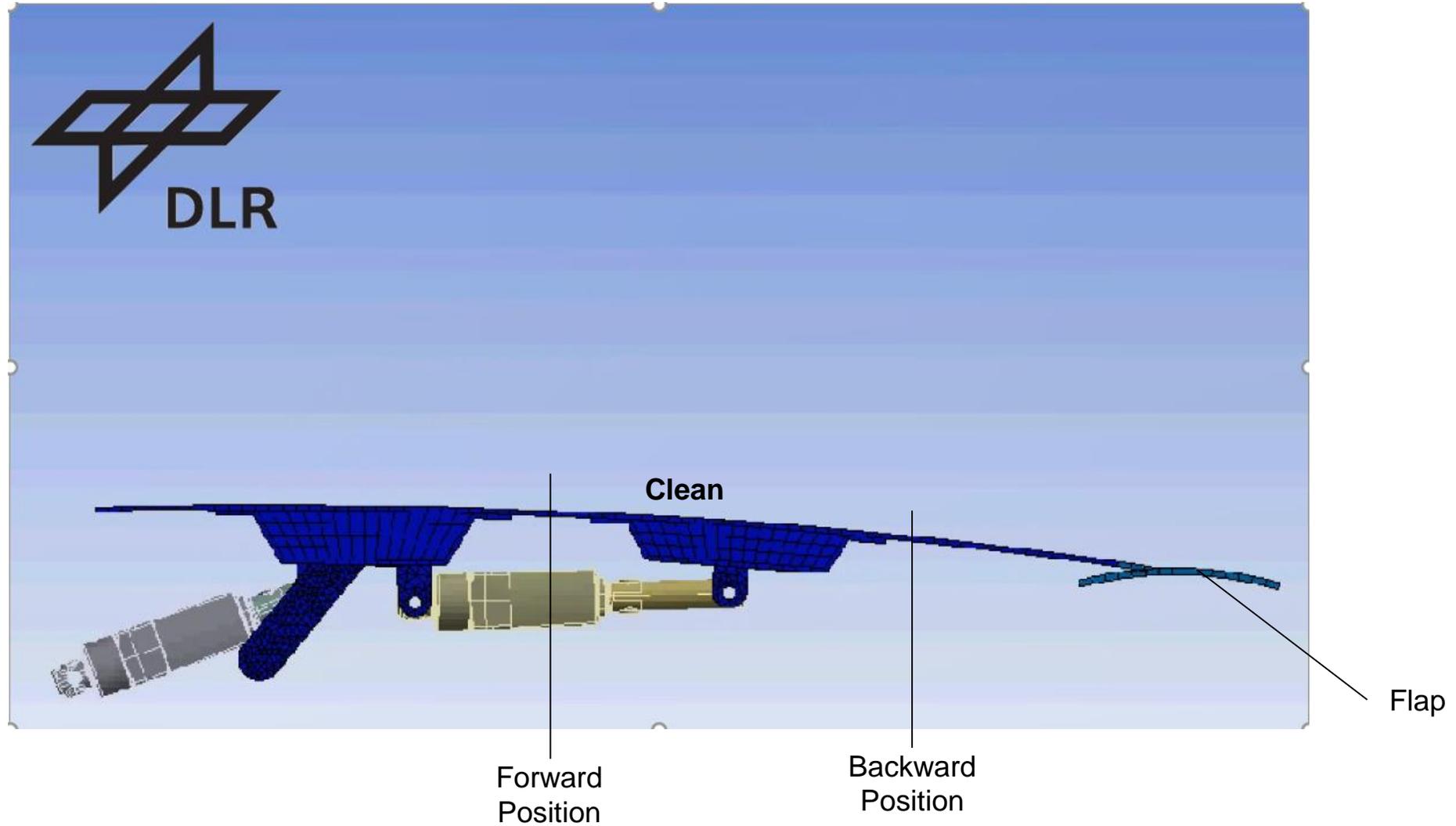
- Allowable structural skin strain
- Contact pressure to flap
- Max. actuator forces
- Available design space



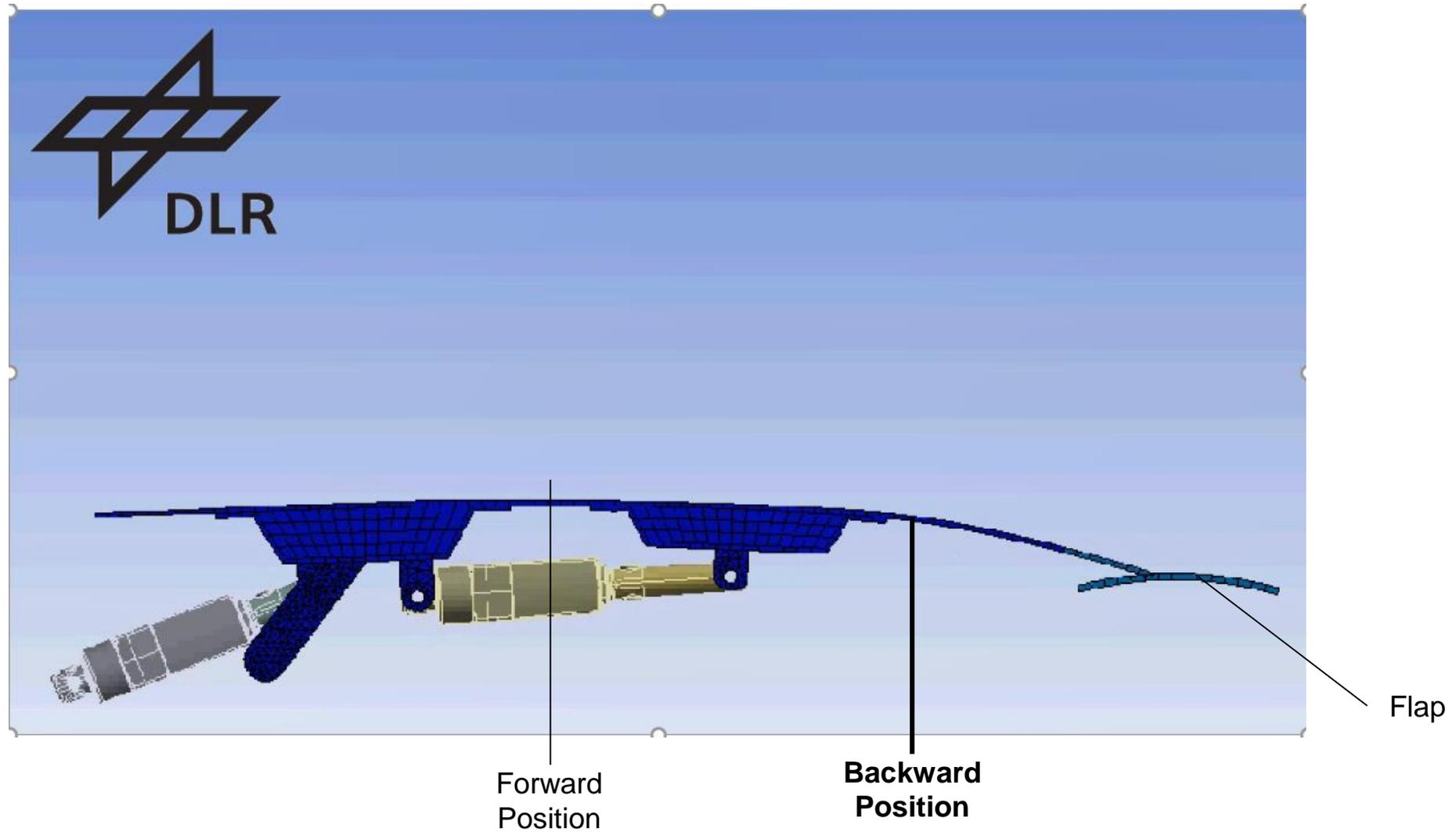
FE Simulation of the Adaptive Spoiler



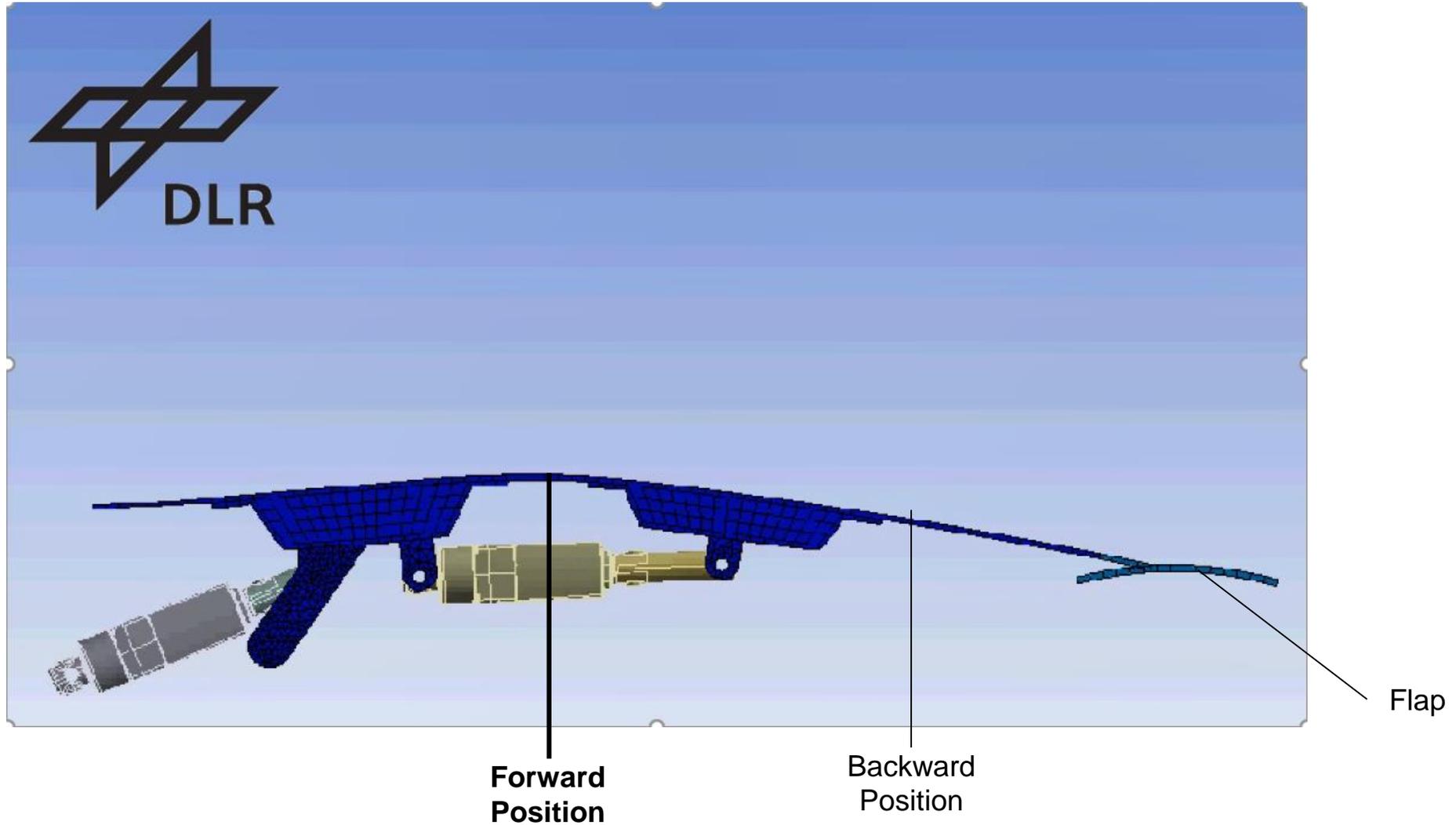
FE Simulation of the Adaptive Spoiler



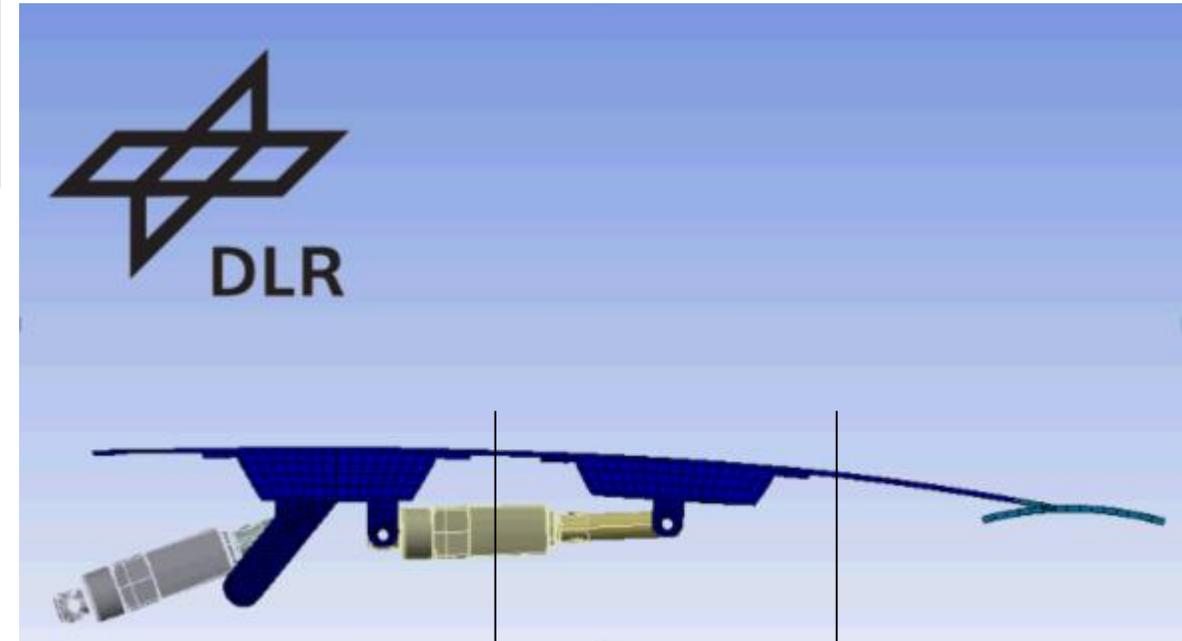
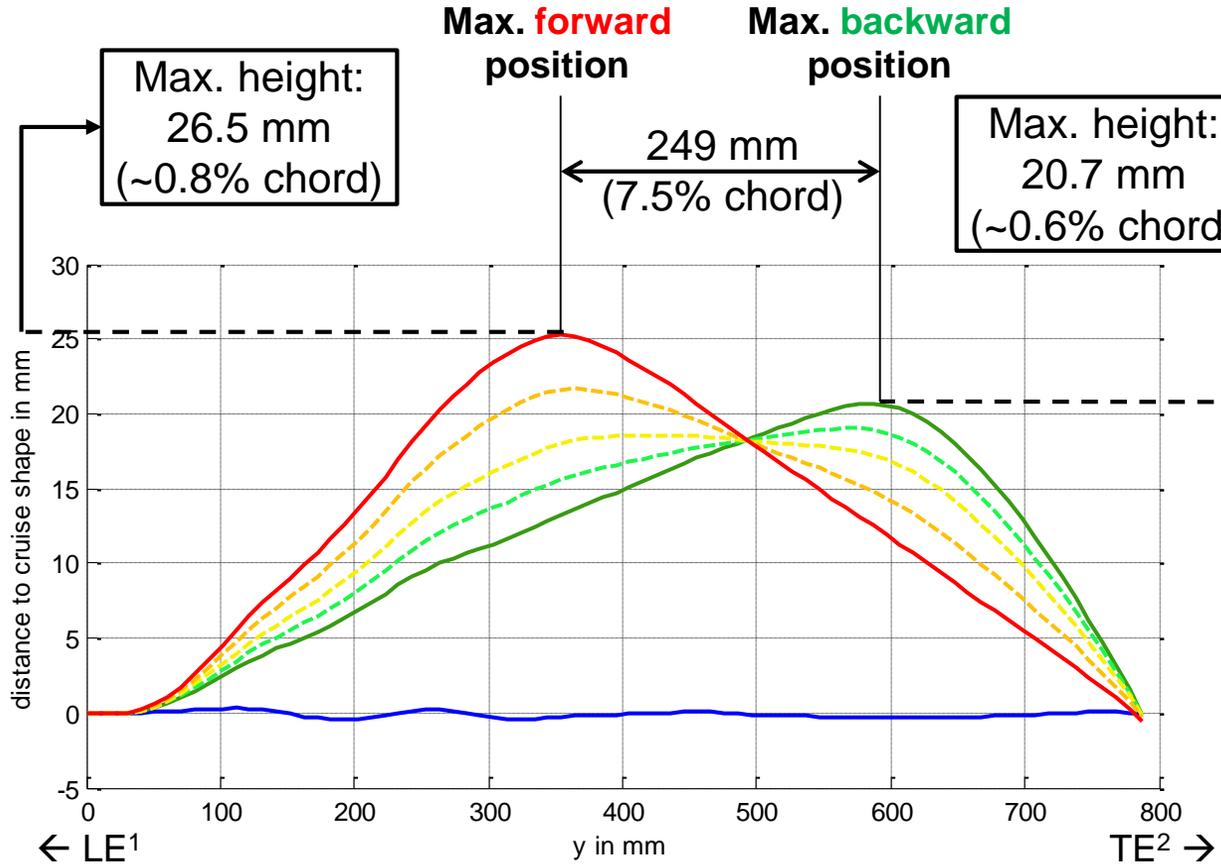
FE Simulation of the Adaptive Spoiler



FE Simulation of the Adaptive Spoiler



Max. Forward & max. Backward Bump Position



Forward Position

Backward Position

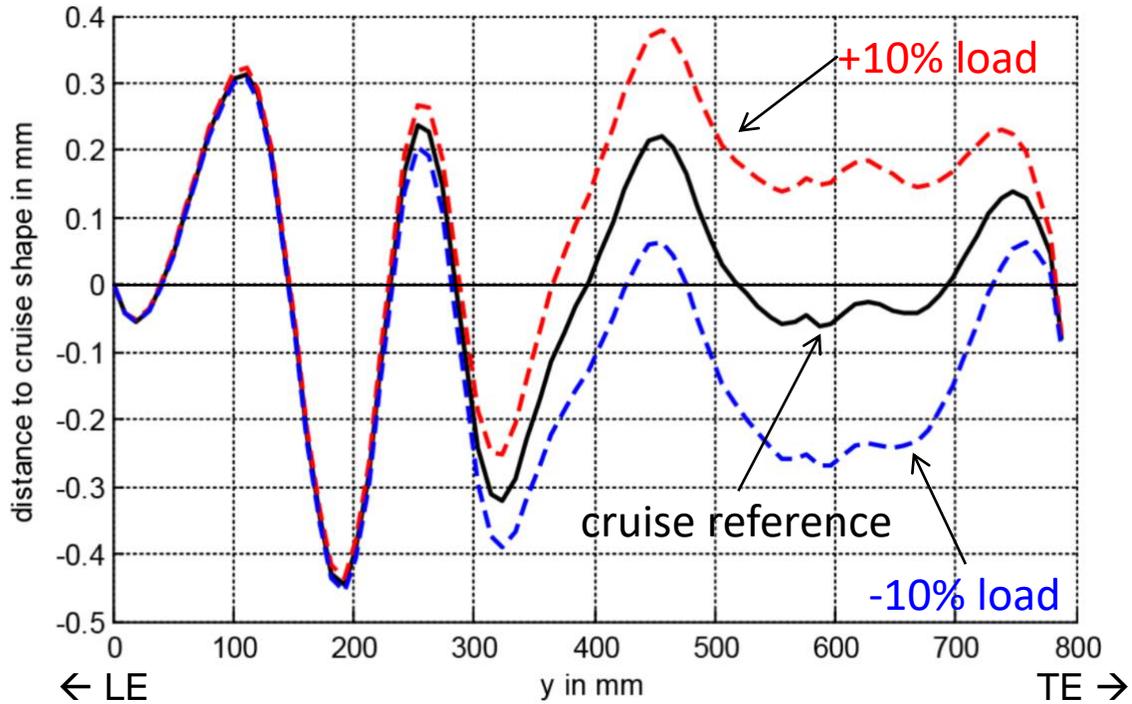
Stronger backward shock requires higher backward bump.



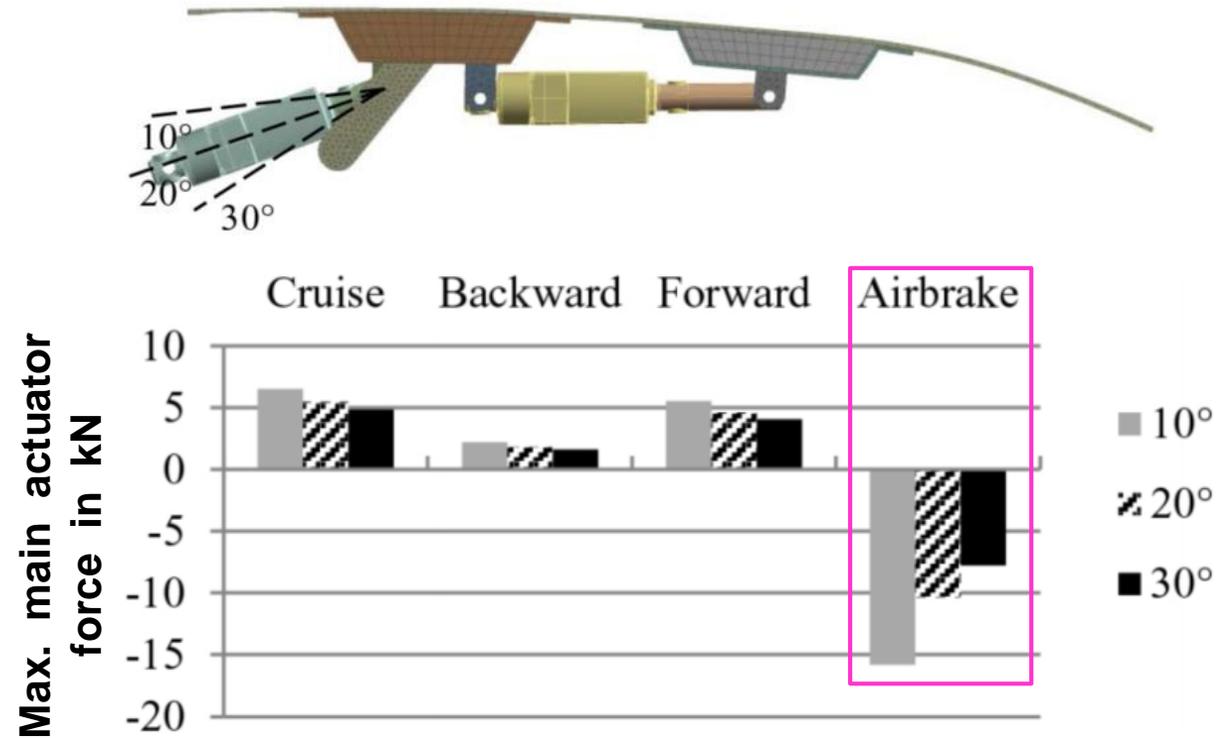
¹LE: Leading edge
²TE: Trailing edge

Simulation Results

Pressure load variation
(Cruise: 4000 Pa \pm 10%)



Main actuator angle variation

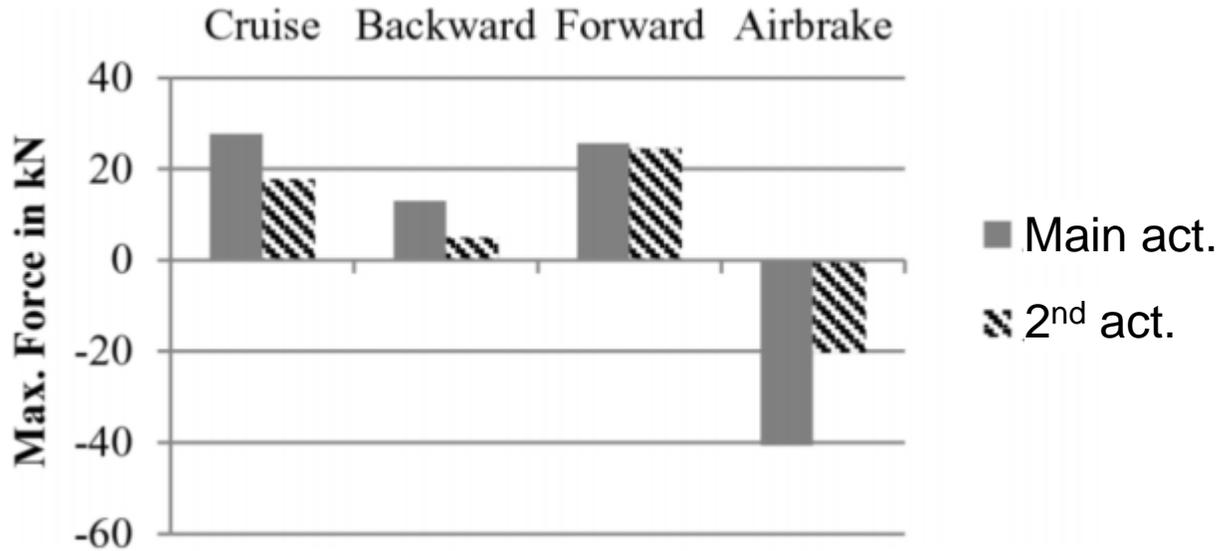


Pressure variation impact on shape deviation
smaller ± 0.5 mm

Not only reducing loads is design driving but also the
limited installation space for higher angles

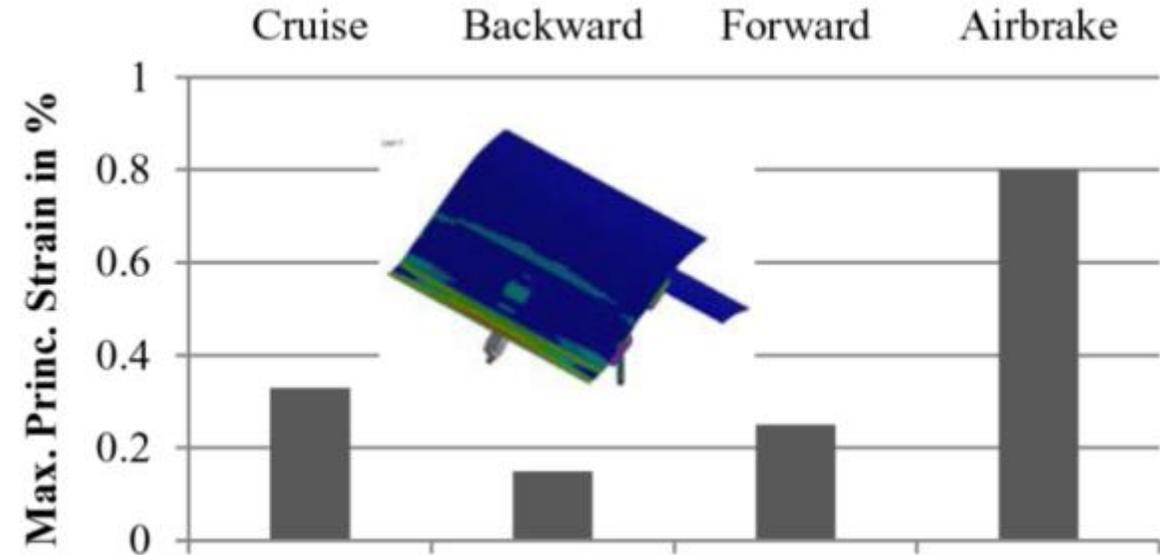
Simulation Results

Aktuator Forces



Max. force 1st actuator: 40 kN Airbrake
 → Smaller than design limit
 Max. force 2nd actuator: 20 kN Airbrake
 Max. forces cruise & bump: 25 – 27 kN

Structural Strain



Max. principle strain: 0.8% in flexible hinge
 → Challenge



Conclusion & Outlook

- Conclusion:
 - An adaptive spoiler SCB variable in height and position has successfully been designed
 - SCB position variation of about 7.5% chord
 - SCB max. height: 0.6% to 0.8% chord
 - Flexible hinge structure is most critical / challenging part
 - Contour deviations and actuator loads stay within design limitations
- Outlook
 - Aerodynamic analysis of bump shapes
 - Higher position variation ($\geq 10\%$ chord) → e.g. variation of reinforcement positions
 - Backward crest higher than forward crest
 - Reduction of flexible hinge loads (Airbrake)
 - Get rid of guiding devices (will save material and weight but increase flexible hinge loads)
 - Replacement of secondary actuator by a feasible mechanism would save weight



Acknowledgements

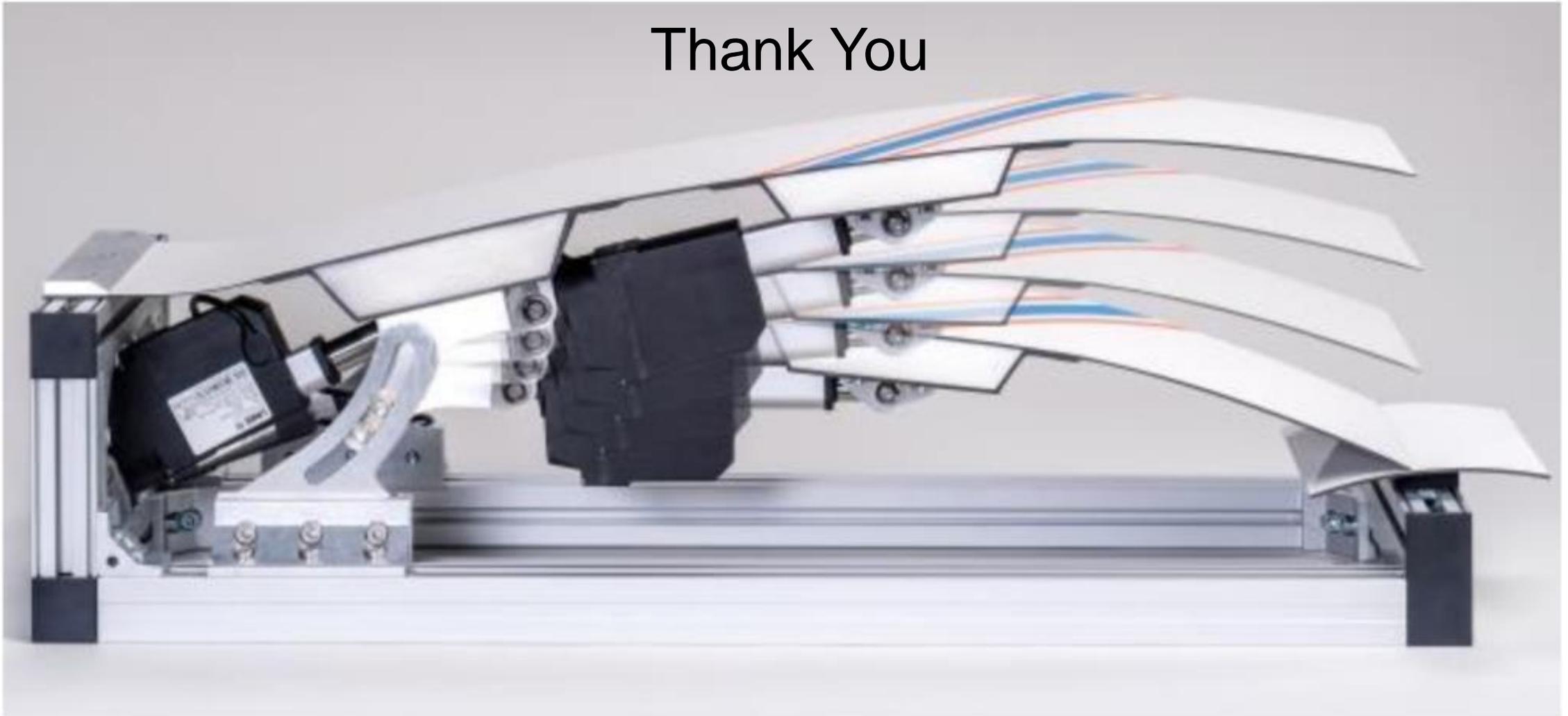
The here presented work has received funding by the federal ministry for economic affairs and energy (BWMi) within the framework of the federal aviation research program, in scope of the LDAinOp¹ project (FKZ: 20A1302B).

Special thanks M. Kintscher (DLR) who created this spoiler model in collaboration with S. Bauss, W. Machunze and J. Kirn from Airbus.

¹LDAinOP: Low Drag Aircraft in Operation



Thank You



Sources

- [1] A. Sommerer, T. Lutz, and S. Wagner, “Numerical optimisation of adaptive transonic airfoils with variable camber,” presented at the Proceedings of the 22nd ICAS Congress, Harrogate, UK, Sep. 2000.
- [2] M. Kintscher and H. P. Monner, “Structural Concept of an Adaptive Shock Control Bump Spoiler,” in SAE International, Sep. 2017, pp. 2017-01–2164, doi: 10.4271/2017-01-2164.

