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Design and manufacturing of a morphing flap for wind turbine blades

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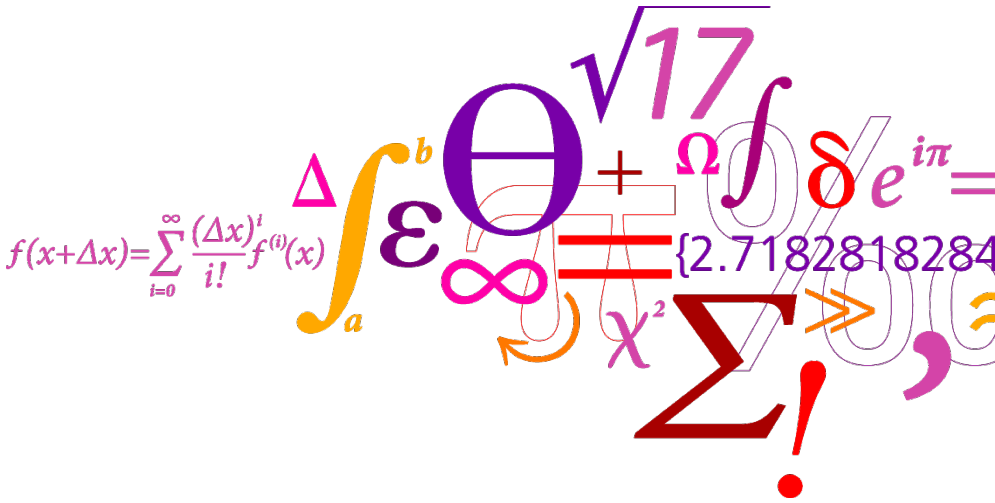
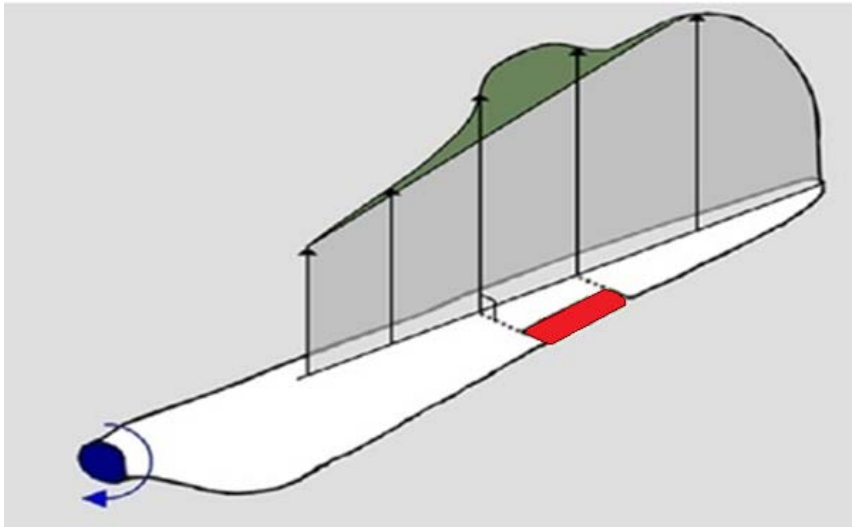
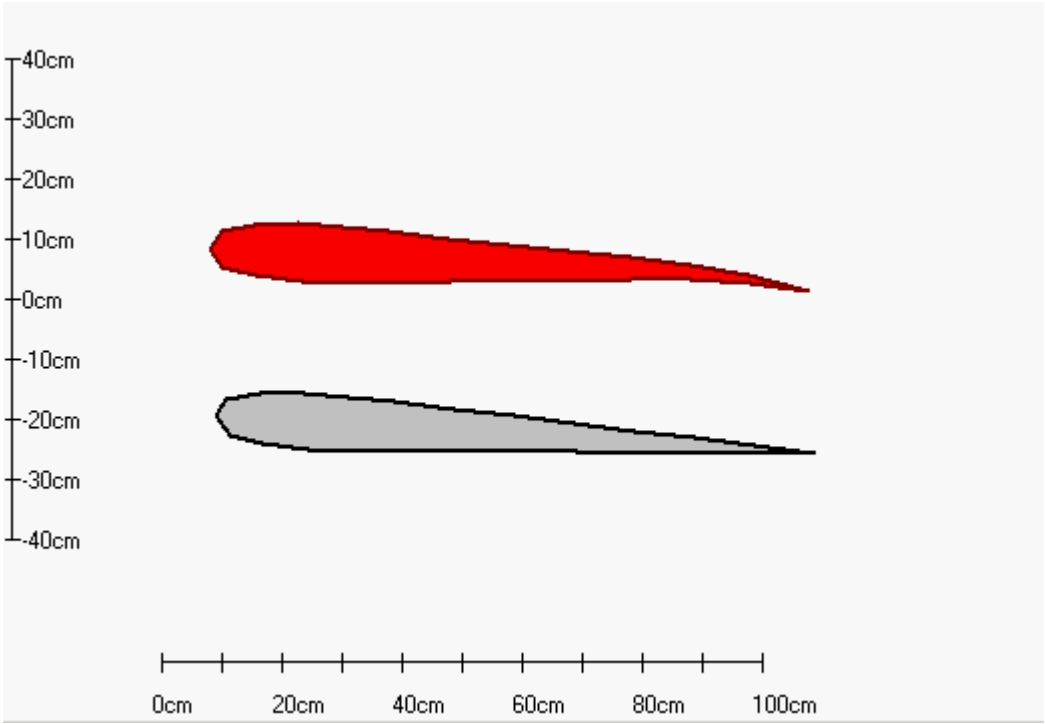


Outline

- Background
- Designs and prototypes
- Summary





Past:
The pitch system enabled the wind turbine to actively regulate loads (full blade)

Our hope:
The flap system will open up new blade designs for wind turbine application (local flow control)

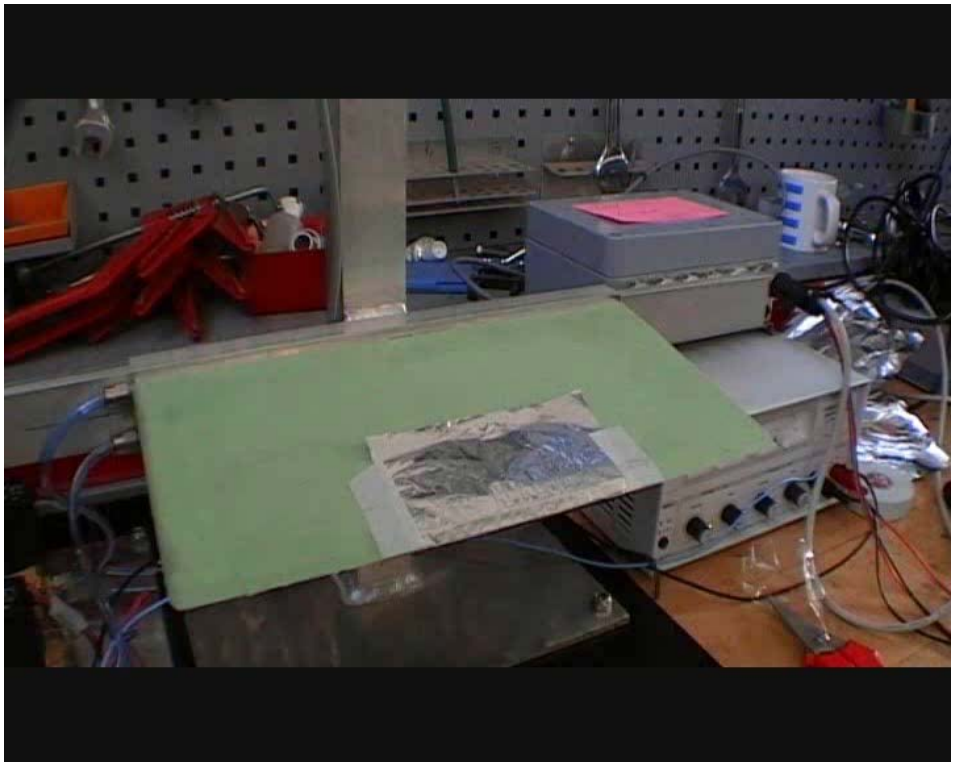
Numerical studies have indicated that the flap system have significant load reduction potential

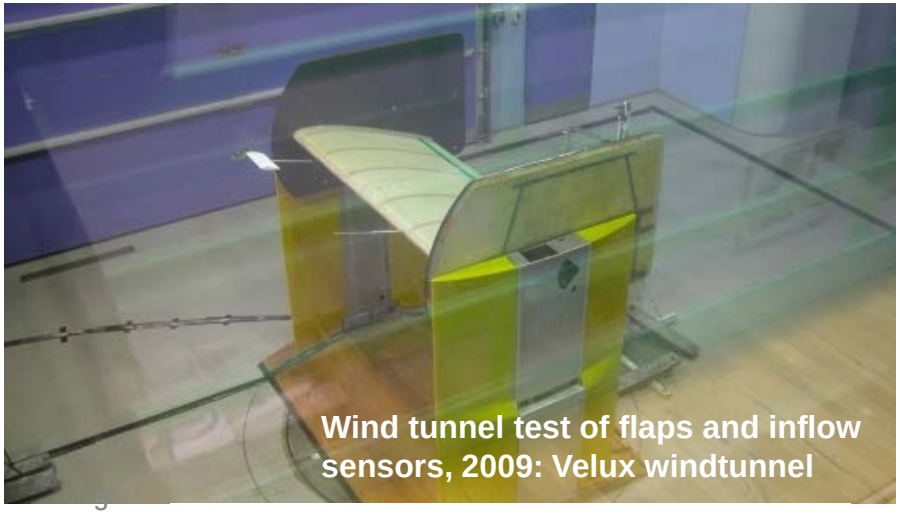
Table III. Comparison of results from aeroservoelastic investigations with active flaps on the Upwind 5MW RWT.

article	c_f [%]	dr_f/r [%]	δ [$\pm^\circ$]	T.I. [%]	shear exp. [-]	V_{av} [m/s]	reduction in std of RBM [%]	reduction in DEL [%]	controller
Riziotis et al. 2008	10	15-47	6	-	0.2	8, 12, 16	30-35 (range)	-	PID
Andersen et al. 2008	10	63	8	14-18	0.14	7, 11, 18	-	36.2-47.9	HPF+inflow
Lackner et al. 2009	10	20	10	NTM, ETM	0.2	8, 12, 16, 20	-	5.6-24.6	PID
Barlas et al. 2009	10	20	10	NTM	0.2	8, 11.4, 16	5.7-22.4	-	PID
Andersen et al. 2009	10	15-30	8	-	11.4	-	-	25-37	HPF
Resor et al. 2010	10	24	10	6	0.2	15	26-30.9	27-31.3	PD, HPF+notch
Wilson et al. 2010	10	24	10	6	0.2	15	13.3	15.5	LQR
Berg et al. 2010	10	25	10	6	0.2	15	8.7-18.1	10.9-17	PD, LQR
this article	10	18	8	6, NTM	0.2	7, 11.4, 15	10.9-30.7	10.9-27.3	MPC+inflow

Barlas, Thanasis; Van Der Veen, Gijs; van Kuik, Gijs; Model Predictive Control for wind turbines with distributed active flaps: Incorporating inflow signals and actuator constraints. Article first published online: 17 NOV 2011 DOI: 10.1002/we.503

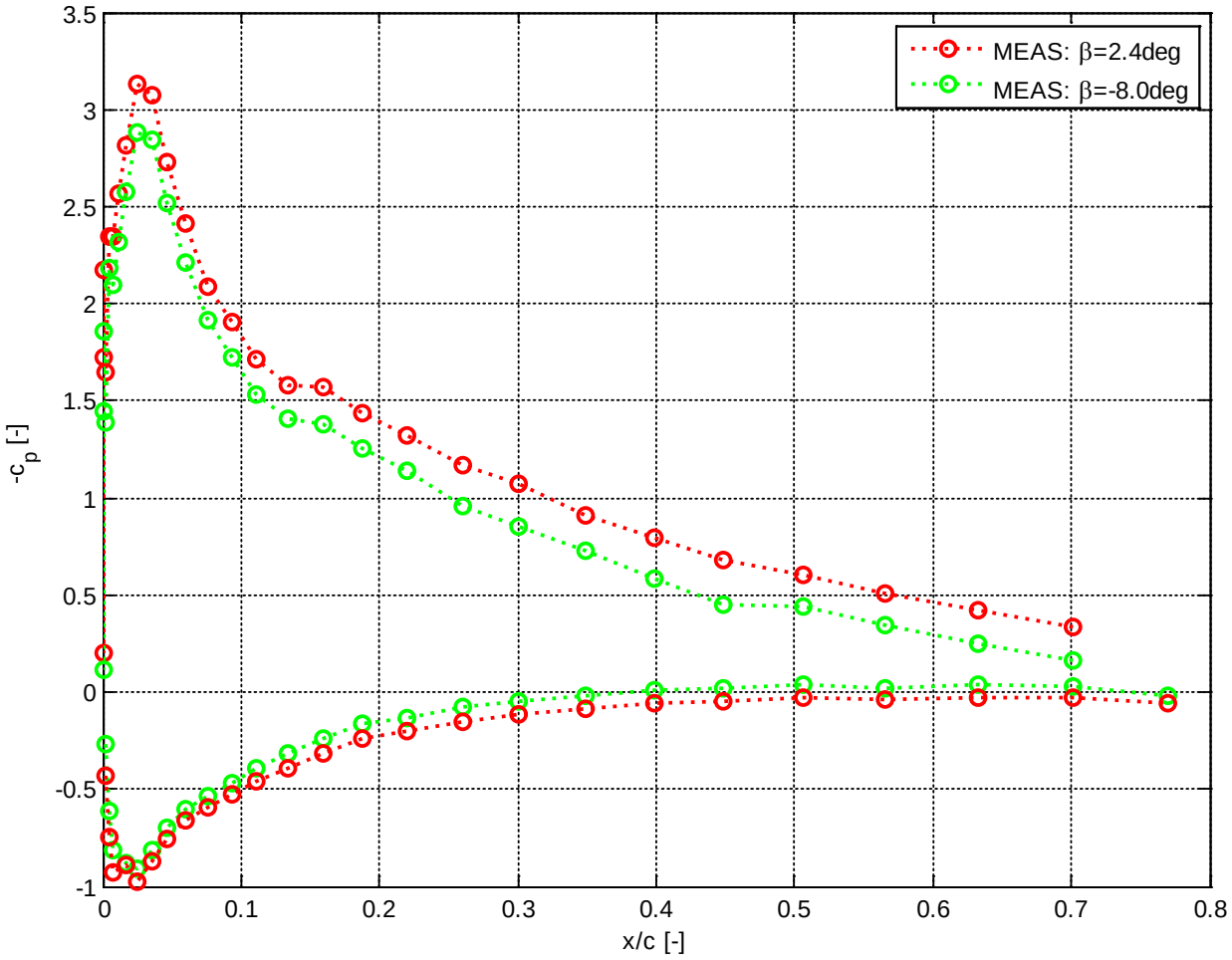
Wind tunnel experiments have shown that the flap system can reduce blade loads





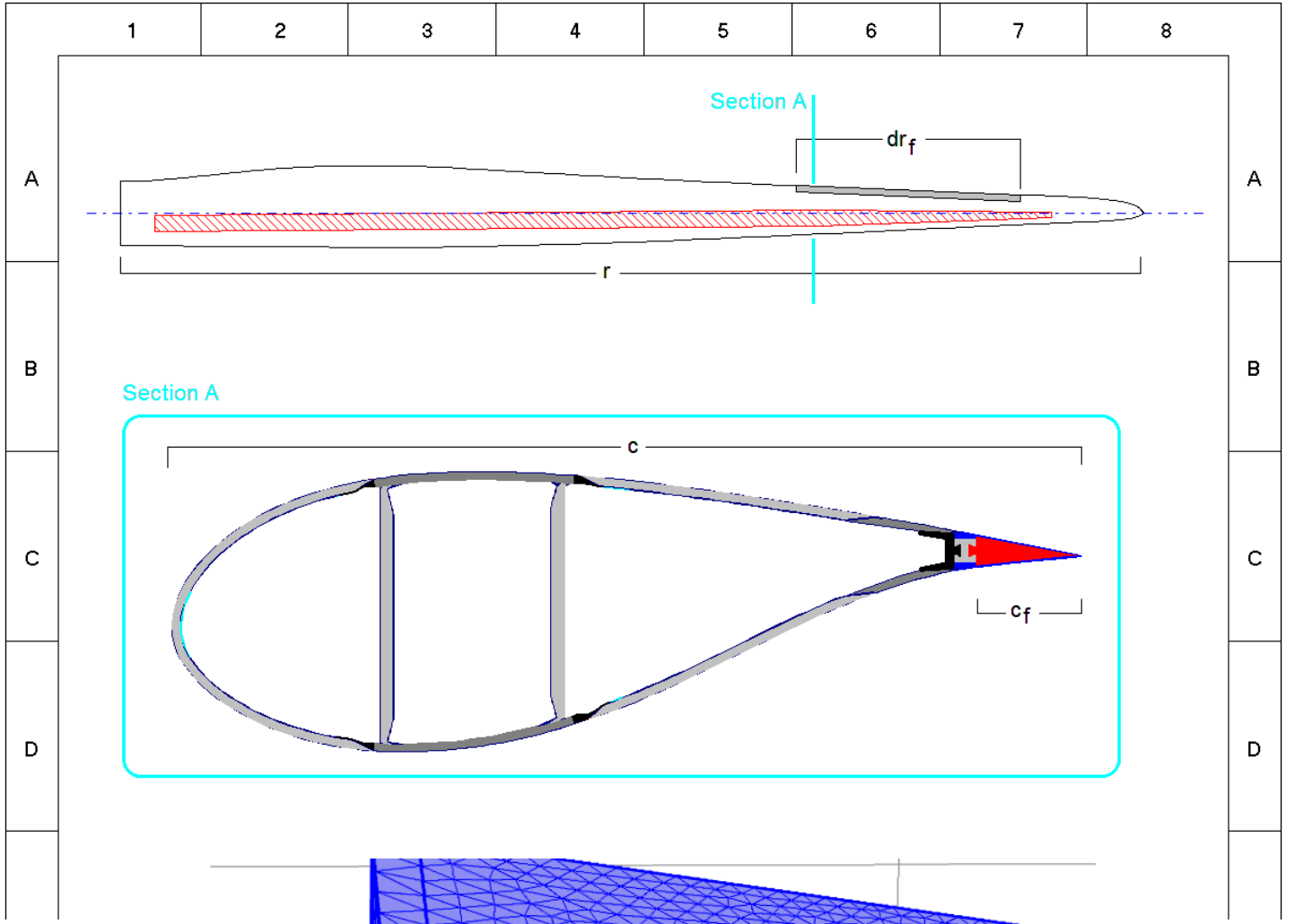
Wind tunnel test of flaps and inflow sensors, 2009: Velux windtunnel

Wind tunnel experiments have shown that the flap system can reduce blade loads

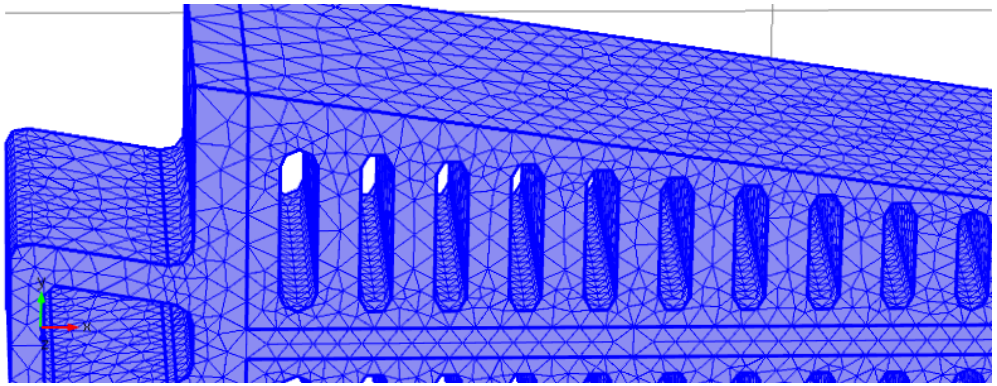


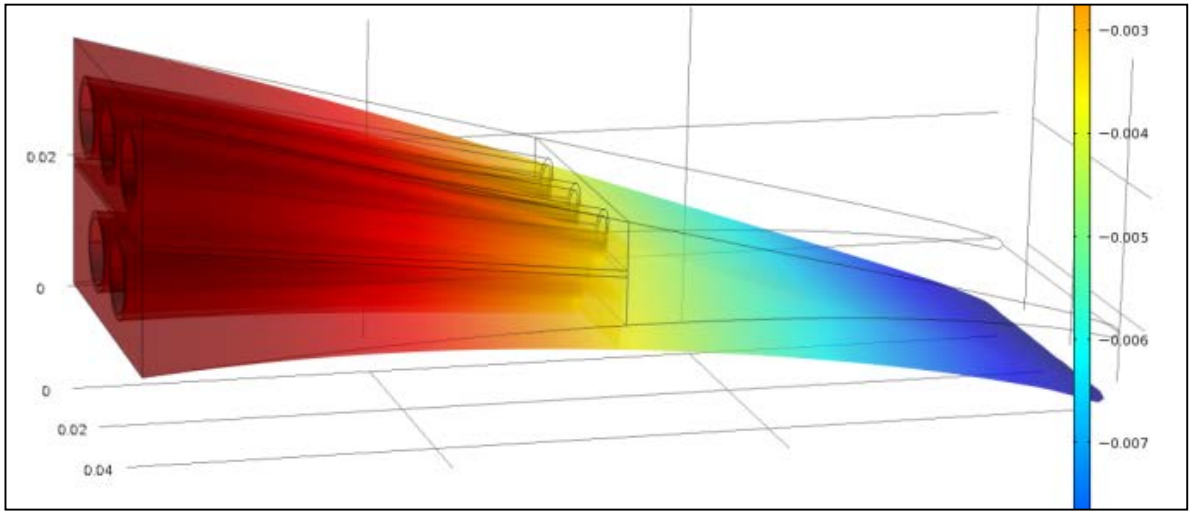
AOA=8deg

The flap system will affect many levels of todays blade design

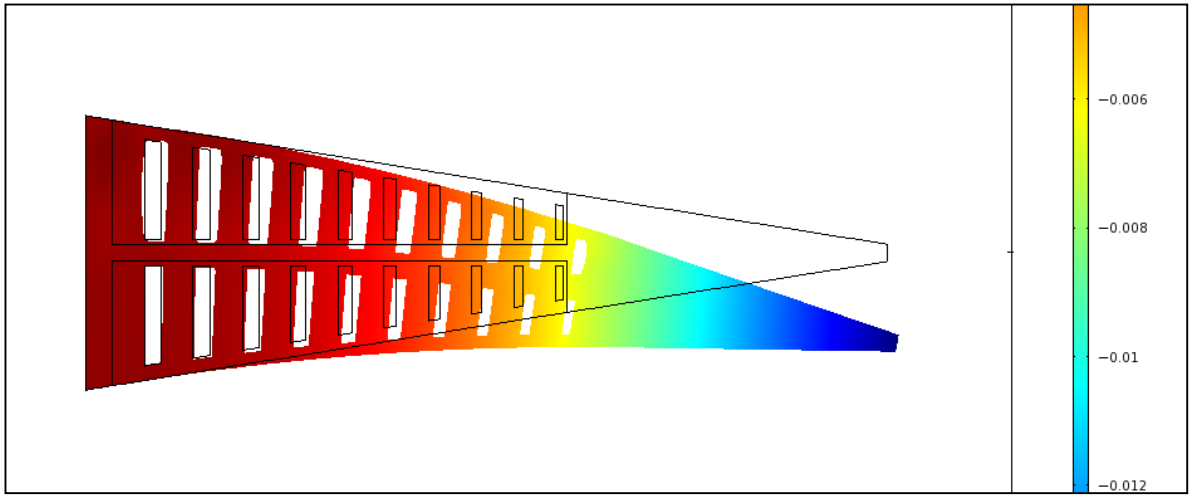


Focus: the flap design



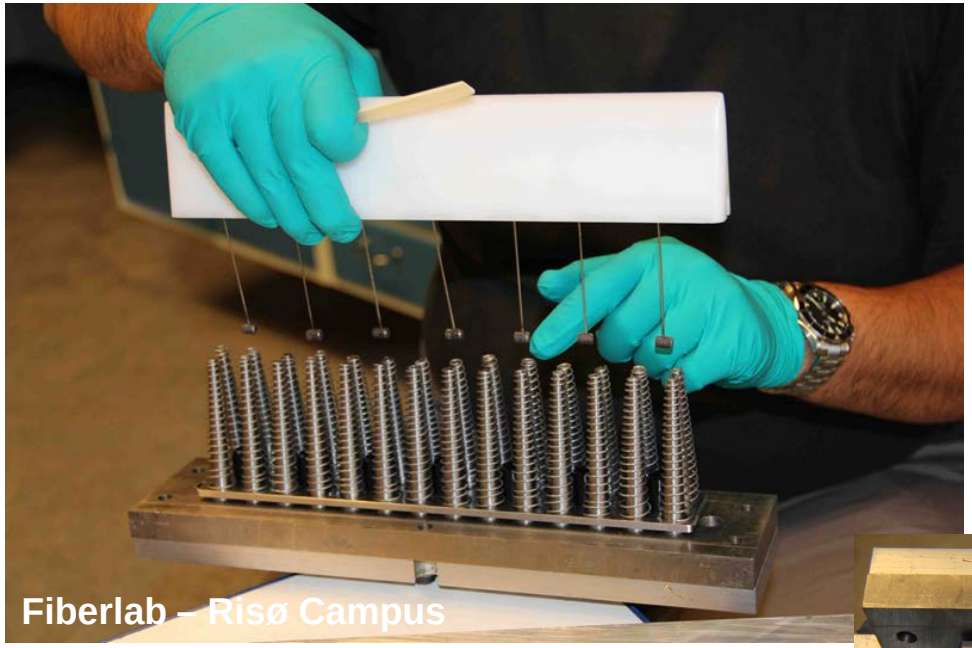


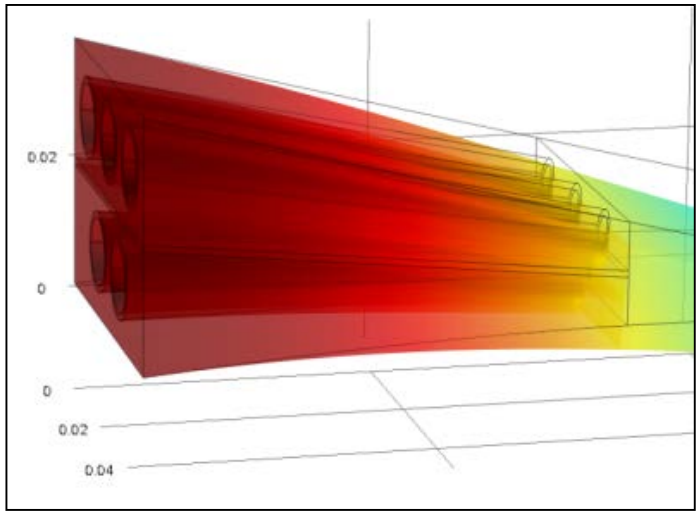
CHORDWISE CAVITIES FOR MOULD MANUFACTORING



SPANWISE CAVITIES FOR EXTRUSION

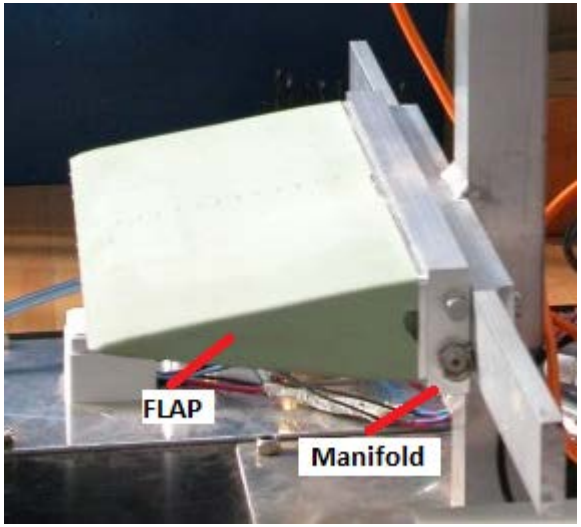
Chordwise cavities for mould manufactoring



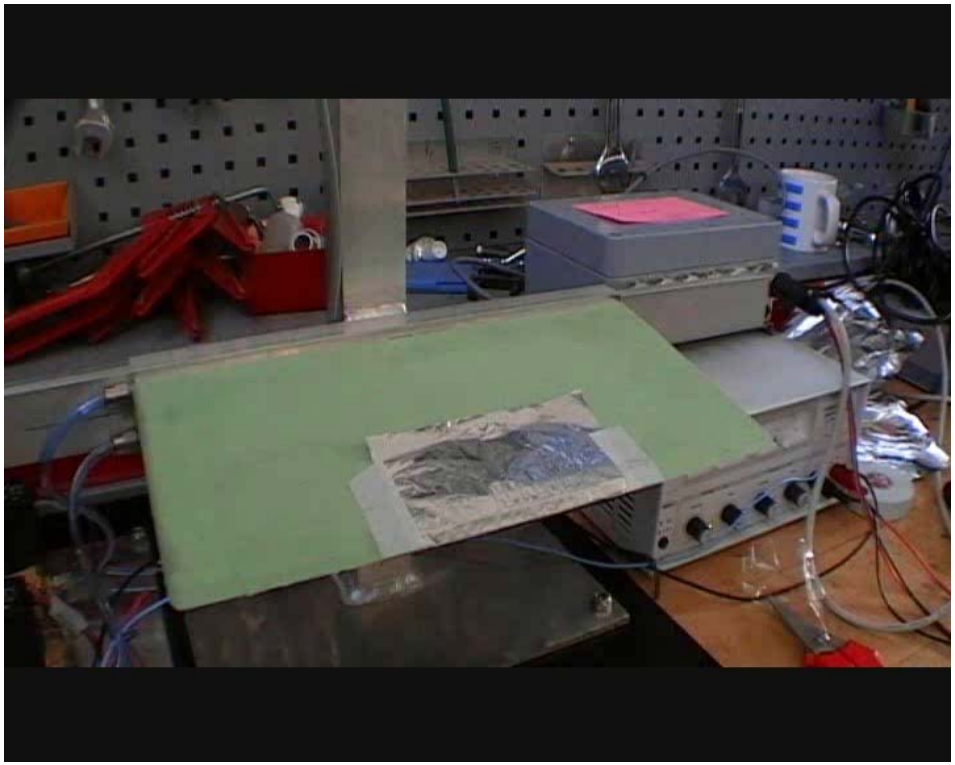


Cavities had to be reinforced in order to maintain deflection characteristics

Chordwise cavities for mould manufactoring

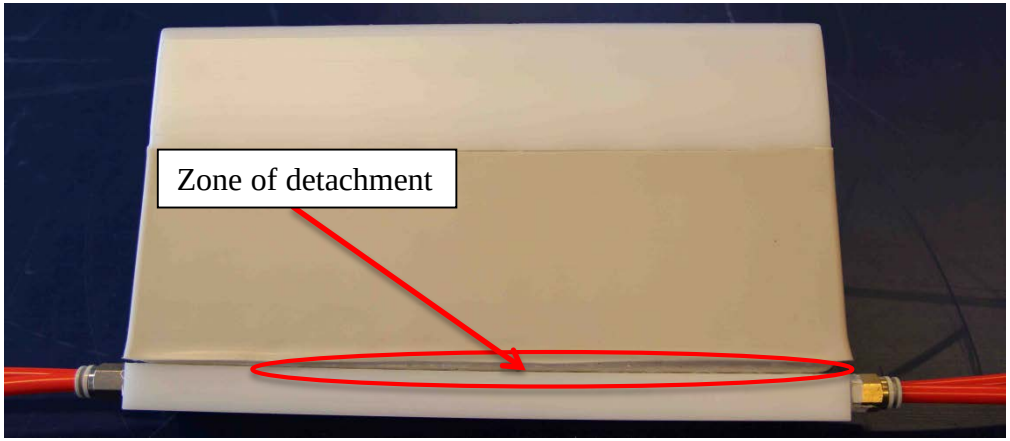


Large surface contact area for both hydraulic and pneumatics solutions



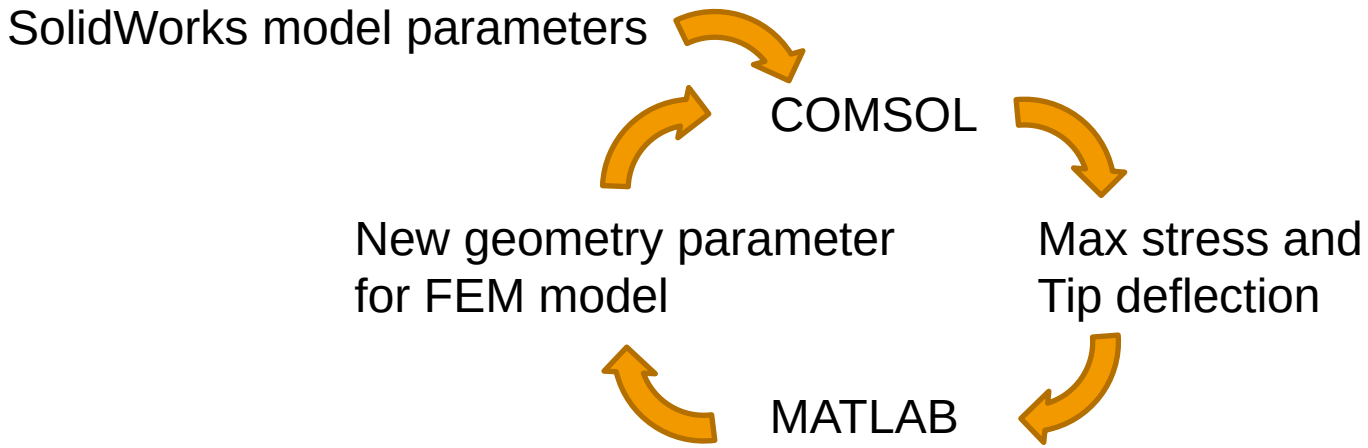
"Development of the controllable rubber trailing edge flap technology for MW turbines" . Advances in Wind Turbine Rotor Blades. 13 -

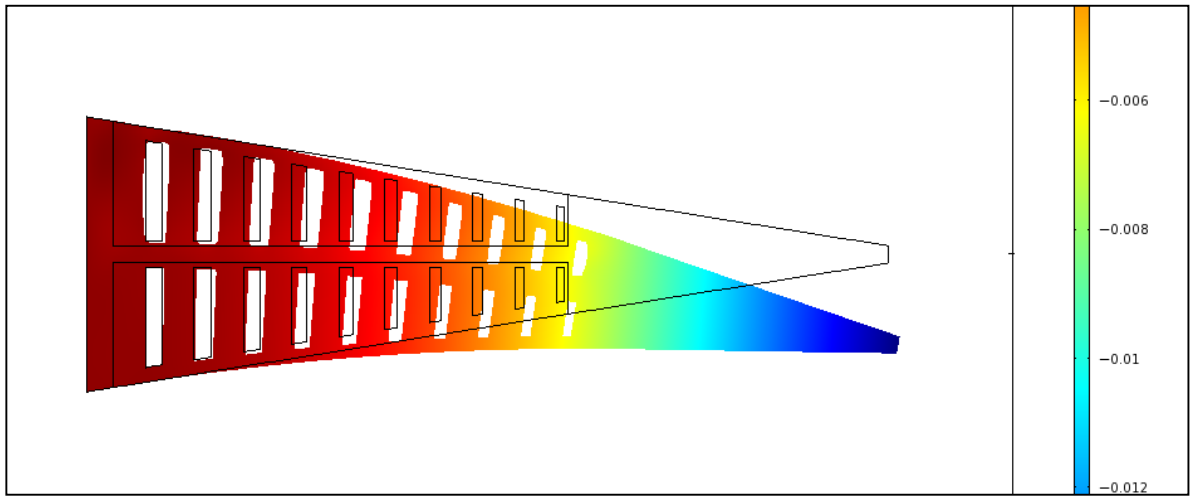
Zone of detachment problem



"Development of the controllable rubber trailing edge flap technology for MW turbines" . Advances in Wind Turbine Rotor Blades. 13 -

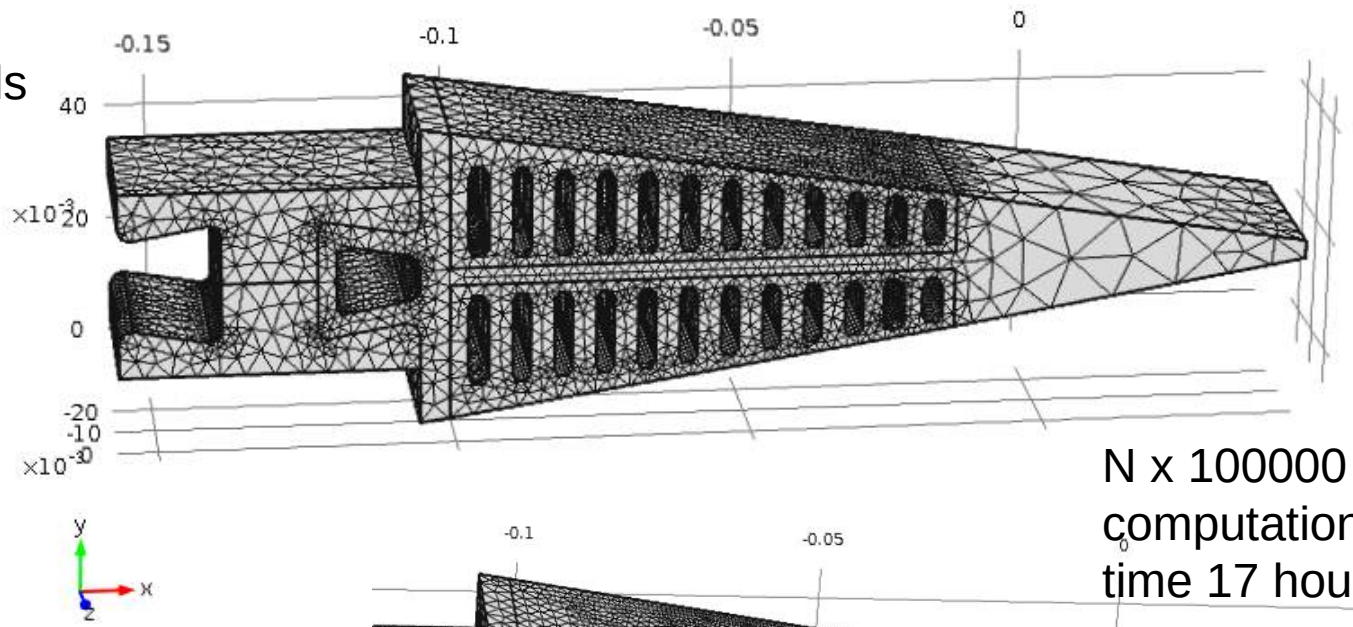
Spanwise cavities for extrusion





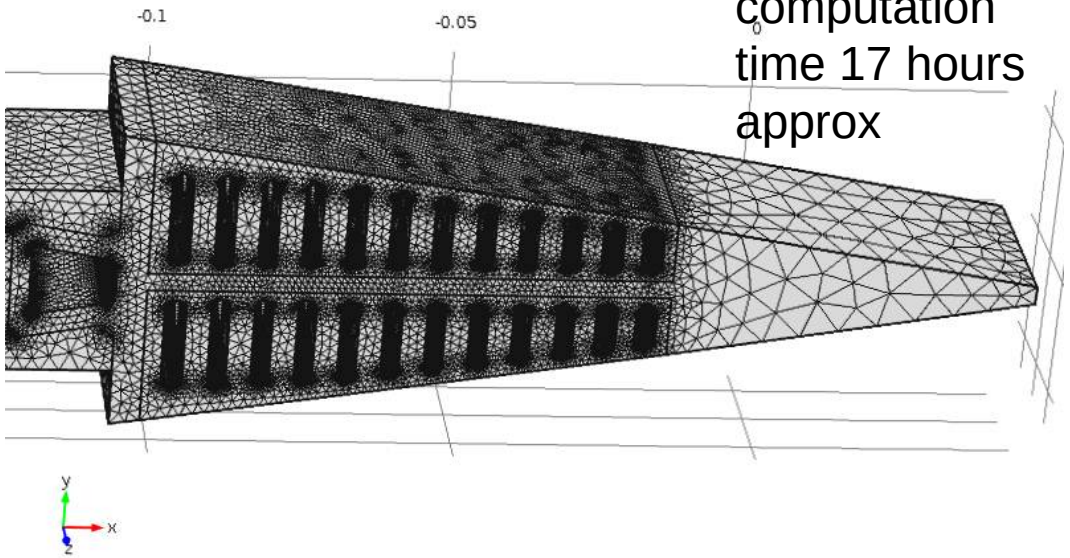
Spanwise cavities for extrusion

N x 1000 cells computation time 15min approx

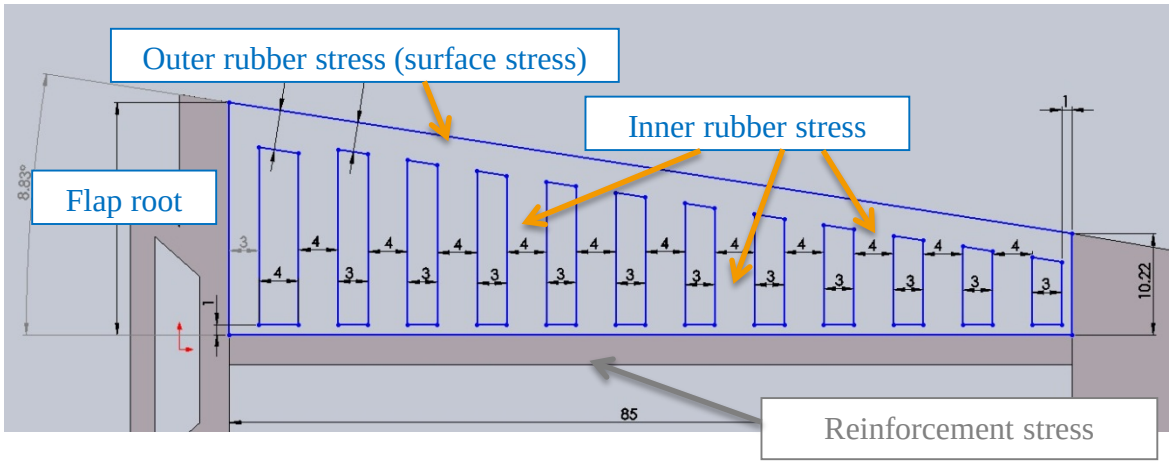


N x 100000 cells computation time 17 hours approx

Free thetrahedal elements in an unstructured mech



Spanwise cavities for extrusion

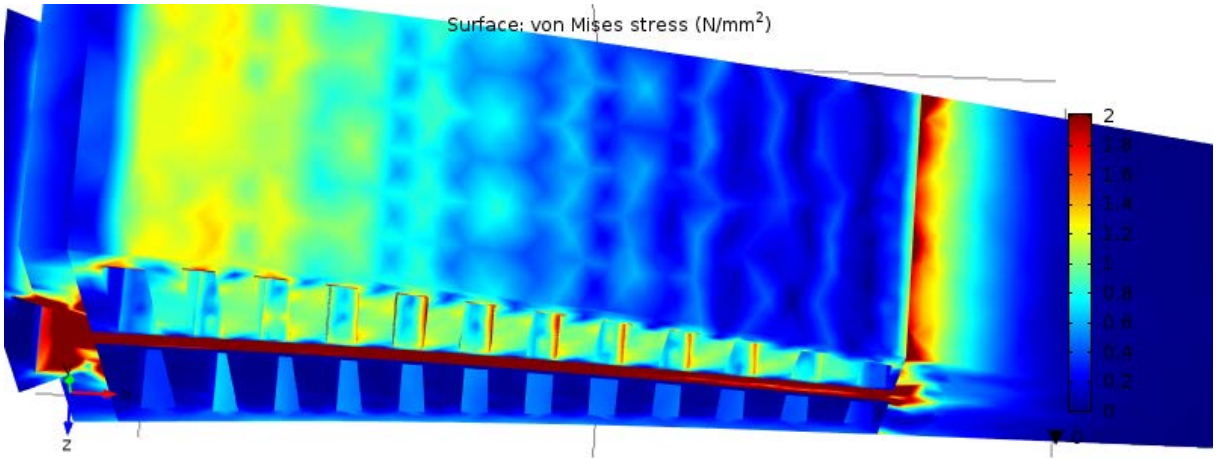


Cavity pressures investigated for 1,2,3,4,5,6,7 and 8 bar overpressure

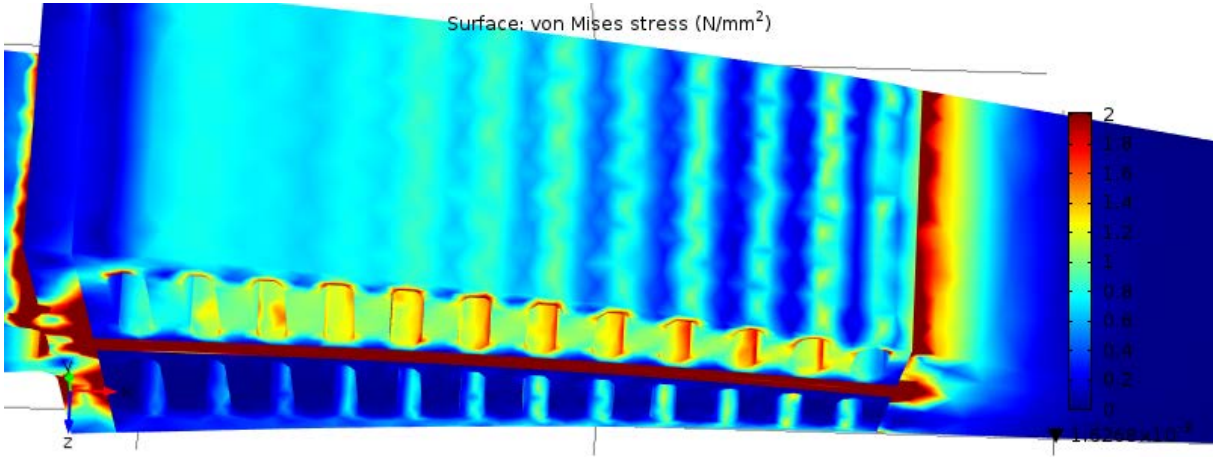
Santoprene 101-73 thermoplastic vulcanizate
Wacker 4670 silicon

Target:
maximum stress' for the rubber flap part at 15% elongation is 8MPa

Spanwise cavities for extrusion

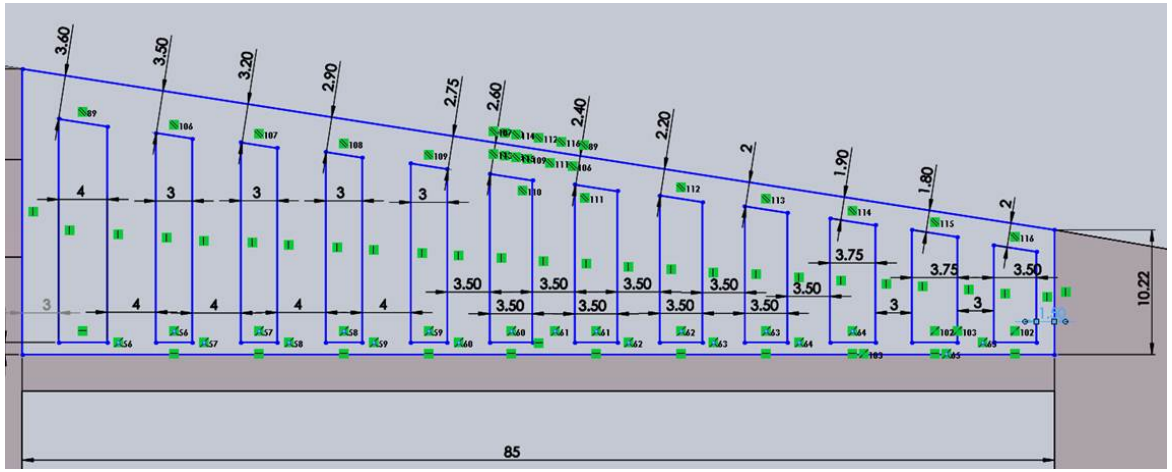


Far away from 8MPa but un-even distribution of work load

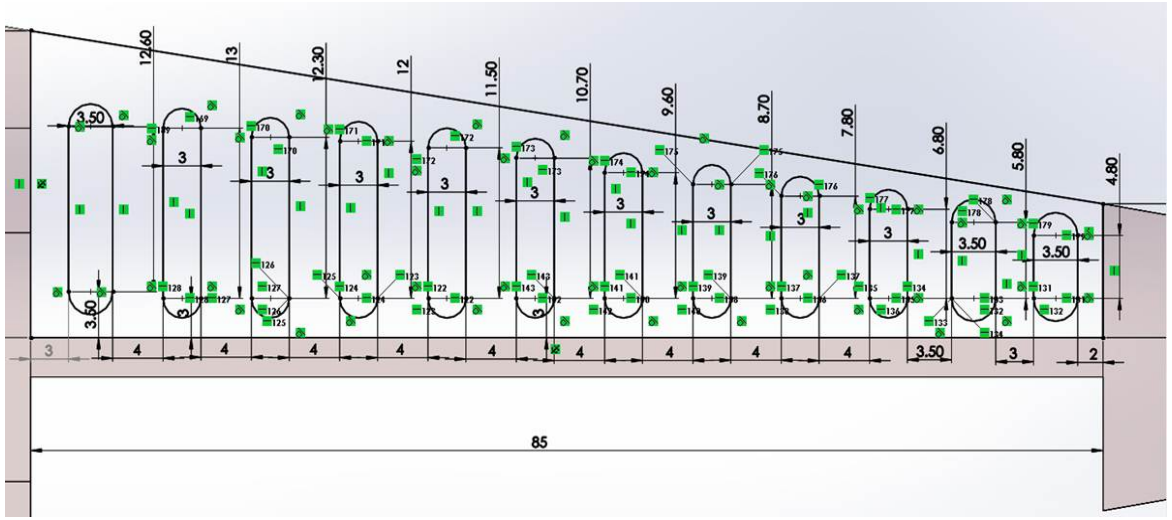


Here the full surface is at work causing a more even flap deflection

Spanwise cavities for extrusion

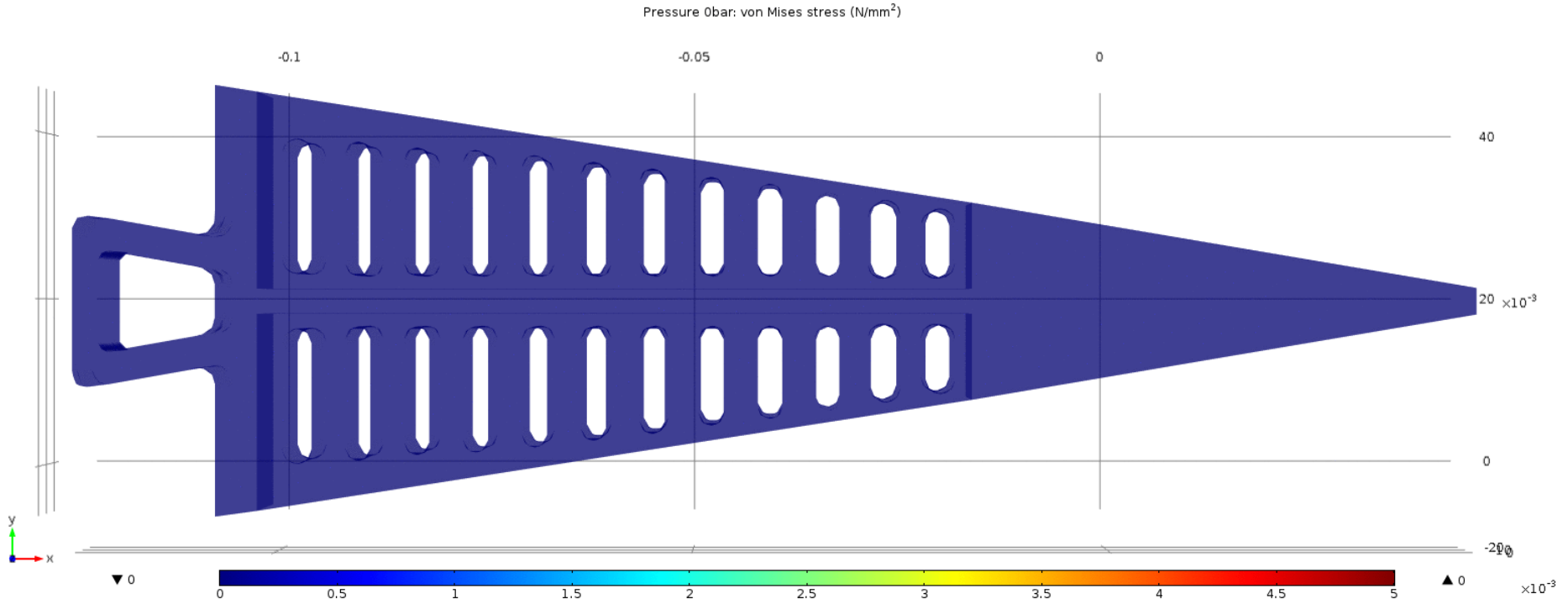


Sharp edges



Rounded edges

Spanwise cavities for extrusion



Numerical results

		Flap deflection		Rubber			Reinforcement	
				outer	Inner	w/ part.	inner	w/ part.
Cavity	pressure	angle	displa.	Stress	Stress	safty fac.	stress	saf. fac.
design	bar	deg	mm	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
Rounded	4	4.2	11.0		1.7	2.3 (3.48)	8	11
old square	6	6.6	17.4	3.2	4.1	5.5 (1.45)	12	16
Square	6	6.8	17.8	2.5	4.0	5.4 (1.48)	12	16
Rounded	6	6.5	17.1	2.4	2.6	3.5 (2.29)	12	16
old square	8	8.3	21.9		6.1	8.2 (0.97)	14	19
Square	8	8.9	23.5		6.0	8.1 (0.99)	14	19
Rounded	8	9.1	23.9		4.1	5.5 (1.45)	14	19

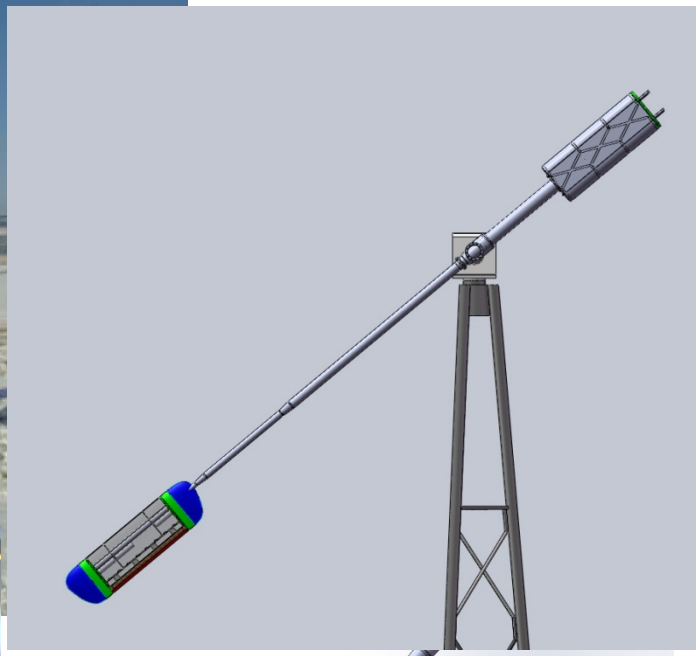
Conclusion

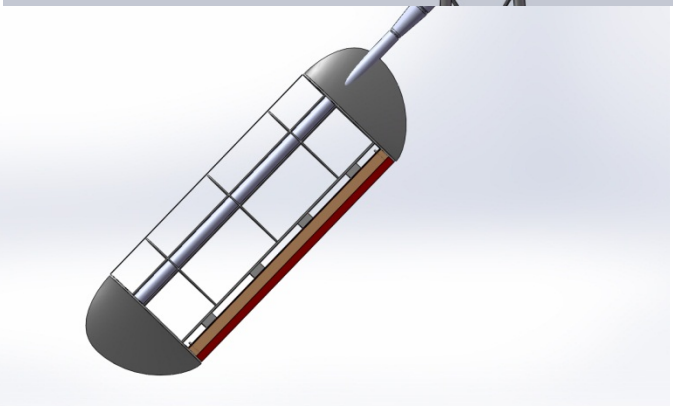
The new spanwise cavity design lowers the critical stresses.
(8.2MPa -> 5.5MPa for 8bar overpressure w/ 1.35 saftyfactor)
(5.5MPa -> 3.5MPa for 6bar overpressure w/ 1.35 saftyfactor)

Compared to the original design the flap deflection angles remain almost the same.

According to the FEM models used it is recommended to use round edges instead of sharp edges for the cavities

Future...





Thank you for your attention!