LOAD ALLEVIATION ON WIND TURBINE BLADES USING VARIABLE AIRFOIL GEOMETRY

Wind Turbine

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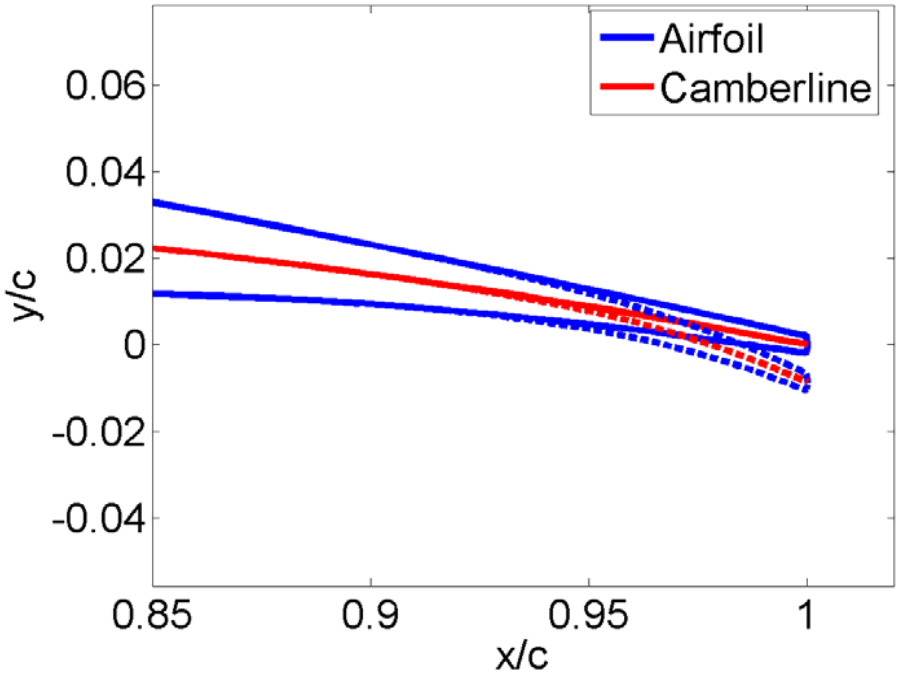
Christian Bak and Thomas Buhl

www.risoe.dk

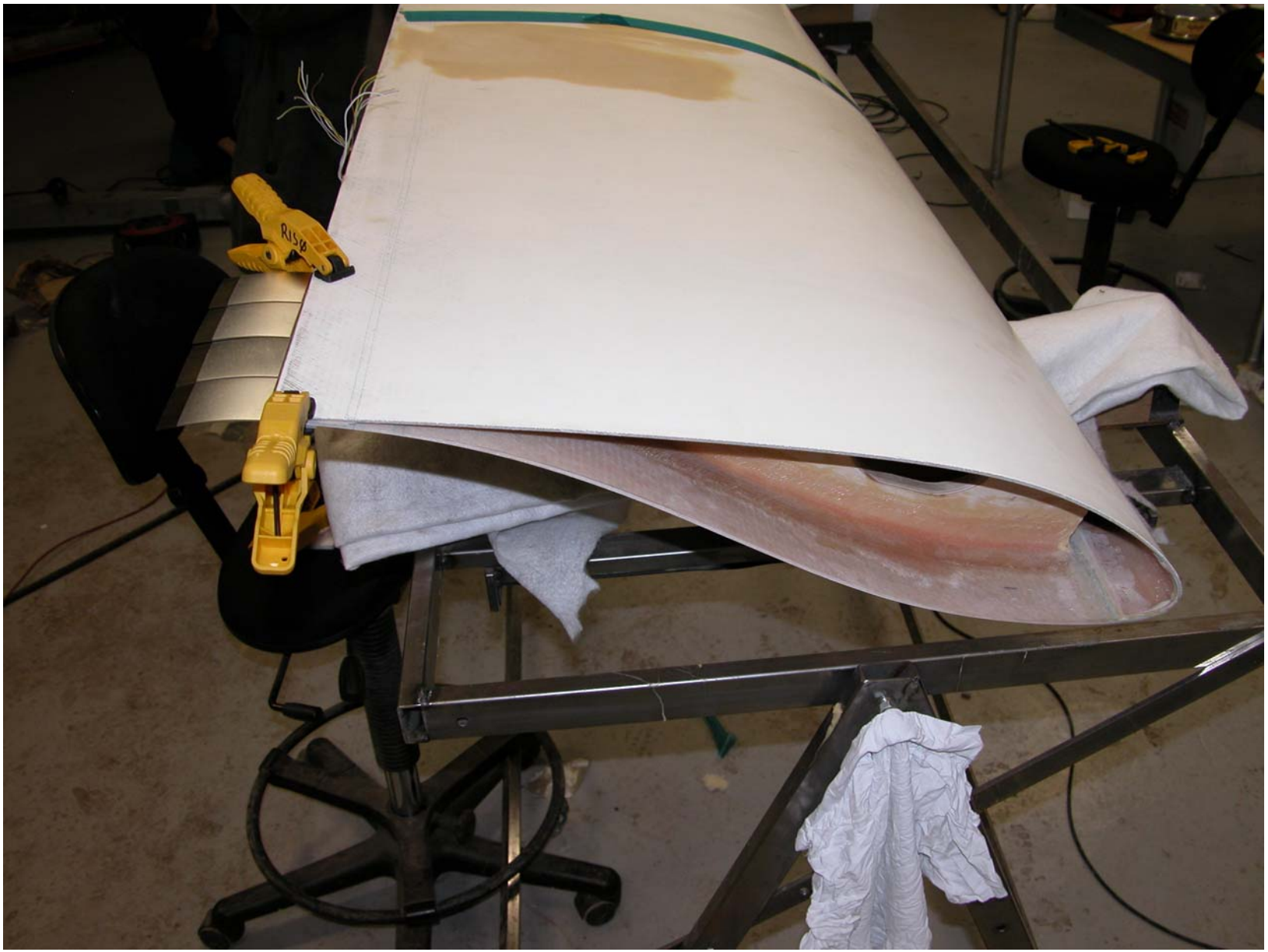
The variable geometry (or flap)

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



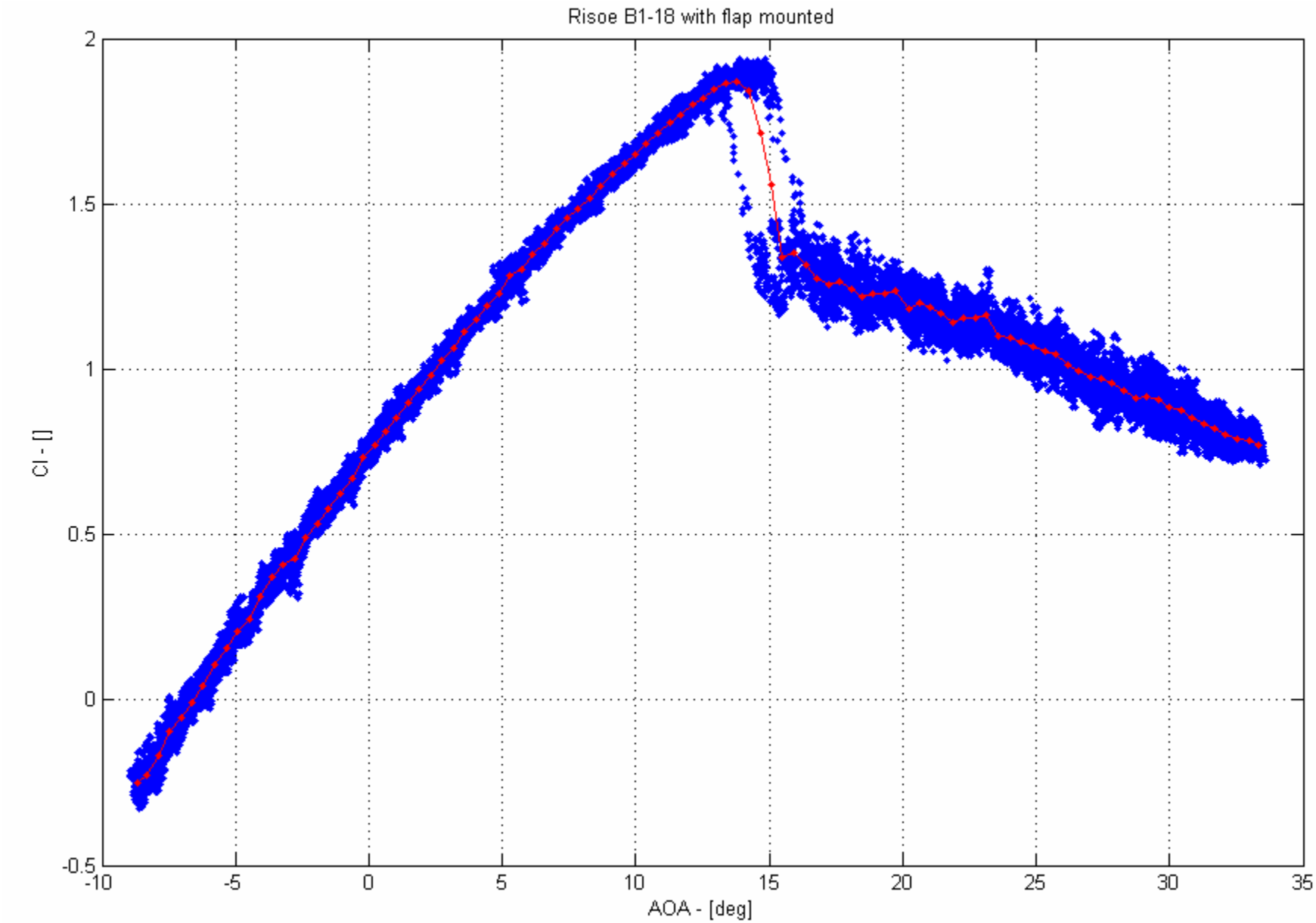
- Piezo-electric material

The blade – Risoe B1-18

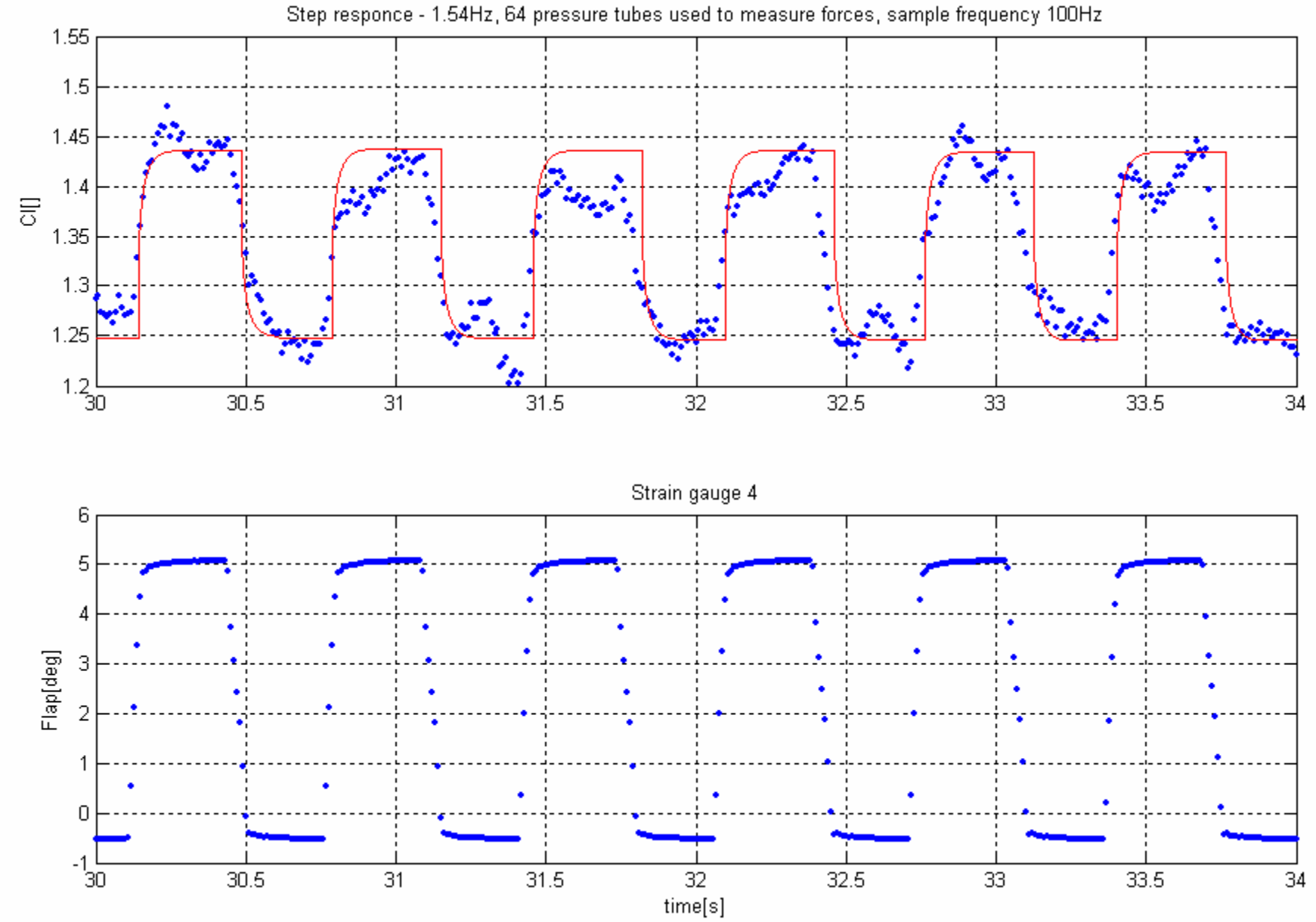


SHOW VIDEO (3min)

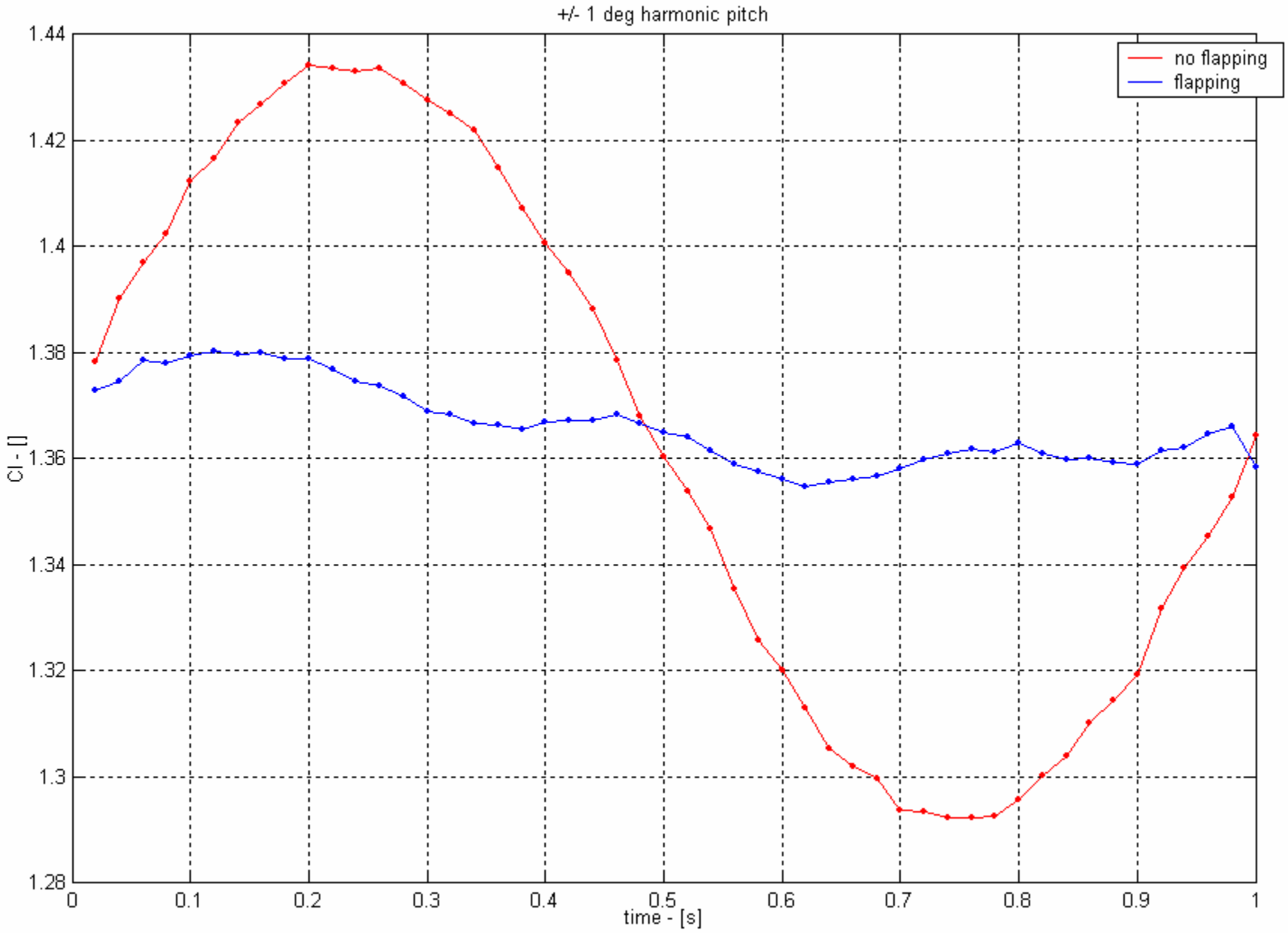
Result (step flap)



Result (step flap)

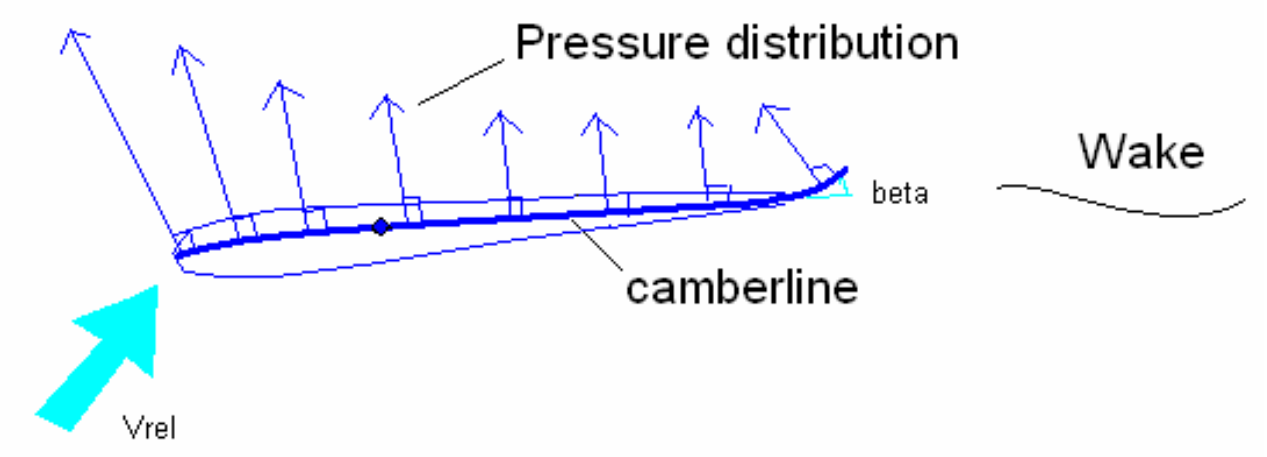


Result (pitch + flap)

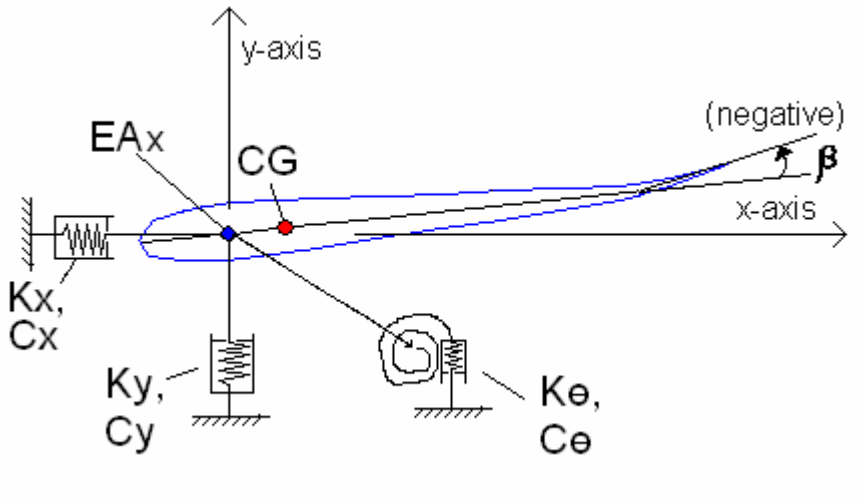


Modelling the TE flap – Mac Gaunaa

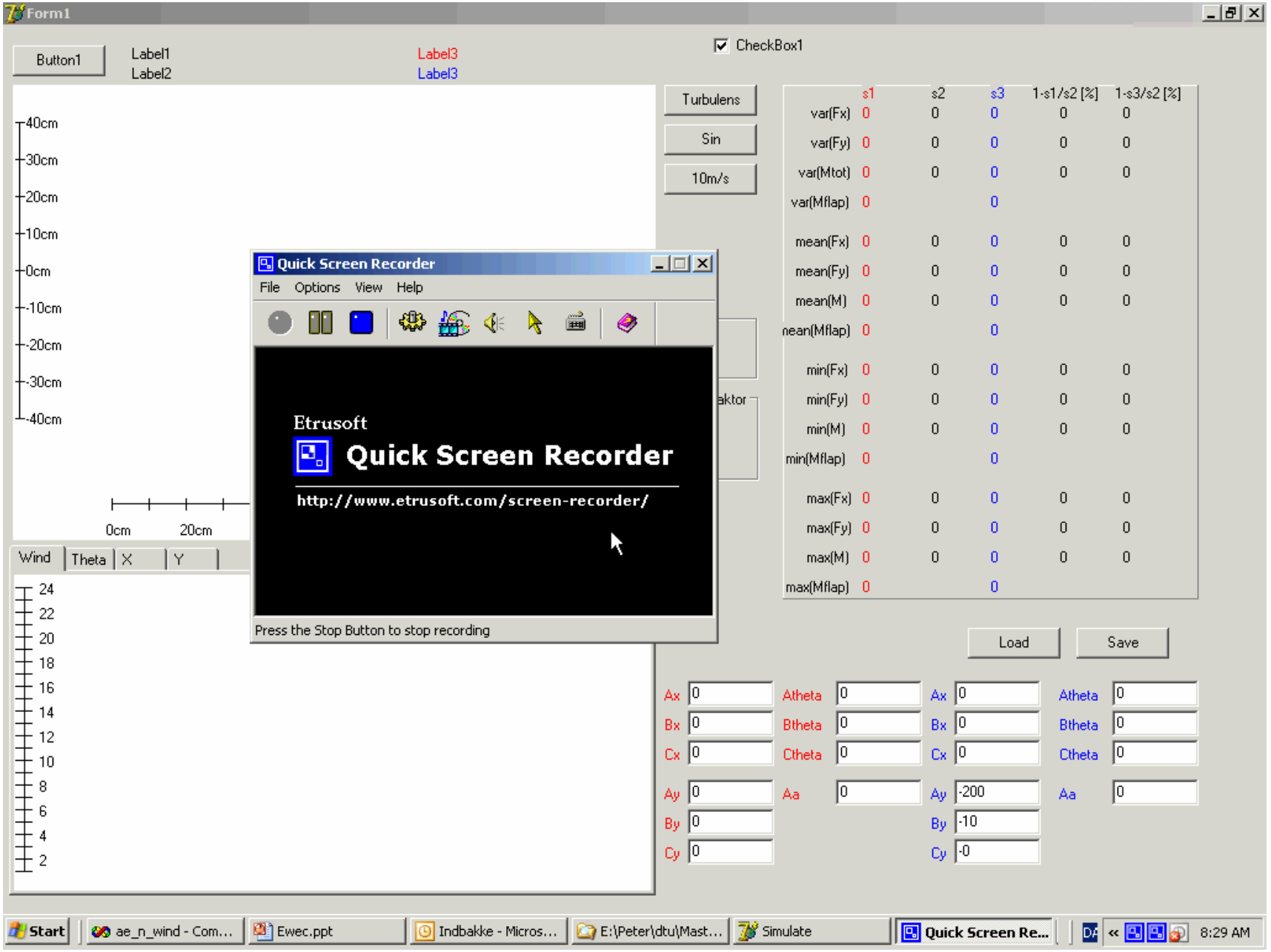
- Unsteady thin-airfoil potential model
- Model expansion of camber-line
- Dynamic wake modeled using a series of indicial functions



2D model



SHOW 2D MODEL (2min)



SHOW 2D MODEL (2min)

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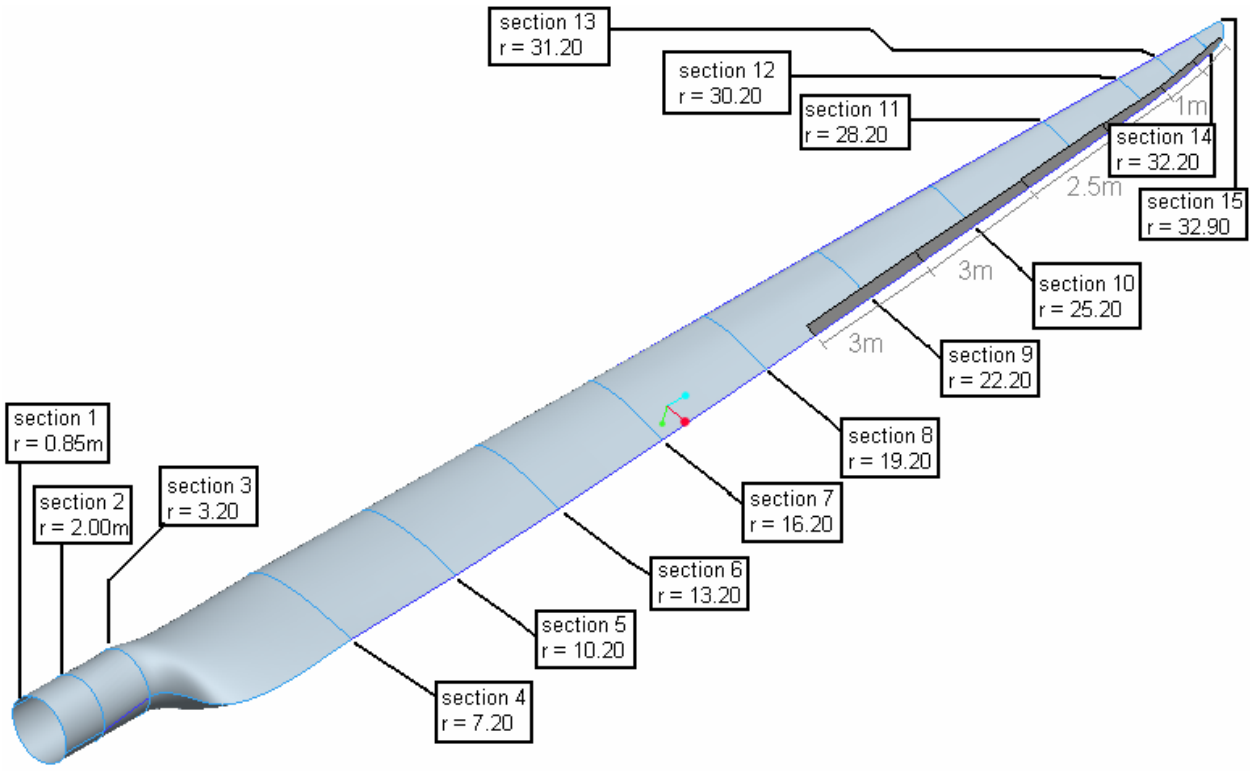
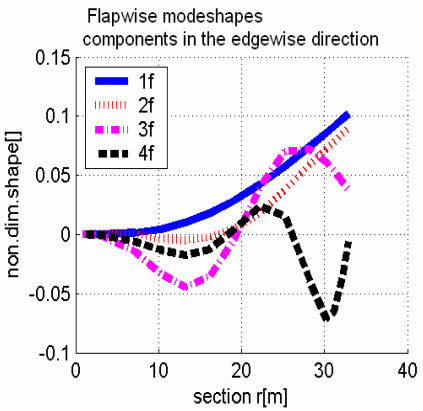
2D.avi

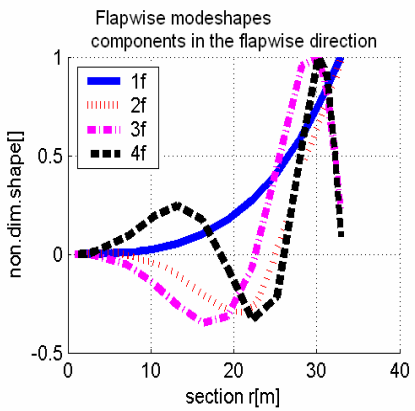
3D model

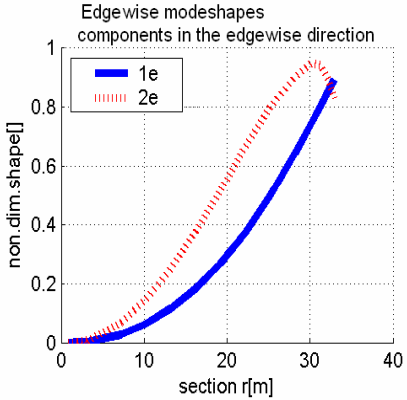

section 13
r = 31.20
section 12
r = 30.20
section 11
r = 28.20
section 14
r = 32.20
section 15
r = 32.90
1m
2.5m
3m
3m
section 10
r = 25.20
section 9
r = 22.20
section 8
r = 19.20
section 7
r = 16.20
section 6
r = 13.20
section 5
r = 10.20
section 4
r = 7.20
section 1
r = 0.85m
section 2
r = 2.00m
section 3
r = 3.20

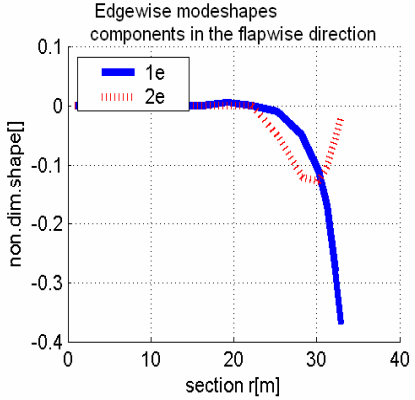
3D model structure

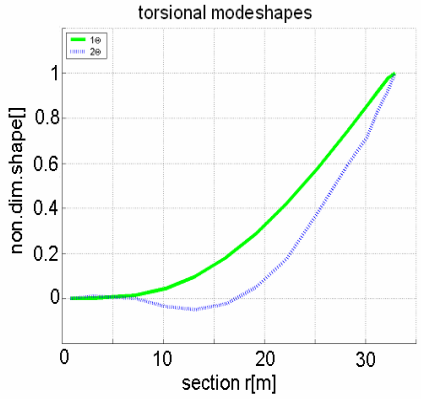
- Slender cantilever beam theory
- Blade length 33m
- Known structural data
- Mode shapes and eigenfreq. 1f,2f,3f,4f,1e,2e,1Θ,2Θ











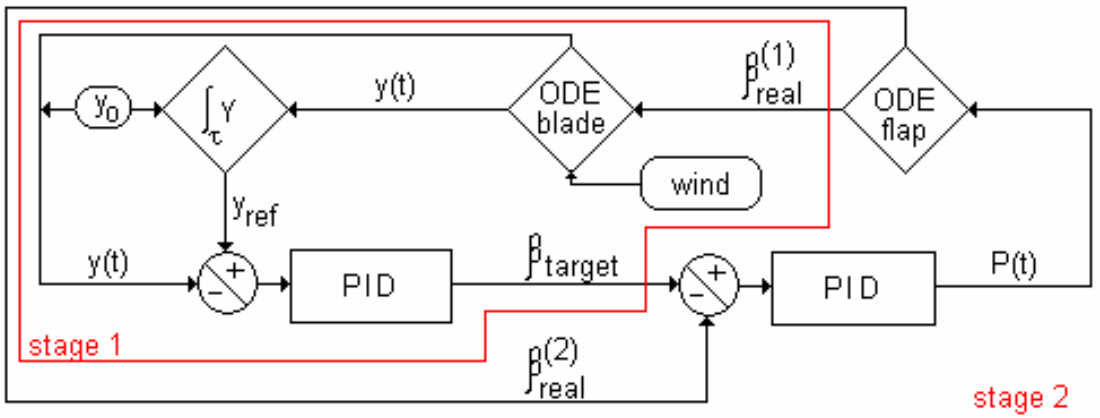
3D model aerodynamic

- 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”

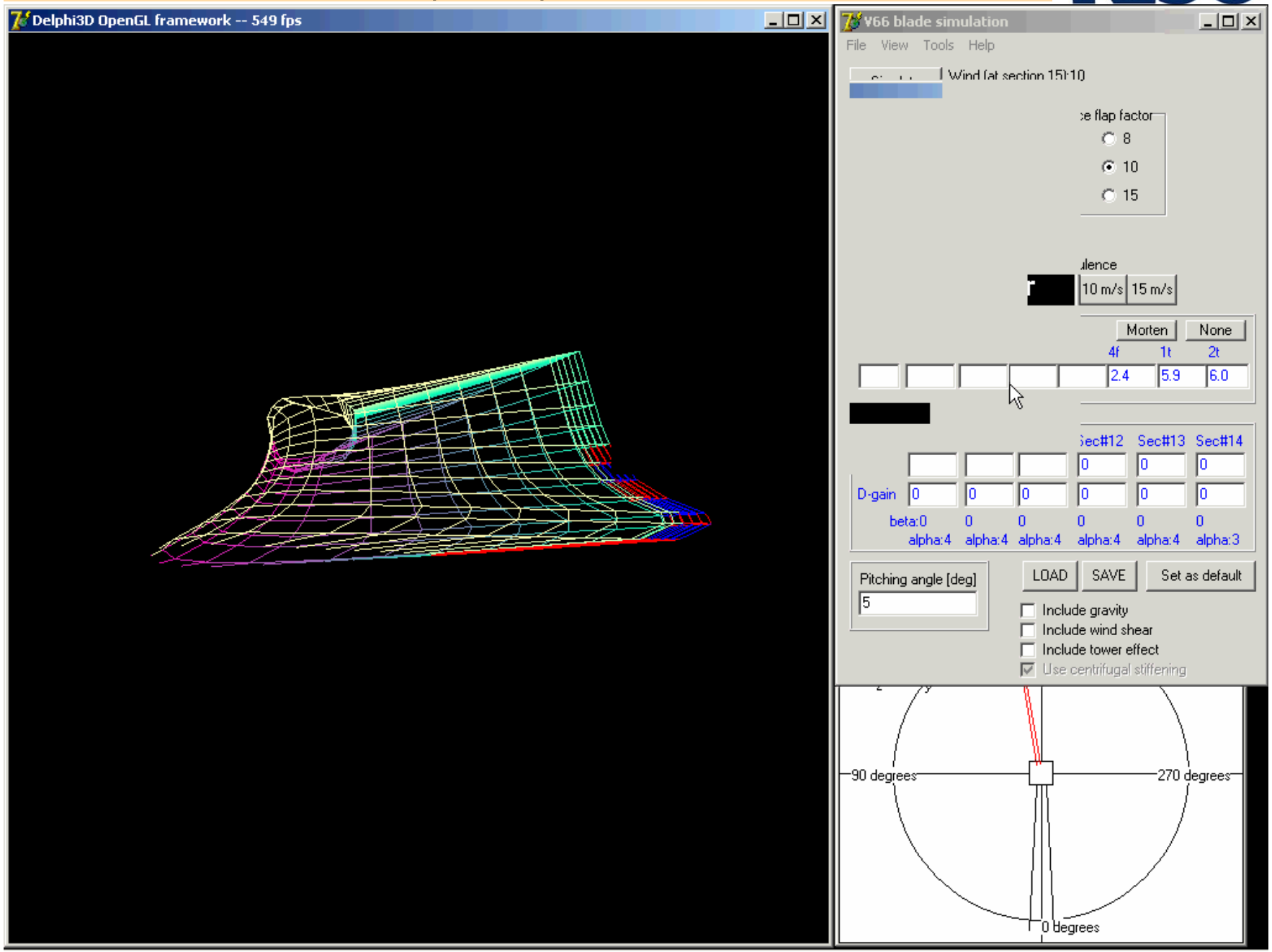
3D model control

- SET FLAP ANGLE USING SIMPLE PID FEEDBACK LOOP

Object function:
Minimizing equivalent flapwise root moment



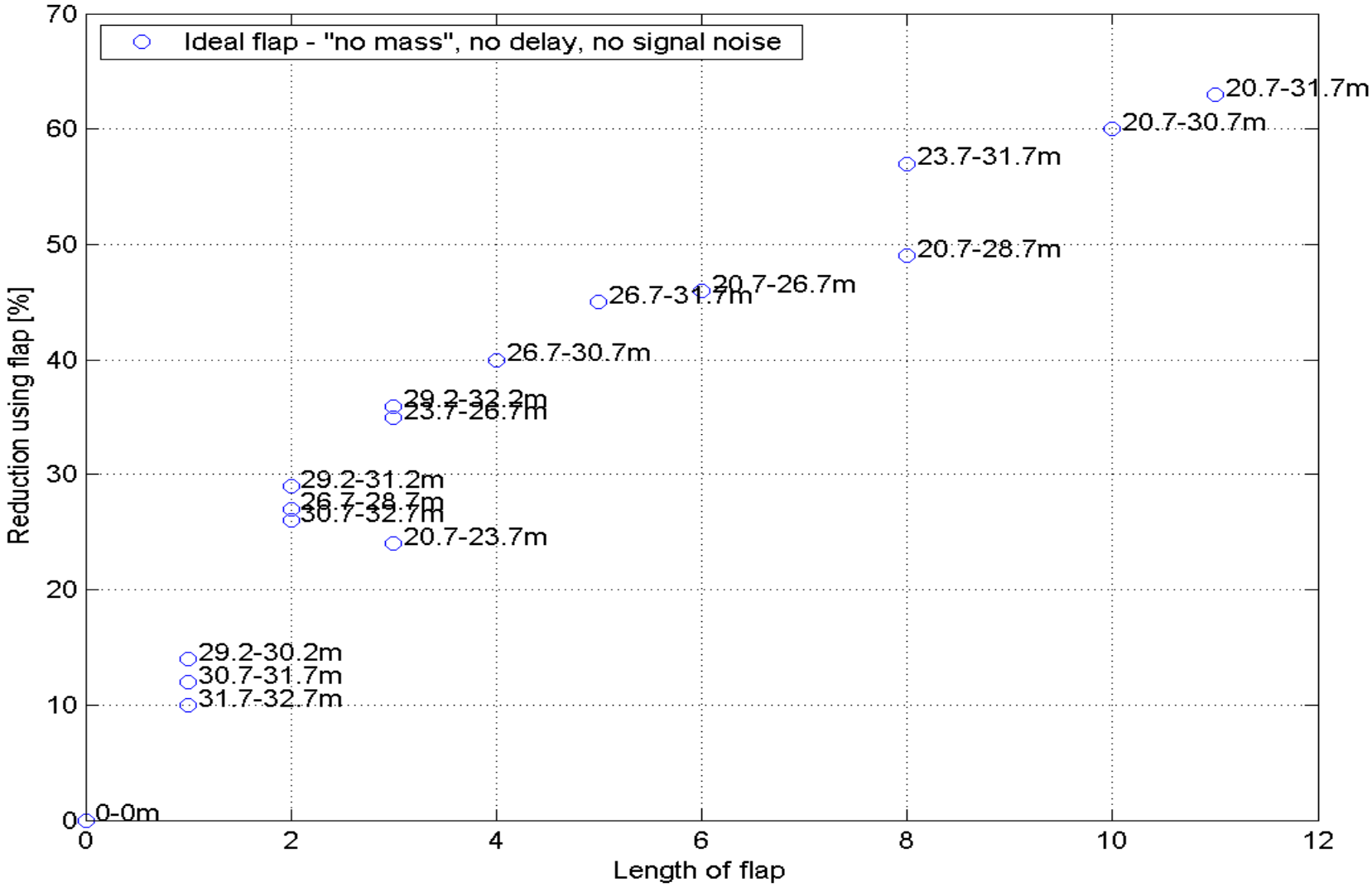
SHOW 3D MODEL (5min)



SHOW 3D MODEL (5min)

3D.avi

3D model results (1)



3D model results (2)

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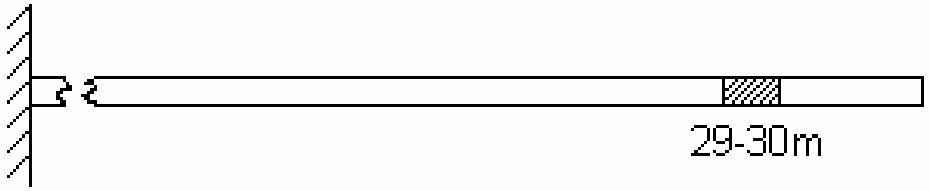
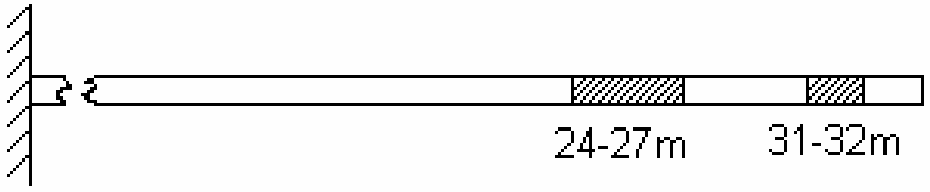
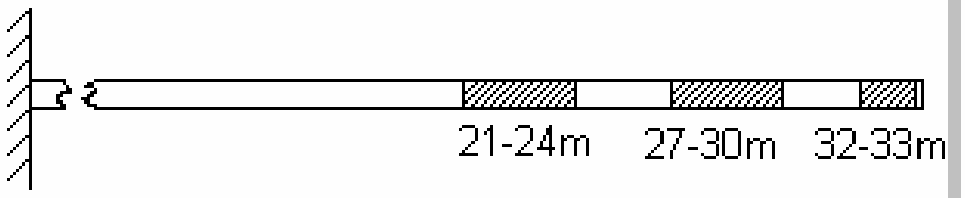
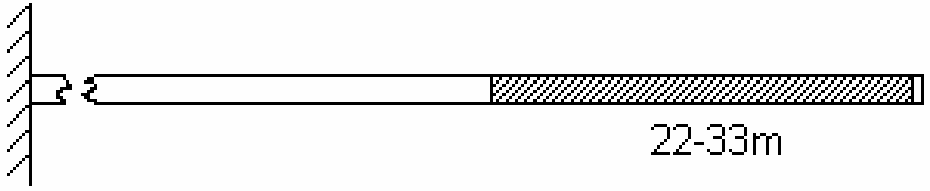
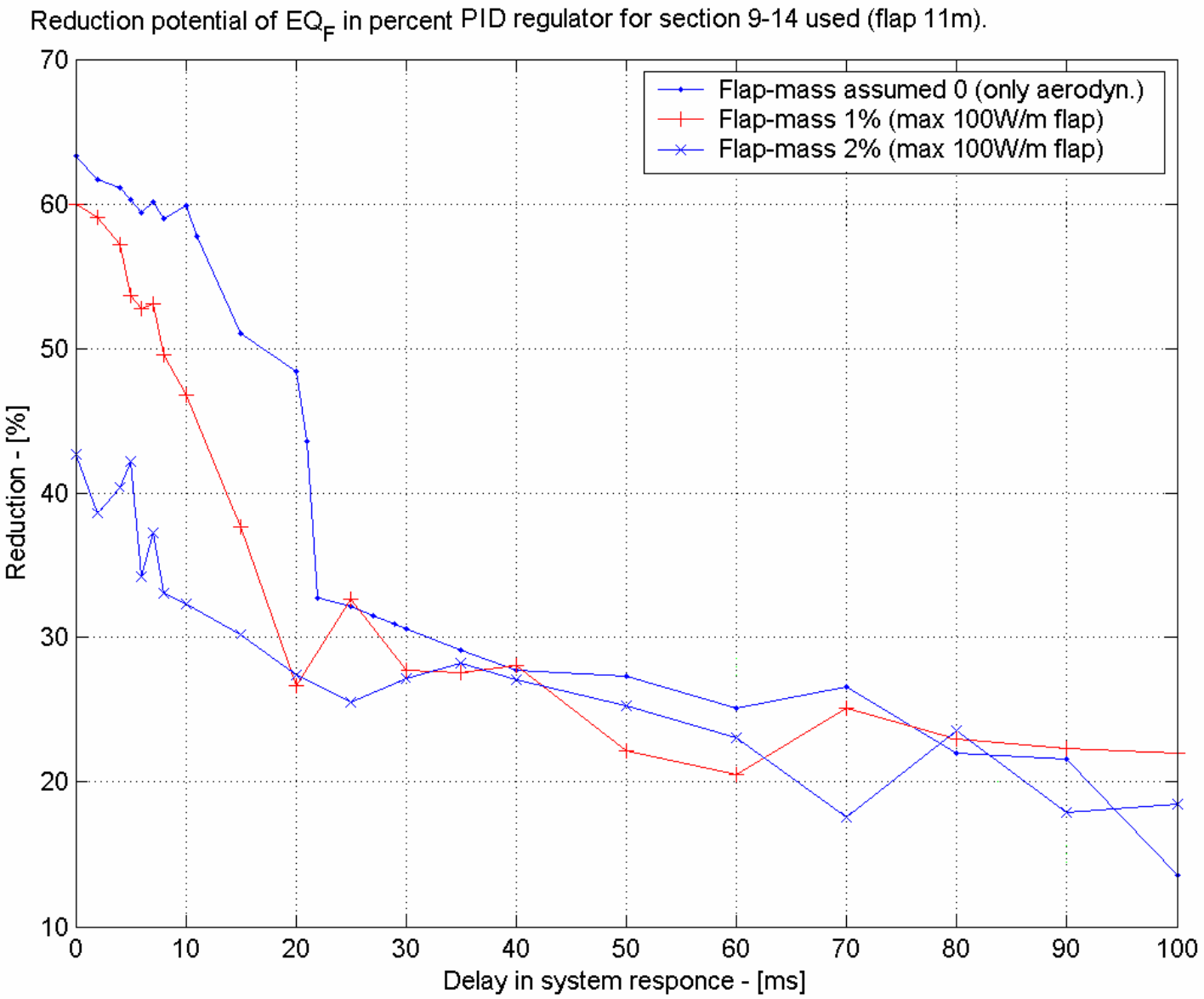
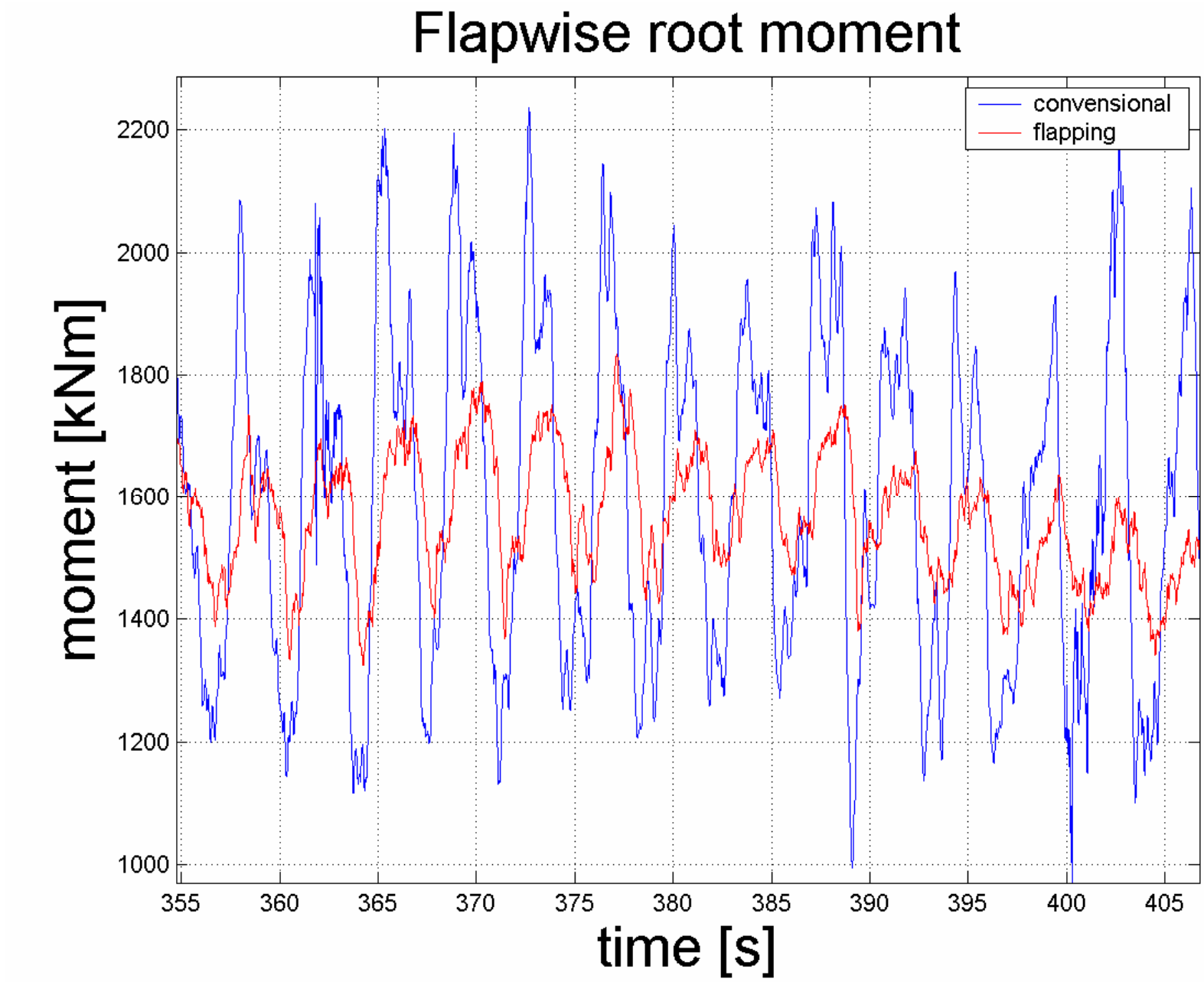
given flap	best radial location of given flap	flapwise root moment - maximum reduction potential — fatigue
one meter flap available		14%
four meters flap available		50%
seven meters of flap available		62%
eleven meters of flap available		65%

3D model results (3)



Open questions

- Measure flapwise deflection
- Power output
- Gain
- …


Flapwise root moment
convensional
flapping
moment [kNm]
2200
2000
1800
1600
1400
1200
1000
355
360
365
370
375
380
385
390
395
400
405
time [s]