SELECTIVELY DEFORMABLE STRUCTURES FOR DESIGN OF ADAPTIVE WING SMART ELEMENTS AS PART OF ACTIVE AEROELASTIC WING CONCEPT

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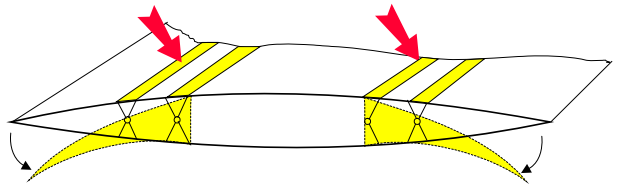
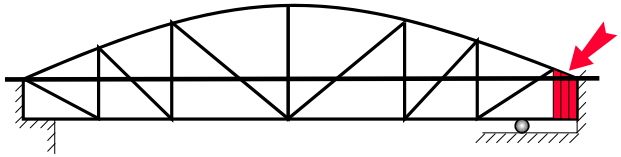
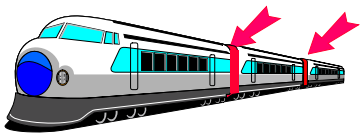
Some Applications of Selectively Deformable Structures - SDS



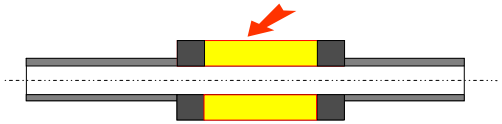
Adaptive wing



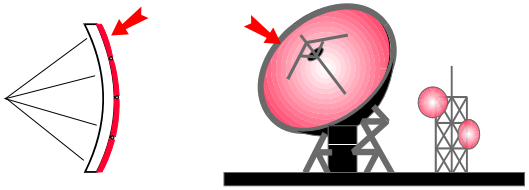
Temperature compensators for bridges; slotless joints in concrete highways



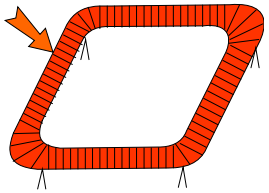
Wagons of train slotless connection; damping structure



Temperature compensators for pipelines

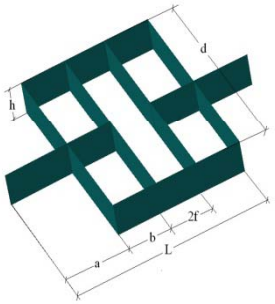


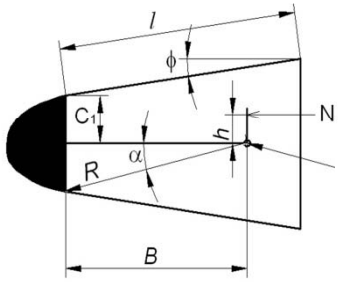
Adjustable projection-screens and aerials



Conveyer belt

Smart Leading Edge based on SDS - Structure





rotation center

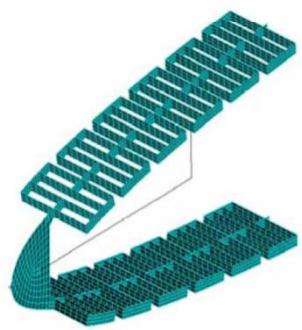
The cell tension-compression stiffness and bending stiffness of the cell supporting elements:

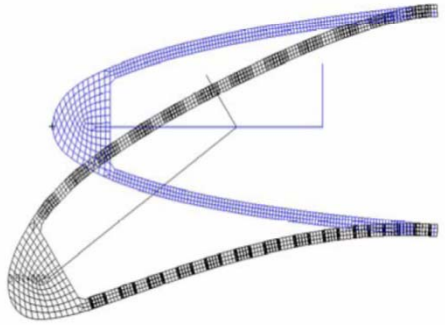
$$\frac{U}{P} = \frac{d^3}{16EJ}\left(\frac{1}{3} - \frac{bd}{D} - \frac{d^2}{2D}\right) \qquad EJ = \frac{Eh^3t}{12}$$

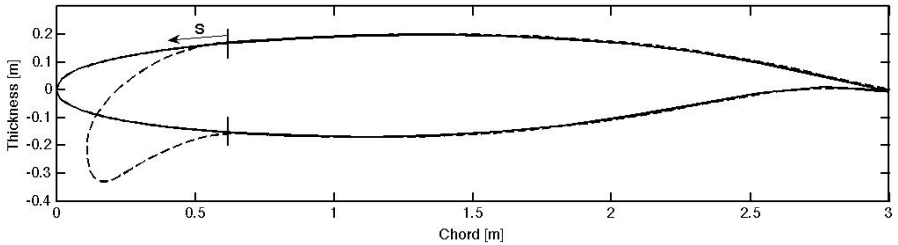
Bending stiffness of the cell:

$$\frac{\varphi}{M} = \frac{1}{EJ}\left(\frac{a}{2} + \frac{d^3}{24b^2} + \frac{L}{4}\right)$$

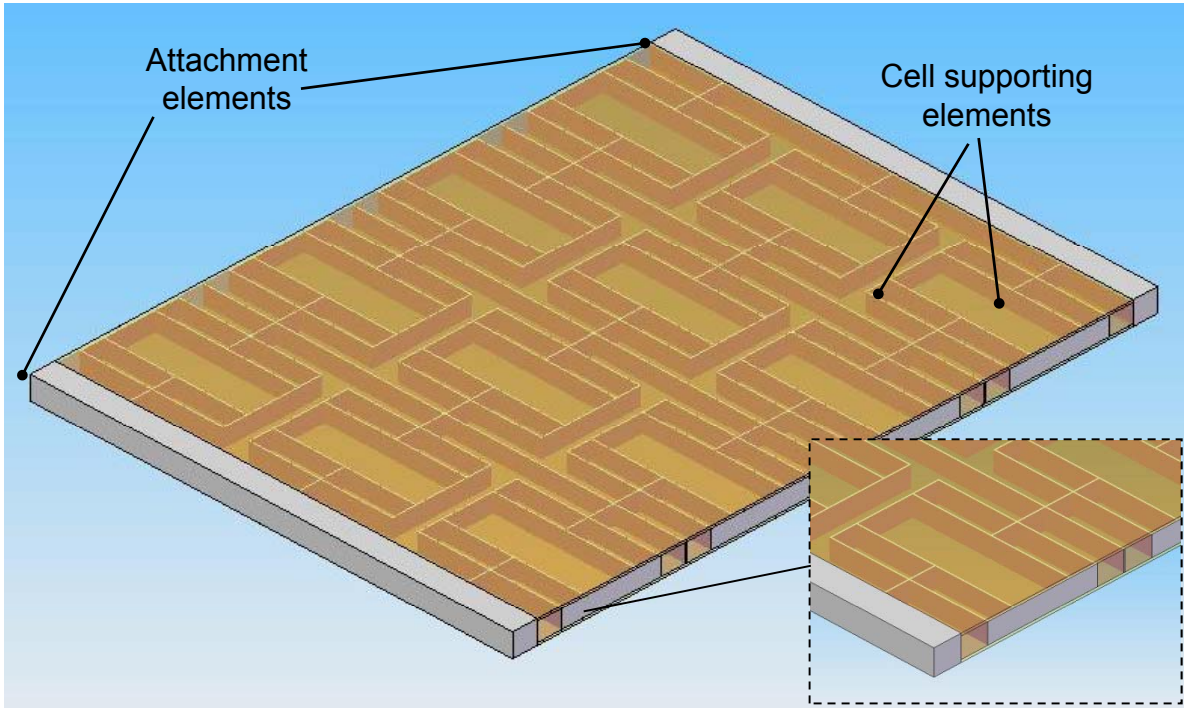
φ is the angle of rotation of the section under the moment *M*.







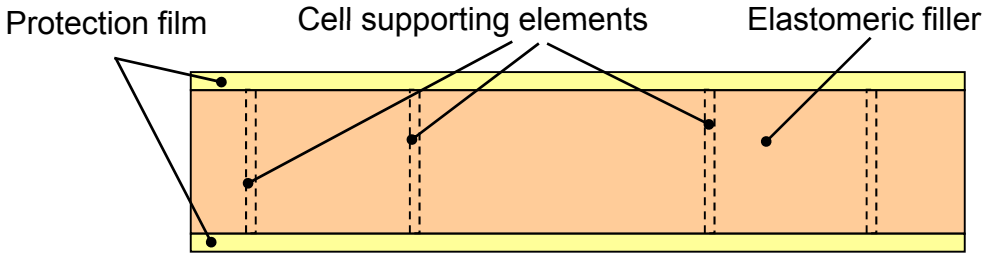
Panel of Adaptive Wing Element

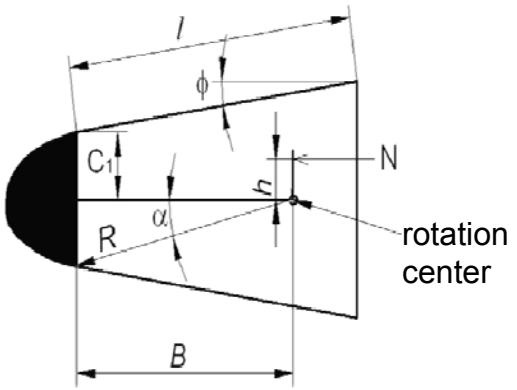


Force *N*, required for turn of a rigid nose of a profile on the angle φ:

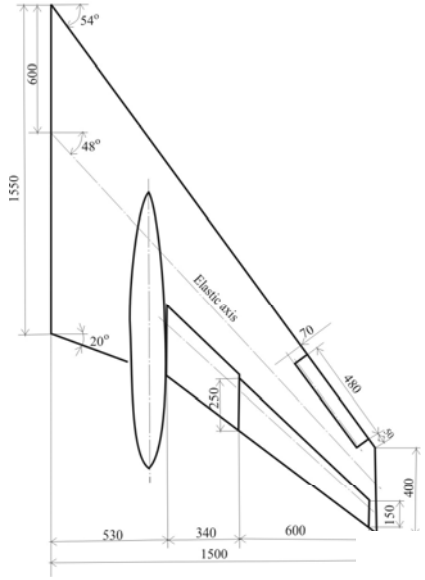
$$N \approx \frac{R\gamma}{h}\left\{K_t \cos(\beta)\left(\frac{C_1}{\operatorname{tg}\varphi}+B\right)\sin\varphi + \right.$$

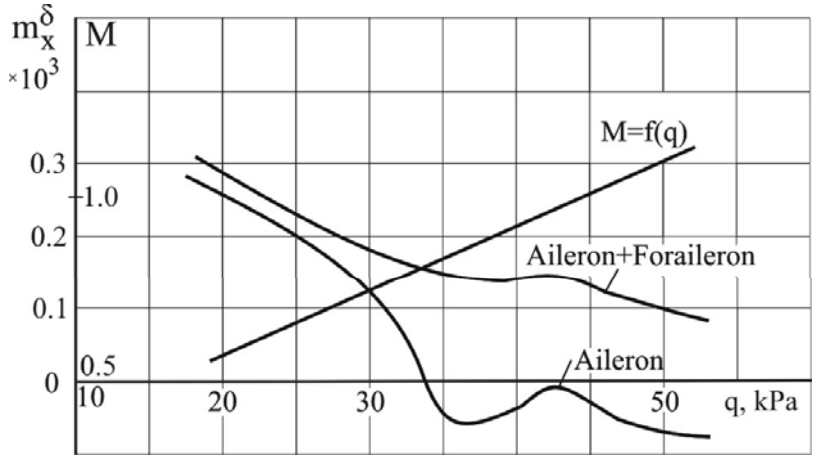
$$\left. + \frac{3K_b \sin\beta}{l^3}\left[\left(\frac{C_1}{\operatorname{tg}\varphi}+B\right)\cos\varphi - \frac{C_1}{\cos^2\varphi}\right]\right\}$$



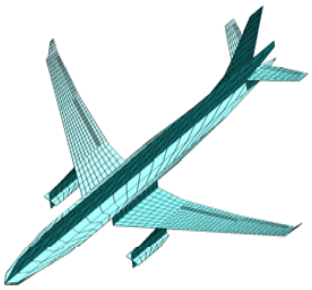


Active Aeroelasticity Concept; multidisciplinary Approach

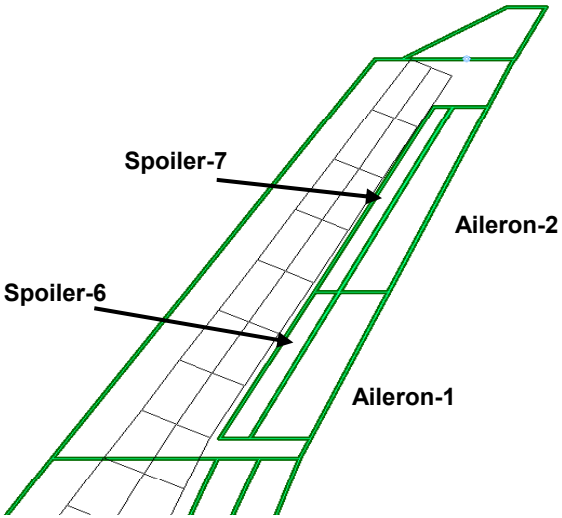


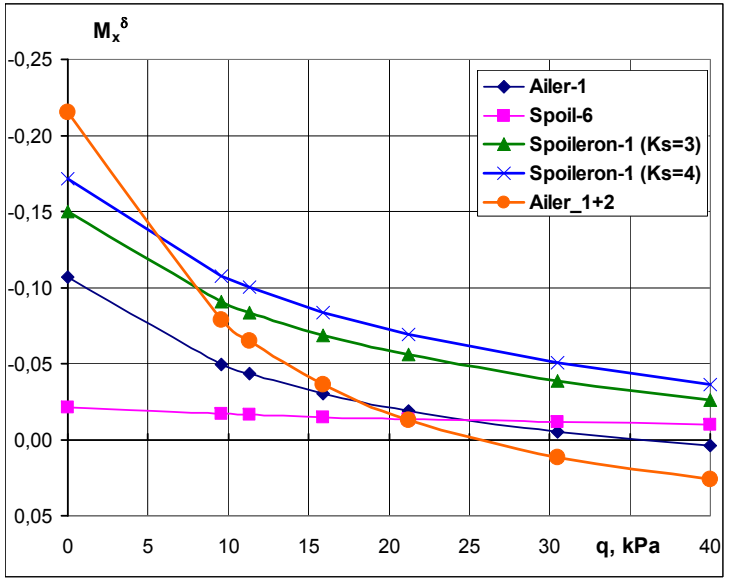


Roll control effectiveness of aileron and foraileron; Multifuctional elastically scaled transonic wind tunnel model

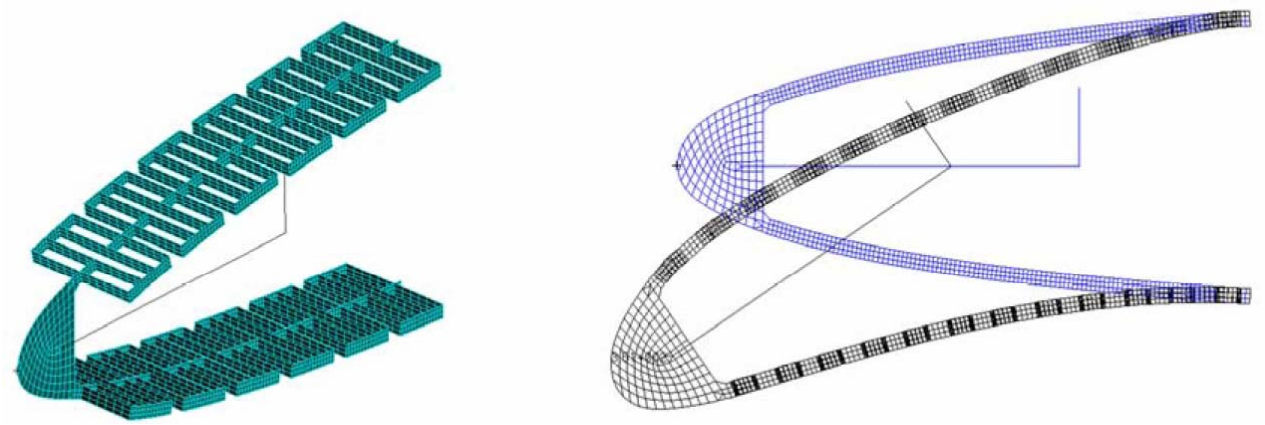


Roll effectiveness of spoileron (spoiler + aileron);ARGON - software



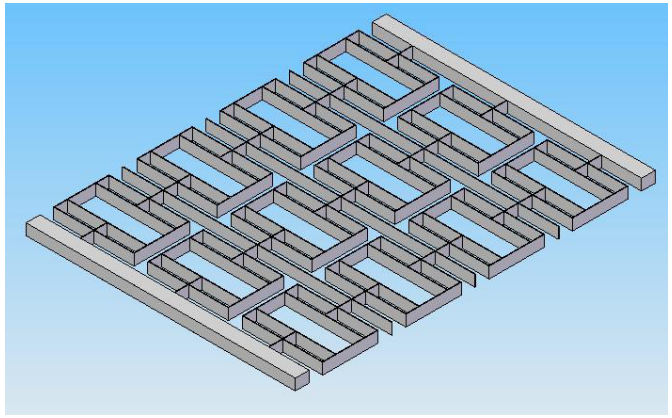


Smart Leading Edge with Elastomeric Filler

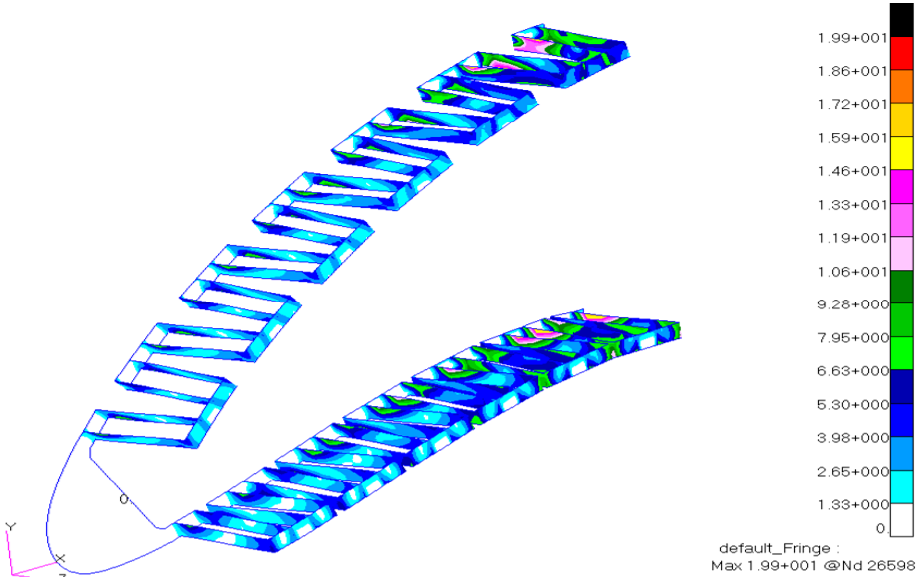


Typical stress-distribution of SLE one chordwise row of SDS-structure

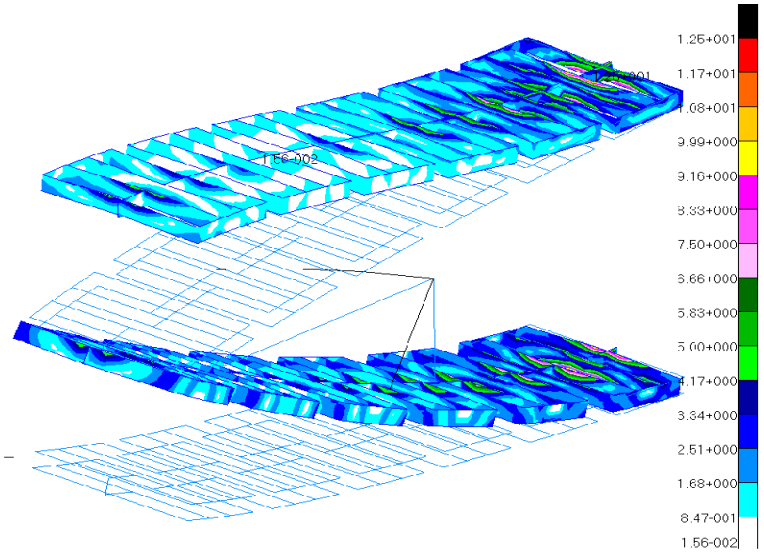
Elongation 25% SLE chord, deviation 30 degrees

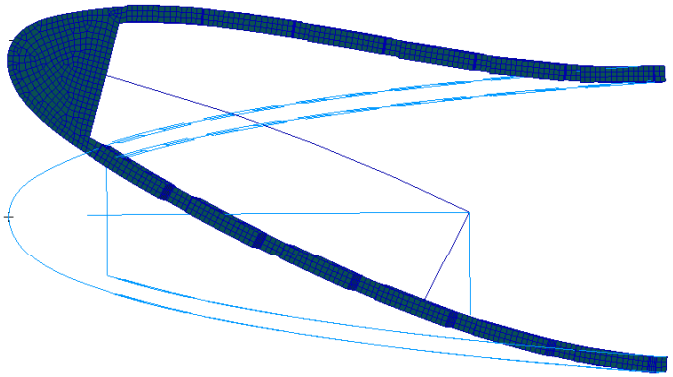


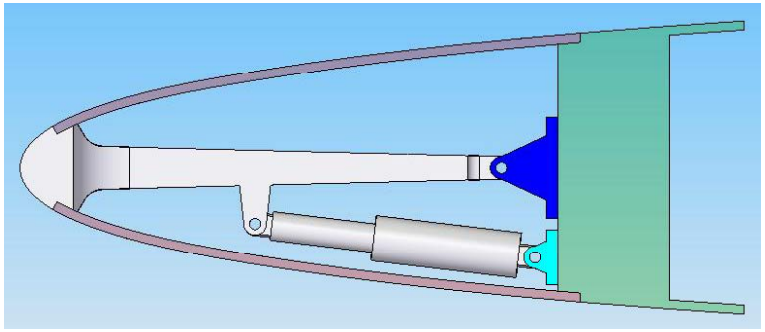
SDS-panel without elastomeric filler

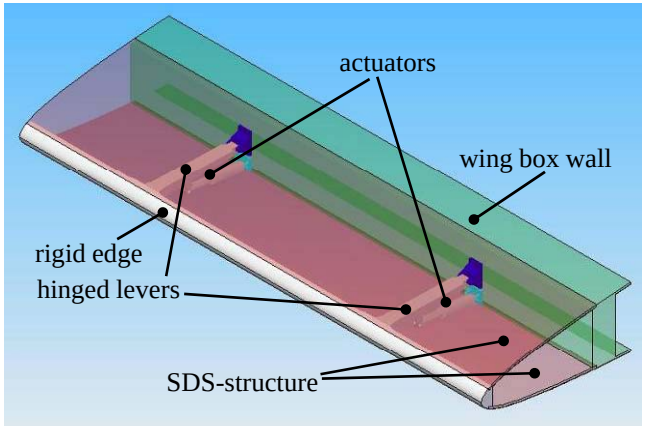


Smart Leading Edge with Elastomeric Filler; Deflection up





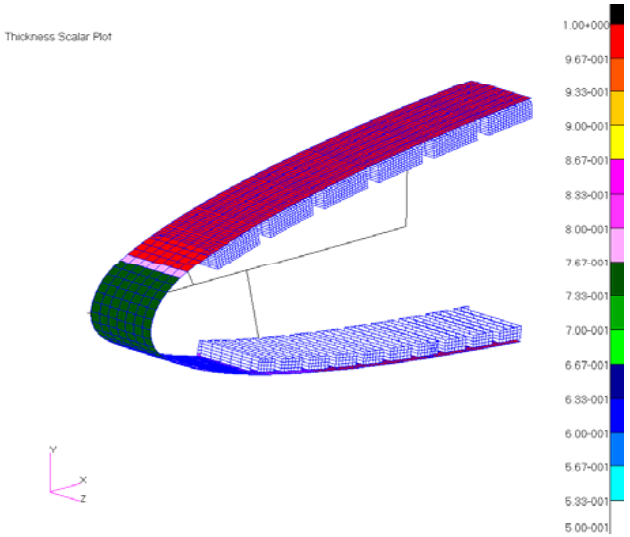


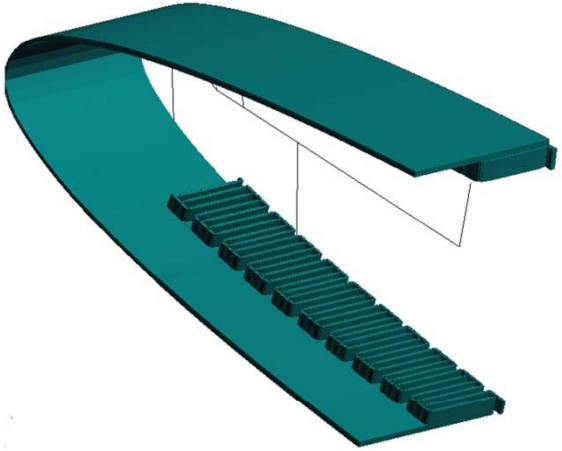


Use of aeroelasticity concept. Adaptive differentially deflected smart leading edge (forward aileron – foraileron) – SDS-structure with elastomeric filler.

Typical stress-distribution of SLE one chordwise row of SDS-structure for deflection up.

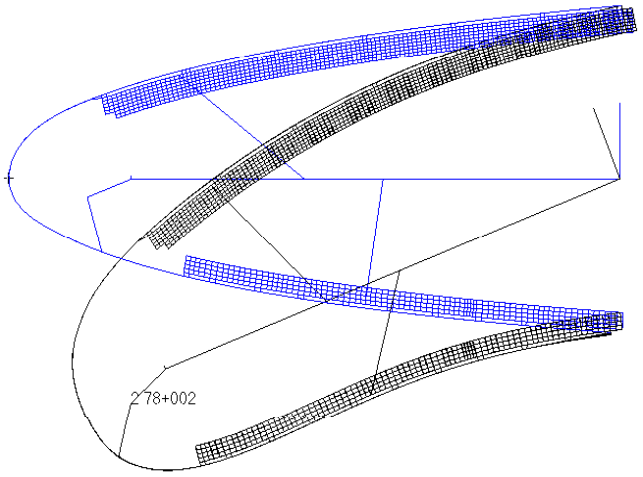
Smart Leading Edge: Flexible Skin SDS-Structure



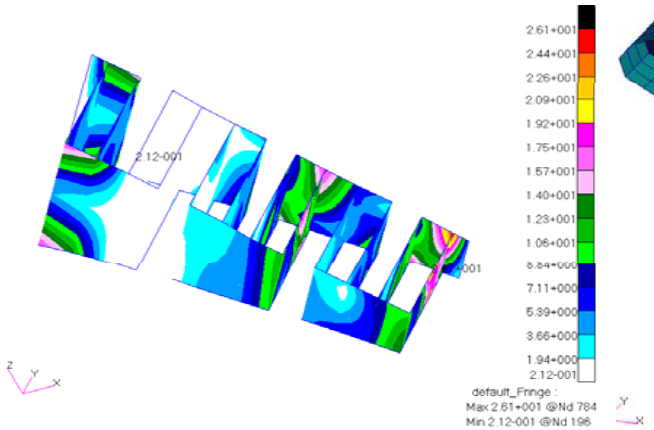


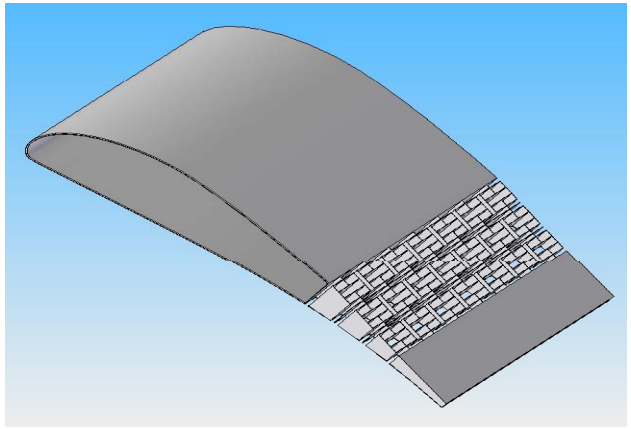
The second variant of the adaptive smart leading edge (SDS-structure as supporting element of flexible skin), deflected by the rigid lever and hinged rods.

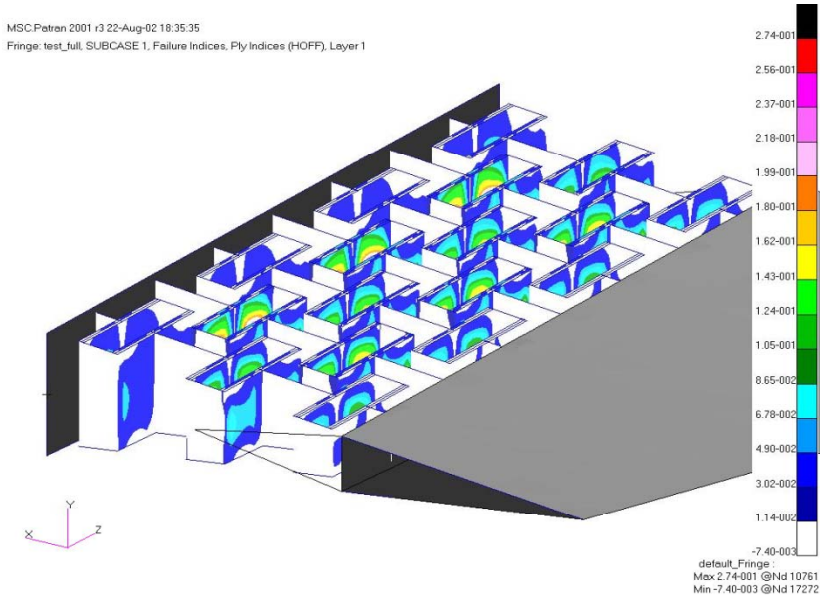
Typical stress-distribution of the SLE elastic skin.



Smart Trailing Edge Based on SDS-Structure



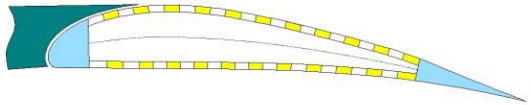


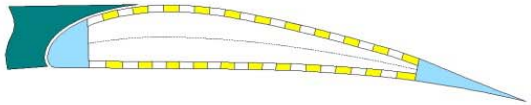


Smart Trailing Edge – (SDS-structure with elastomeric filler).

Typical stress-distribution of STE one chordwise row of SDS-structure.

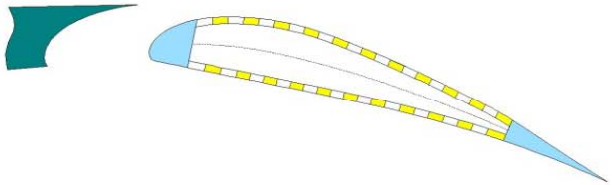
Smart Trailing Edge Based on SDS-Structure



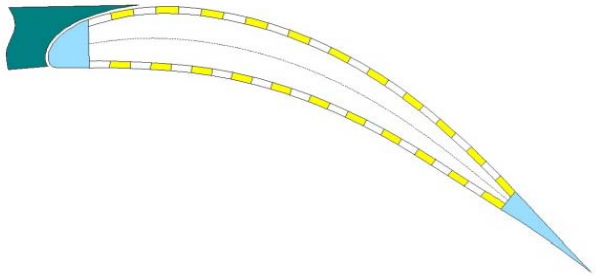


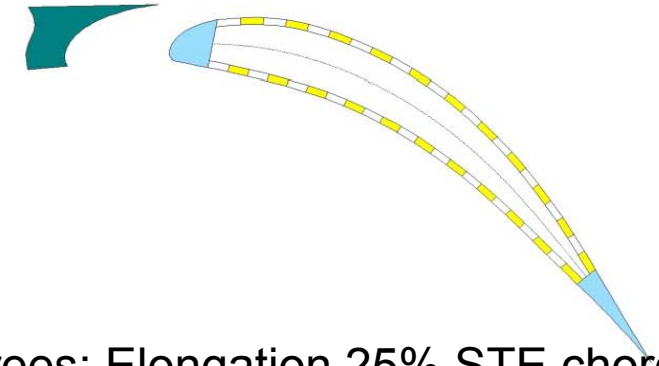
Initial Position of Full Size STE based on SDS-structure with elastomeric filler

Using of special rotary and linearly shifted drive system inside STE, between upper and lower SDS -panels



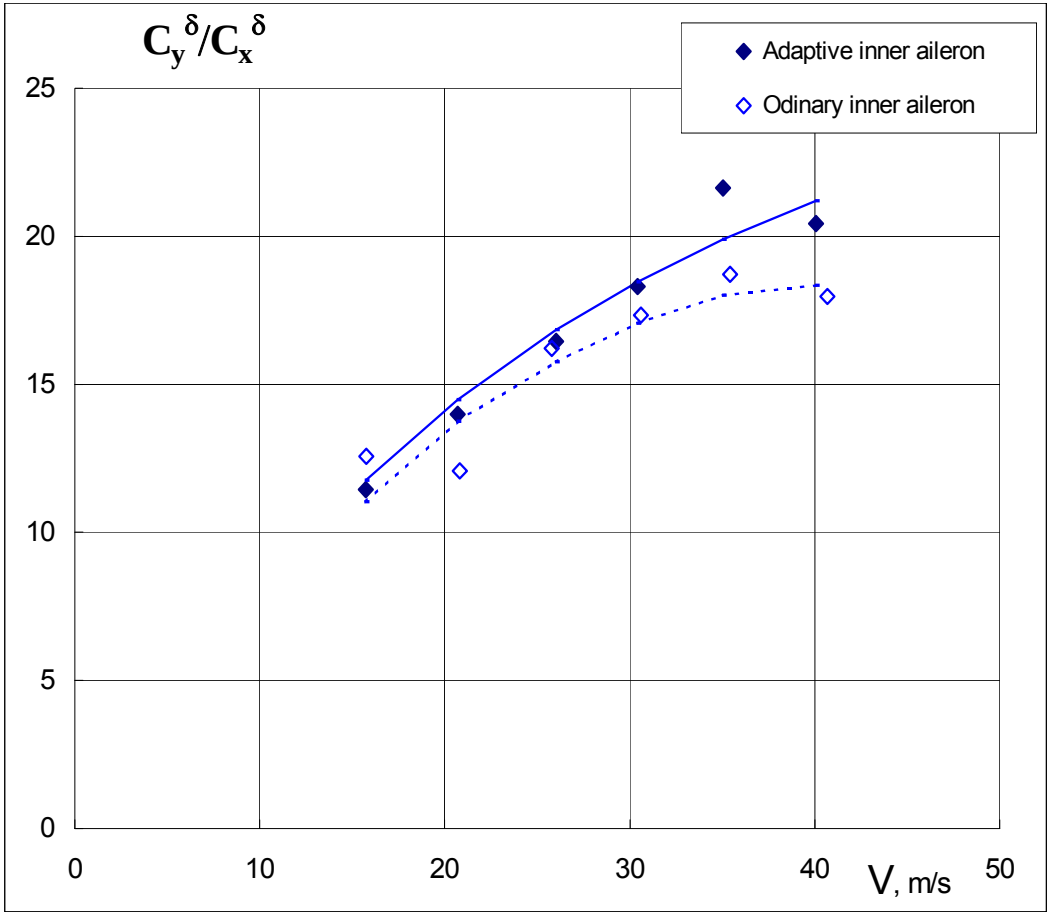
Single Slot STE Deflection 15 degrees

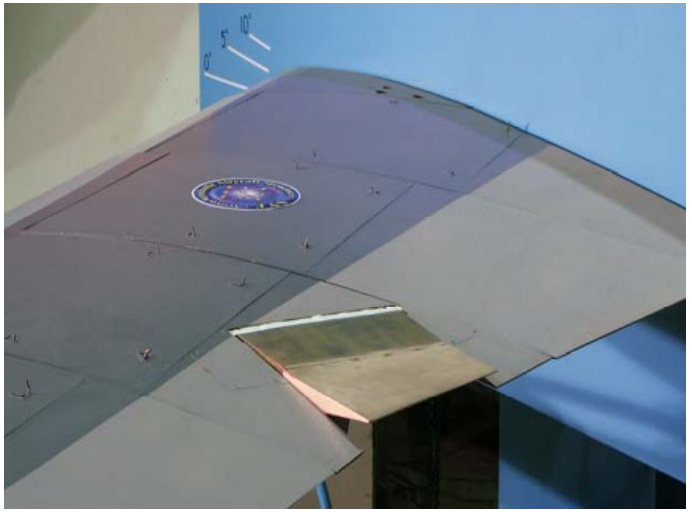




Slotless and Single Slot STE Deflection 15 degrees; Elongation 25% STE chord

Smart aileron based on using of selectively deformable structure – SDS

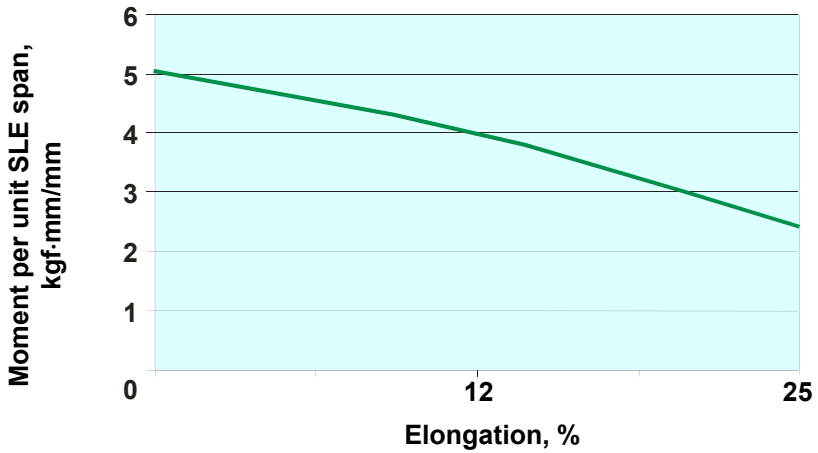


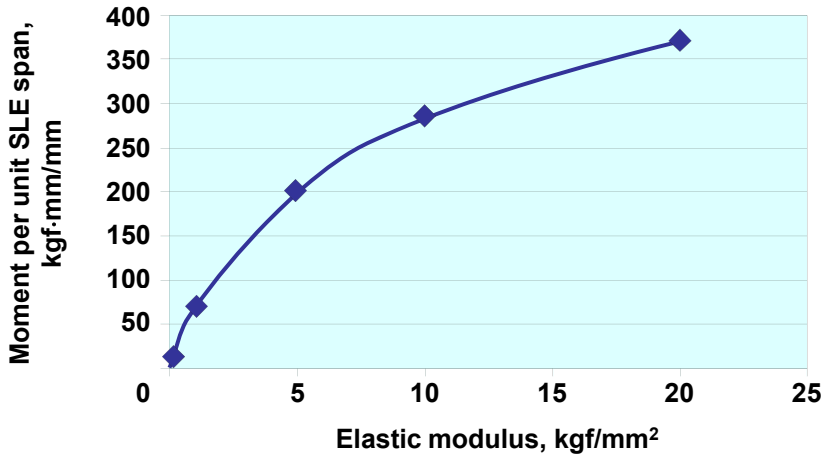


SDS-structure without elastomeric filler

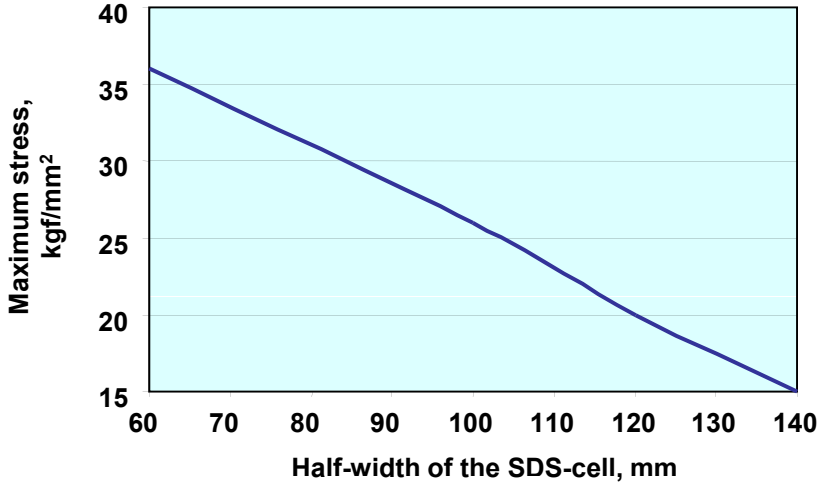
Lift to drag ratio for ordinary and adaptive inner aileron versus wind tunnel flow speed.

SDS Properties Investigations

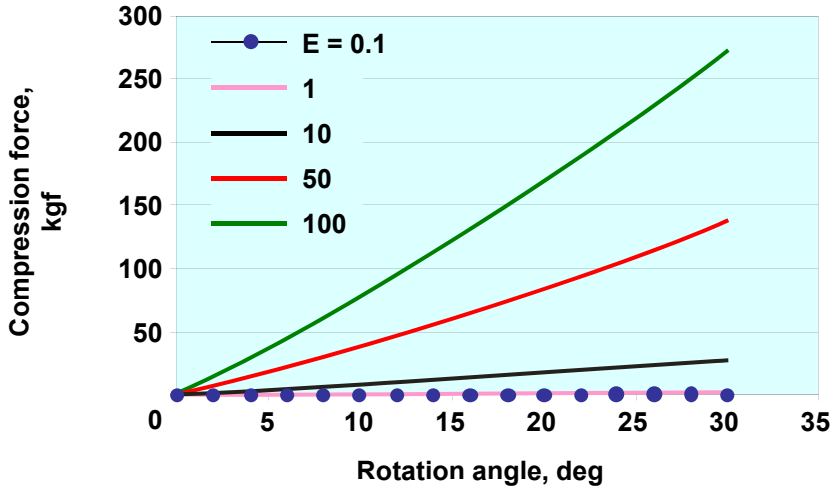




Dependence of deviation moment on elongation level and elastic modulus of filler

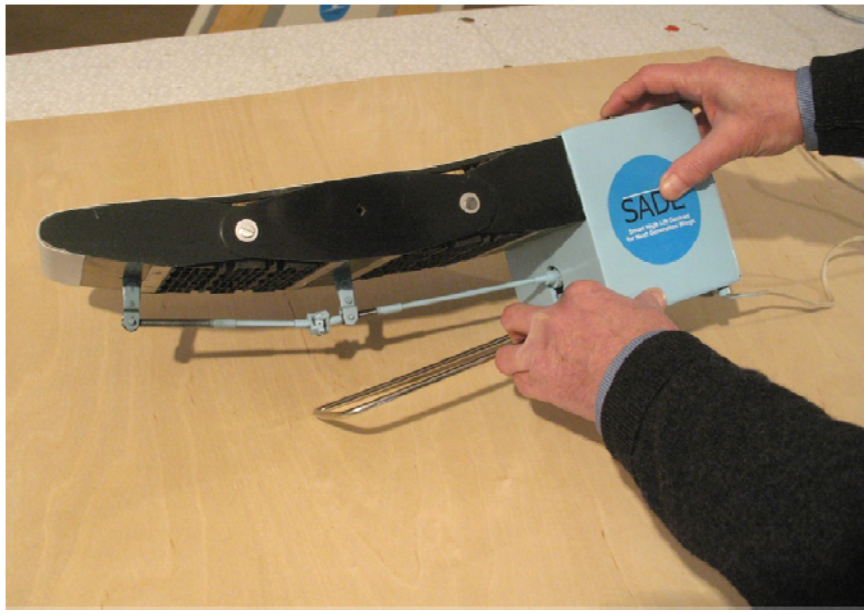


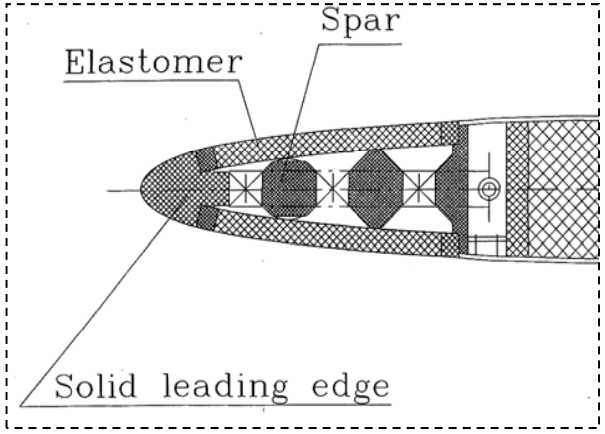
Dependence of maximum stresses on half-width of the cell

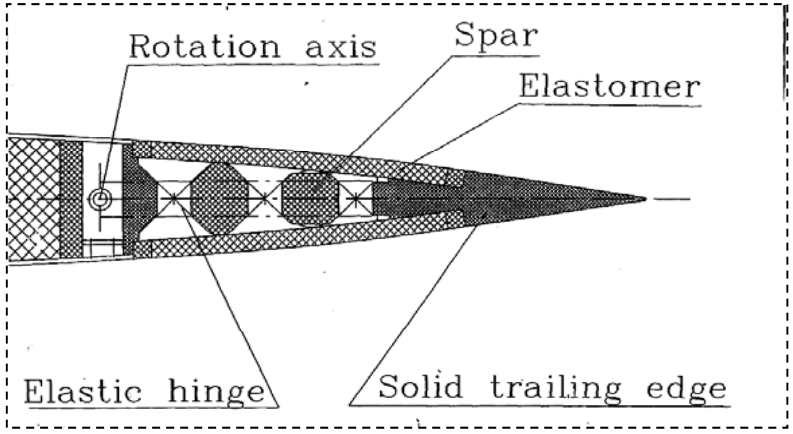


$E_{elast}/E_{eff\ SDS}$ = 0.05–0.1 – for good external shape of SLE

Adaptive Wing (SLE and STE) Maquetts Based on SDS Concept

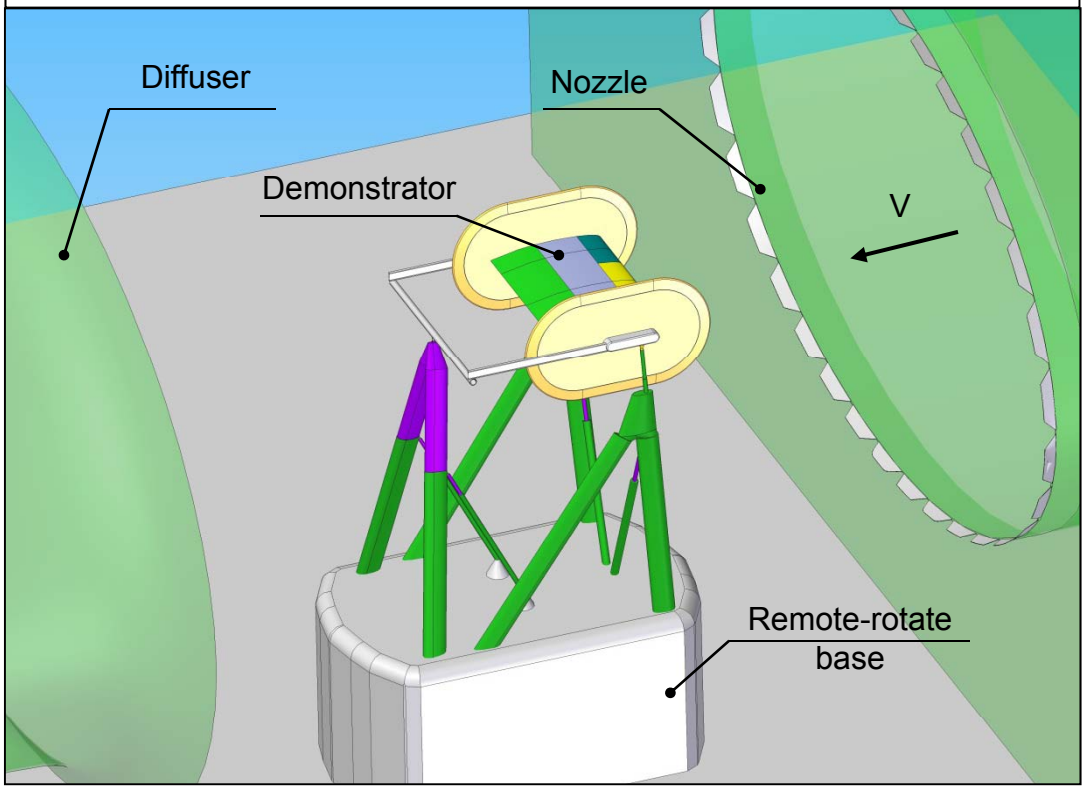




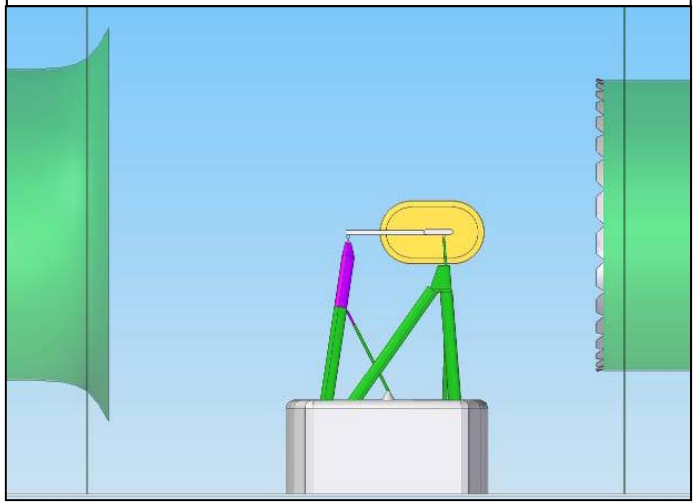


SADE Project Large-scale Demonstrator

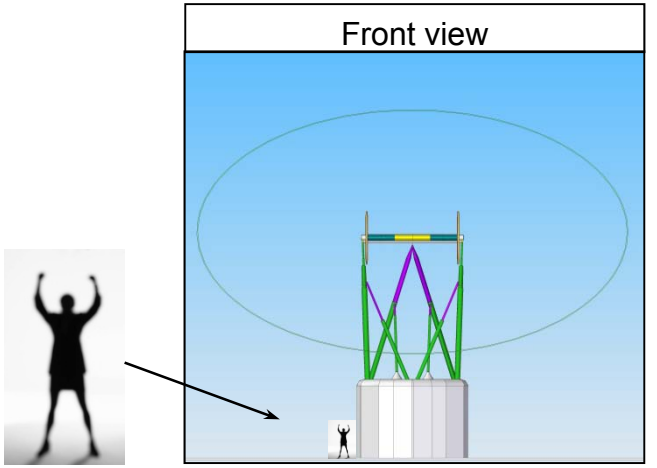
Isometric view



Side view

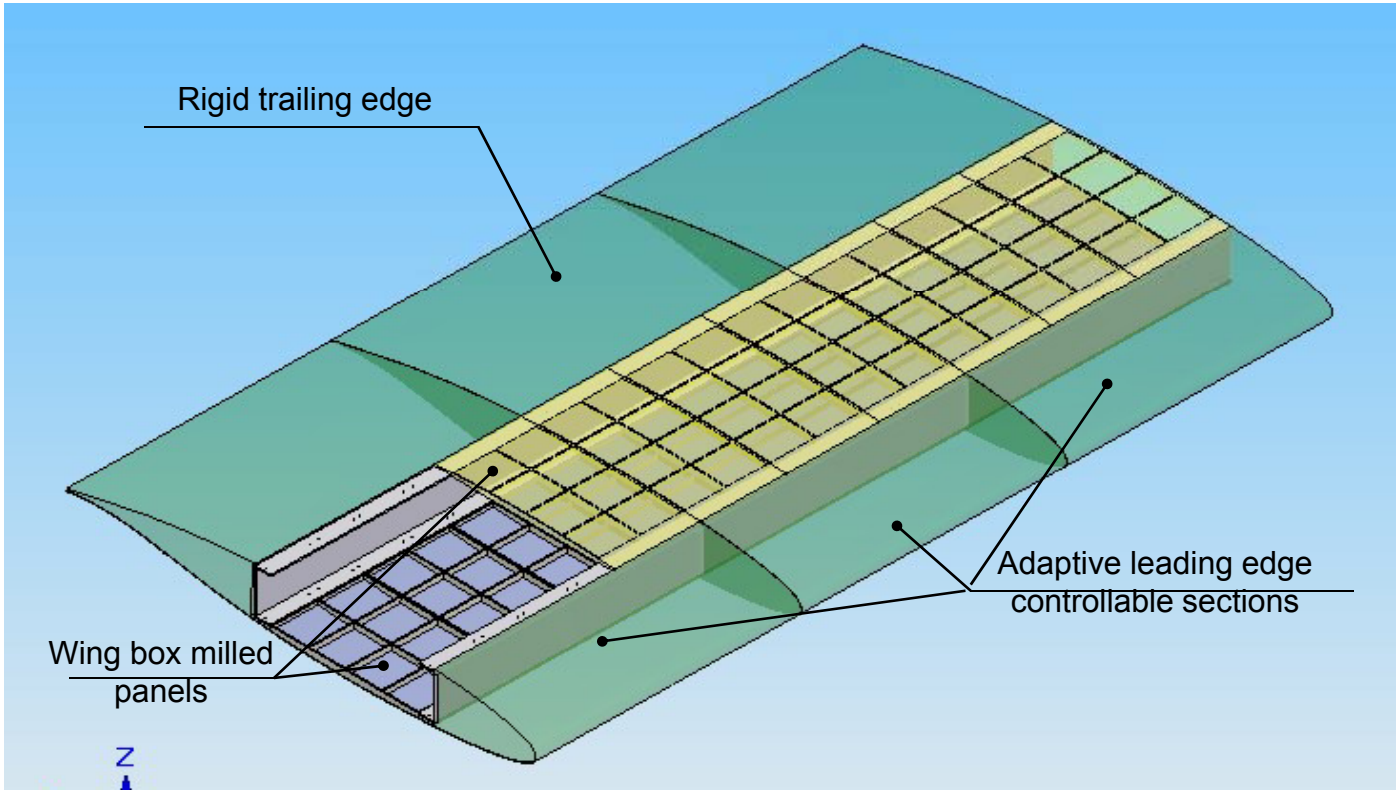


Front view

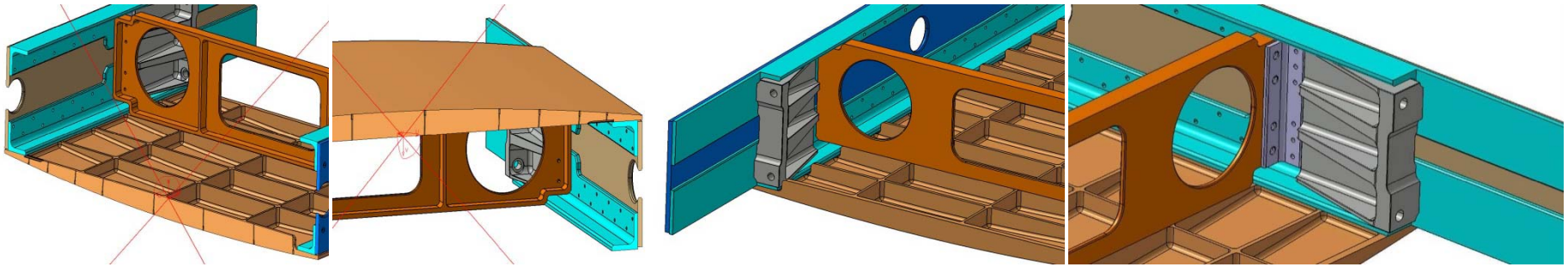


Aerodynamic wind tunnel TsAGI T-101
large-scale model with side-plates

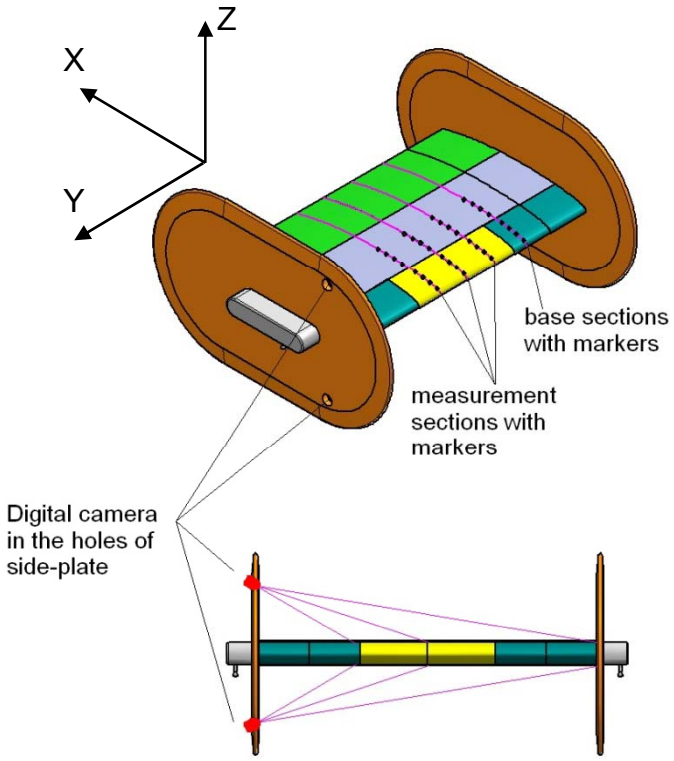
Wind Tunnel TsAGI T-101 Aerodynamic Model

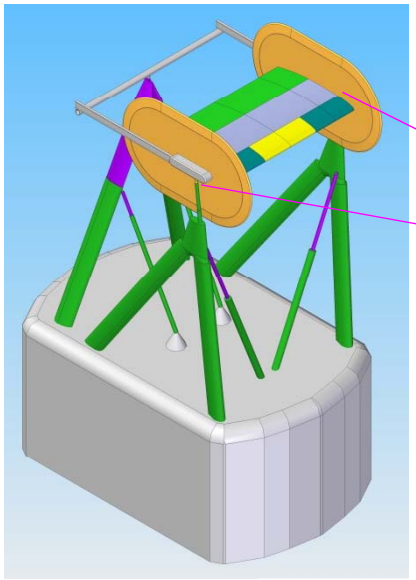


Wing box with controls (3 sections of smart leading edge – SLE and 1 section of single slot flap – STE).

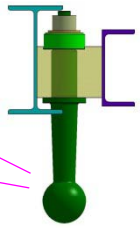


SADE Project Large-scale Demonstrator Measurements

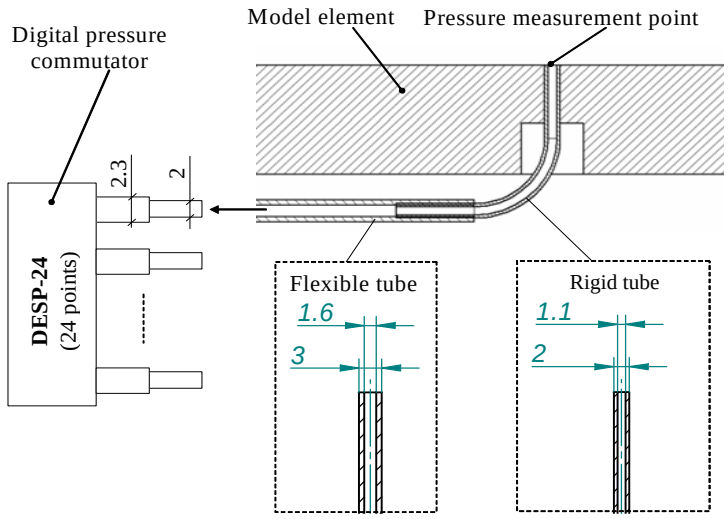




Spherical hinge joint



Pressure distribution measurements



Videogrammetric system for optical measurements of the skins deformation and shape of three sections of SLE in span direction

Conclusions

- SADE Project focuses on the structural challenge of realizing morphing high lift devices, based on results of research activities focusing on the "use of aeroelasticity" or Active Aeroelastic Wing concept. Appropriate methods have been developed, and important experimental and analytical results of multidisciplinary studies have been obtained to substantiate prospects of the concept regarding safety, high weight efficiency and as result - competitiveness of advanced airplanes.
- Development and evaluation of the potential of morphing airframe technologies based on SDS – Selectively Deformable Structures has been observed. Further evaluation and development is necessary before smart control based on SDS-structure can be used as production tool.
- The principal scheme of large-scale SADE project demonstrator for the wind tunnel of TsAGI T-101 is shown.
- The principal task of demonstrator wind tunnel tests, ground vibration and stiffness measurements is to show main advantages of adaptive smart elements of the next generation wings.
- The demonstrator that was designed can prove the feasibility of the developed by European partners concepts as a part of the international SADE Project of the 7th European Framework Program funded by the European Commission.