WP 1B3: Smart Rotor

Mid-term results

Prof.dr.ir. Gijs van Kuik

Thanks to:

Teun Hulskamp
Harald Bersee
Thanassis Barlas

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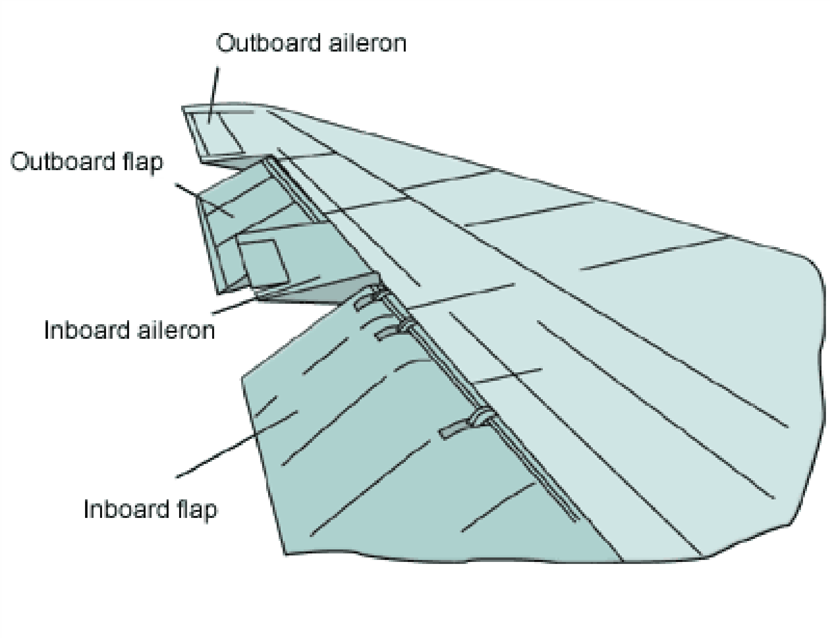
UpWind

Distributed control along the blade

Controlling the blade load by active control of the aerodynamics with spanwise distributed devices

So: We want this control capability …



…without compromising the robustness of current blade technology

What are the topics?

"Smart" = sense, compute a reaction and react.

So the issues/research areas are:

- Aerodynamics
- Structural integration/Actuators
- Sensing
- Control

Moreover, a solution is wanted, that is integrated in the current functionality and/or structure of a HAWT blade

Experiment to show potential

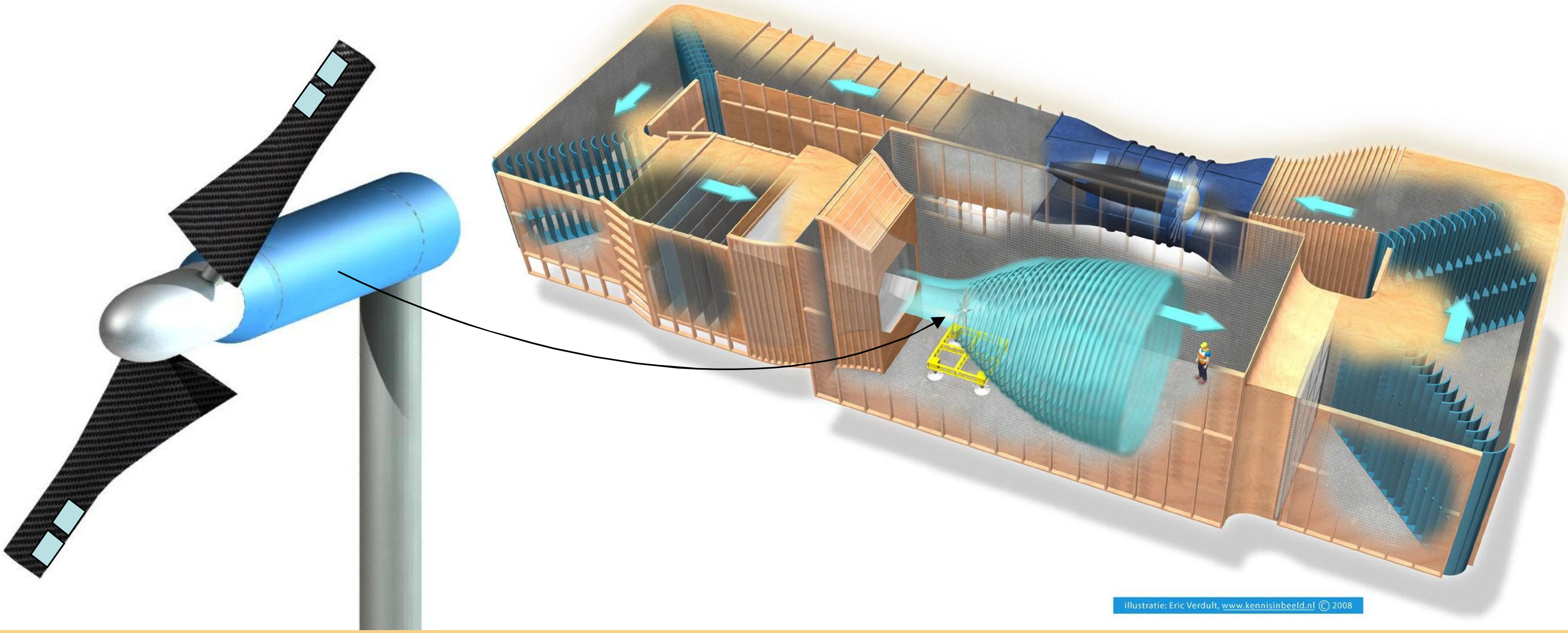
View from the bottom:

Present status

Three main lines:

- Experiments
- Integration by means of rotor design
- Detailed analyses

Experiment: Model rotor in wind tunnel



- 2 bladed 1.8m diameter rotor in new early Open Jet Facility of TU-Delft, February 2009

Integration by Design: requirements for smart rotors

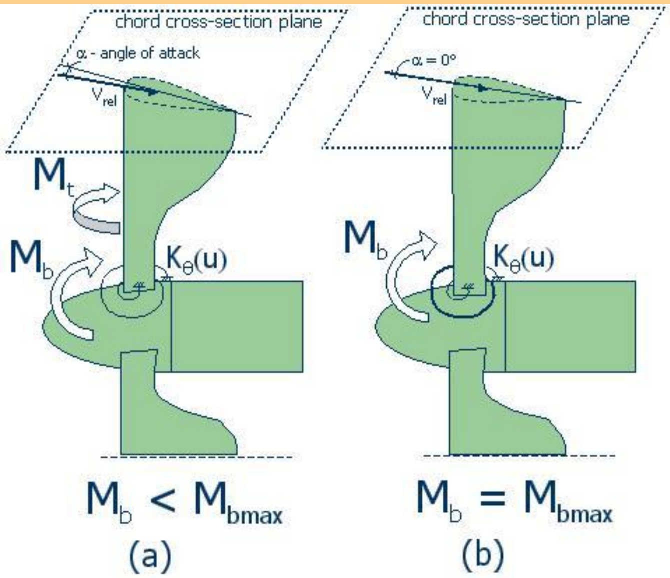
- Analysis of Upwind reference turbine, required flap angles for load alleviation.
- Aerodynamic surfaces (type, length, amplitude, bandwidth) max +-15 deg. deflection of a 10%c flap, suffices to alleviate yaw loads, EOG, EDC locally
- Blade structure (fatigue, stability, lay-out)
- Actuators (deflection, bandwidth, structural integration)
- Sensors (signal type, placement)
- Controllers (control strategy, hardware
- Interfaces (type, power)

Detailed analysis by partners

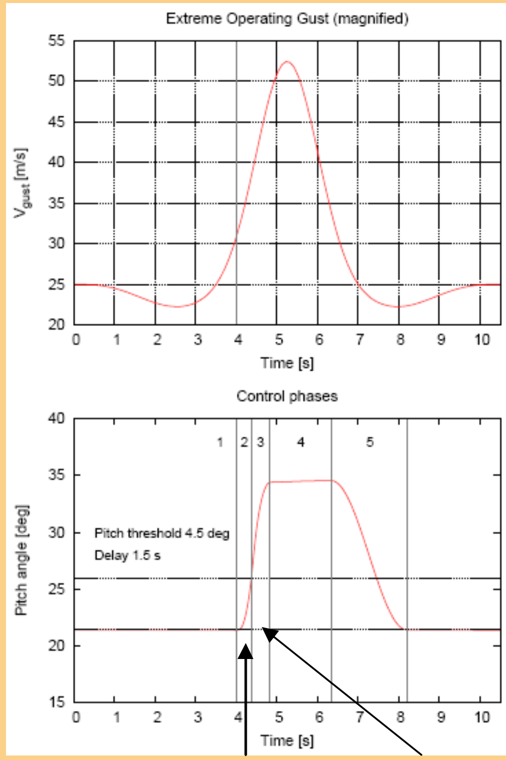
- DUWIND, TU-Delft (Nl)
- Risø National Laboratory (DK)
- Energy research Centre of the Netherlands -ECN (NL)
- University of Stuttgart (D)
- LM Glasfiber A.S. (DK)
- Fundación Robotiker (E)
- VTT Technical Research Centre of Finland (SF)
- Instytut Podstawowych Problemow Techniki -PAN (PL)
- Institute of Physics, Academy of Sciences of the Czech Republic (CZ)

Adaptive blade-hub connection to alleviate extreme loads

Device with very fast tunable torsional stiffness, by rheo-logical fluid

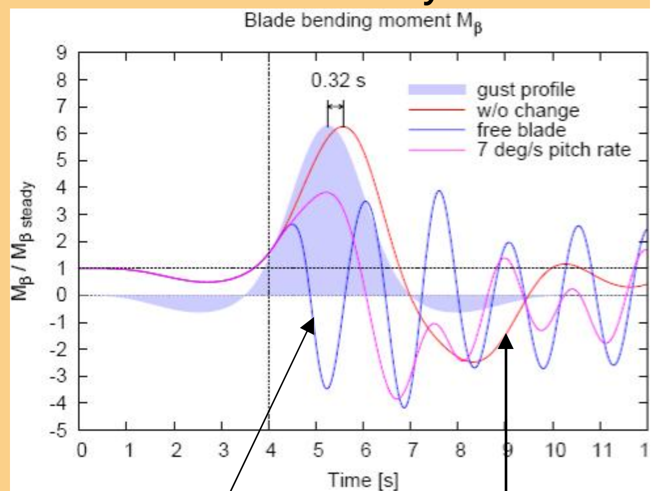


Simulation EOG



unclutch reconnect

Prelim. results with-out reconnection yet



Unchanged pitch system

Pitch system totally free

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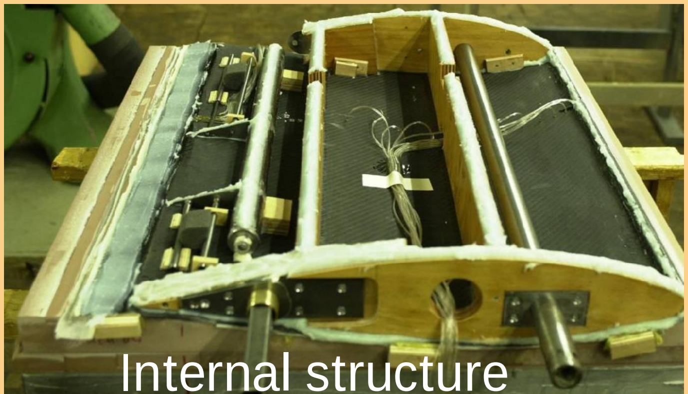
IPPT PAN

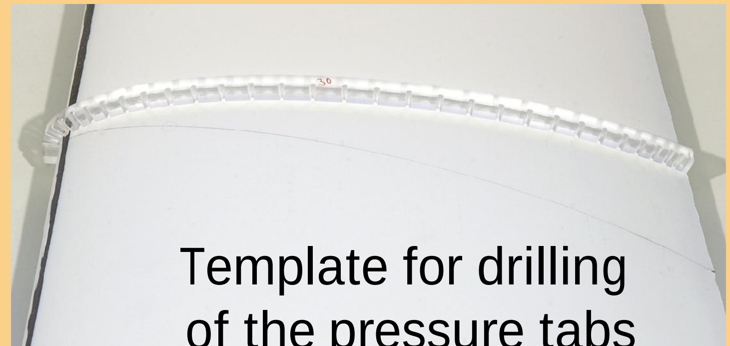
UpWind

Aerodynamic experiments on airfoil with flap

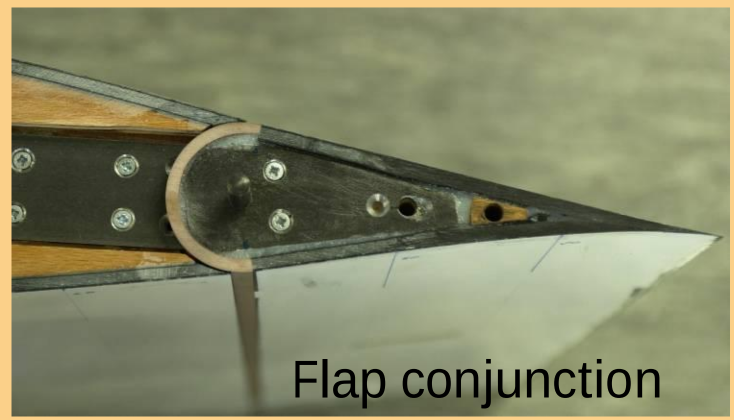


Internal structure

Measurement of lift, drag, pressures, flow viz. Transition, Re=1.5 , 2.5 10^6

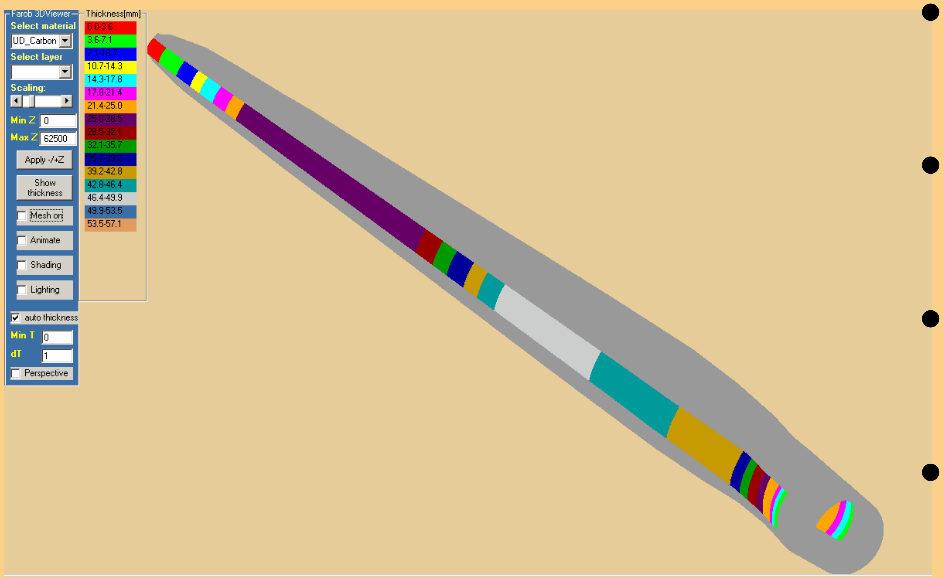


Template for drilling of the pressure tabs



Flap conjunction

Anisotropic Blade Design

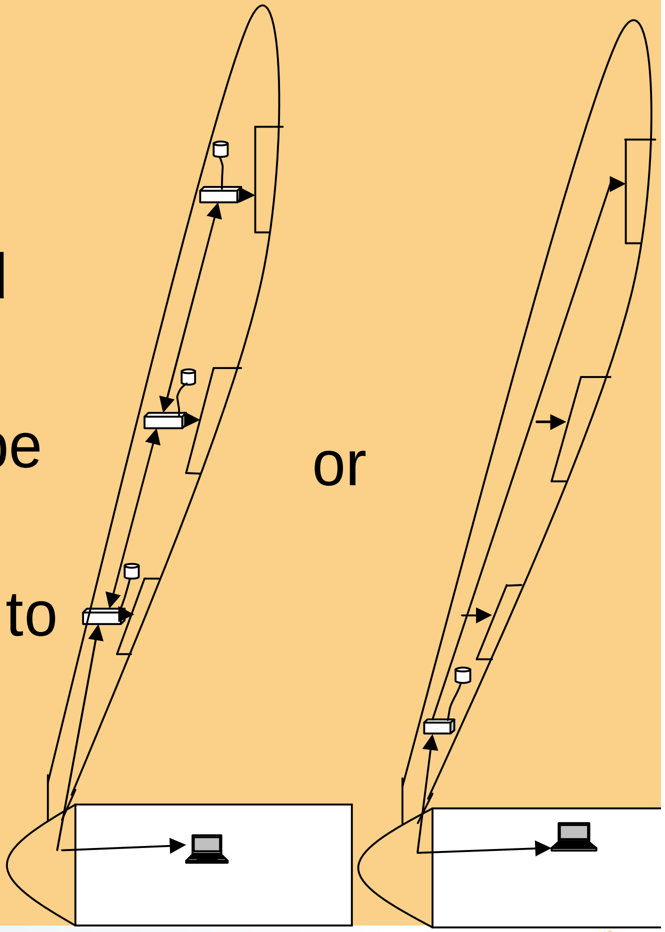


- Lower loads by coupling blade elastic deflections
- Carbon in Spar Caps (to increase coupling potential)
- Modifications of the unidirectional fiber material
- Flap – twist (to feather) coupling shows highest potential

- However, loads tend to move to other signals: flap ↓ edge↑
- Currently developing blade optimization to overcome this

Sensors and Control Strategy:

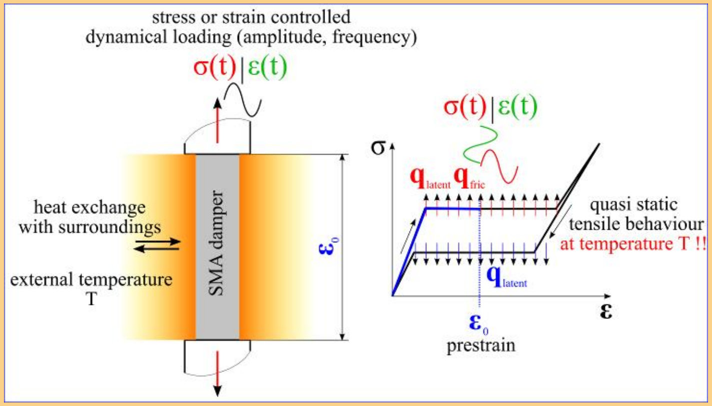
- Based on simulations, a 2-axis DC accelerometer with +/- 5g is required.
- Several control systems located close to the local signals (sensors, actuators and controls). This is preferred
- Requires the main control algorithm to be split into separate ones, for each flap.
- Suitable when sensors are placed close to the flap.
- If a distributed control algorithm is not possible => Centralized Control..

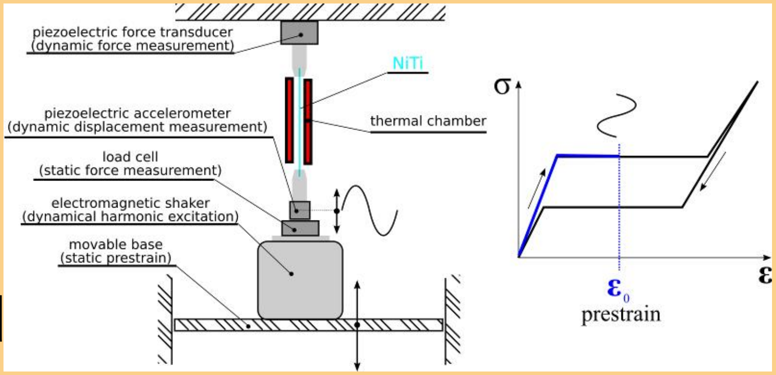


Shape Memory Alloy

SMA as damper

- Passive vibration damping by the energy dissipation due to the cyclic stress-induced mar-tensitic transformation (SMT).
- Experimental evaluation of damping
- Harmonic excitation in the strain control regime
- Environmental temperature around wire is actively controlled
- Positive results

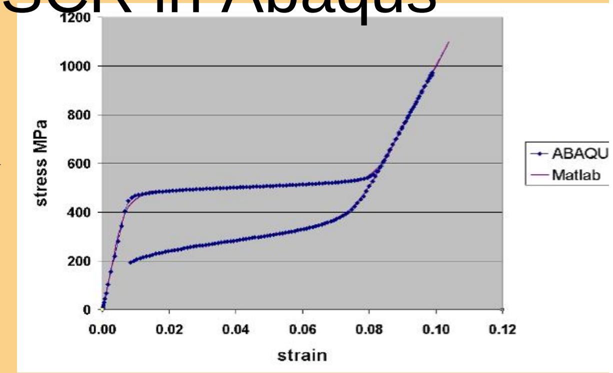


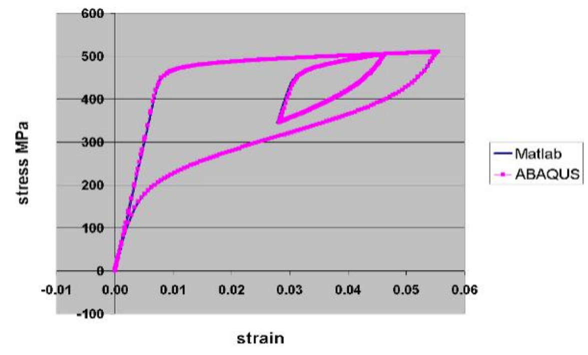


SMA material modeling in FEM

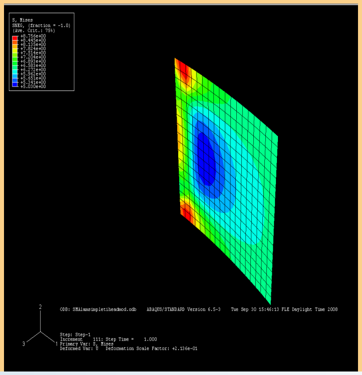
Implementation of the iRLOOP model of ASCR in Abaqus

Results with SMA wire only:
Superelasticity
Small loops





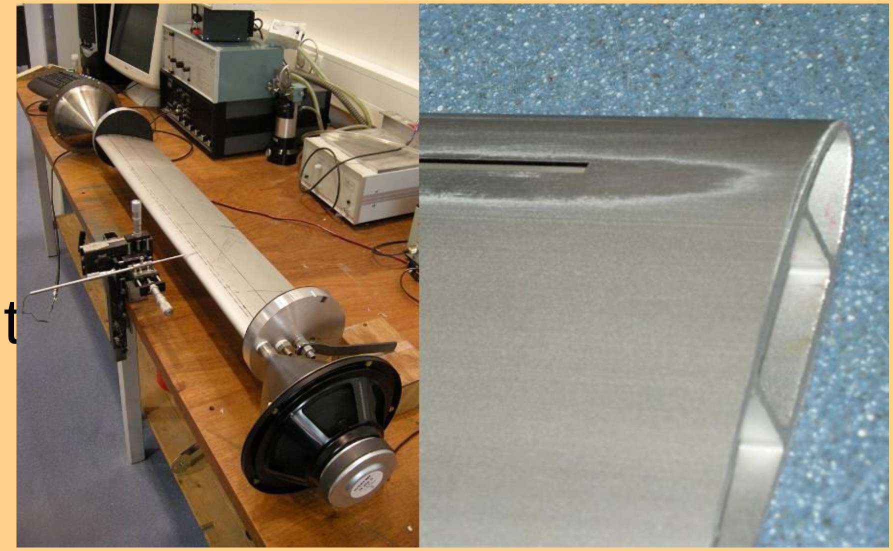
Results of a laminate with embedded SMA wires: Matrix, Shell surface



Synthetic Jets

Numerical:

- Test of turbulence models
- comparison with exp. data).
- Parallelization of the URANS met
- Parameter study.



Experimental:

- Naca 0018 model, University Twente silent wind tunnel, actuation by loadspeakers
- First test of synthetic jet from slits on suction side close to the leading edge (boundary layer separation control).
- Towards pitch control / camber control.

Thank you

There must be questions……

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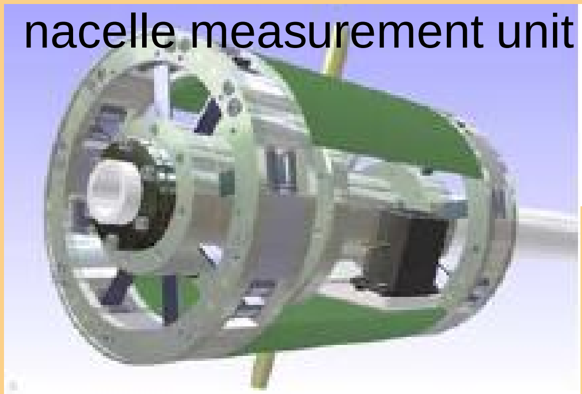
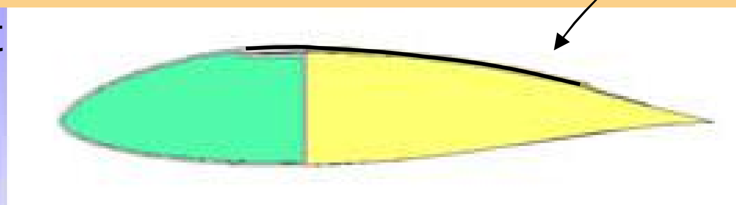
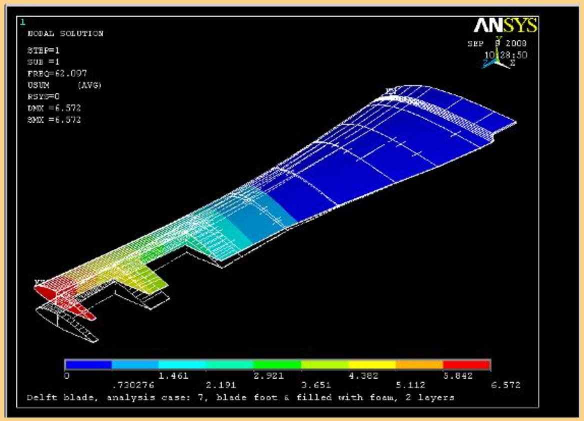
UpWind

Design of Wind Tunnel model







- Scaled blade dynamics
- Scaled periodic and stochastic wind disturbances
- Real-time controller