Damage tolerant design and condition monitoring of composite material and bondlines in wind turbine blades: Failure and crack propagation.

PO.ID 067

G. Pereira, L. P.Mikkelsen, M. McGugan
Technical University of Denmark, Department of Wind Energy, Email: **gfpe@dtu.dt**

DTU

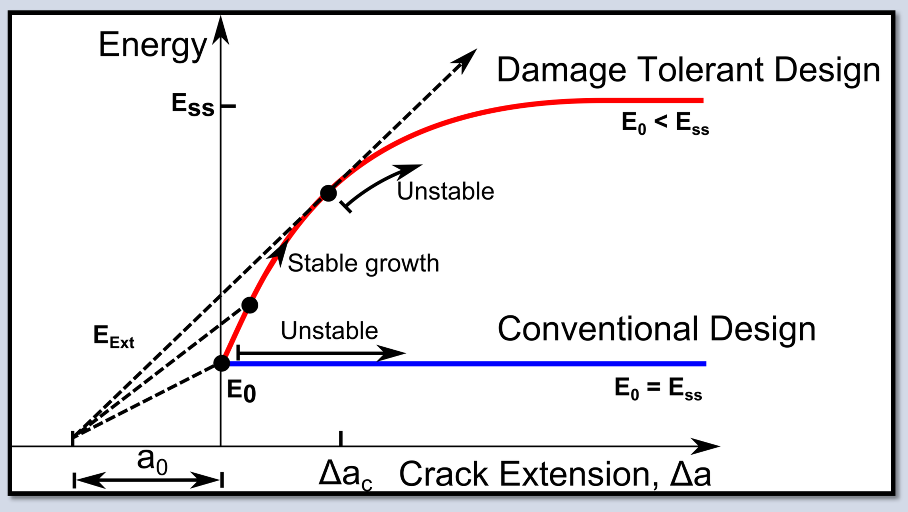
Abstract

The trend for wind energy structures shows a fast increase in the size of the components, especially wind turbine blades. Thus, the industry relies on advances in materials technology and design philosophy to deliver the most cost-effective light-weight structures. This project proposes a methodology for a reliable design, damage detection and maintenance of wind turbine rotor blades using a condition monitoring approach and a damage tolerance design.

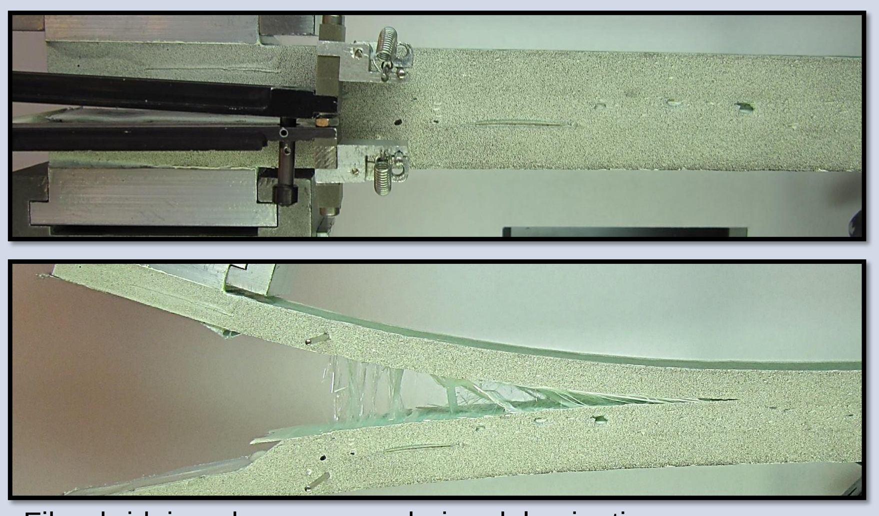
Damage Tolerant Design

Wind Turbine blade: Composite material and Bondlines

Designing a wind turbine blade using a damage tolerance philosophy and a structural health monitoring system, will permit the structure to operate despite the presence of damage, such as due to fatigue, intrinsic/discrete damage, manufacturing defects, or severe accidental damage that occur during the operational life. Also, this approach will enable a "real time" reactive maintenance of the structure. This is achieved not by only accepting the presence of damage, but by controlling it and using the full mechanical capability of the material and structure.



Fracture Energy Vs Crack Extension: Damage tolerant design.

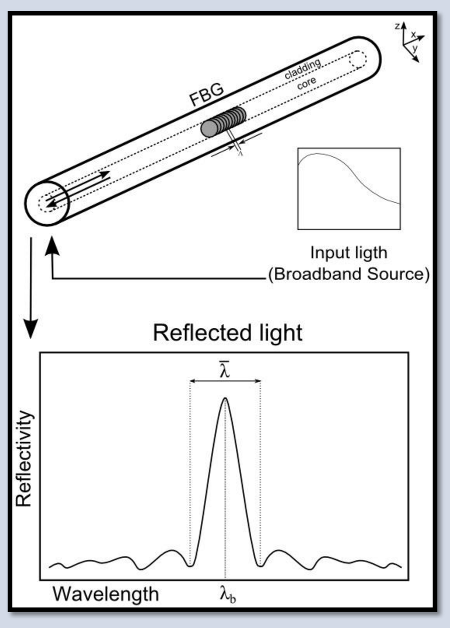


Fibre bridging phenomenon during delamination.

Objectives

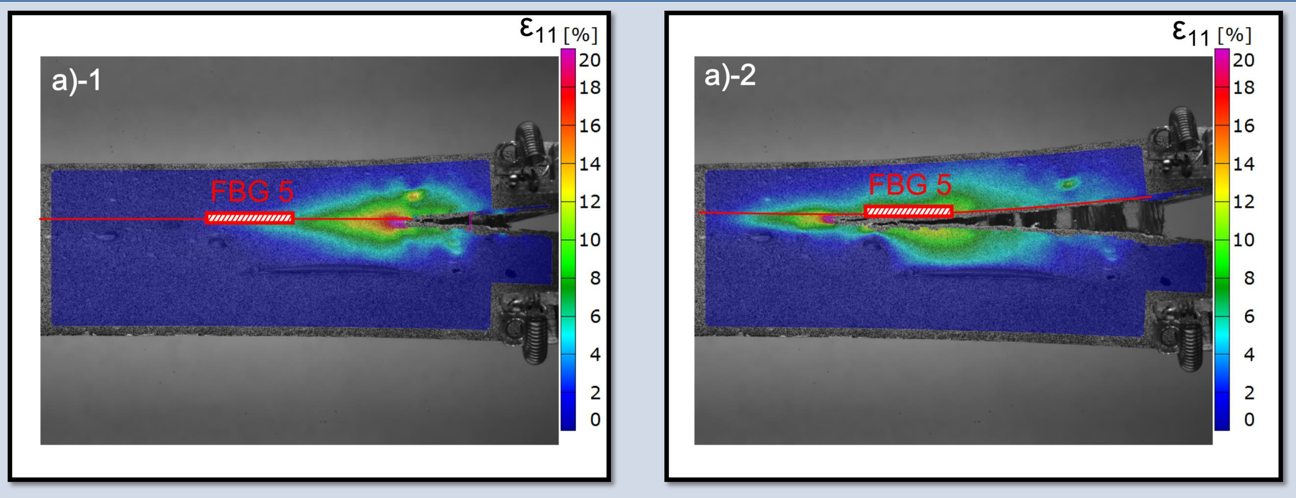
- **Developing a damage tolerance approach for Wind turbine blade sub-structures.**
- **Finite Element Method Model describing the crack growing mechanisms.**
- **Crack detection and monitoring technique using Fibre Optic Sensors.**
- **Experimental validation of the damage tolerance- structural health monitoring concept.**

Crack Detection: Fibre Bragg Gratings

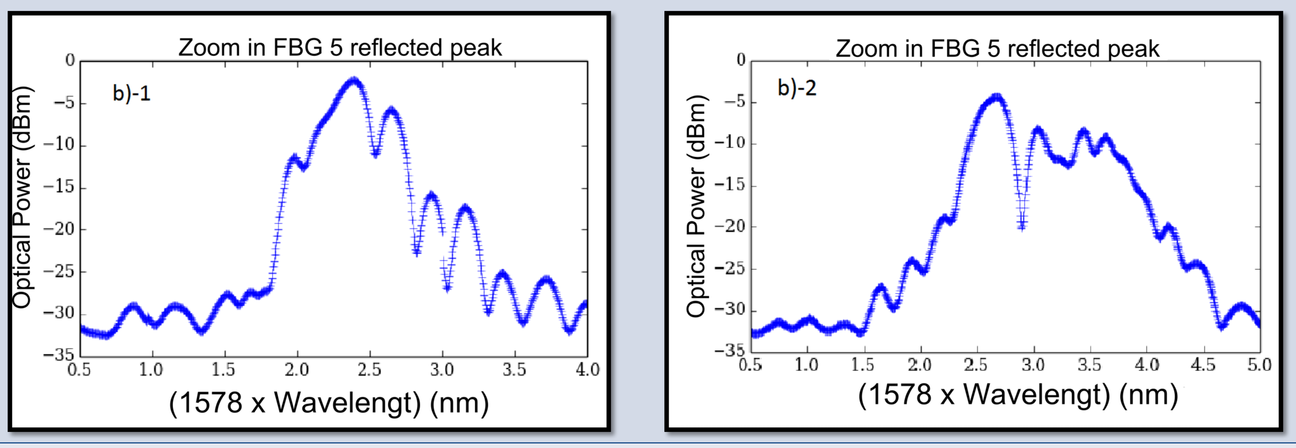


- Can be embedded in the composite materials or structural adhesive;
- Small diameter (125 µm);
- Multiplexing, Immunity to electromagnetic fields, Chemical inertness, Immunity to optical power fluctuations, High resolution;
- Capability to measure different parameters: Strain, Temperature, non-uniform strain, transverse strain, acceleration, etc.
- Don't need cable, the fiber is the cable and sensor at same time;

Experimental Validation: Crack Detection



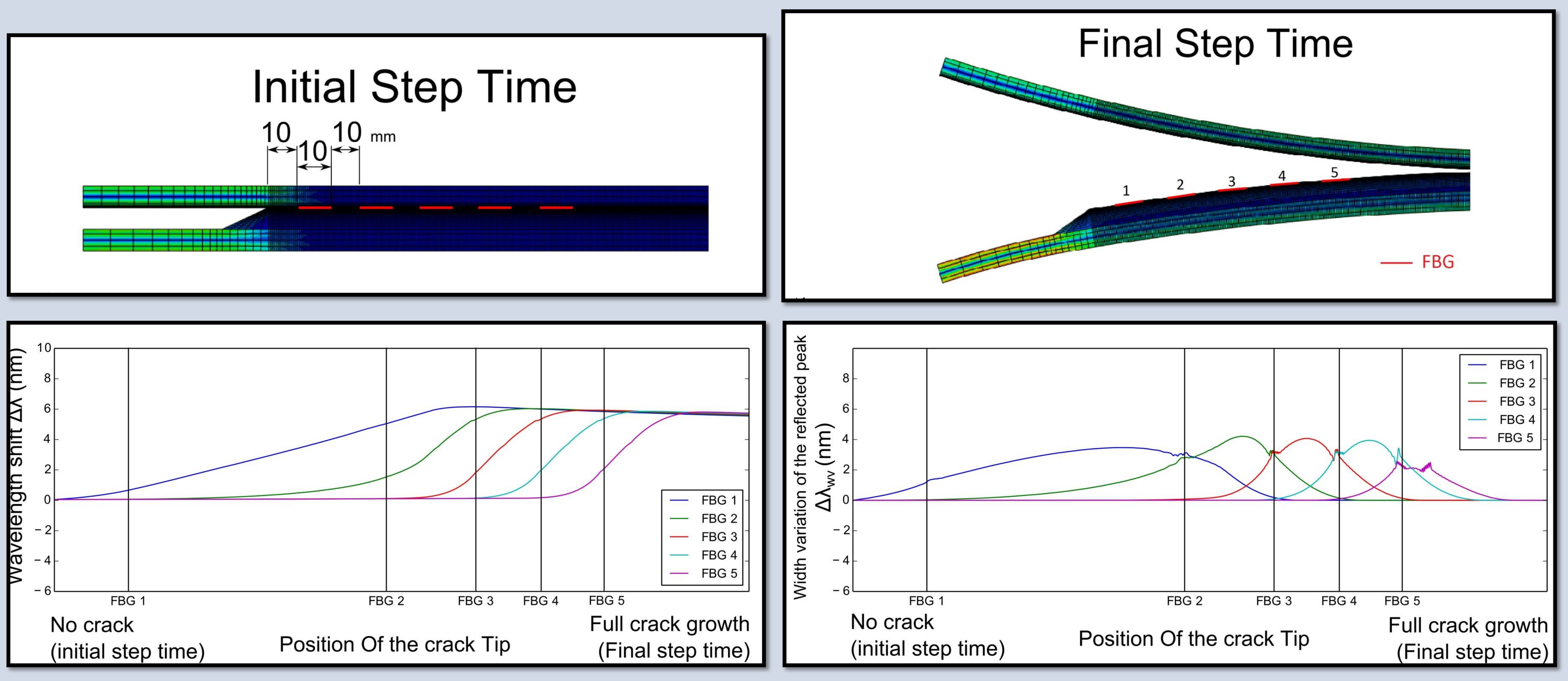
It was possible to detect and track cracks using **Fibre Optic Sensors.**



The output measured parameters are independent of the loading type, geometry and boundary conditions, and are depending only on the proximity of the crack.

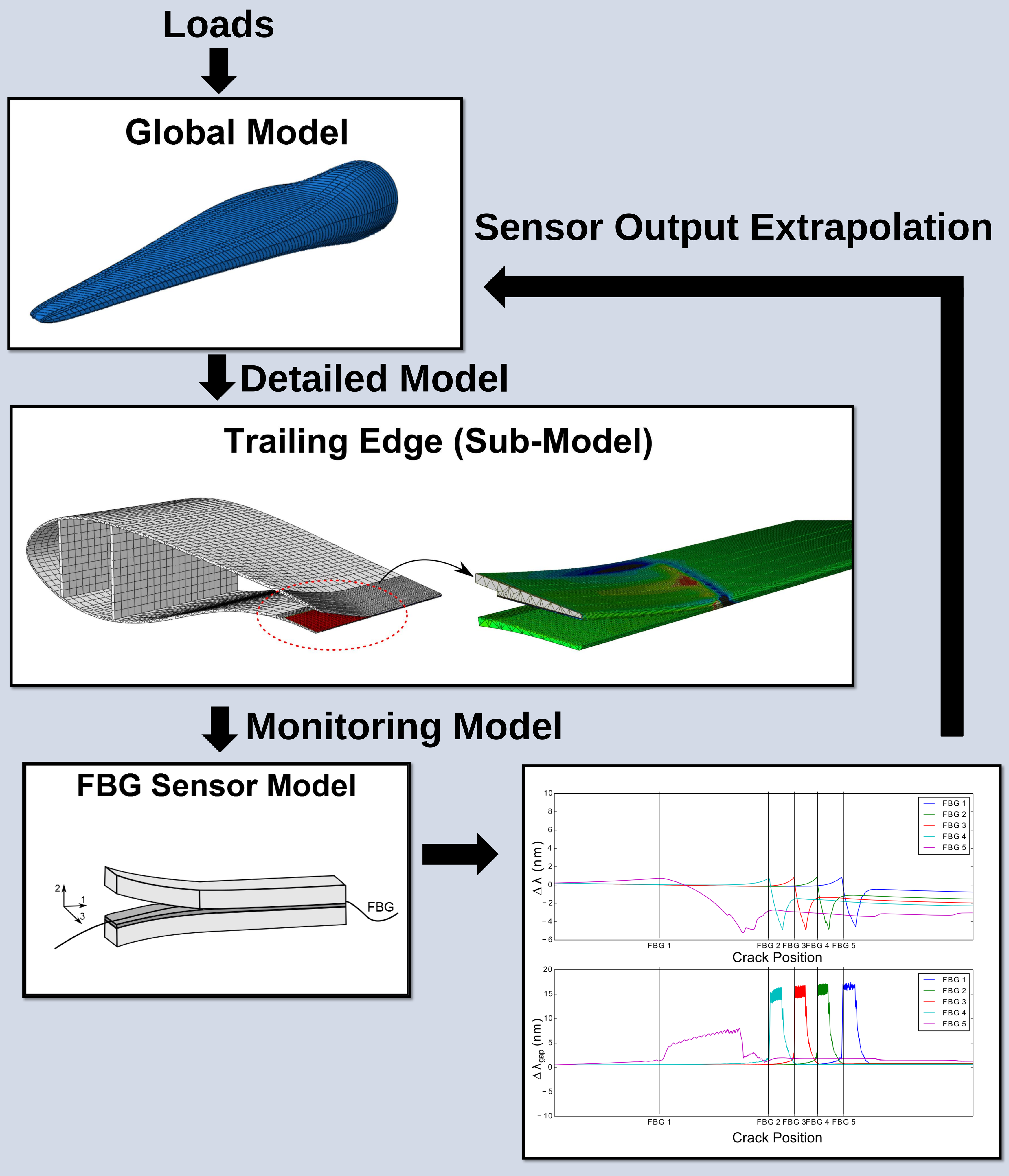
Finite Element Method
Damage Tolerant Design + Structural Health Monitoring

The equations describing the work principle of the Fibre optic sensor were implemented in the Finite Element Method Model.



With this Structure-sensor model, it becomes possible to study the application of this monitoring technique in other locations, predict the sensor output and track different types of damage.

Conclusions



➢This concept will lead to a condition monitoring maintenance: detection of damages by sensors, characterization of damage (type and size), model predictions of residual life, giving information that enables decision-making with respect to whether a damaged blade should be repaired or replaced.

References

1. M. McGugan, G. Pereira, B. Sørensen, H. Toftegaard, K. Branner, Damage Tolerance And Structural Monitoring For Wind Turbine Blades, Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences 373 (2035). doi:10.1098/rsta.2014.0077.
2. G. Pereira, L. P. Mikkelsen, M. McGugan, Crack Detection in Fibre Reinforced Plastic Structures Using Embedded Fibre Bragg Grating Sensors: Part-A and Part-B, Submitted to Composite Structures.

MARE-WINT new MAterials and REliability in offshore WINd Turbines technology