Engineering

Offshore Wind/Marine

Andy Morris

E.ON Engineering

Setting the Scene

Renewable Energy: Integral to the UK Government's Strategy for tackling climate change

- Target of 20% of UK Energy from Renewable sources by 2020 (Ref DTI Energy Review Report July 2006)
- BERR UK Renewable Energy Strategy Consultation, June 2008

  £100Billion investment in next 12 years; Large increase in Wind Power

Technology Development and Innovation; key to meeting the challenge

Agenda

- **An End Users Approach**
- **Wind Power – Blade Composites**

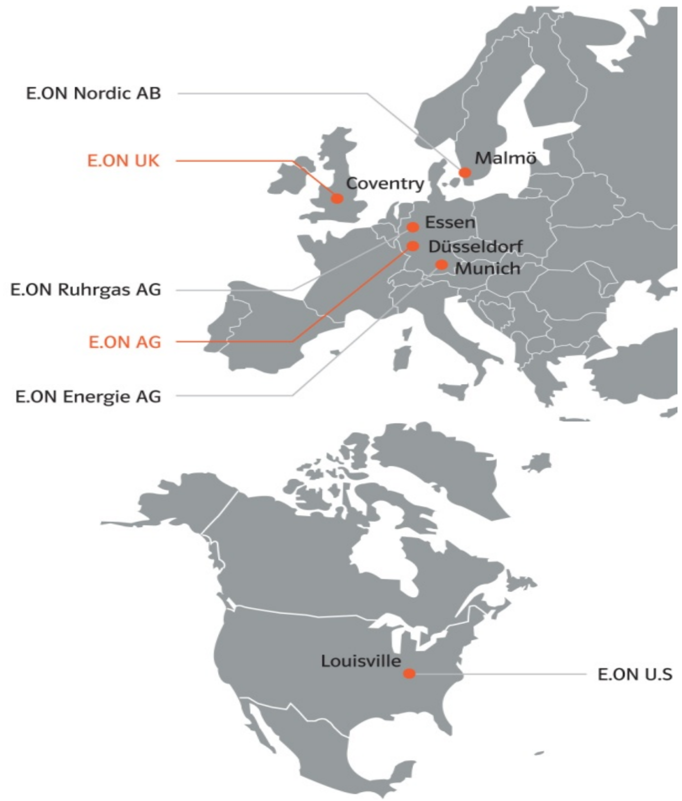
  Manufacturing

  Experimental testing, Structural Health Monitoring, Material Durability

  Computational Modelling

  Non-Destructive Testing
- **Marine Devices**
- **Summary**

The world's largest investor owned power and gas company



E·ON Engineering

End Users Approach

Operation and Maintenance: Need to adapt from trusted approach used on Conventional Plant.   Cornerstones such as…..

Informed Owner and Operator	Service data, Broad and Holistic Eng/Science support, Focussed R&D.
Inspection and Maintenance Plan	Wide fleet knowledge, Consistent plan, Component and/or System specific.
Condition Assessment	Predominantly Inspection based assessments, Plant on outage, Repair, Limited on-load monitoring.
Handling unexpected failures/events	Failure analysis, Safety case, Additional testing, Feedback learning outcomes.

Offshore Wind Power – Turbine Blade Composites

Horizontal Axis Offshore Turbines

Offshore vs Onshore

- Same turbine concepts
- Offshore: Larger areas for farm development
- Offshore: Higher wind exposure levels
- Offshore: More limited local environmental impact

Additional Offshore Challenges

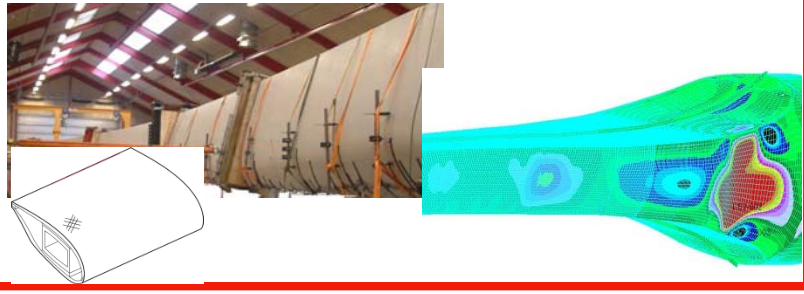
- Effects of Marine Environment on the Structure
- Implementation of Cost-effective and Safe Operation and Maintenance Procedures; supported by sound science – More arduous environment

Engineering

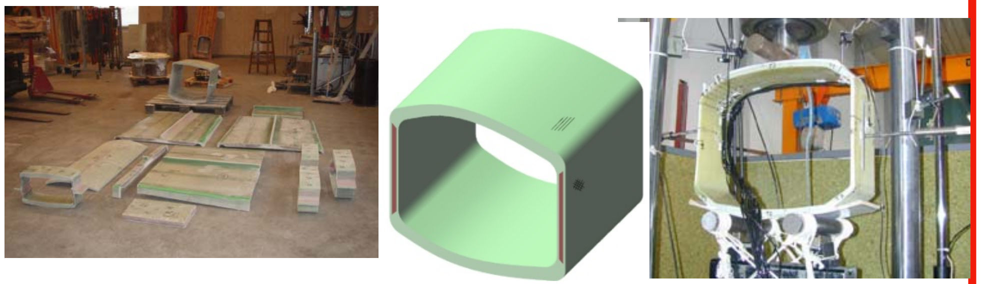
Material Behaviour and Ultimate Performance is Dependent on Knowledge of;

- Structural Design Details
- Manufacturing Process
- As manufactured condition on entering service (All blades pass certification tests, so why be concerned?)
- Service conditions (Load, Environment, etc)
- Inspection (How, Which Location, What are we looking for, If we find something is it important?) and Maintenance Feedback
- Computational Modelling (Improve planning, Data required? Capability?)
- Effective refurbishments (Procedures, Durability?)

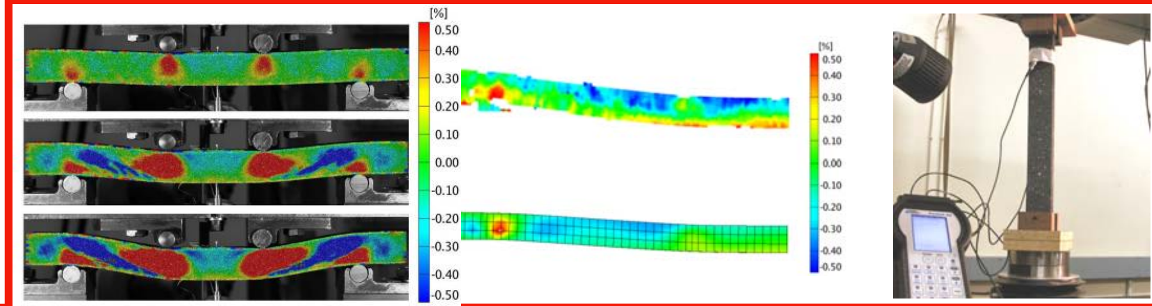
Now some current research being undertaken to illustrate the above



Full Scale Testing



Sub Components



Small Specimens

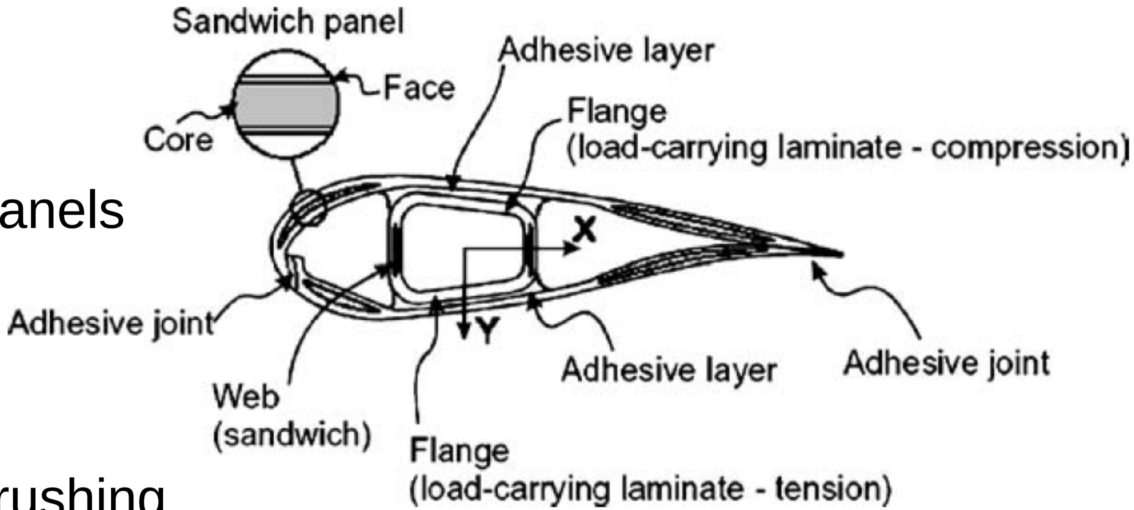
Service Experience

Research & Development

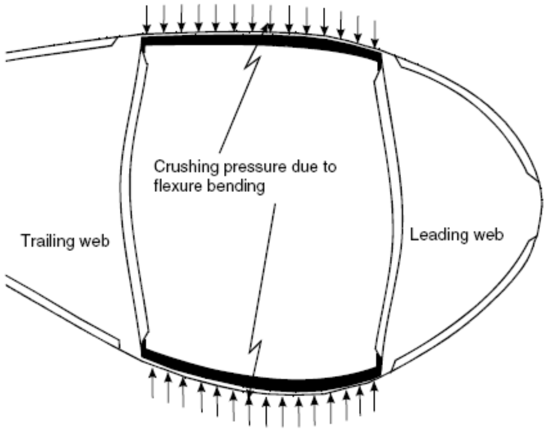
Technology Transfer

Blade Characteristics

- Hollow Profile
- Mix of Laminates/Sandwich Panels
- Different loading types
- Flap-wise loading – flexure
- Flexure loading – additional crushing load – Brazier effect
- Internal beams/webs add stiffness
- Fibre-reinforced polymers, wood etc
- Thermosetting Resins; polyester, vinylester, epoxy
- Blade components are adhesively bonded
- IEC 61400-1 (Design loading)



Sketch Ref: Bronsted et al, 'Composite Materials for Wind Power Turbine Blades. Annual Review of Materials Research, 2005. **35:** p505



Ref: Jensen et. al. (2006), Composite Structures

As Manufactured Imperfections or Features

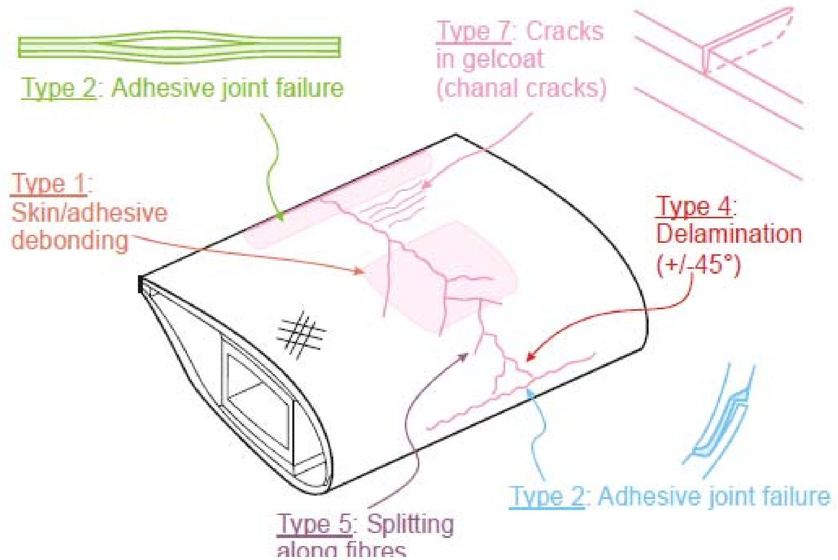
- Resin infusion, with vacuum assist
- Some resin preimpregnated fabrics – laid up
- Cured
- Components adhesively bonded

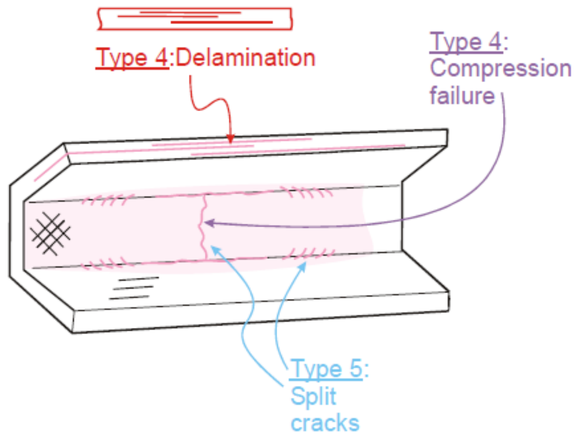
Imperfections

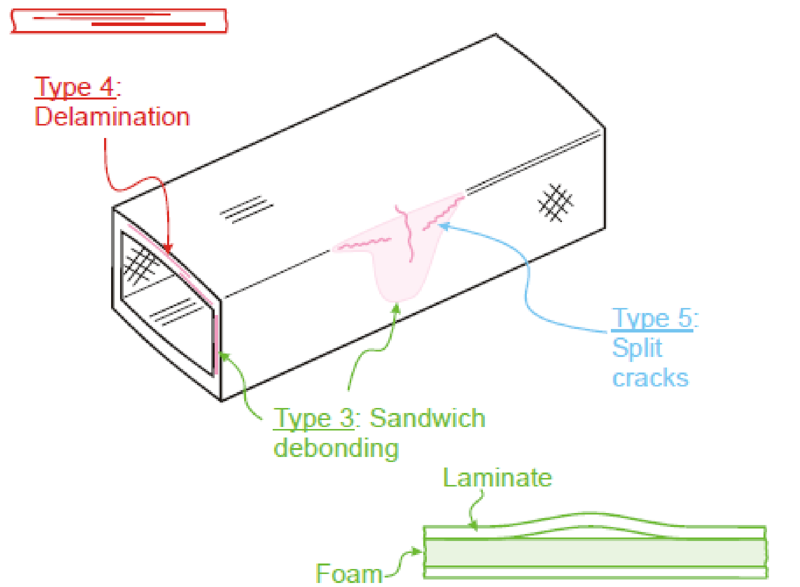
- Delaminations
- Poor curing – local zones
- Wrinkles, Fibre defects
- Voids/Dry-Zones
- Misalignment of fibres
- Sandwich structures (Core/skin debonds; Core imperfections)
- Bonded joints, voids – partial filling, lack of adhesion - contamination

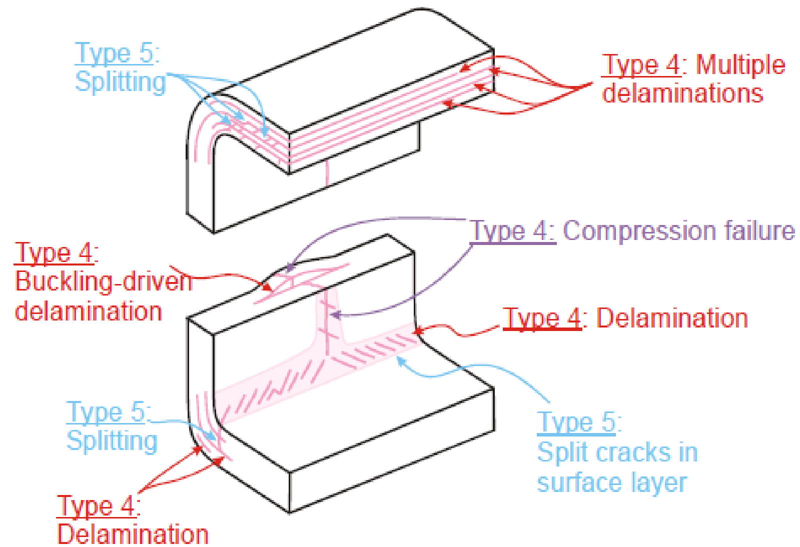
Engineering

Modes of Failure - Fracture









Ref: Sorensen et al, "Improved design of large wind turbine blade of fibre composites based on studies of large scale effects", Riso-R-1390(EN), 2004

Perspective

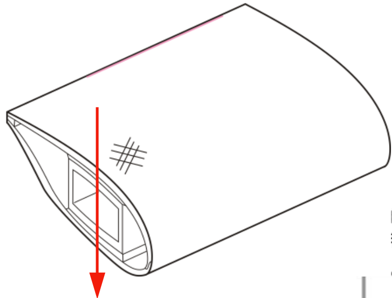
Modelling/Prediction of damage evolution and assessment of its significance requires;

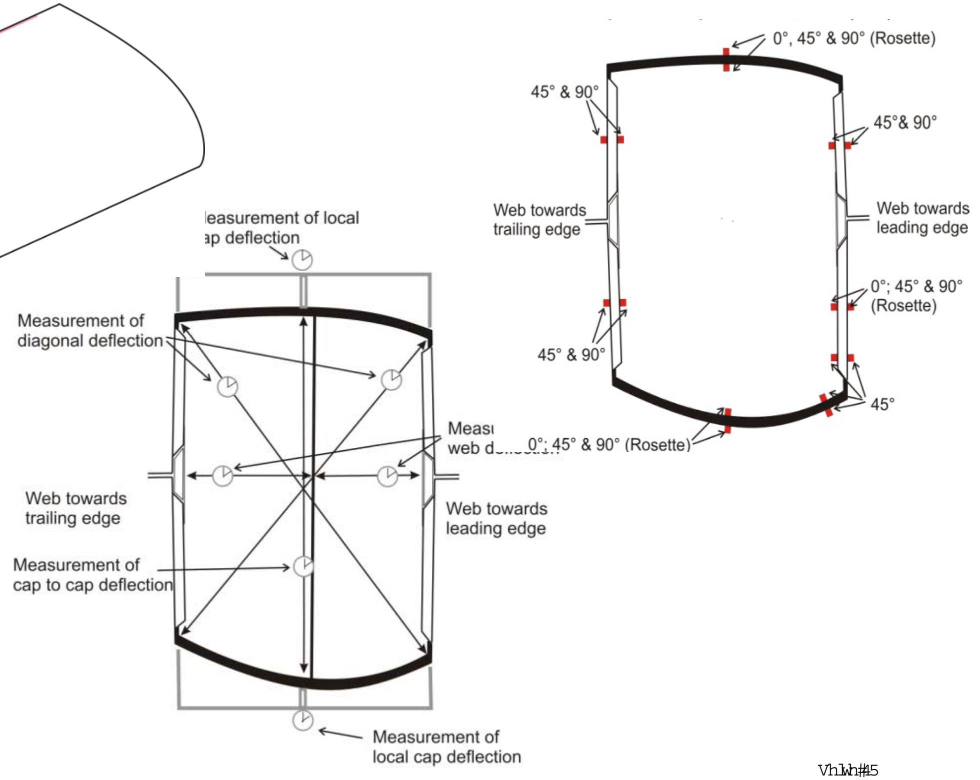
- Multiscale modelling → Global to Local damage models
- Failure Mechanisms, Significance? Evolution? Scaling – from test to production blades
- Understanding failure under service conditions
  - Repair durability
  - Use of Structural Health Monitoring

Some Details on Current E.ON Research……Full scale to small specimen

Full Scale Testing

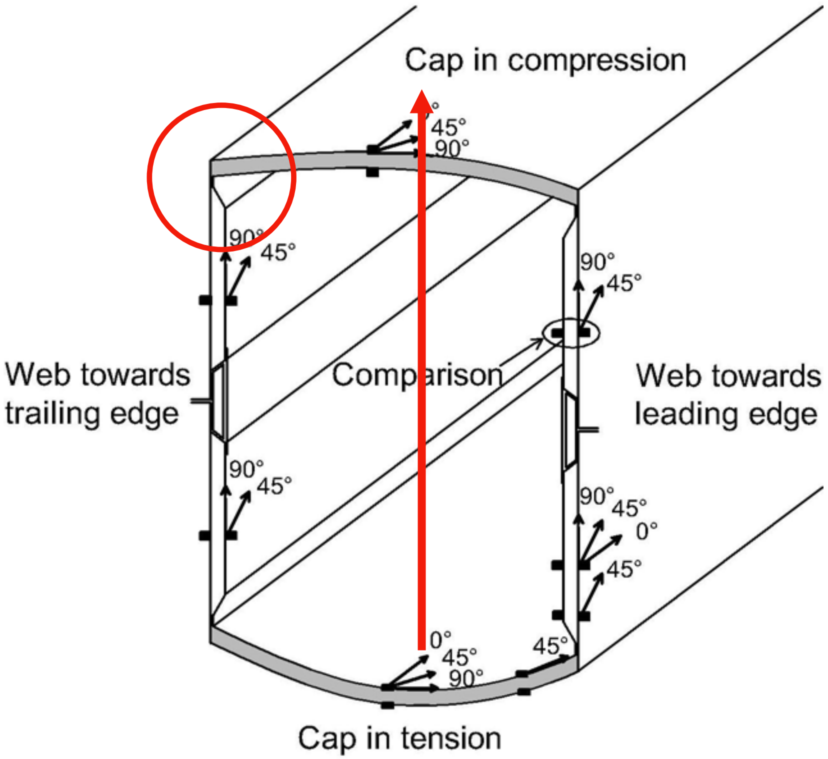
- Girder Preparation: Failure modes
- Pre Test Inspections: Laser Shearography
- Displacement transducers
- Resistance strain gauges
- Acoustic Emission
- 3D Deflection measurement - ARAMIS
- Post Test Inspections: Laser Shearography + Sectioning

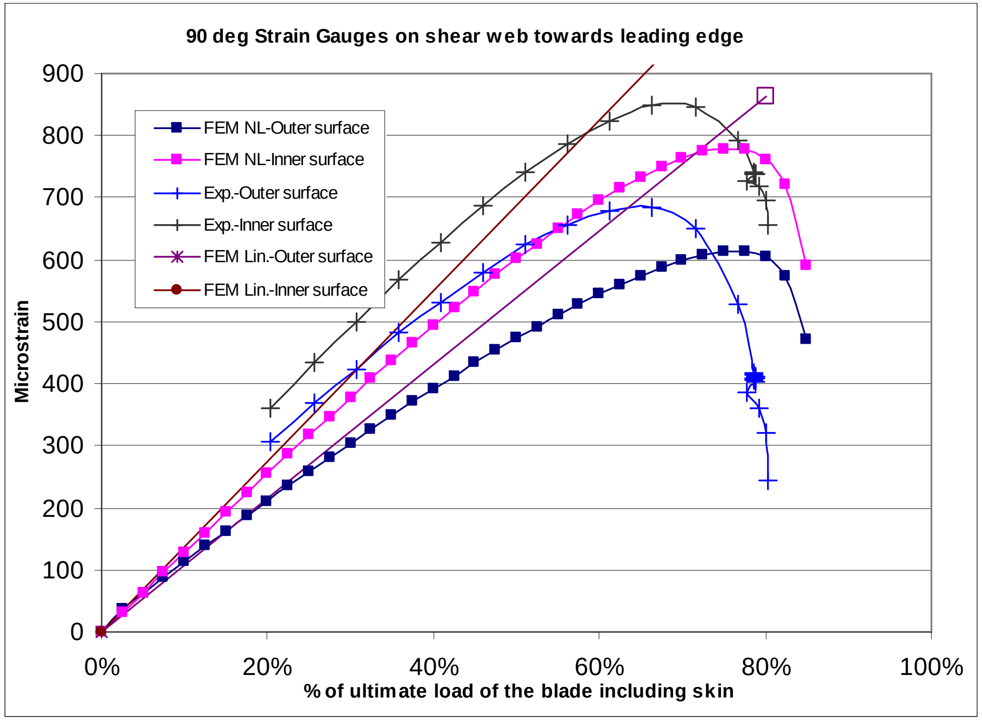




Ref; Jensen, Morris, "Full Scale Testing and Finite Element Simulation of a 34 Metre Long Wind Turbine Blade", NAFEMS World Congress, May 2007

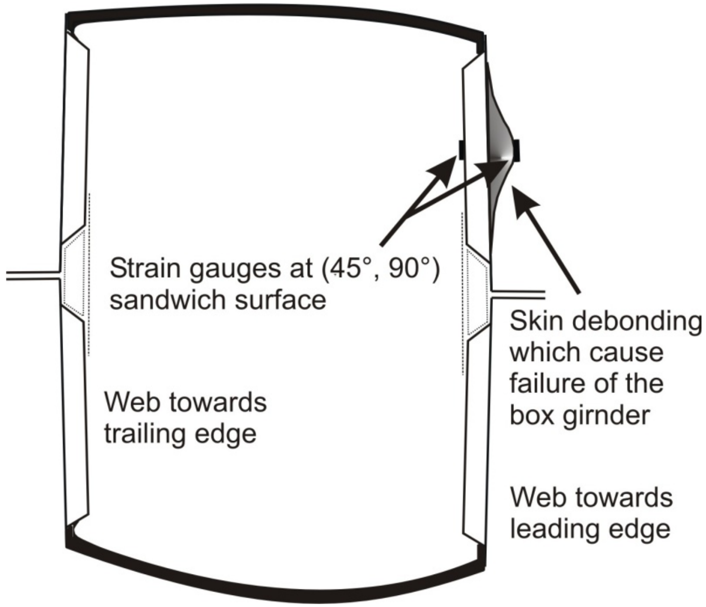
Finite Element Modelling vs Experimental Test





- Ultimate test blade failure; initiated by de-bonding failure in sandwich webs
- Non-linear FE global model; reasonable at tracking global strains
- Need to know detail design features

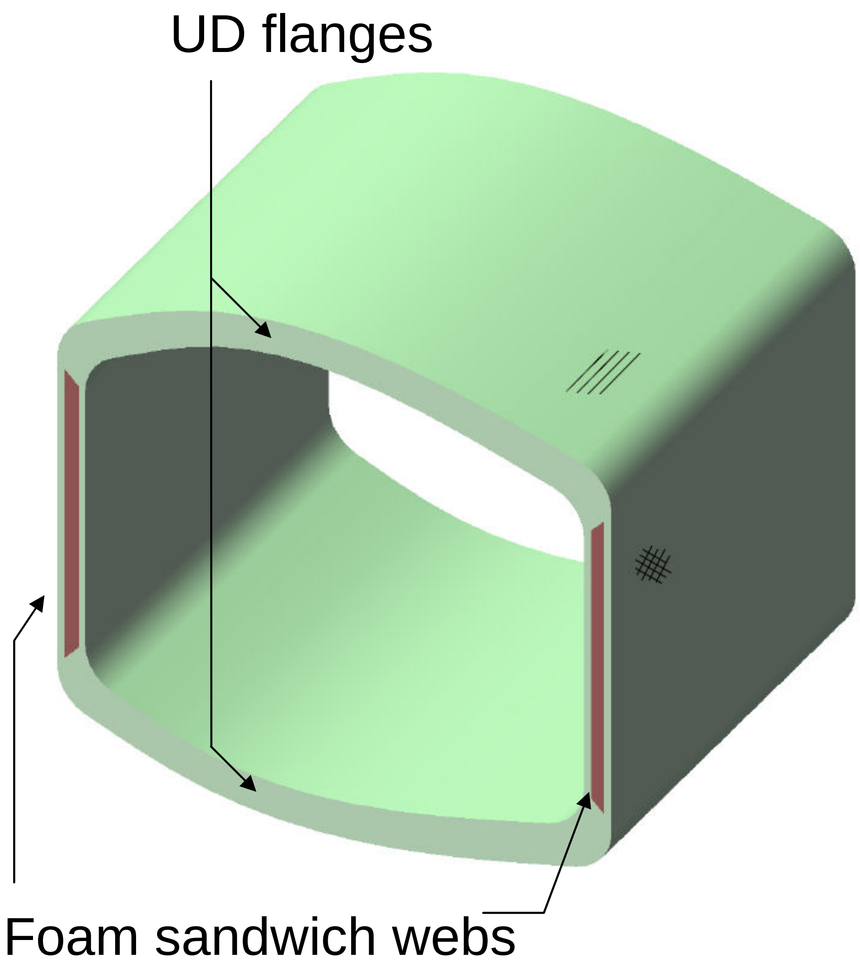
Ref; Branner, Morris et al "Effect of Sandwich core properties on ultimate strength of a wind turbine blade", 8th International Conf on Sandwich Structures, ICSS 8, 2008



Shear debonding (or wrinkling) of the outer skin leads to ultimate failure

- Laminate Flange Panel bending
- Sandwich Panel bending and buckling
- Future proposed tests

Box-Beam Overview

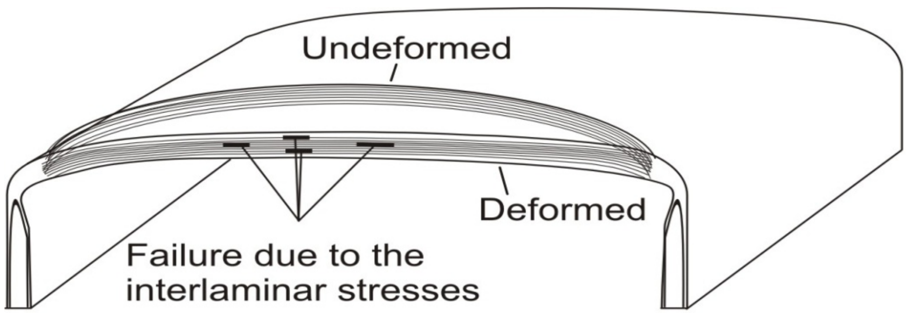


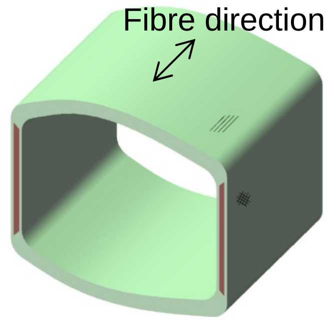
Lightweight materials:

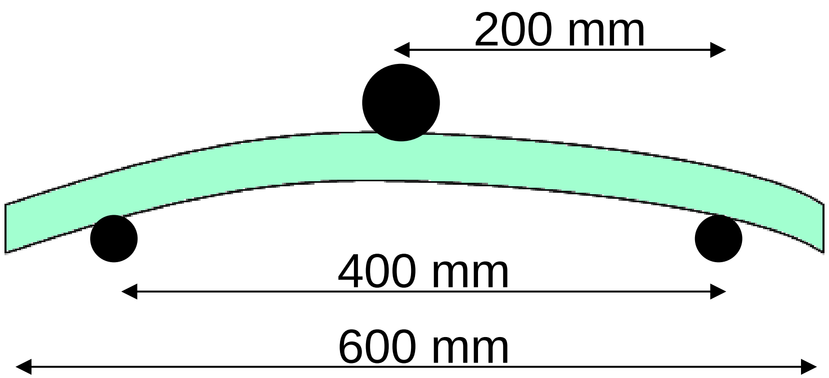
- Glass-fibre with epoxy resin
- PVC foam

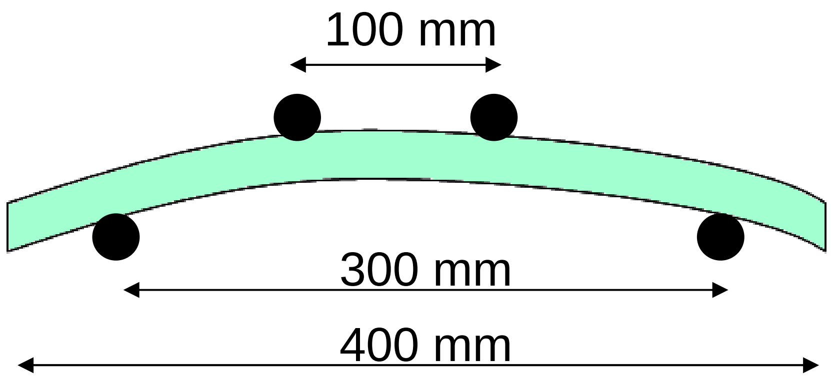
- Unidirectional fibres for flange - built up in layers
- ±45^{o} biaxial outer layers of flanges
- ±45^{o} biaxial layers for webs – foam centre creates sandwich
- Dimensions vary along blade length

Flange Testing



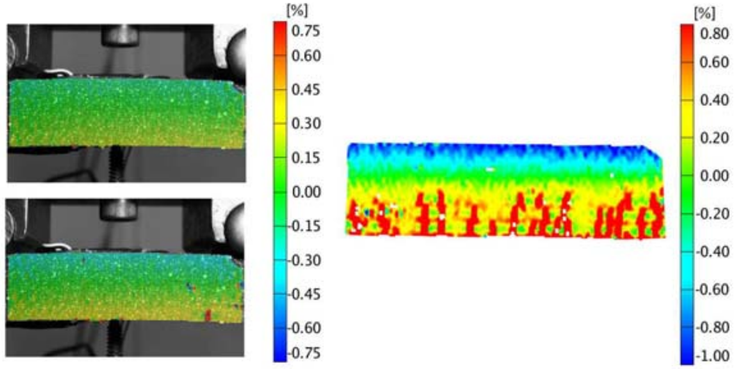


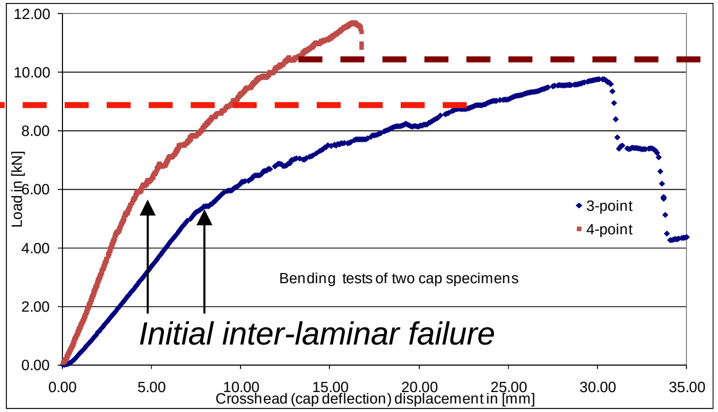




Ref; Dear, Morris et al "Digital Image Correlation Based Failure Examination of Sandwich Structures for Wind Turbine Blades", 8th International Conf on Sandwich Structures, ICSS 8, 2008

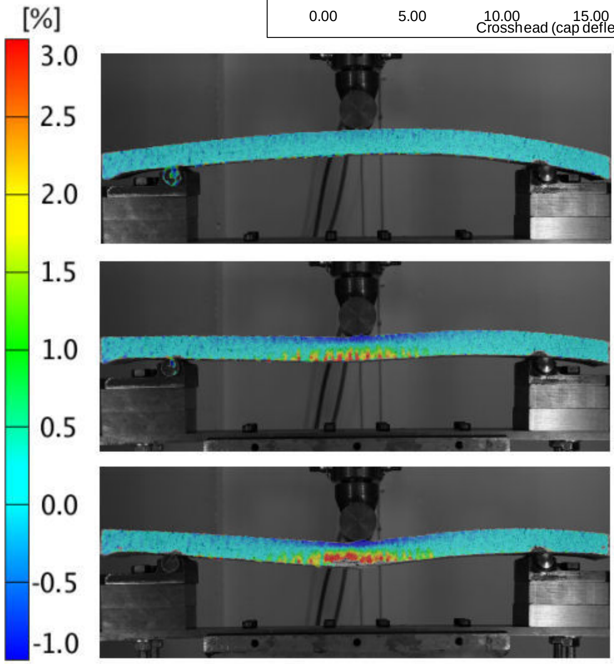
Engineering

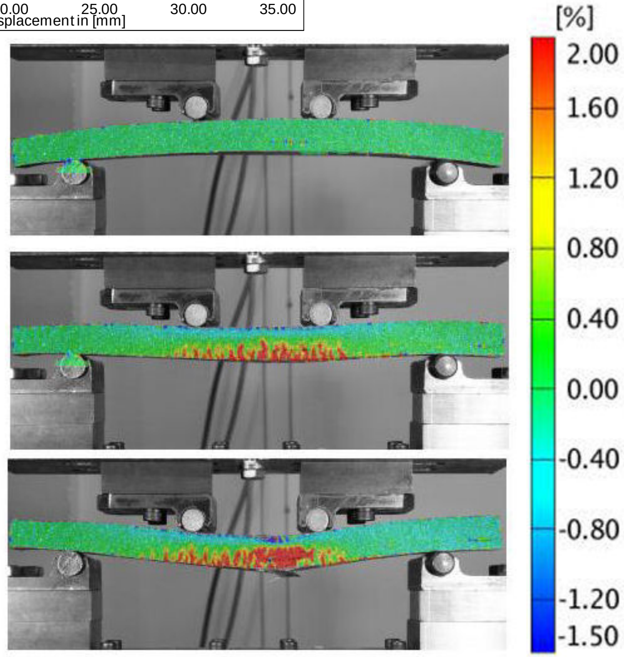




3 Point

4 Point





Bending strain (horizontal) plots

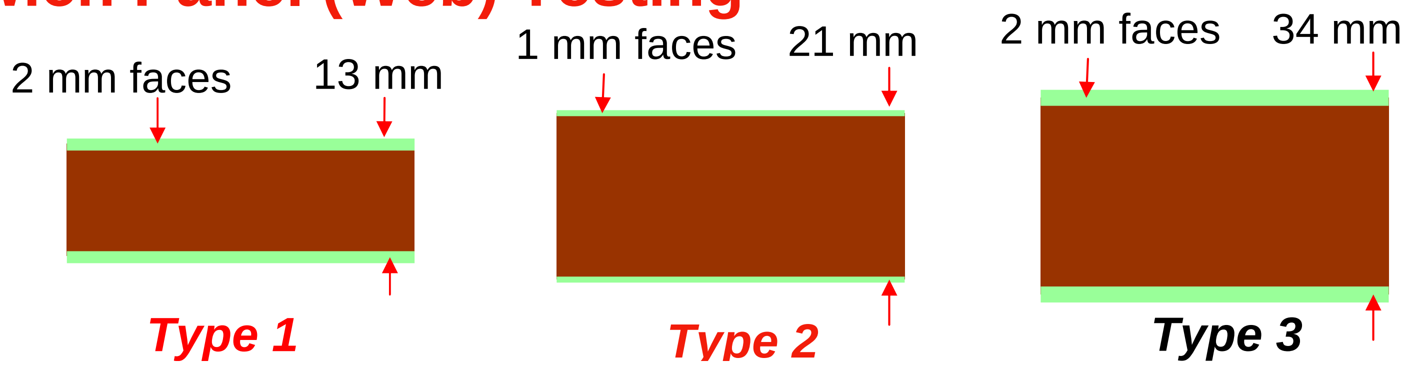
Experimental Test

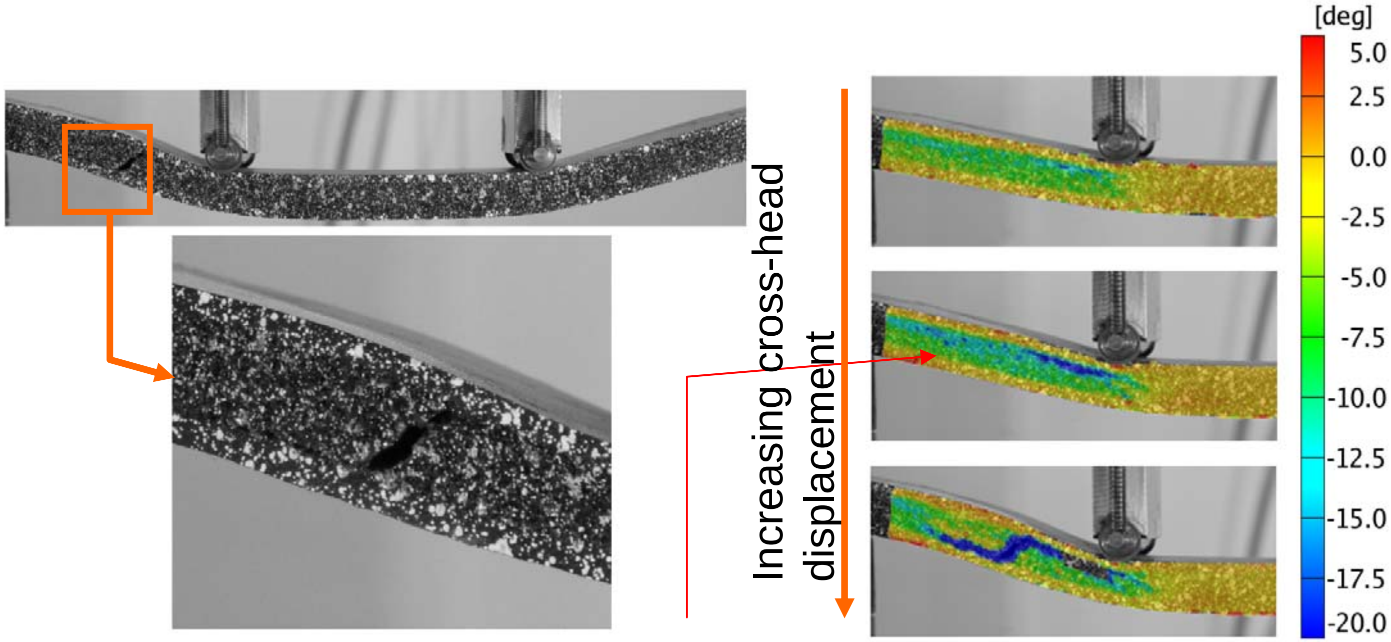
Interlaminar cracks initiate at 4-8mm cap deflection

Full scale test

Cap deflections up to 6mm

Sandwich Panel (Web) Testing





Build up of shear in adhesive identified followed by debonding of skin/core and core shear failure (Type 1 Specimen)

Proposed 2009…..

Instrumented sub component

- DIC
- Conventional metrology
- Acoustic Emission (benchmarked off small scale testing)
- Modelling!

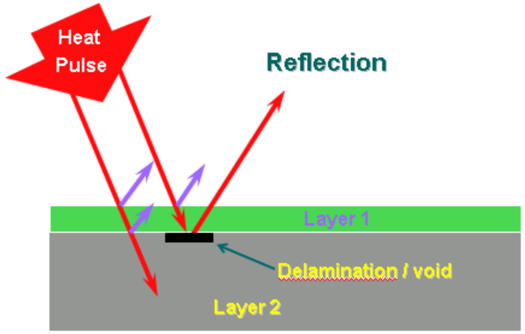
- Aim: Define Effective Structural Health Monitoring Strategies e·on Engineering

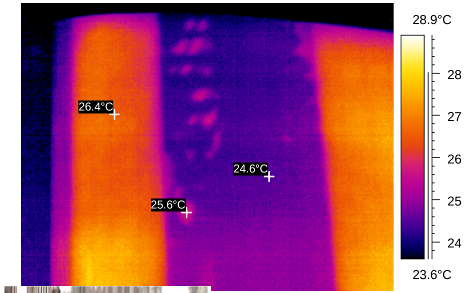
Non-Destructive Testing

To detect, size and characterise defects that might impact on reliability

- Ultrasonic
- Transient thermography
- Laser shearography
- Radiography

- Each has strengths and weaknesses and needs further development before a practical system can be implemented





e·on | Engineering

Marine

Similar philosophy/challenges apply

- Wave loading
- Survivability in harsh environment
- Structural Dynamics in marine environment
- Materials behaviour
- Need for condition monitoring

Computational methods developing to become faster, cheaper and better. Experimental techniques are developing less quickly – how do we reconcile/adapt experimental techniques to keep pace?

E.ON Engineering

Summary

- Integrated approach to understanding material behaviour; under service conditions

  Experimental methods, Damage initiation and evolution

  Consideration of manufacturing and design features

  Environmental effects

  Modelling

- Broad based and informed Structural Health Monitoring Strategy
- Development of NDE techniques
- Utilisation of UK testing facilities; small scale to full scale
- Underpinning/Enhancing certification procedures
- Durability of repairs

Engineering

Thank You For Your Attention