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

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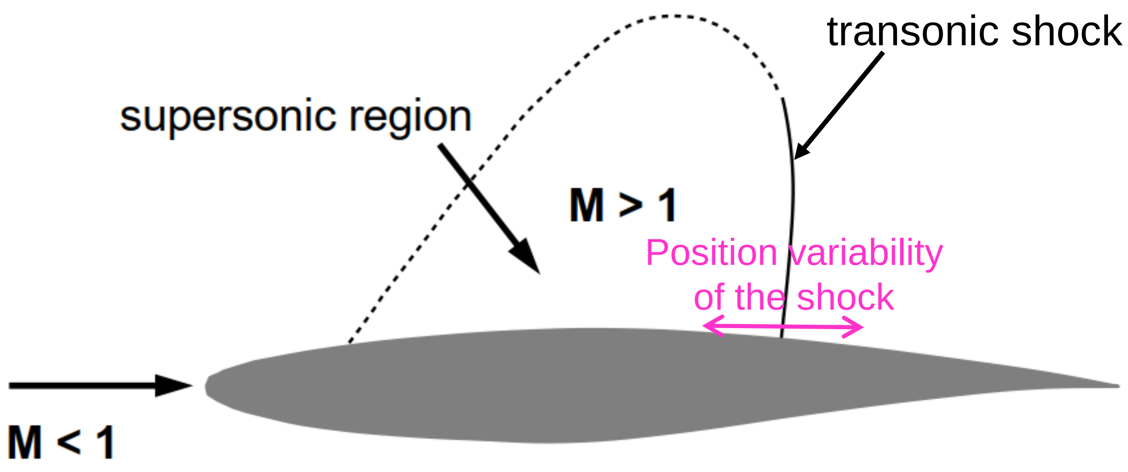
Overview

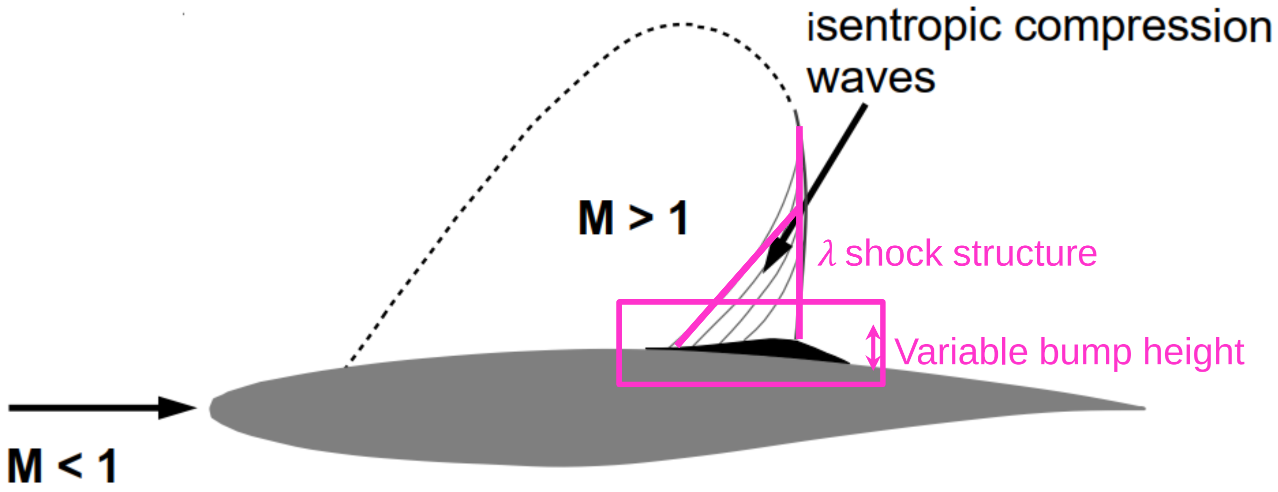
- Aerodynamic basics of shock control bumps
- Adaptive Spoiler
- Finite Element Simulation
- Conclusion & Outlook

Aerodynamic Background of Shock Control Bumps (SCBs)

Uncontrolled
High wave drag



Controlled (SCB)
Wave drag reduction



→ Adaptive SCB on the spoiler

M: Mach number

[1]

Design Space and Goals

Design of the model:

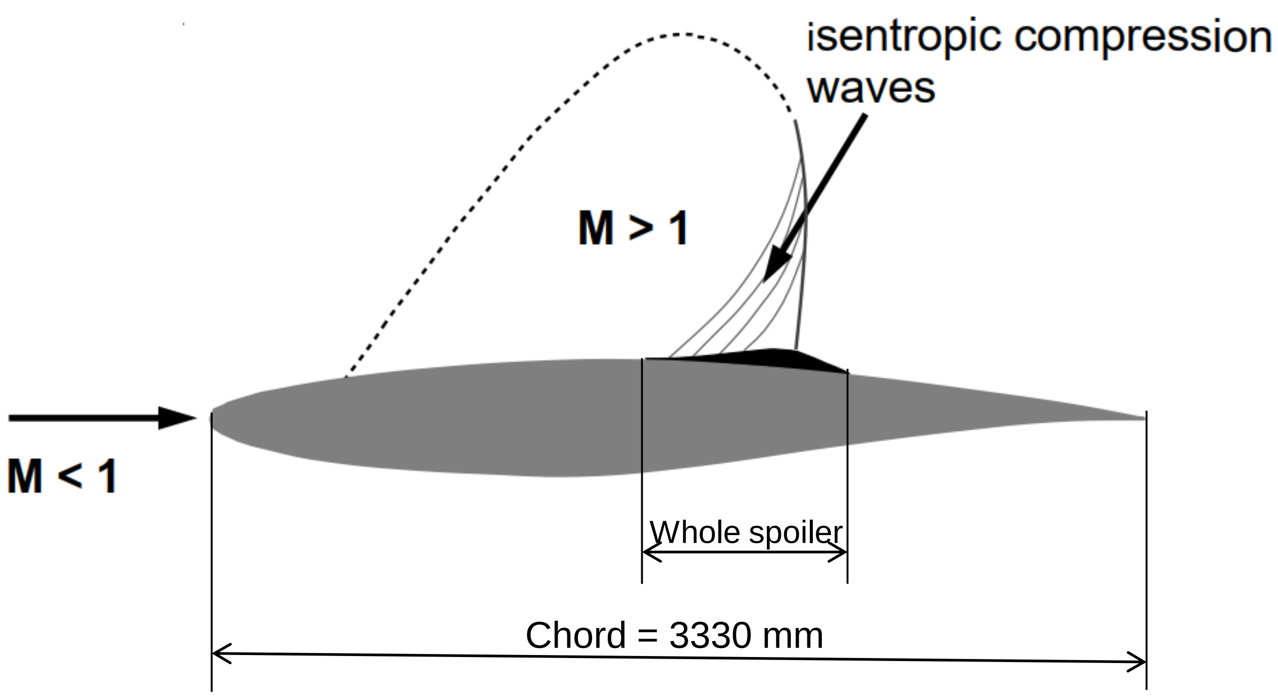
- Shock location: 60% - 70% chord length
- Spoiler length: 785 mm (~23.6% chord)
- Spoiler span: 1600 mm
- Spoiler skin material: from HexPly M21 prepreg
- Reinforcement core material: Rohacel foam

Goals:

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

Controlled (SCB)

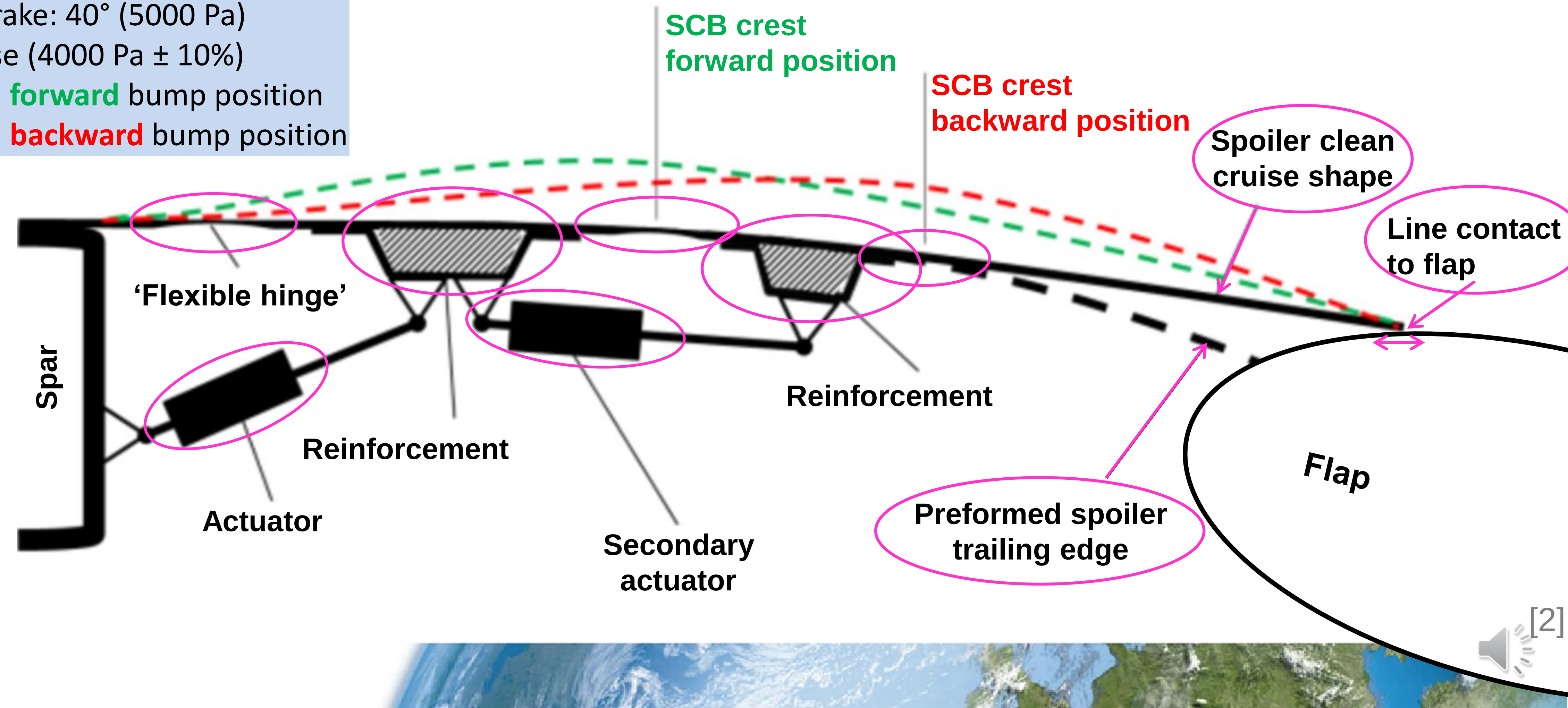
Wave drag reduction



[1]

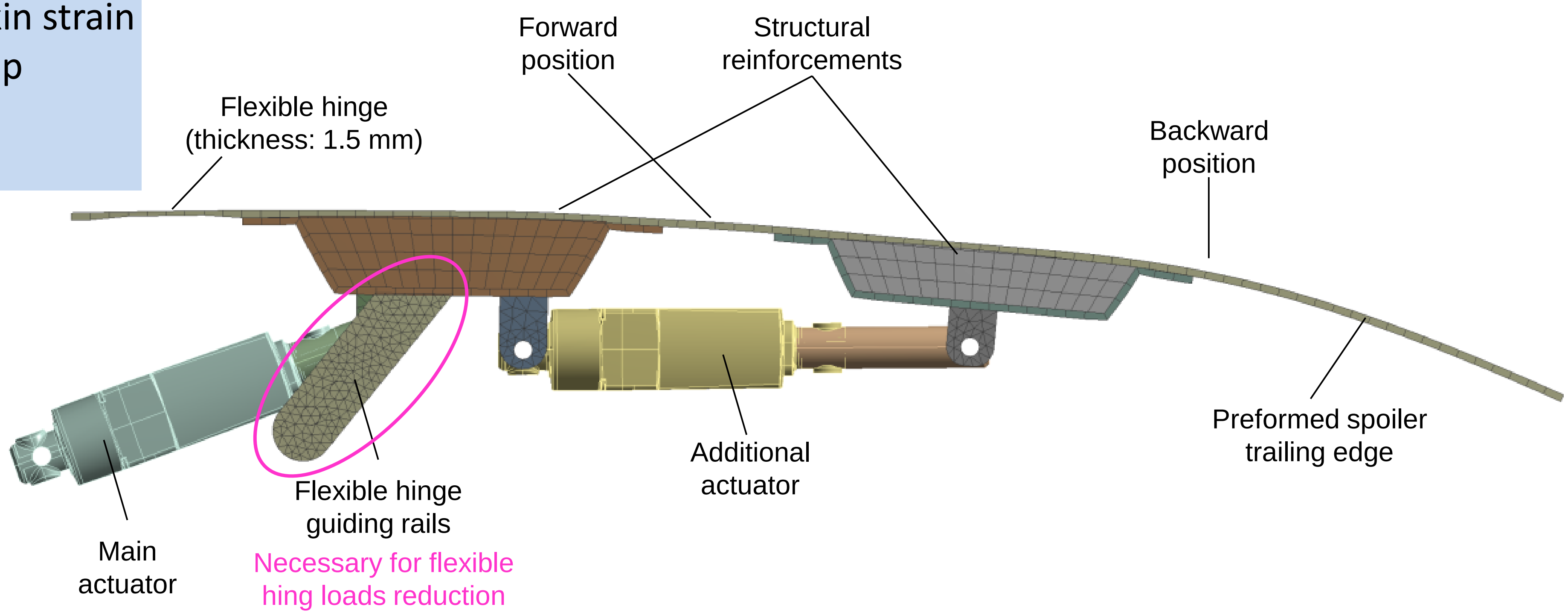
Adaptive Spoiler
Variable in SCB Height and Position

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

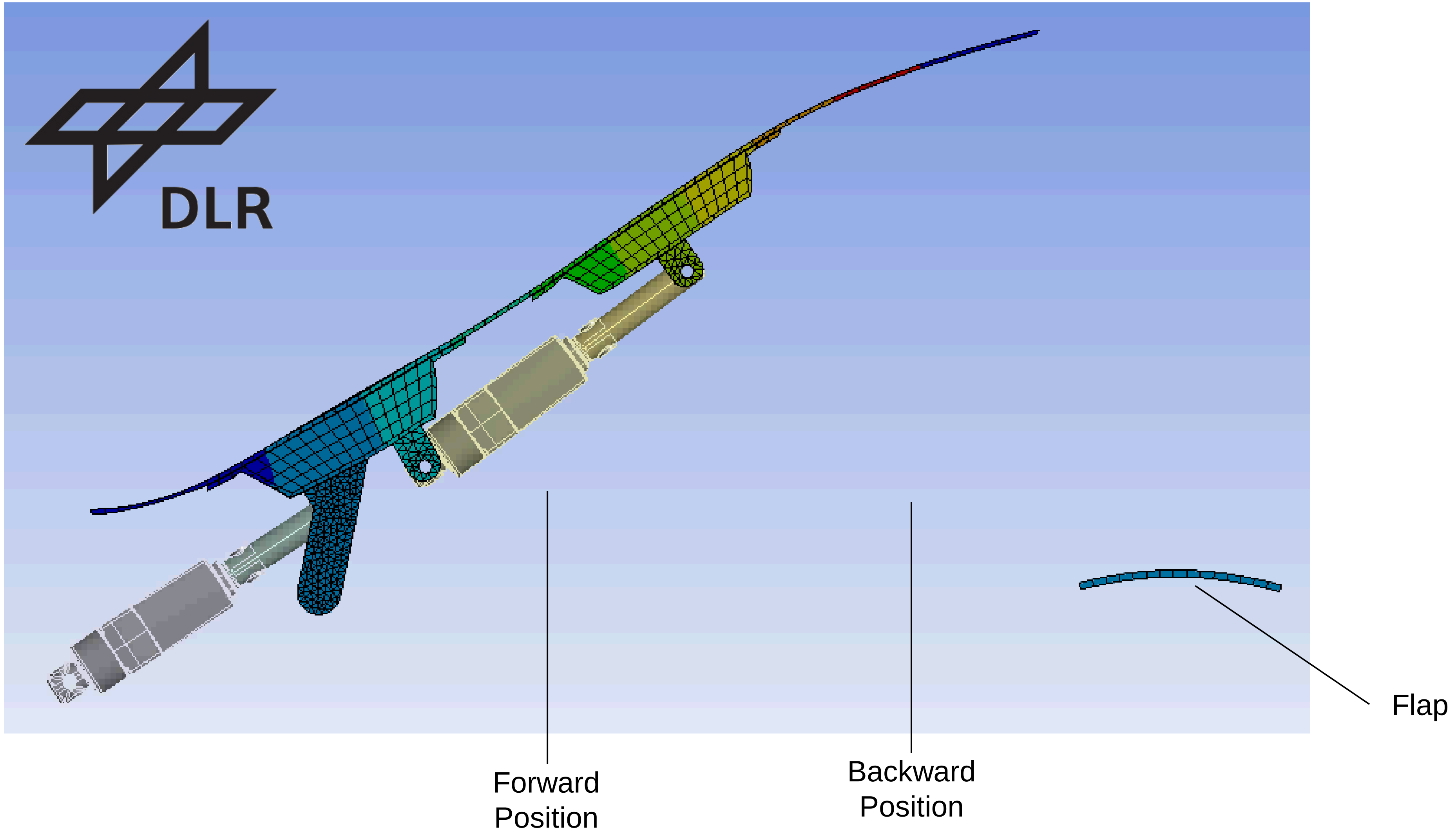


Adaptive Spoiler
Finite Element (FE) Model

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

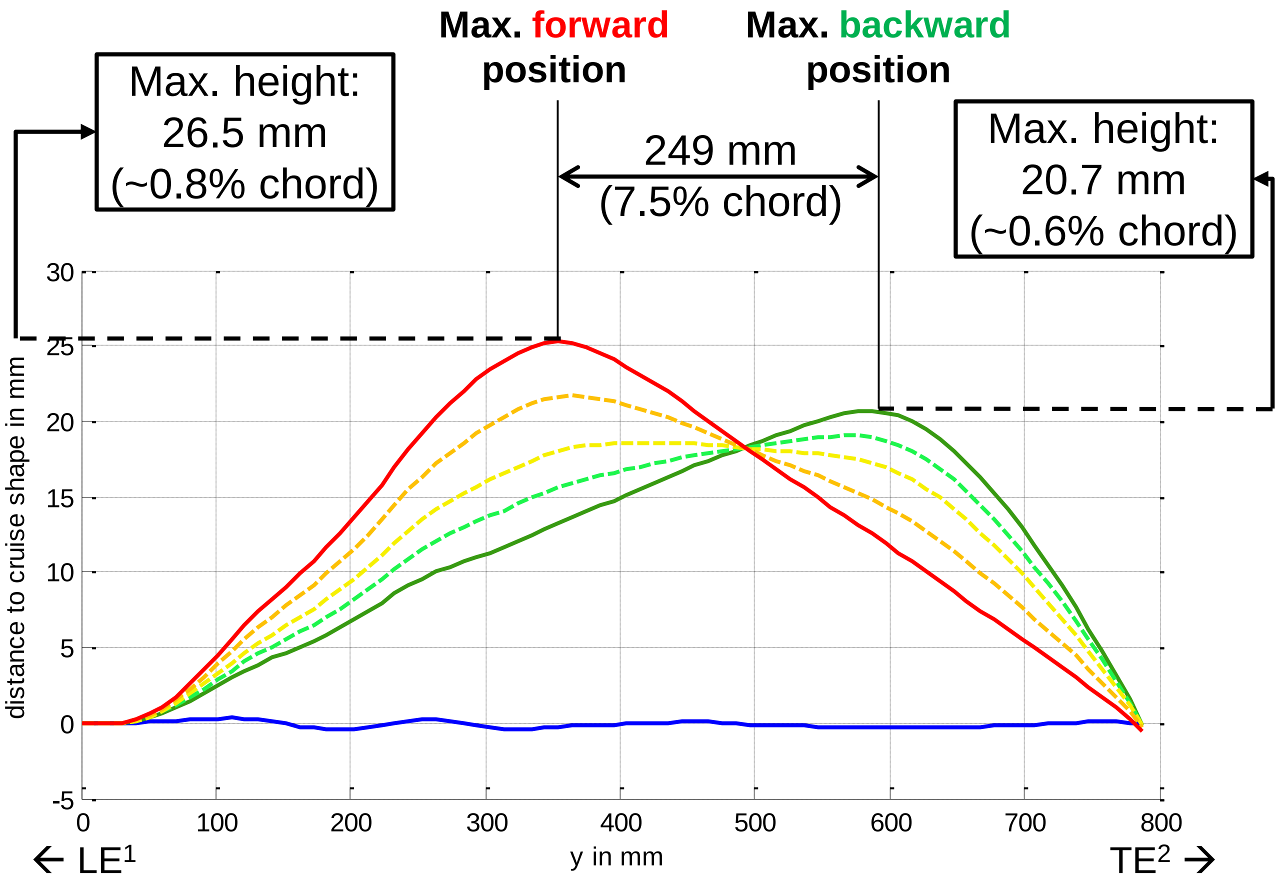


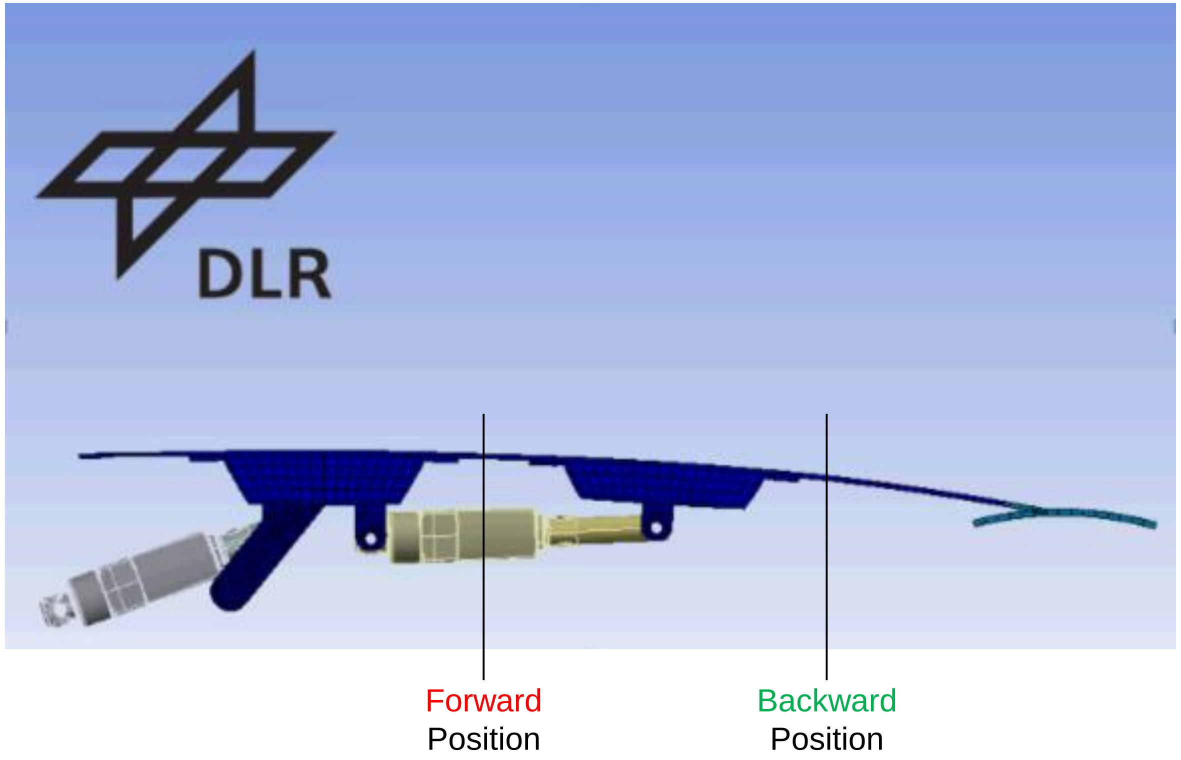
FE Simulation of the Adaptive Spoiler



[2]

Max. Forward & max. Backward Bump Position





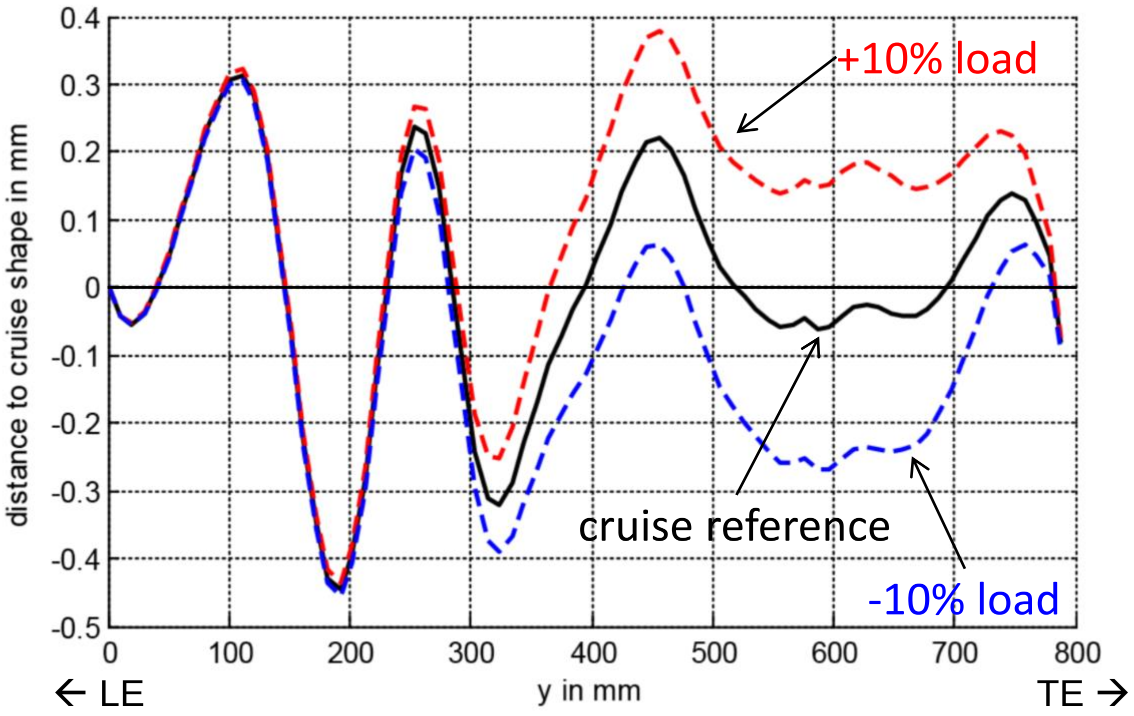
Stronger backward shock requires higher backward bump.

[1]LE: Leading edge
[2]TE: Trailing edge

[2]

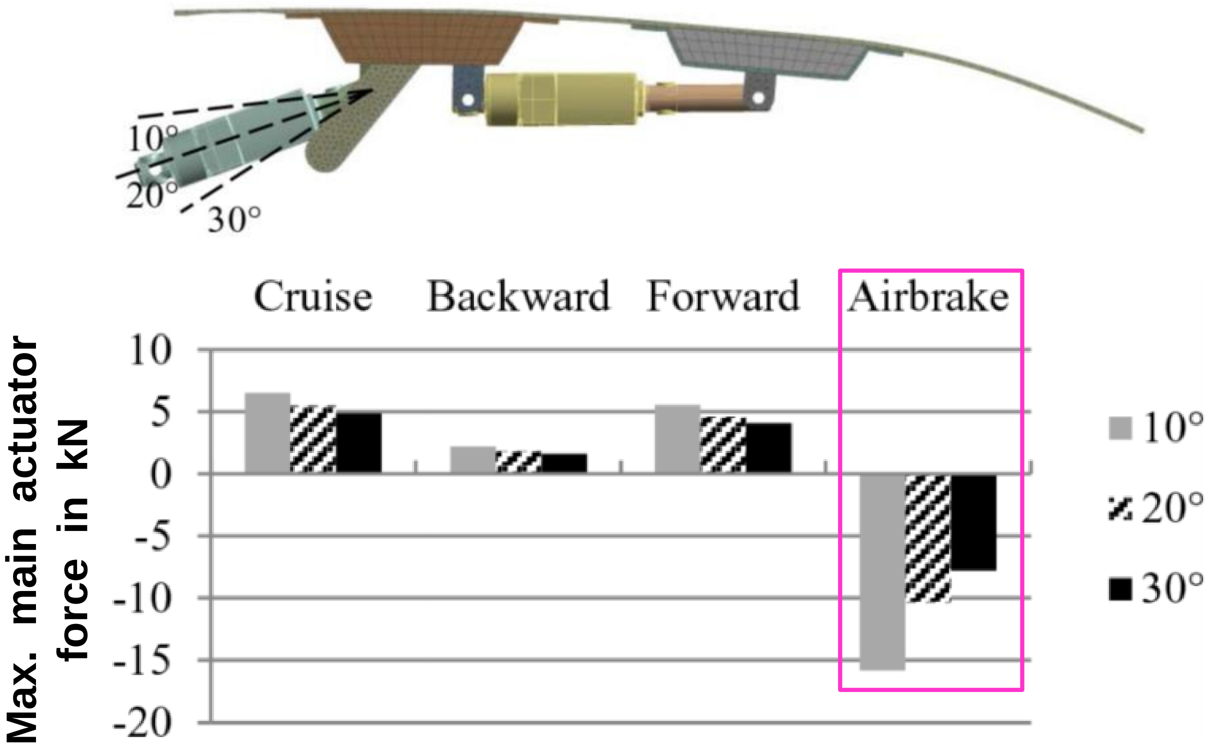
Simulation Results

Pressure load variation
(Cruise: 4000 Pa ±10%)



Pressure variation impact on shape deviation smaller ±0.5 mm

Main actuator angle variation

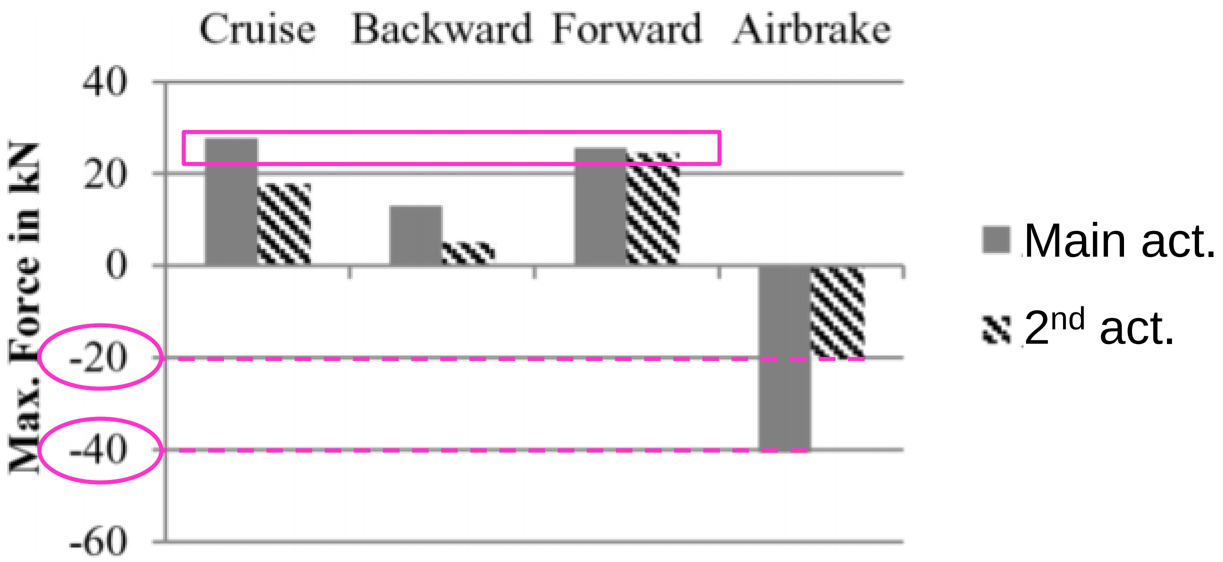


Not only reducing loads is important but also the limited installation space for higher angles

[2]

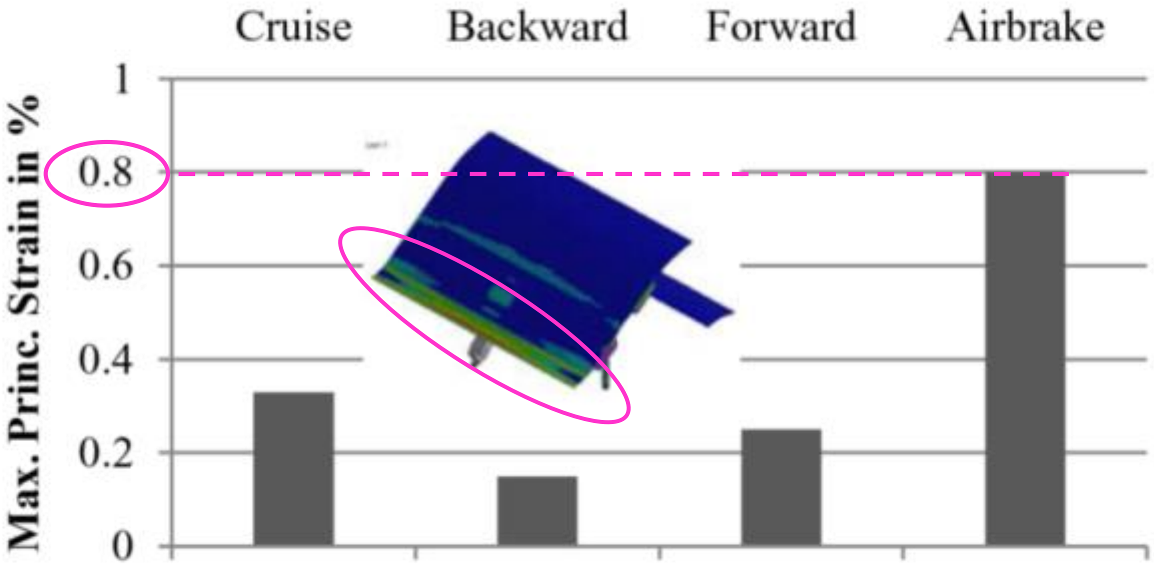
Simulation Results

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

[2]

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 (≥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 LDAinOp[1] project (FKZ: 20A1302B).

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[1]LDAinOP: 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.