

LOAD ALLEVIATION ON WIND TURBINE BLADES USING VARIABLE AIRFOIL GEOMETRY



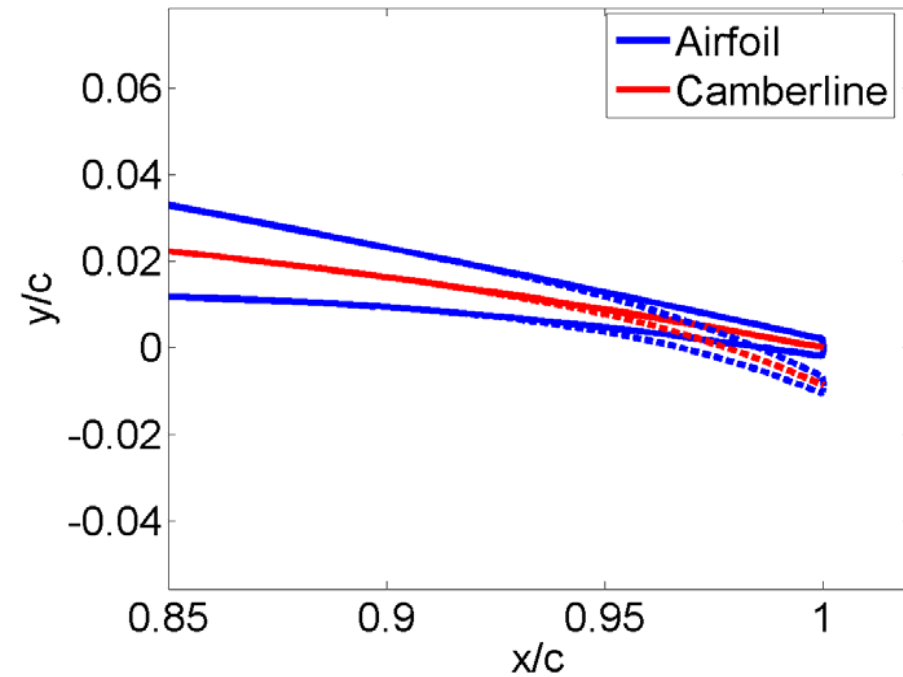
Peter Bjørn Andersen, Mac Gaunaa,
Christian Bak and Thomas Buhl

Wind Turbine

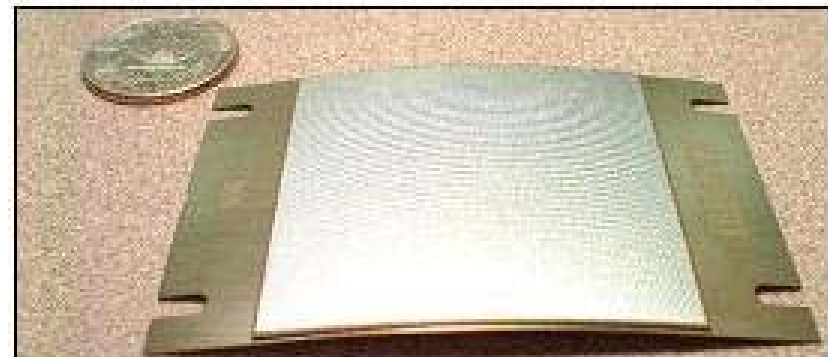
www.risoe.dk

The variable geometry (or flap)

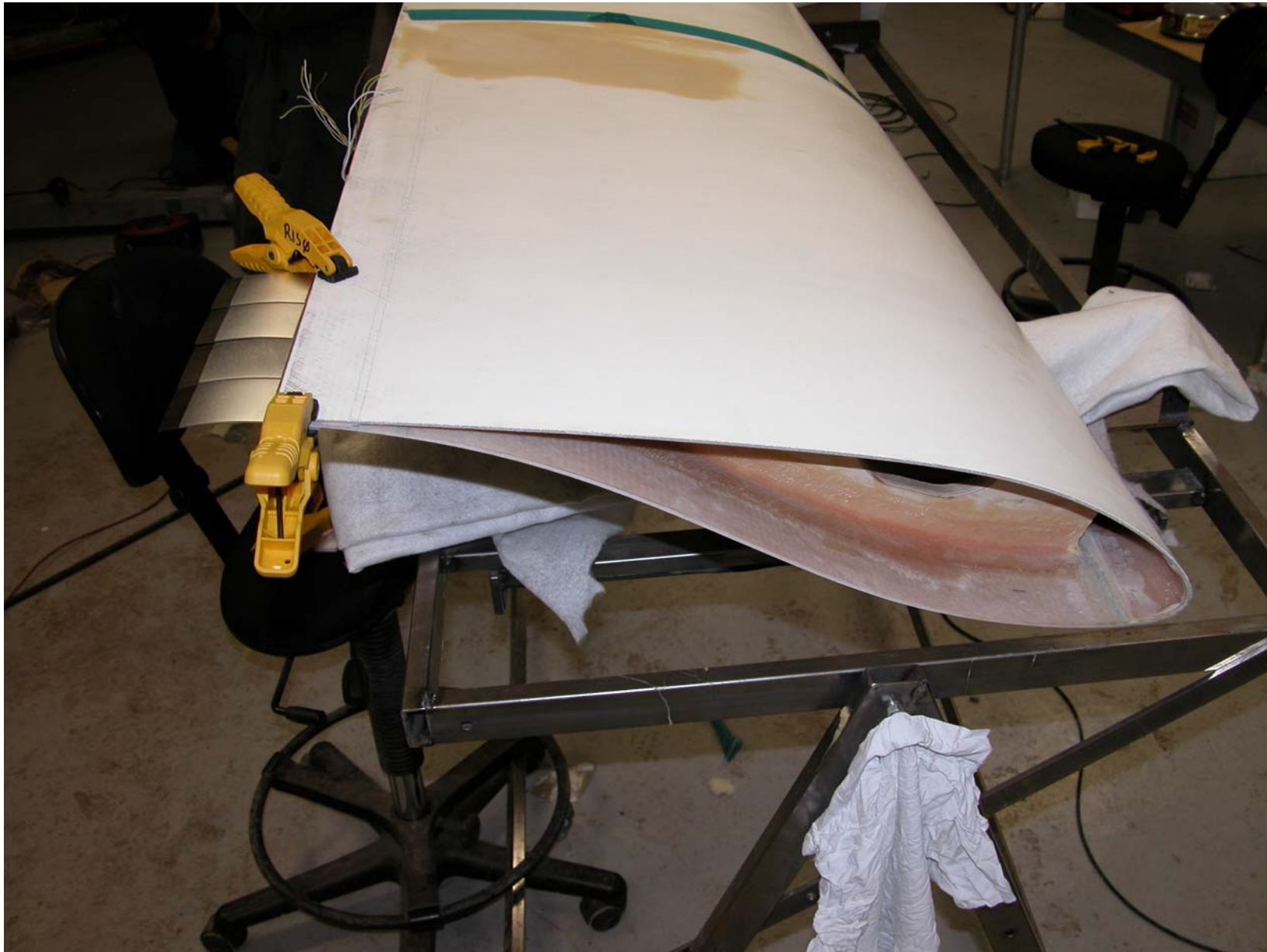
- 10% chord length
- Allowed deflections +/- 5 deg



- Piezo-electric material



The blade – Risoe B1-18

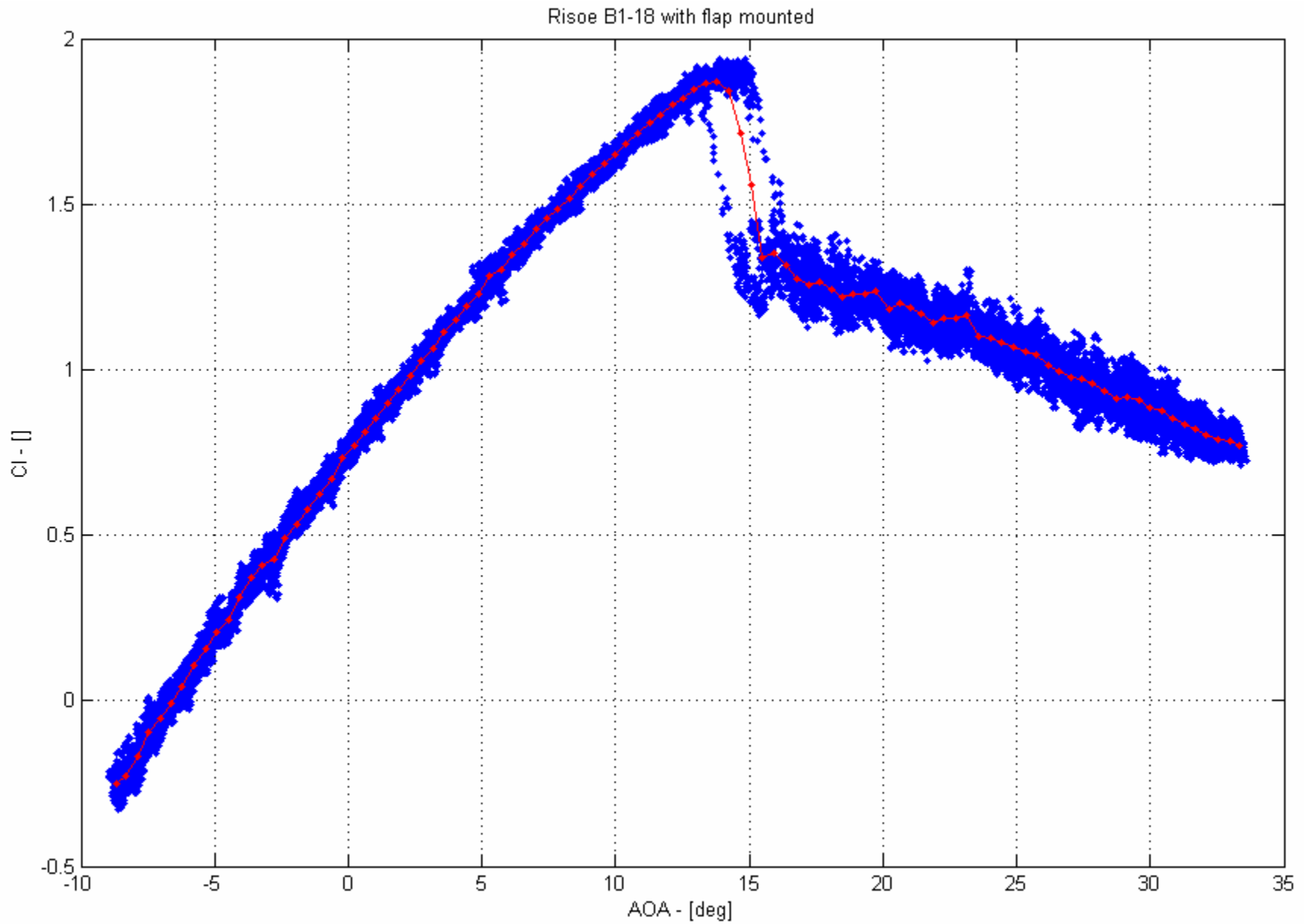


SHOW VIDEO (3min)

RISO



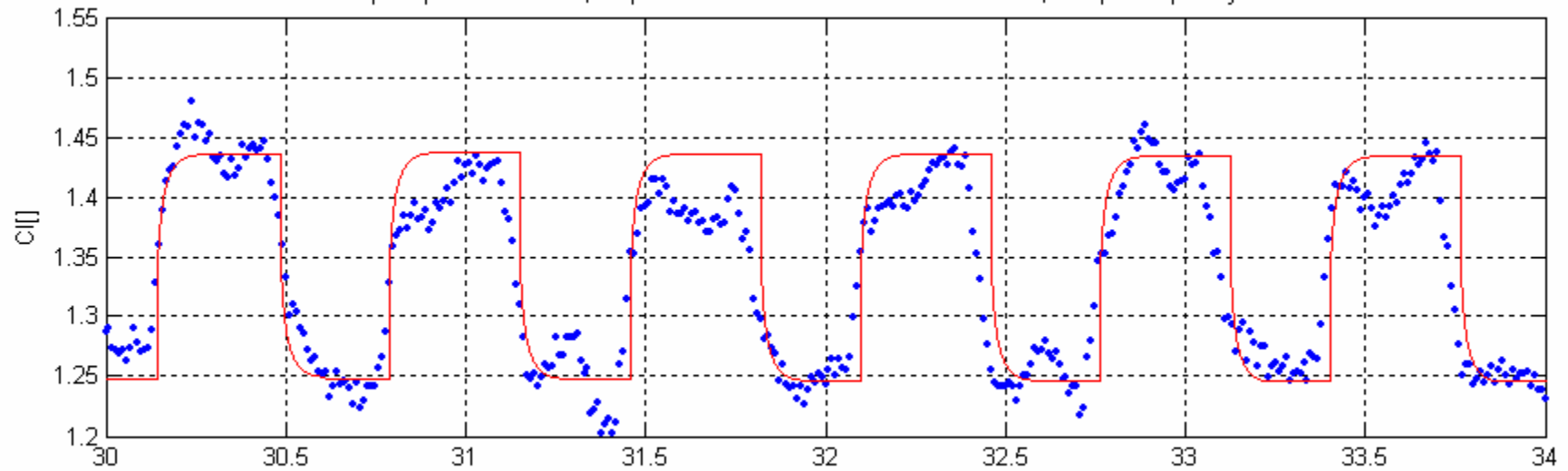
Result (step flap)



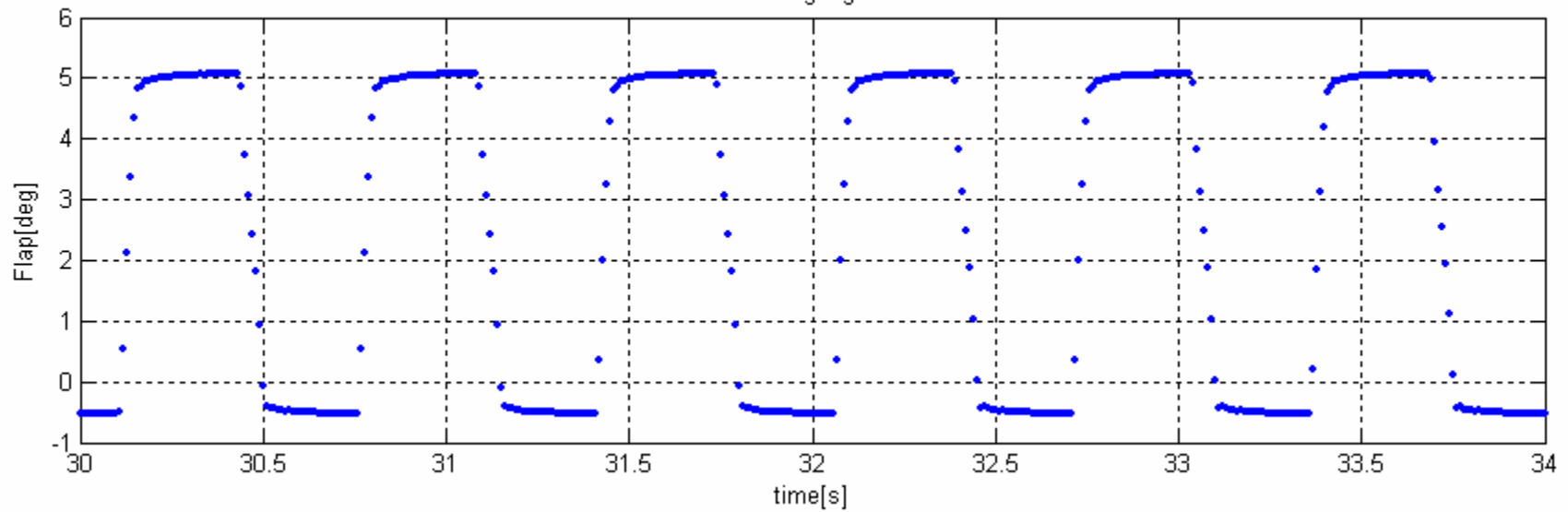
Result (step flap)



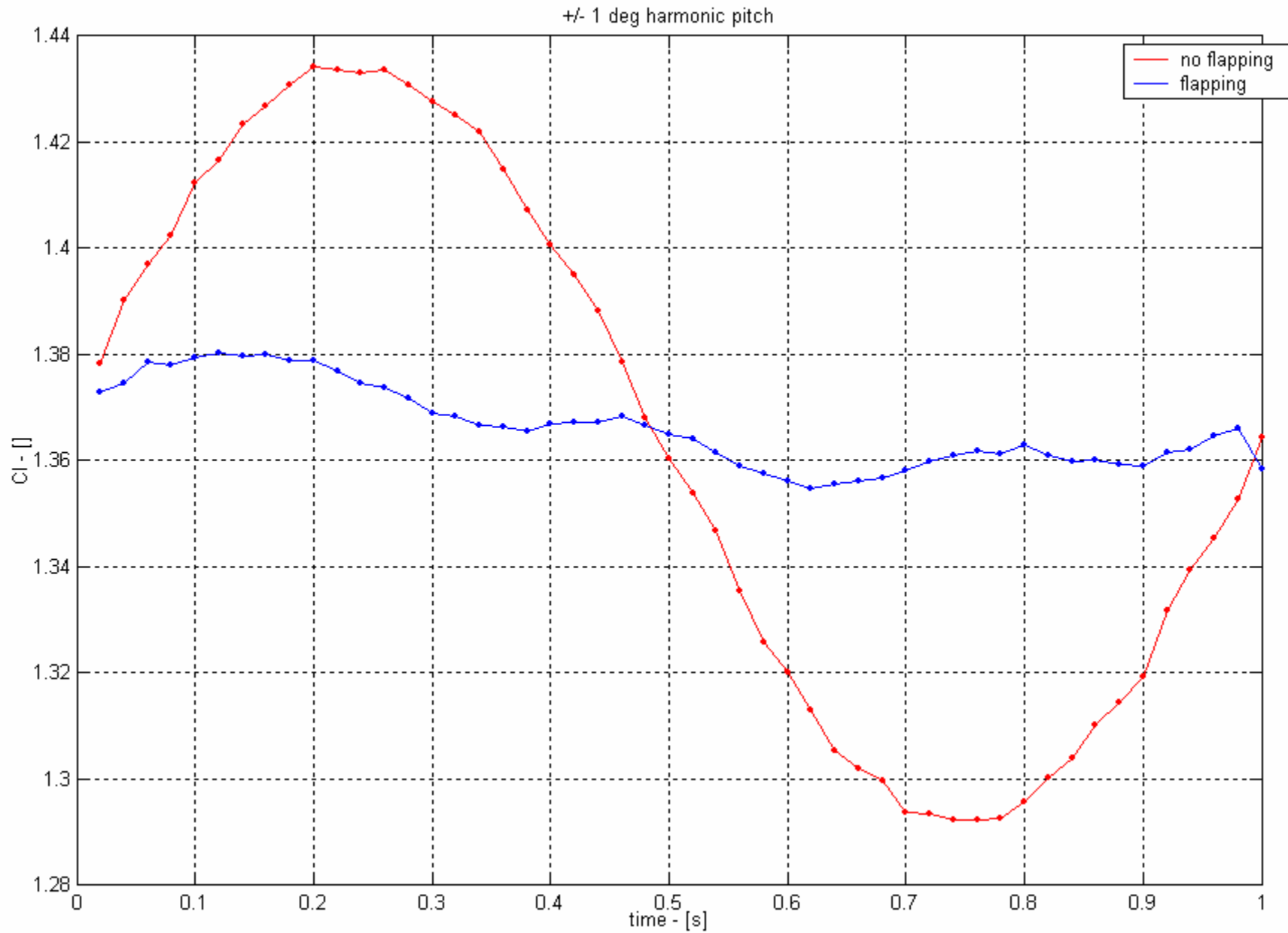
Step response - 1.54Hz, 64 pressure tubes used to measure forces, sample frequency 100Hz



Strain gauge 4

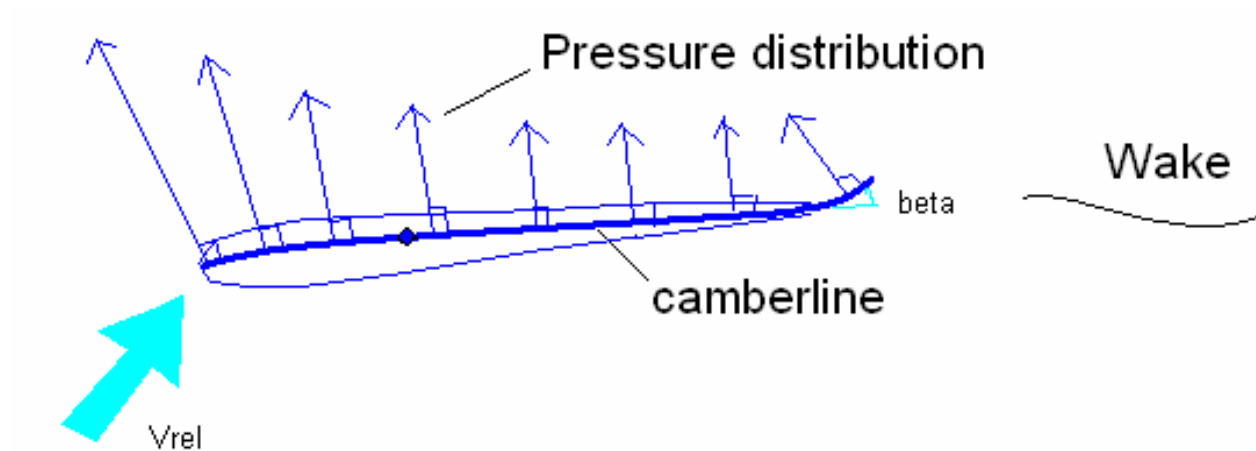


Result (pitch + flap)

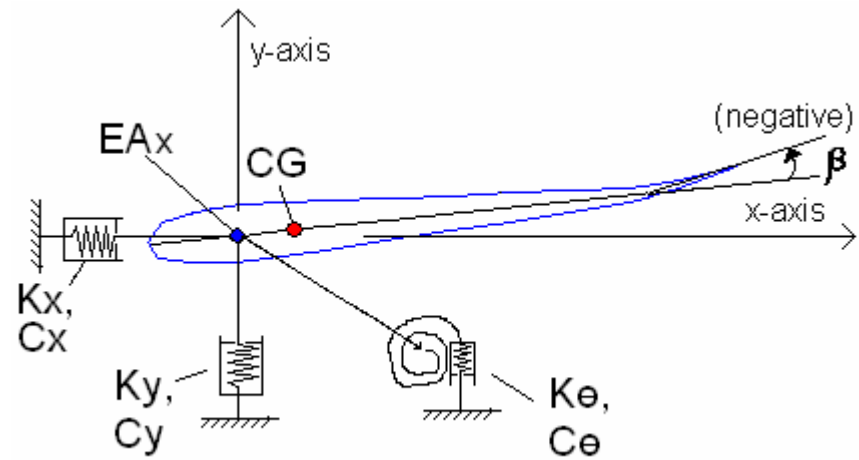


Modelling the TE flap – Mac Gaunaa

- Unsteady thin-airfoil potential model
- Model expansion of camber-line
- Dynamic wake modeled using a series of indicial functions



2D model



SHOW 2D MODEL (2min)



Form1

Button1 Label1 Label2 Label3 Label3

CheckBox1

Turbulens Sin 10m/s

	s1	s2	s3	1-s1/s2 [%]	1-s3/s2 [%]
var(Fx)	0	0	0	0	0
var(Fy)	0	0	0	0	0
var(Mtot)	0	0	0	0	0
var(Mflap)	0		0		
mean(Fx)	0	0	0	0	0
mean(Fy)	0	0	0	0	0
mean(M)	0	0	0	0	0
mean(Mflap)	0		0		
min(Fx)	0	0	0	0	0
min(Fy)	0	0	0	0	0
min(M)	0	0	0	0	0
min(Mflap)	0		0		
max(Fx)	0	0	0	0	0
max(Fy)	0	0	0	0	0
max(M)	0	0	0	0	0
max(Mflap)	0		0		

aktor

Load Save

Ax 0 Atheta 0 Ax 0 Atheta 0
 Bx 0 Btheta 0 Bx 0 Btheta 0
 Cx 0 Ctheta 0 Cx 0 Ctheta 0
 Ay 0 Aa 0 Ay -200 Aa 0
 By 0 By -10
 Cy 0 Cy -0

Quick Screen Recorder

Etrusoft
Quick Screen Recorder
<http://www.etrusoft.com/screen-recorder/>

Press the Stop Button to stop recording

Wind Theta X Y

24
22
20
18
16
14
12
10
8
6
4
2

0cm 20cm

40cm
30cm
20cm
10cm
0cm
-10cm
-20cm
-30cm
-40cm

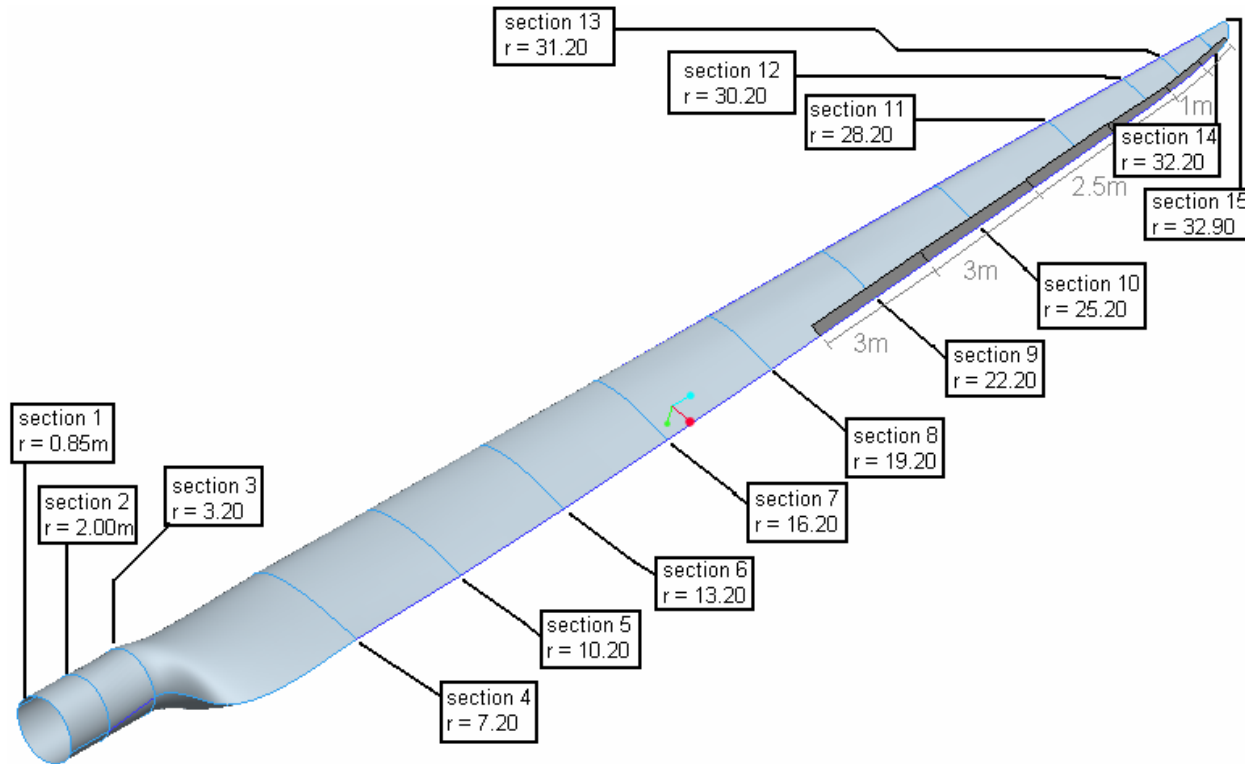
Start ae_n_wind - Com... Ewec.ppt Indbakke - Micros... E:\Peter\dtu\Mast... Simulate Quick Screen Re... 8:29 AM

SHOW 2D MODEL (2min)



[2D.avi](#)

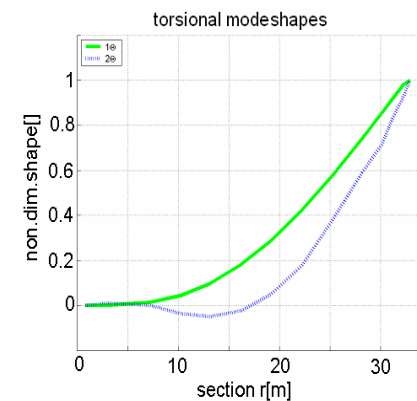
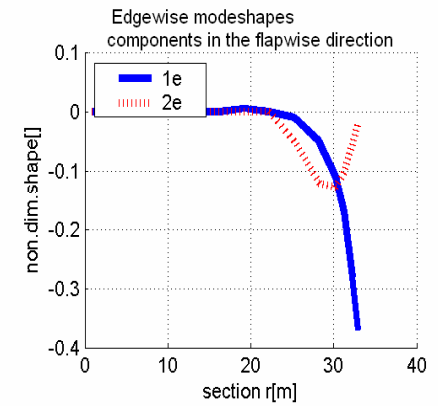
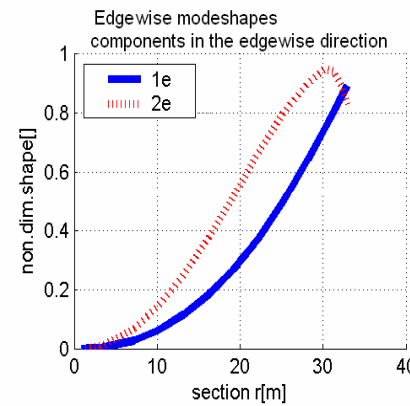
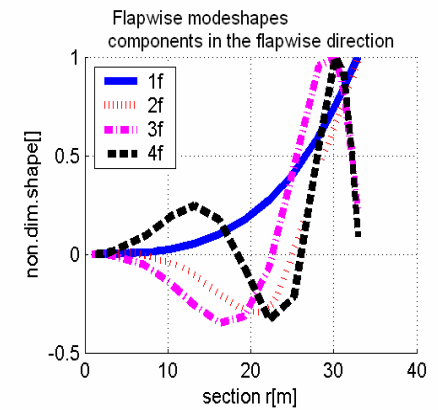
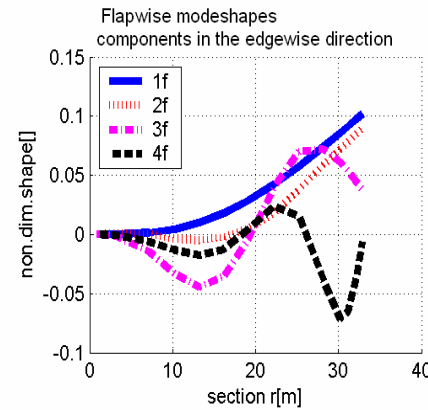
3D model



3D model structure



- Slender cantilever beam theory
- Blade length 33m
- Known structural data
- Mode shapes and eigenfreq.
1f,2f,3f,4f, 1e,2e, 1 Θ ,2 Θ



3D model aerodynamic



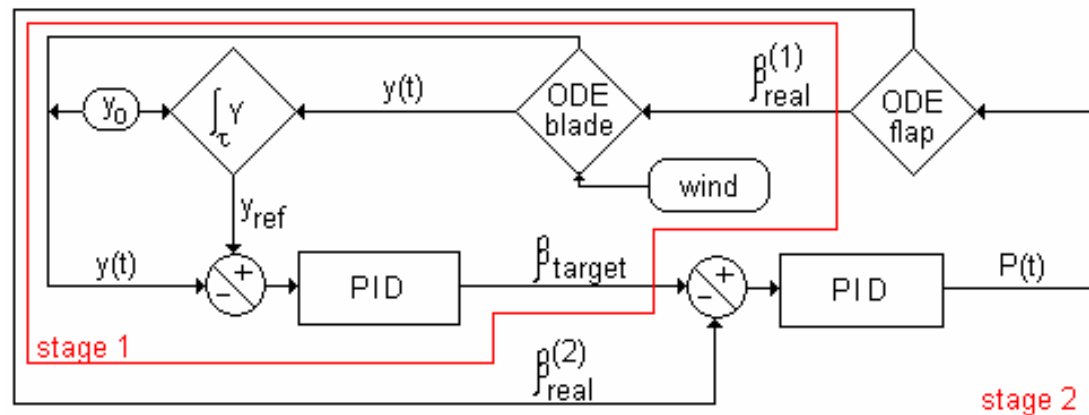
- Turbulent wind series “Paul S. Veers”
- Induced velocity “Bramwell”
- Dynamic inflow model “TUDk”
- Tip-loss factor “Prandtl”
- Known static lift and drag
- Dynamic flow “Mac Gaunaa”

3D model control



- SET FLAP ANGLE USING SIMPLE PID FEEDBACK LOOP

Object function:
Minimizing equivalent flapwise root moment

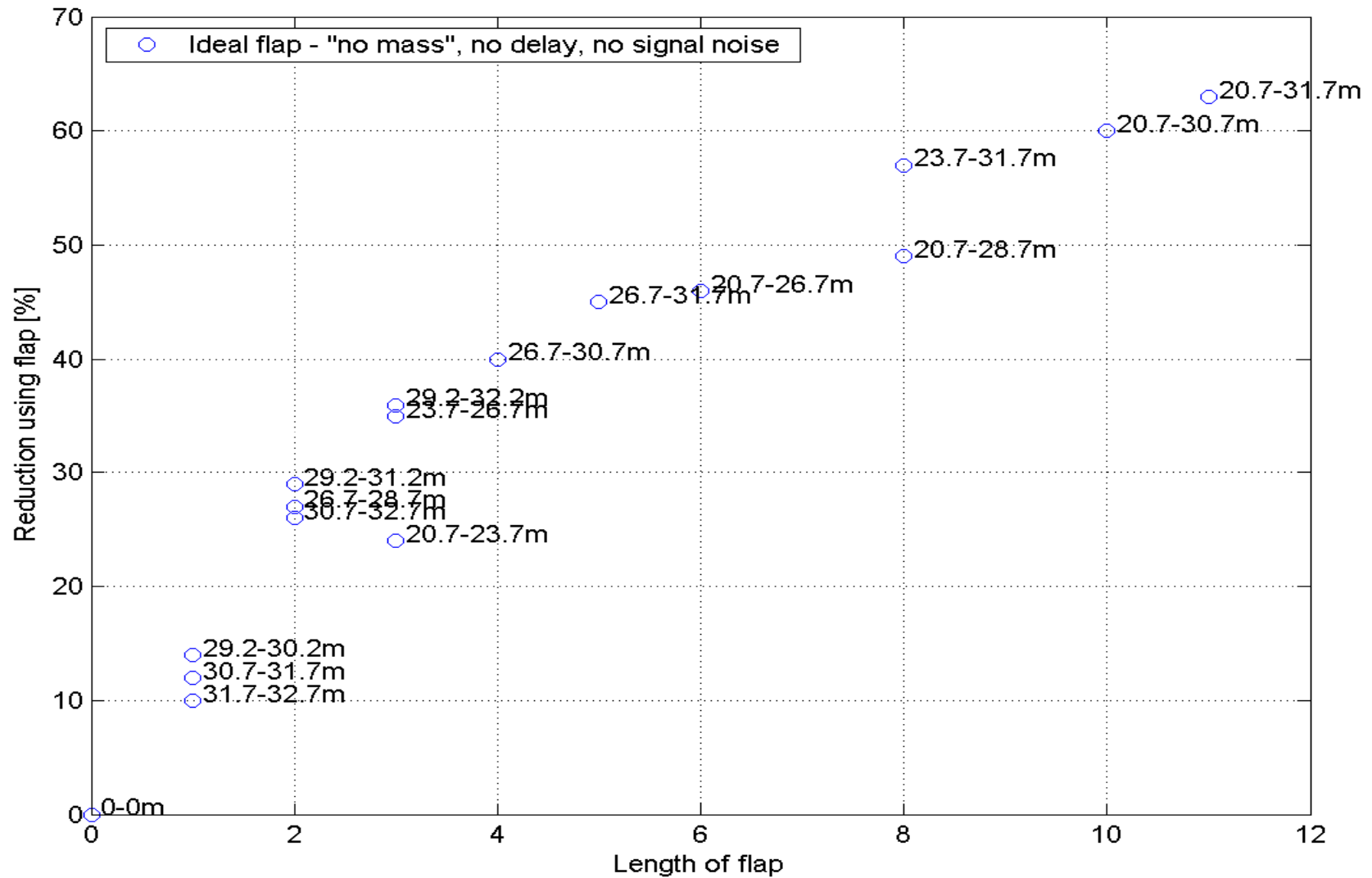


SHOW 3D MODEL (5min)

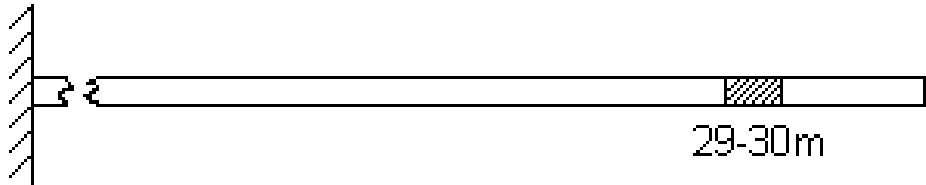
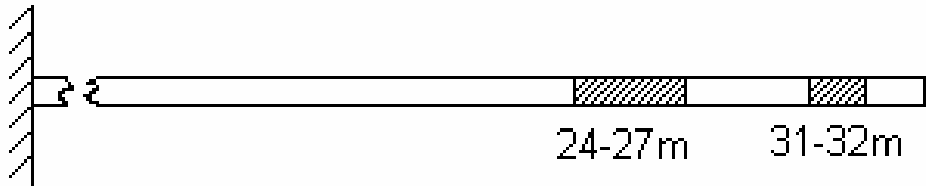
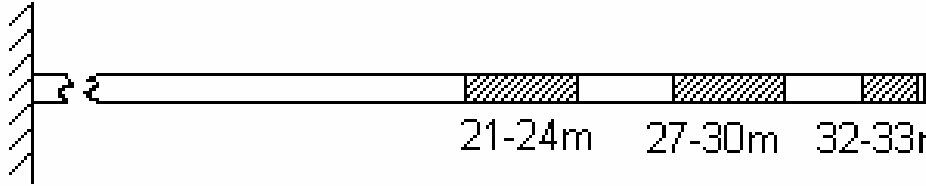
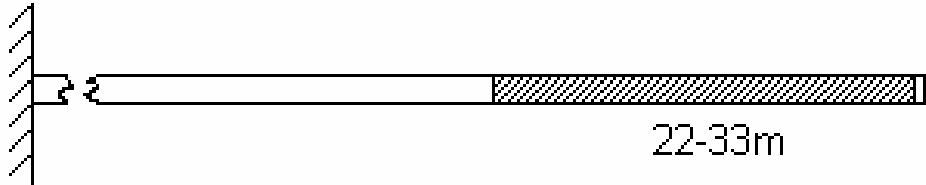
RISO

[3D.avi](#)

3D model results (1)



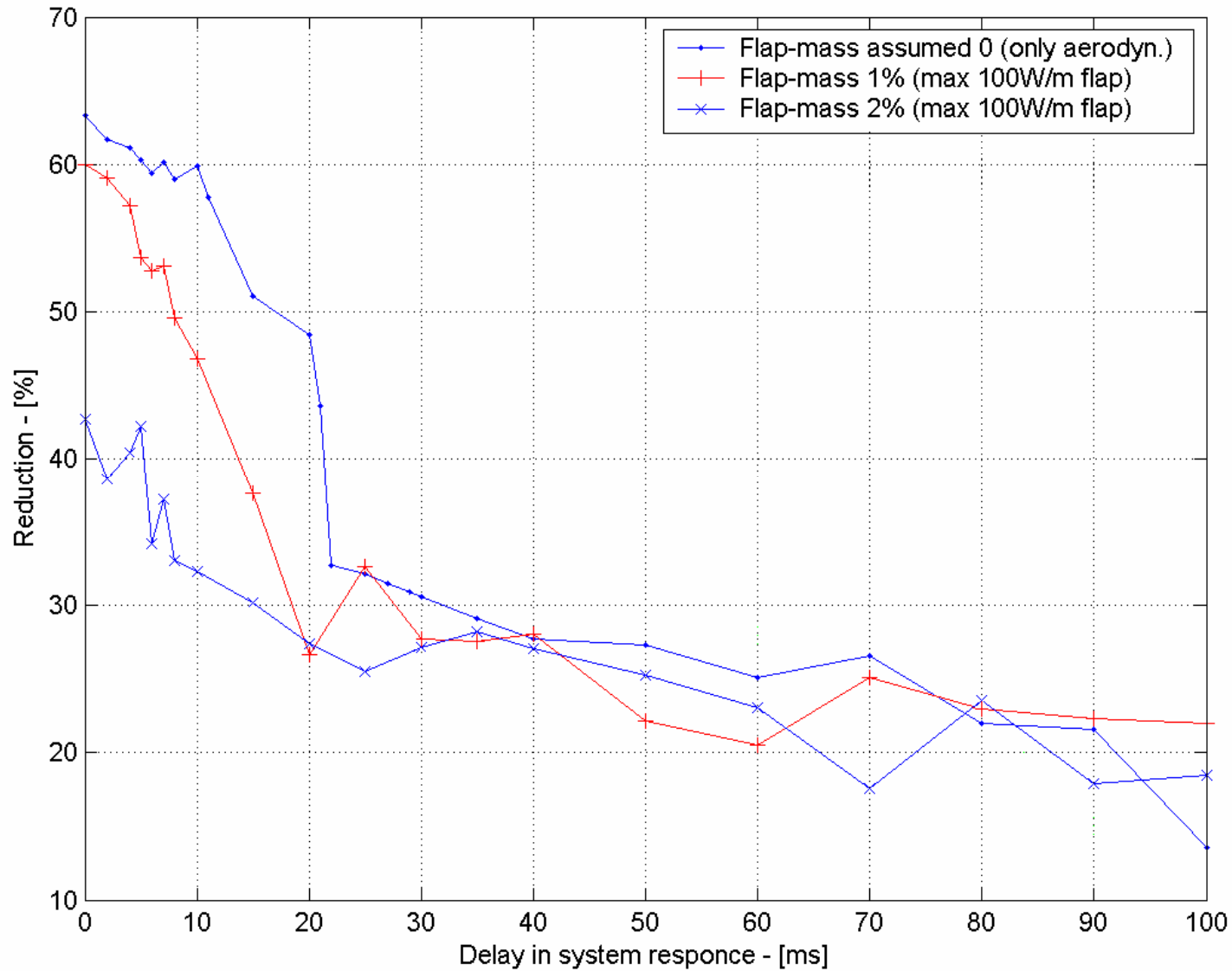
3D model results (2)

given flap	best radial location of given flap	flapwise root moment - maximum reduction potential – fatigue
one meter flap available	 <p>29-30m</p>	14%
four meters flap available	 <p>24-27m 31-32m</p>	50%
seven meters of flap available	 <p>21-24m 27-30m 32-33m</p>	62%
eleven meters of flap available	 <p>22-33m</p>	65%

3D model results (3)



Reduction potential of EQ_F in percent PID regulator for section 9-14 used (flap 11m).



Open questions



- Measure flapwise deflection
- Power output
- Gain
- ...

Flapwise root moment

