Impact of resin uptake of core materials on buckling of wind turbine blades

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Introduction

Sandwich construction in wind turbine rotor blades

- Sandwich constructions mainly used in panels and webs to prevent buckling
- Core materials used: PVC, PU, PET foam and balsa wood
Introduction

Sandwich failure modes

- Intracellular face dimpling (a)
- Symmetric and antisymmetric face wrinkling (b)
- Face wrinkling due to tensile rupture of bonding, core crushing, tensile rupture of core (c)
- Shear crimping (d) occurs when shear stiffness of core is low compared to bending stiffness of facings
Core material model

Modeling of infused properties

- Dry core (a) and resin infused slits (b)
- "Smeared" core properties were determined using Nickel's model
Core material model

Material properties

| Property   | Epoxy resin [11] | Dry core [10] | Infused core | Unit   |
|------------|------------------|---------------|--------------|--------|
| $E_x$      | 3089.8           | 48.5          | 193.3        | MPa    |
| $E_y$      | 3089.8           | 48.5          | 50.9         | MPa    |
| $E_z$      | 3089.8           | 48.5          | 193.3        | MPa    |
| $G_{xy}$   | 1129.2           | 17.3          | 44.2         | MPa    |
| $G_{xz}$   | 1129.2           | 17.3          | 70.3         | MPa    |
| $G_{yz}$   | 1129.2           | 17.3          | 18.2         | MPa    |
| $\nu_{xy}$ | 0.368            | 0.400         | 0.398        | -      |
| $\nu_{xz}$ | 0.368            | 0.400         | 0.398        | 0.398  |
| $\nu_{yz}$ | 0.368            | 0.400         | 0.398        | -      |

- Shear crimping dominating through-the-thickness shear modulus $G_{xz}$ and in-plane stiffness $E_x$ increased by a factor of 4
Full blade model benchmark

Finite element blade

- Shell model (a) and solid model (b)
- A zoom into spar cap region (red box) simplified as a plate (c)
- Shear forces introduced via rigid body elements (RBE3)
Full blade model benchmark

Finite strip element model (FINSTRIP) of cross section

- FINSTRIP model discretization
- Buckling mode shapes of critical cross-sections with dry and infused parametrization
Full blade model benchmark

Failure modes and buckling resistance

| Model                      | Dry  | Infused |
|----------------------------|------|---------|
| FE shell (ANSYS)           | $0.85^a$ | $1.59^c$ |
| FE solid (MSC Marc)        | $1.89^b$ | $1.89^b$ |
| Finite strip (FINSTRIP)    | $1.93^a$ | $1.96^c$ |

(a) 25\%l_b

(b) 35\%l_b

(c) 32\%l_b
Plate model benchmark

Finite element plate

- Plate model (a)
- A zoom into solid (b) and shell model (c)
Plate model benchmark

\[ k = \frac{p_{xcr}b^2}{(\pi^2 B_x B_y)} \]

A2: \( b = 0.5 \text{ m} \)

- Dry (AM, global buckling)
- Dry (AM, shear crimping)
- Infused (AM, global buckling)
- Infused (AM, shear crimping)
- Dry (FE shell)
- Infused (FE shell)
- Dry (FE solid)
- Infused (FE solid)

Length-to-width ratio \( a/b \)

(a)

(b)

(c)

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Conclusions

- The impact of resin uptake of core materials in sandwich constructions is highlighted.
- Shear crimping is captured well by shells, but not by solids when one element is used though the laminate thickness.
- FINSTRIP captures failure mode location as identified in shell model. Safety reserve factor is, however, far too optimistic (factor of 2.3).
- It is recommended that designers verify the efficiency of the design tools to capture shear crimping.
- Taking resin uptake into account in design models could potentially reduce core material cost and lead to a more lightweight design.
- Experimental validation of the models' results is required.
Thank You For Your Attention

Any questions?

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