Technology/Process
TRL 3

NTNU

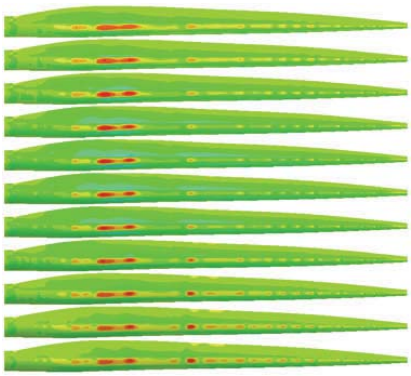
Buckling resistant blades

Innovation description

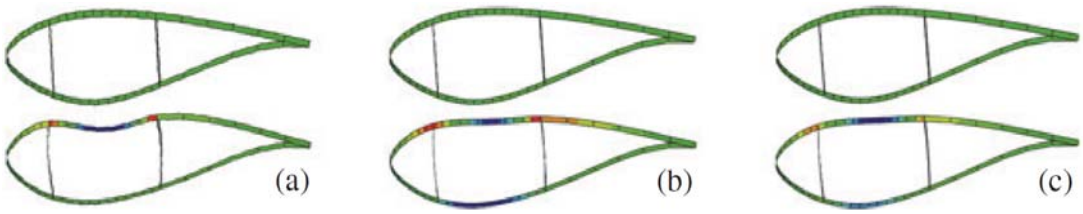
The potential for load alleviation and increased critical buckling load through the use of unbalanced fibre layup has been documented for a large number of design cases through simulations and laboratory experiments.
The inherent directional properties of composite materials has been used to increase the critical buckling load of a 70m carbon/glass hybrid wind turbine blade. The effect of changing the fiber orientations of the less stiff, off-axis glass fiber plies was studied via nonlinear finite element buckling simulations. The orientation of the stability plies was found to influence the onset of the Brazier effect, which further influenced blade stability and buckling failure location. Although both blade weight and laminate thickness remained constant, an increase in critical buckling load of 8% was achieved with a negligible change in bending stiffness. The more stable blade allowed for removal of material leading to a decrease in maximum laminate thickness and a drop in blade mass of 3.3%. Modifications to the ply stacking sequence and carbon fiber usage were also considered and were found to affect the buckling load but not necessarily the optimum fiber orientation of the stability plies

Blade (degrees)	Solution steps (#)	CBL	CBL location blade span (m)	1st Flap freq. (Hz)	LPF (%)	U2 (m)	E-11 (%)	UR3 (deg)
0	5	1.319	22.5	0.788	98.24	3.73	−0.1198	0.860
±10	7	1.361	18.4, 23.5	0.781	98.20	3.80	−0.1221	0.764
±20	11	1.438	18.4, 22.8	0.763	98.11	4.00	−0.1291	0.587
±30	7	1.517	22.5	0.736	98.00	4.31	−0.1401	0.467
±40	15	1.614	18.4, 22.5	0.711	97.95	4.63	−0.1515	0.433
±45	19	1.663	18.1, 22.5	0.702	97.95	4.76	−0.1560	0.445
$\pm 45_B$	41	1.628	18.1, 22.5	0.702	97.88	4.75	−0.1583	0.376
$\pm 45_a$	NR	1.659	18.1, 22.5	NR	100	4.80	−0.159	NR
±50	9	1.709	18.1, 22.5	0.695	97.96	4.85	−0.1594	0.474
±60	10	1.779	18.1, 22.8, 33.1	0.688	98.03	4.94	−0.1630	0.586
±70	20	1.796	22.8, 33.1	0.686	98.10	4.97	−0.1639	0.775
$\pm 70_b$	8	1.634	19.1, 31.9, 35.9, 37.5, 41.3	0.692	100	4.97	−0.1578	0.806
±80	17	1.762	33.1	0.686	98.16	4.97	−0.1638	1.014
90	11	1.735	33.1	0.685	98.19	4.97	−0.1638	1.153

CBL: critical buckling load U2 = flapwise bending deflection at blade tip. E-11 = minimum logarithmic strain in carbon fiber. UR3 = maximum twist at blade tip.



Buckling locations for the 11 different stability ply orientations.



Transverse strain at 23m span exhibiting the influence of the Brazier effect for the stability ply orientations (a) 0°, (b) ±45° and 90°.

Impact

- **Increased buckling resistance**
- **Retain buckling resistance with lower blade weight**

References

- **Cox, K. and Echtermeyer, A. "Effects of composite fiber orientation on wind turbine blade buckling resistance," Wind Energy, October 2013, Online. DOI: 10.1002/we.1681Include one or two references where more information about the innovation can be found**
- **Kevin Cox, Lift Control of Adaptive Wind Turbine Blades with Bend-Twist Coupling, Thesis NTNU**