A parametric wind turbine blade structural model

B. Pascual, O. Caretta, J. Halliday

G. Dutton, P. Bonnet, M. Clarke, C. Evans, D. Hankin, G. Ellwood

SUPERGEN WIND – Wind Energy Technology

Science & Technology Facilities Council – Rutherford Appleton Laboratory

Objectives

To develop a parametric structural blade model based on finite element (FE) analysis capable of answering questions of the kind:

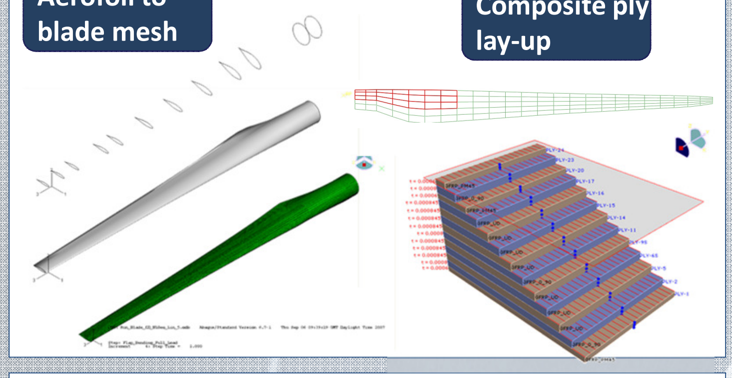
- Which are the best blade materials?
- What is the optimum blade lay-up?
- What is the best internal structure?
- What (if any) are the size limits for wind turbine blades?
- What stresses do control devices and bend-twist coupling generate in a blade?
- What is the effect on loads (static, fatigue life) of rotor wake?

Method

- Python script front end for automation of the Abaqus FE package
- Modular program
- Realistic load application, including quasi-static aerodynamic loading
- Ultimate strength & fatigue analysis
- Developing dynamic implementation (gust loading, wake operation)

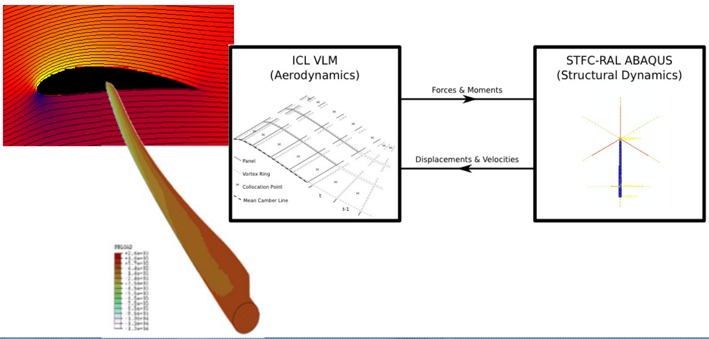
Aerofoil to blade mesh

Composite ply lay-up



Aerodynamic loading

Wake model coupling



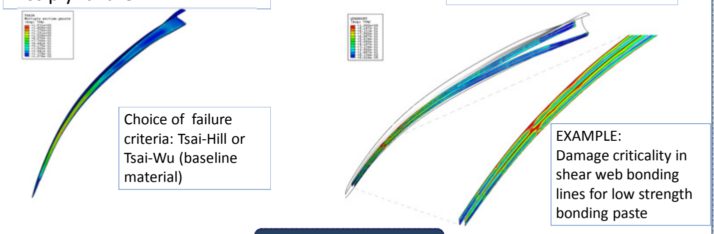
Results from Supergen phase 2

- Implementation of aerodynamic blade surface pressure (c_p) loading
- Sensitivity analysis of blade geometry by parameter sweep
- Structural models for Supergen 2 MW and 5 MW exemplar wind turbine blades
- Ultimate static and fatigue strength analysis (see below)
- Interpretation facility for thermoelastic blade stress measurements
- Analysis of NAREC multiaxial blade test procedure
- Dynamic analysis feasibility study and smart blade performance assessment

Static strength

Blade skin and shear web – first-ply failure

Bonding paste – cohesive element model

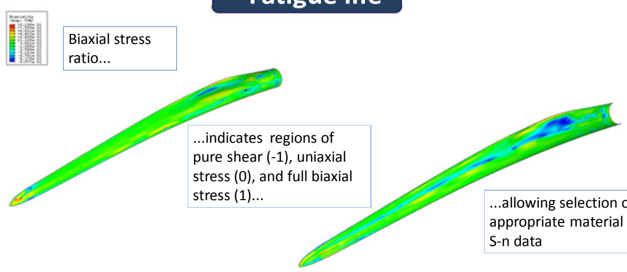


Choice of failure criteria: Tsai-Hill or Tsai-Wu (baseline material)

EXAMPLE: Damage criticality in shear web bonding lines for low strength bonding paste

Fatigue life

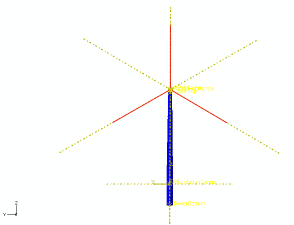
Biaxial stress ratio...



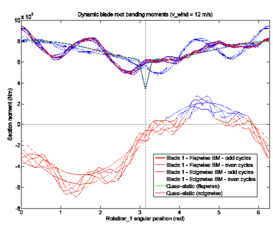
...indicates regions of pure shear (-1), uniaxial stress (0), and full biaxial stress (1)...

...allowing selection of appropriate material S-n data

Rotor-wind field interaction



Aerodynamic load from wake model, applied using DLOAD subroutine.



Beam section properties extracted from 3D blade model

Future work

- Apply methods developed to 80m blade, and assess the effect of increasing size.
- Extend 3D parametric model to analyse rotor blade with aerodynamic flaps and rotor blade with deformable trailing edge and self-twisting composite lay-ups).
- Develop methods for comprehensive fatigue life prediction: use damage equivalent load analysis to assess detailed (3D) structural characteristics.
- Effect of stress concentrations on fatigue life predictions
- Interfacing turbine-level aeroelastic models to detailed fatigue models.

Initial conclusion

- Flexible, parametric blade model for assessment of alternative materials with enhanced static and fatigue properties
- Initial results also available for application to full-scale blade testing, control of smart blades and interpretation of condition monitoring data

http://www.supergen-wind.org.uk

Sponsored by EPSRC Engineering and Physical Sciences Research Council