Optimisation of Wind Turbine Blade Structural Topology

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Introduction

- Wind turbine blades
  - Current blade designs
  - Square-cubic law between power and mass
  - Lightweight blades

Aims and Objectives

The overall aim is to reduce the cost of wind energy by increasing blade structural efficiency (reduce mass)

- Investigate alternative structural layouts using topology optimisation
- Evaluate and understand these layouts in terms of structural efficiency using shape factors
Topology Optimisation

- **Topology optimisation**
  - Gives optimal material distribution
  - Provides non-intuitive solutions
  - Topology is altered by changing a fictional element density
  - This modifies element stiffness

- **Optimisation problem**
  - Seven key load cases
  - Large model size

Objective: \( \min(\max) \) compliance
Subject to: 
\[
\begin{align*}
\nu_f &< 0.125 \\
\delta_{tip} &< 9m \\
\theta &< 2^\circ
\end{align*}
\]
Topography Optimisation

- Trailing edge (TE) Reinforcement
- Offset Spar Caps
Structural Efficiency

• Shape Factors
  - Determines the efficiency of material usage in a structure
  - Account for complex bending
  - Deflection and stress
  - Depend only on the direction of loading

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Deflection Shape Factor

Radius = 25%

Radius = 75%
Stress Shape Factor

Radius = 25%

Radius = 75%
Conclusion

- An alternative structural layout was found using topology optimization
- The new layout is more efficient in terms of minimizing deflection and stress

From this, two observations are made:

1. Alternative layouts could be used to reduce blade weight
2. It is crucial to consider asymmetric bending in wind turbine blades