UPWIND Workshop on EWEC, Brussels, April 1st, 2008

Exploring the design limits of very large wind turbines

R.P.L. Nijssen, T. Westphal, E. Stammes, J.J. Heijdra, D.R.V. van Delft

SIXTH FRAMEWORK PROGRAMME

Intro

Why?

Overview of main topics/results of 2nd year

Why?; the 'BIG' questionnaire

Called 10 people from industry and research

- Statistically absolutely UNSOUND sample of experts that happened to pick up the phone
- Two questions (actually 4)
  - Why bigger blades? (1a)
    - Why not (1b)
  - Vision on consequences of larger blades for:
    - Construction (2a)
    - Material (2b)
- Anonymous (Industry or Research)
- Expert, not spokesman

The ‘BIG’ questionnaire

Note the quotes

“

Key:

I	= only industrial person(s) said this
R	= only research person(s) said this
I, R	= some industrial and some research person(s) said this
(all)	= everybody said this

Why bigger blades (1a)

Energy ~$R^{2.1}$ (all)
- Larger blade length
- Higher hub height
- Lower cut-in speed (R)
- Reynolds effects (I)

€/kWh (all)
- Per unit ~$R^{??}$
  - Cabling
  - Foundation
  - Maintenance
  - Development (I)
- Do we really know this? (I,R)

Limit offshore 70-80 m (I)

Optimum offshore 10 MW (R)

Why bigger blades (1a)

'Non-technical'

- Public demands offshore, offshore demands larger turbines (all)
- "Who has the biggest one" (I)
  - More power (I)

Why not? (1b)

- Square-cube (I, R)
  - Mass ~$R^{2.6\text{-}2.7}$
  - Cascades through WEC
  - NB: less gravity-fatigue cycles for lower rpm (R)
- Stiffness/tower clearance (I, R)
- Size race at the expense of reliability (I)
- Onshore
  - Limit size onshore reached (I, R)
    - NIMBY ~ R
  - Transport (I, R)
  - Large market for shorter (optimised) blades in (R)
    - Asia/3rd world/Countries with low industrialisation and high area/coastline ratio/China
- Manufacturing (I, R)

Why not? (1b)

Fighting square-cube → Chord reduction and increase t/c ratio (I, R/all)

- Hub transport limits bolt radius (I)
  - 2300 i.s.o. 2600 mm
  - Review blade root connection configuration
- Aerodynamics (I)
  - From blade to rod
  - Stall sensitivity
    - (Smart) Accessories: VGs, Slats,
  - Efficiency
    - Scope for higher rpm, λ for offshore (noise)
- Aeroelastics (I)
  - Lead-lag damping
    - Come-back of dampers
    - Bending-torsion coupling

Construction? (2a)

- Stiffer designs (all)
  - Higher t/c ratio of profiles to postpone material change
- More parts designed closer to limit (all)
- Sectional blades (transport onshore) (I, R)
- Condition monitoring (R)
- Manufacturing (I, R)
  - How to increase production volume/speed
  - Bigger series, keep design in portfolio longer (R)
    - Aerospace-like
    - Automation
- Buckling (R)
  - Stiffeners, ribs
    - Manufacturing automation

Material? (2b)

When to go to 'more exotic' material? (all)

- Higher specific stiffness fibres (all)
    - S-glass, basalt, carbon.....hybrids
        - Manufacturing
        - Up to 50-60 m no reason for carbon (I)
        - Aerodynamic restrictions call for carbon soon (I)
- In (large, onshore) Asian market (R)
    - Wood, bamboo
- Developments ongoing in resins (I)

Suppliers love wind industry (I)

Wind industry loves to have supplierS (I)

- Dependency on single supplier might hamper introduction of new materials
- Dependency on oil for resins (R)
    - Alternatives
    - Local product - based, e.g. third world

Material? (2b)

Closer to maximum performance (all)

- Acceptable strain 3500 μ → 4500 μ (I)
- More detailed knowledge required, design factors to account for uncertainties to be decreased
    - Materials performance & reliability
    - Manufacturing & Control, Automation
- Less materials per blade (I)
- Spec's to include manufacturer (I)
    - Do not use brand 'X'
- Design with knowledge of manufacturing environment (I, R)
    - Expect that sometimes specs are not followed (I)

Regard Construction and Material as one (I)

The BIG questionnaire

”

SIXTH FRAMEWORK PROGRAMME

UpWind

UPWIND research agenda

Material behaviour

- Thick laminates

Behaviour of construction

- Subcomponent testing
- Repairs
- Sectional blades

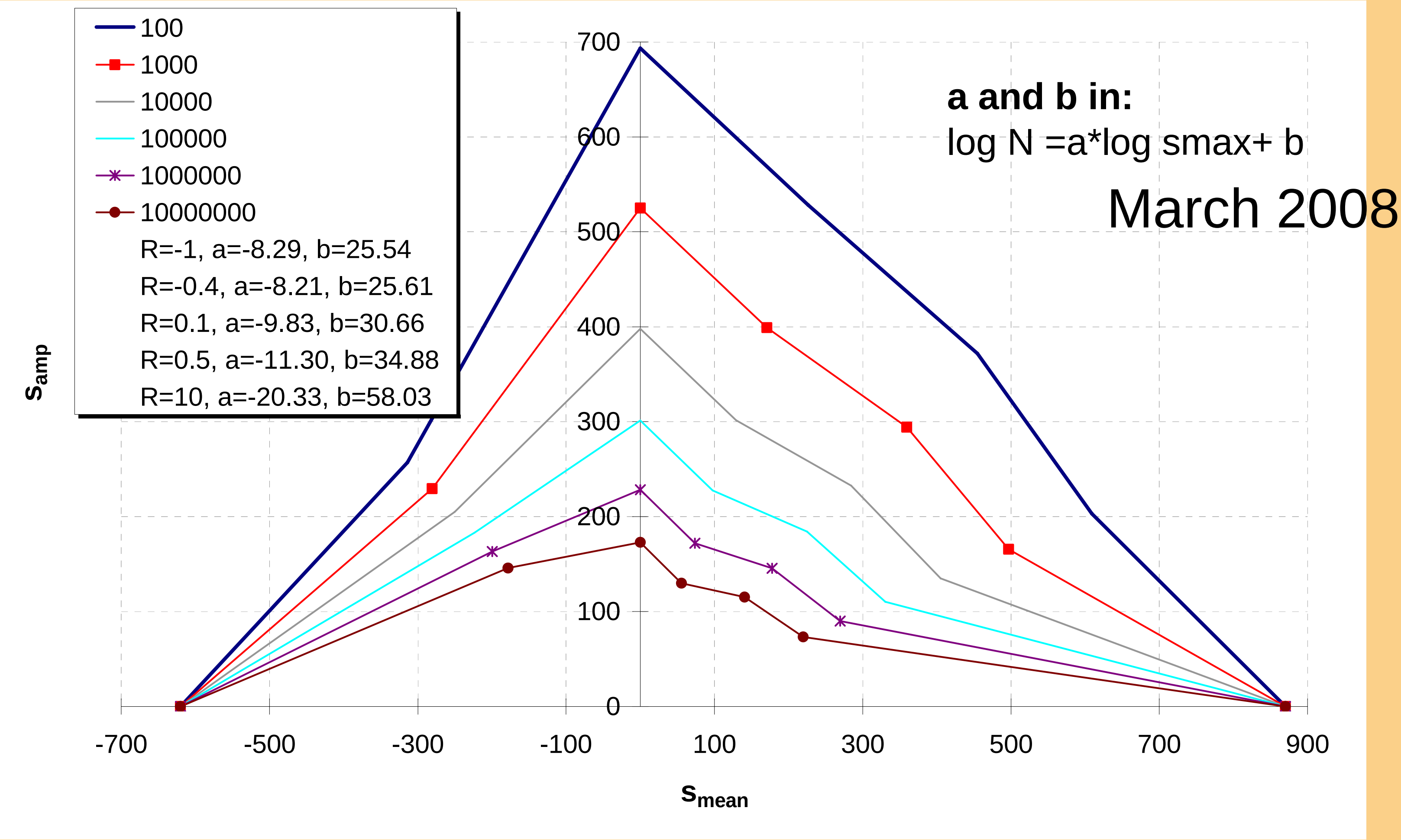
New design concepts

- Damage tolerance
- New materials

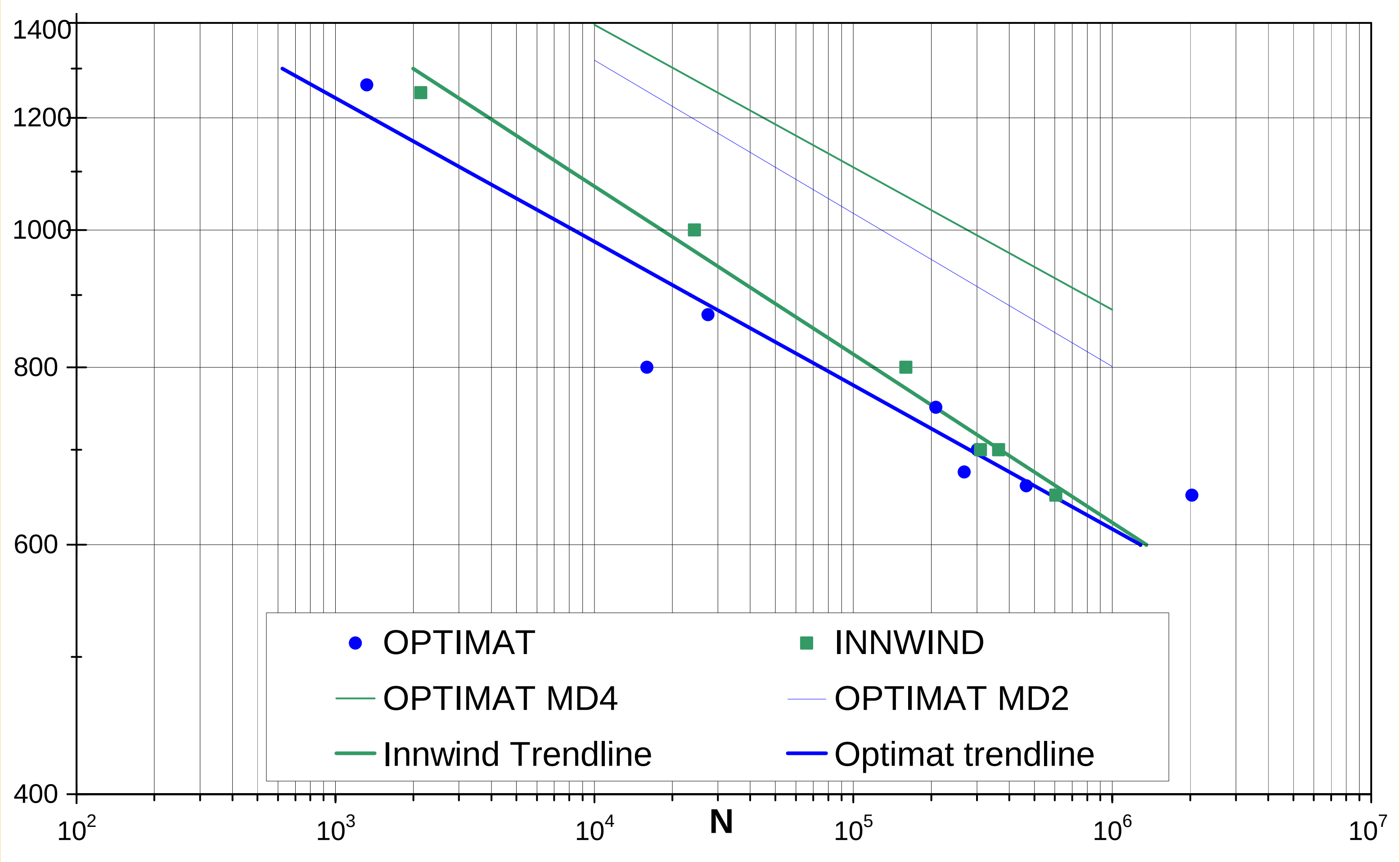
Life cycle analysis

- Nobody mentioned this in questionnaire

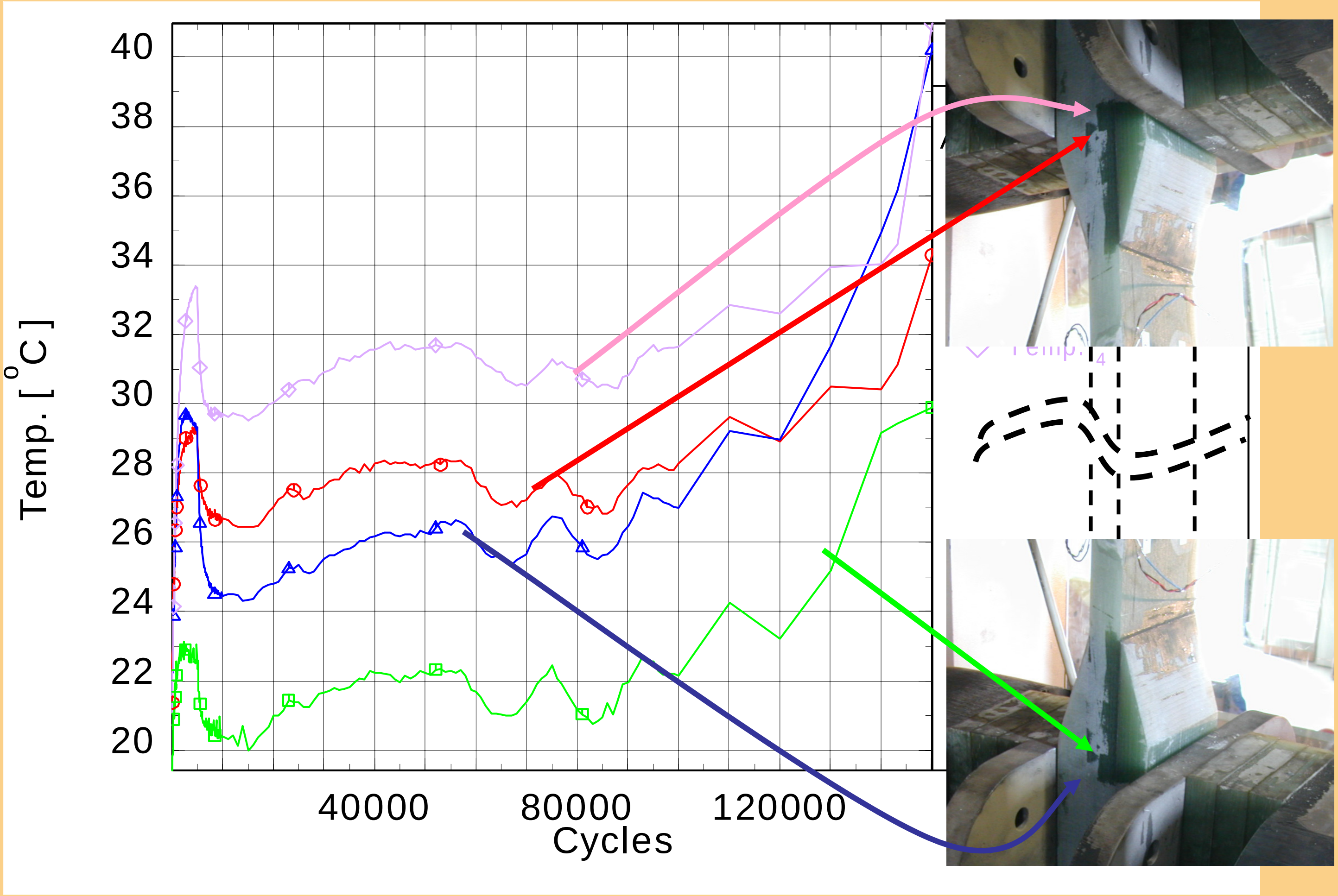
Constant Life Diagram



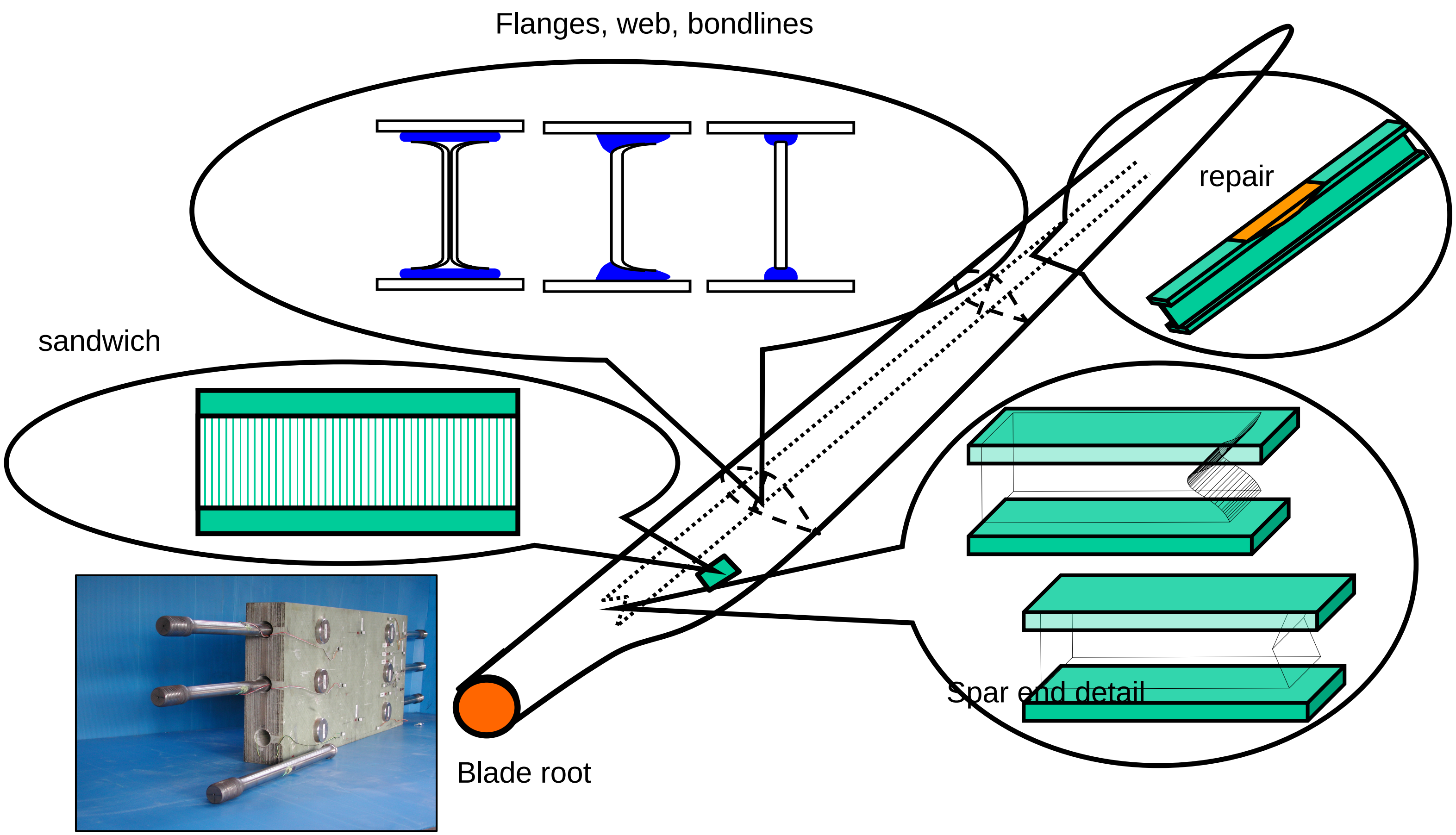
Thick Laminates



Thick laminates

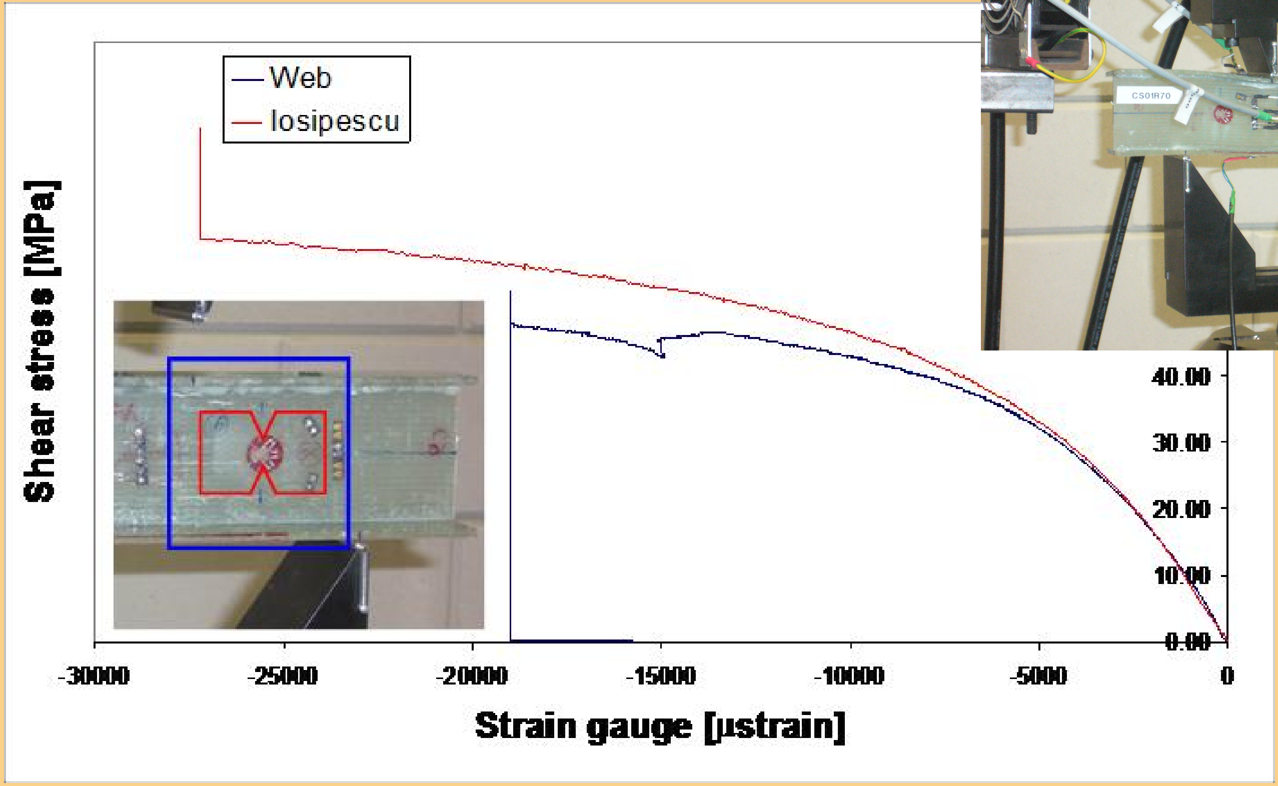


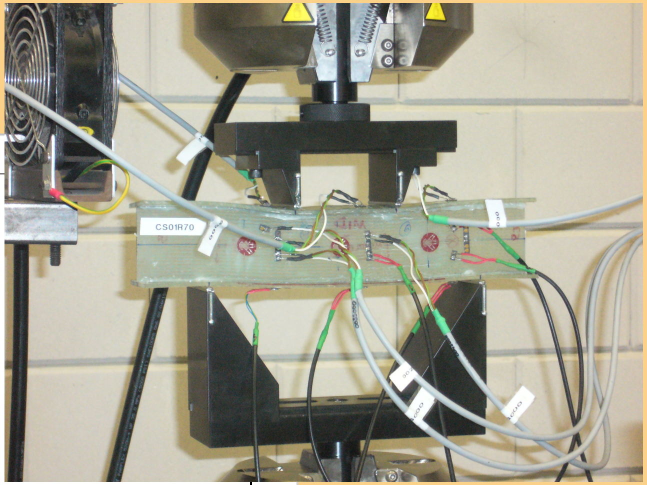
Subcomponent testing



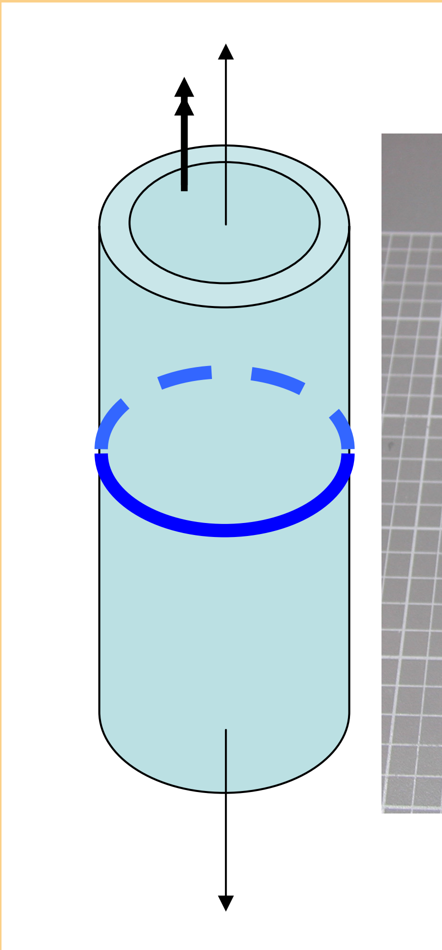
Subcomponent testing

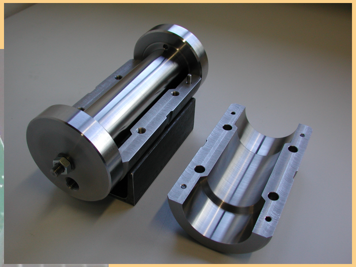
Bondlines & I-beams



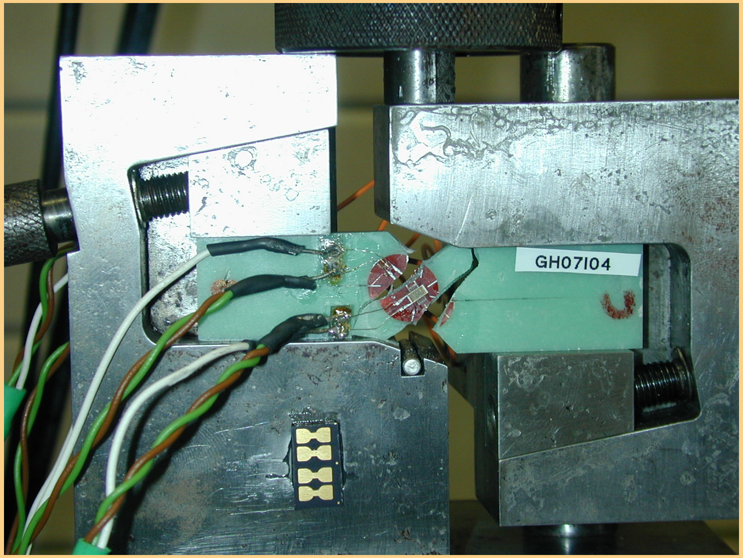


Subcomponent testing





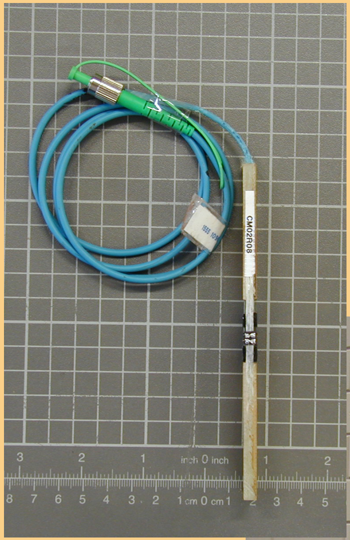
Bondlines' properties

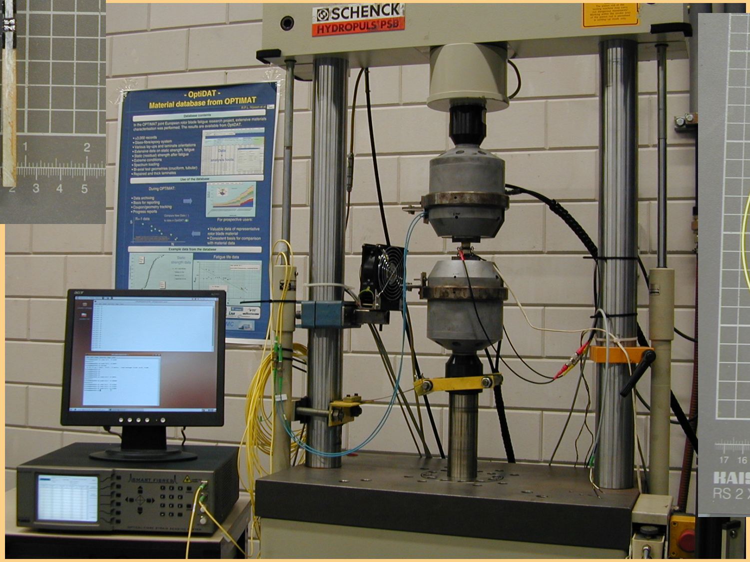


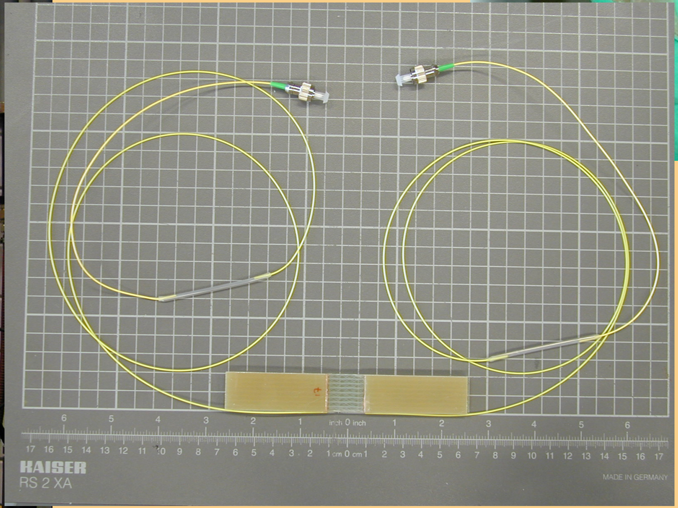
Interaction WP 7 UPWIND

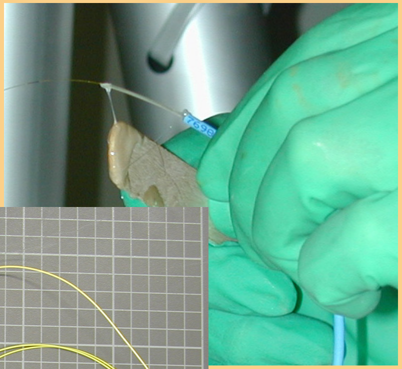
Optical fibre embedding performance

- No negative effects on fatigue performance noted
- Good measurement performance









Concluding remarks

Are Industry and Research blade experts on same planet?

- Economy of scale vs. scaling rules
  - Economy of scale hard to quantify ('we <u>hope</u> project developers based their blade length on something')
  - Better grip on latter for blades
- Square-cube battle dominated by material-construction-manufacturing
  - Decrease cost of energy
  - Increase performance and knowledge

Decommissioning/LCA not mentioned

Further discussion...

Questions/comments?

Statements

- Focus on optimising current blades instead of size race
- Up to 100 m blade length, no material changes needed, only ‘knowledge on material’-improvements
- Industry and Research have the same research agenda for blade improvement
- Subcomponent testing is inappropriate because the blade is an integral structure, not a collection of parts
- Decommissioning of the large number of large blades will not provide significant problems (20 years from now)