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Abstract

Loads acting upon today's and tomorrow's offshore wind turbines of the 10-20MW class pose enormous challenges for their blades' structural integrity [1]. In order to counteract these loads over the turbines' life, blade designers rely on high-strength materials and designs with passive load mitigation - both resulting in a more inhomogeneous mechanical blade structure [2].

Since many tools used for blade design were developed using two-dimensional load data, wind turbine designers today – more than ever – need a holistic picture of the blades' three-dimensional loading that is affected by their inhomogeneous mechanical blade structure.

The authors developed a novel approach for the integral field instrumentation of wind turbine blades that goes well beyond the conventional instrumentation prescribed by IEC standards [3]. This can provide a more complete picture of the dynamics and three-dimensional loads of large offshore wind turbine blades.

Objectives

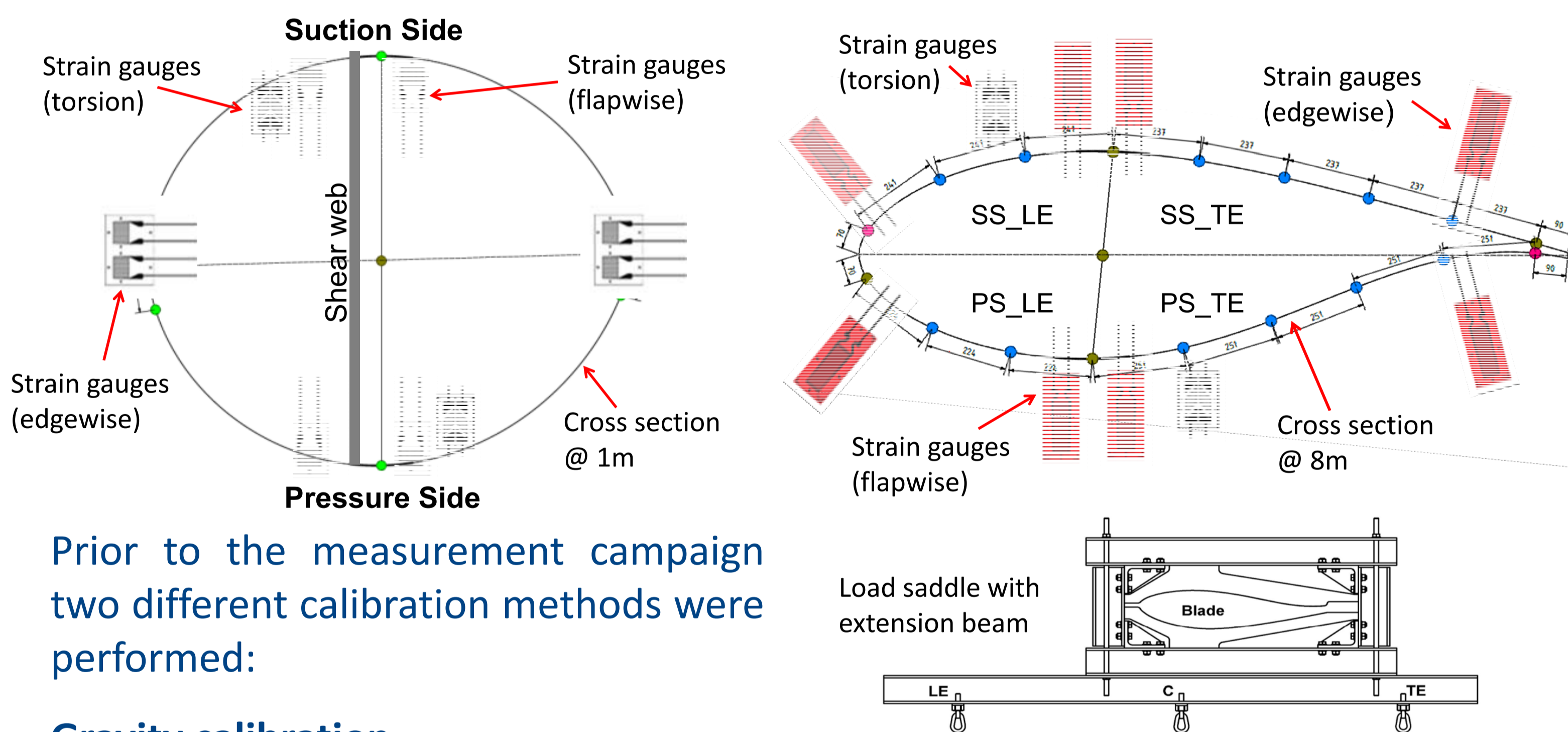
Develop an approach that relies on a customized distribution of measurement points covering the overall loading of the blade cross-section under investigation.

Use a comprehensive calibration procedure that relies on both the blade's gravitational forces and loads applied externally to obtain high-precision measurements of the relevant load components.

Methods

The 20m long geometrical bend-twist coupled blades, developed in the project SmartBlades2, were instrumented with strain gauges to measure flapwise and edgewise bending moments, as well as torsion.

Strain gauges were instrumented at 1m and 8m (spanwise from root).



Prior to the measurement campaign two different calibration methods were performed:

Gravity calibration

The rotor was set to 12 positions (each 30° apart) and all three blades were simultaneously pitched to 0°, 30° and 90° each for the 12 positions. The wind speed was below 3 m/s and only the blades self-weights were used.

External load calibration

Each blade at a time was set horizontally and pitched to 90° (pressure side facing upwards) and loaded with a 907kg weight attached to a load saddle with a rope at a specific spanwise blade position. Attached to the load saddle was an extension beam that allowed applying a positive, zero and negative torsional moment by installing the weight at leading edge (LE), center (C) and trailing edge (TE) respectively.

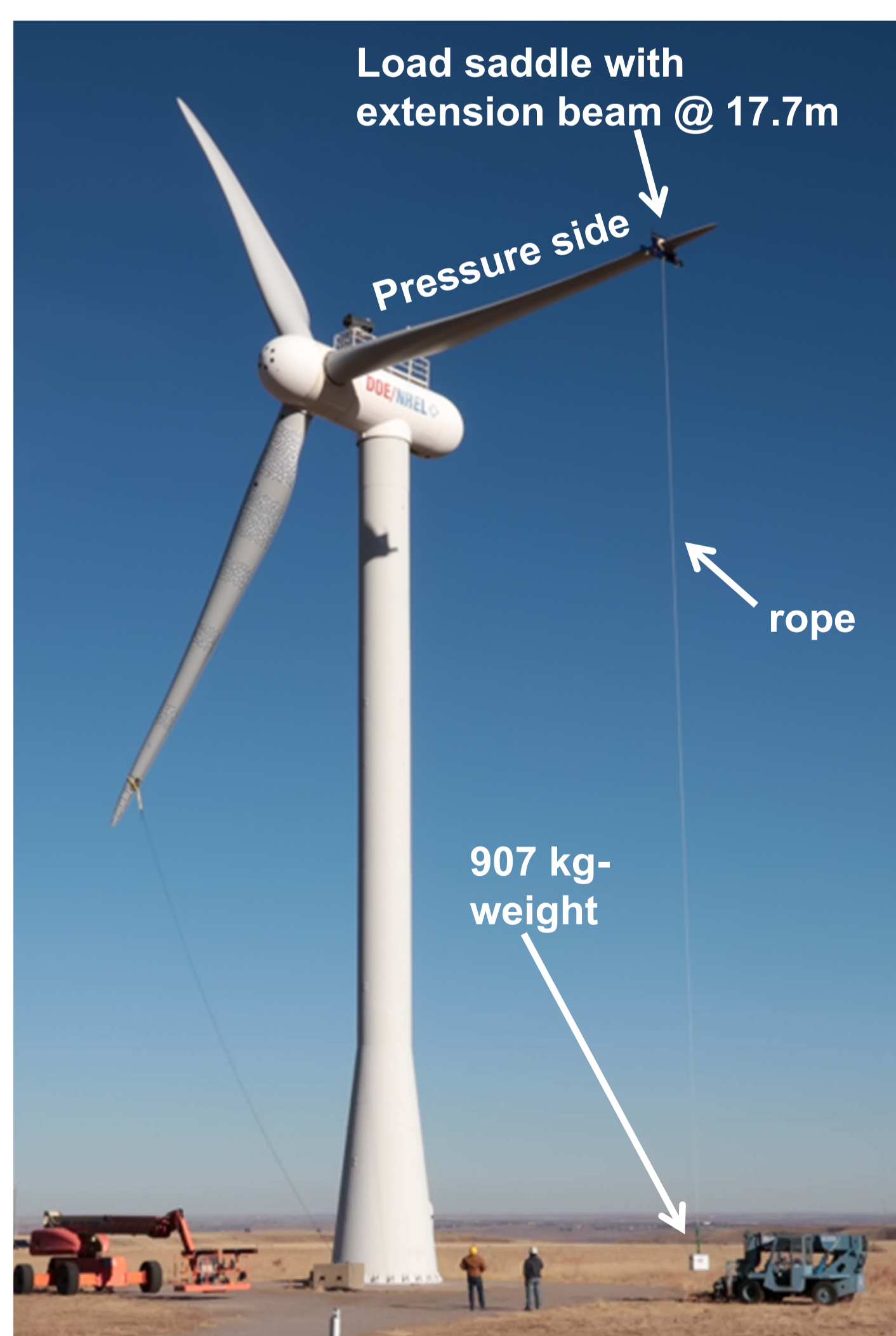
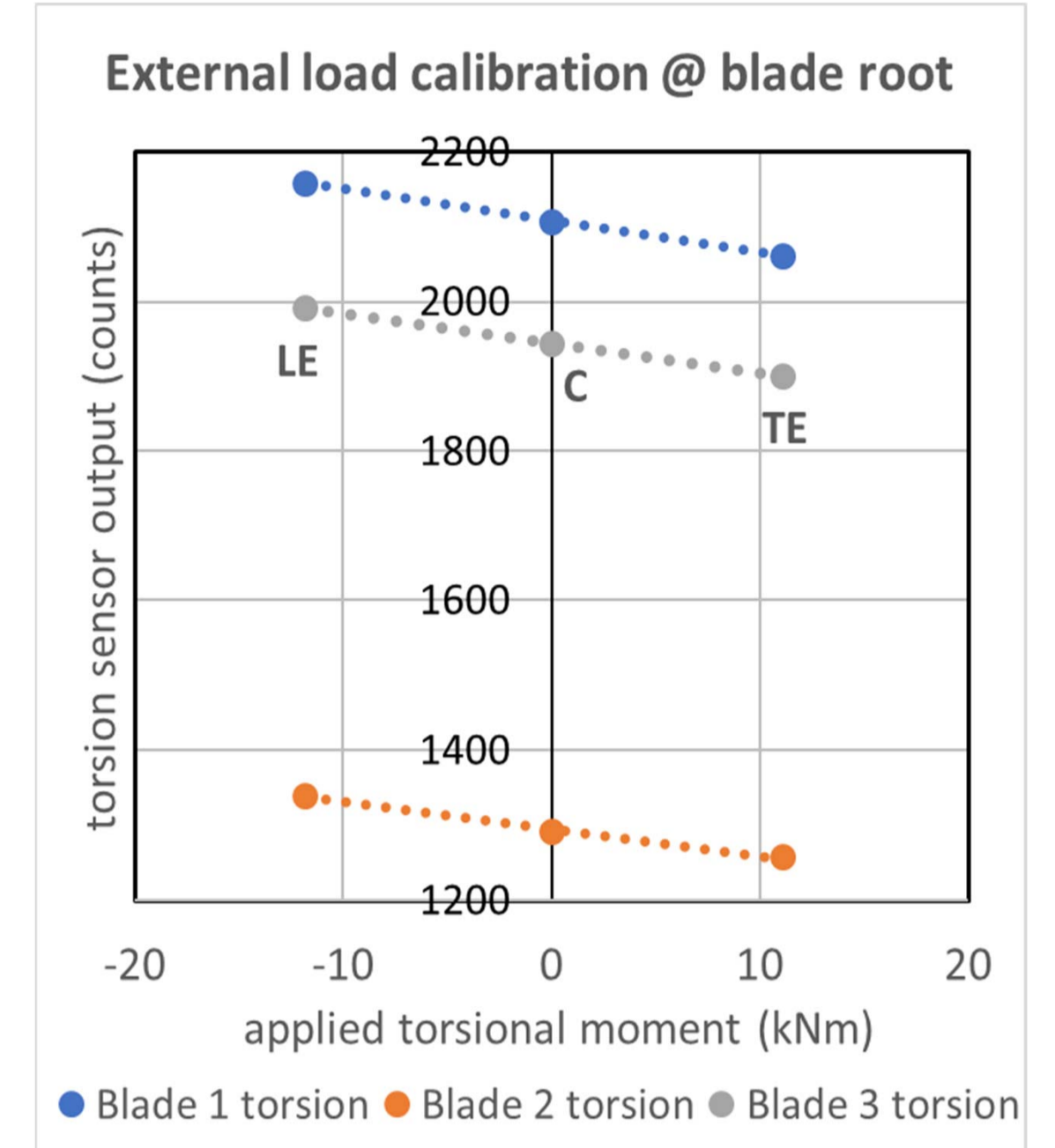


Photo by Lee Jay Fingersh, NREL 59753.

Results

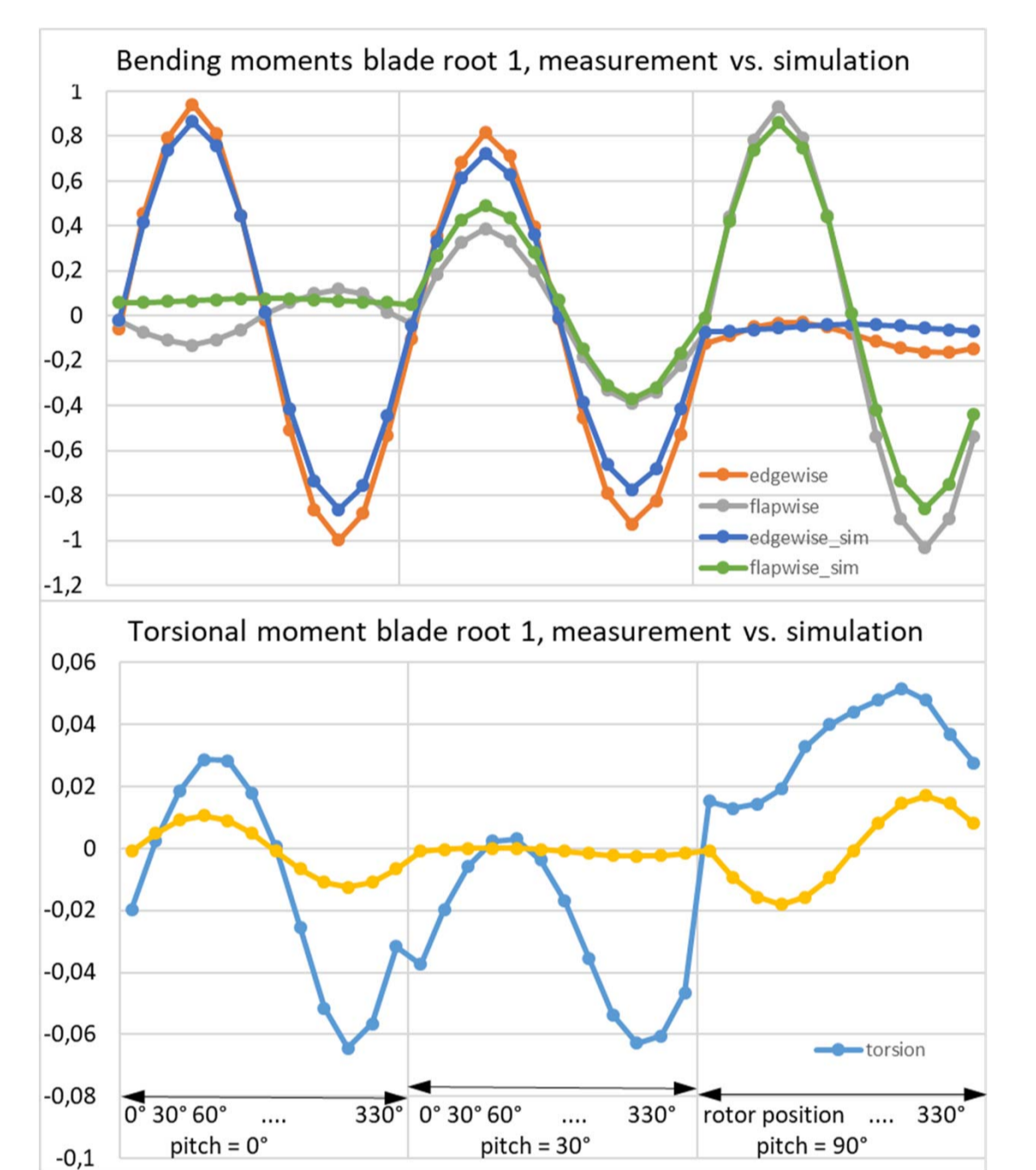
External Load Calibration of Torsion

The diagram on the right shows the measured torsion during calibration with the external load at three chordwise positions (LE, C, TE). Since all three data points are located on one line and the slopes are approximately the same this calibration can be assumed as plausible. The advantage of this calibration compared to the gravity method is that a torsional moment can be applied without a change in the bending moments. In this case the applied torsional moment is ≈5 times larger than the one which would be applied by gravity loads.



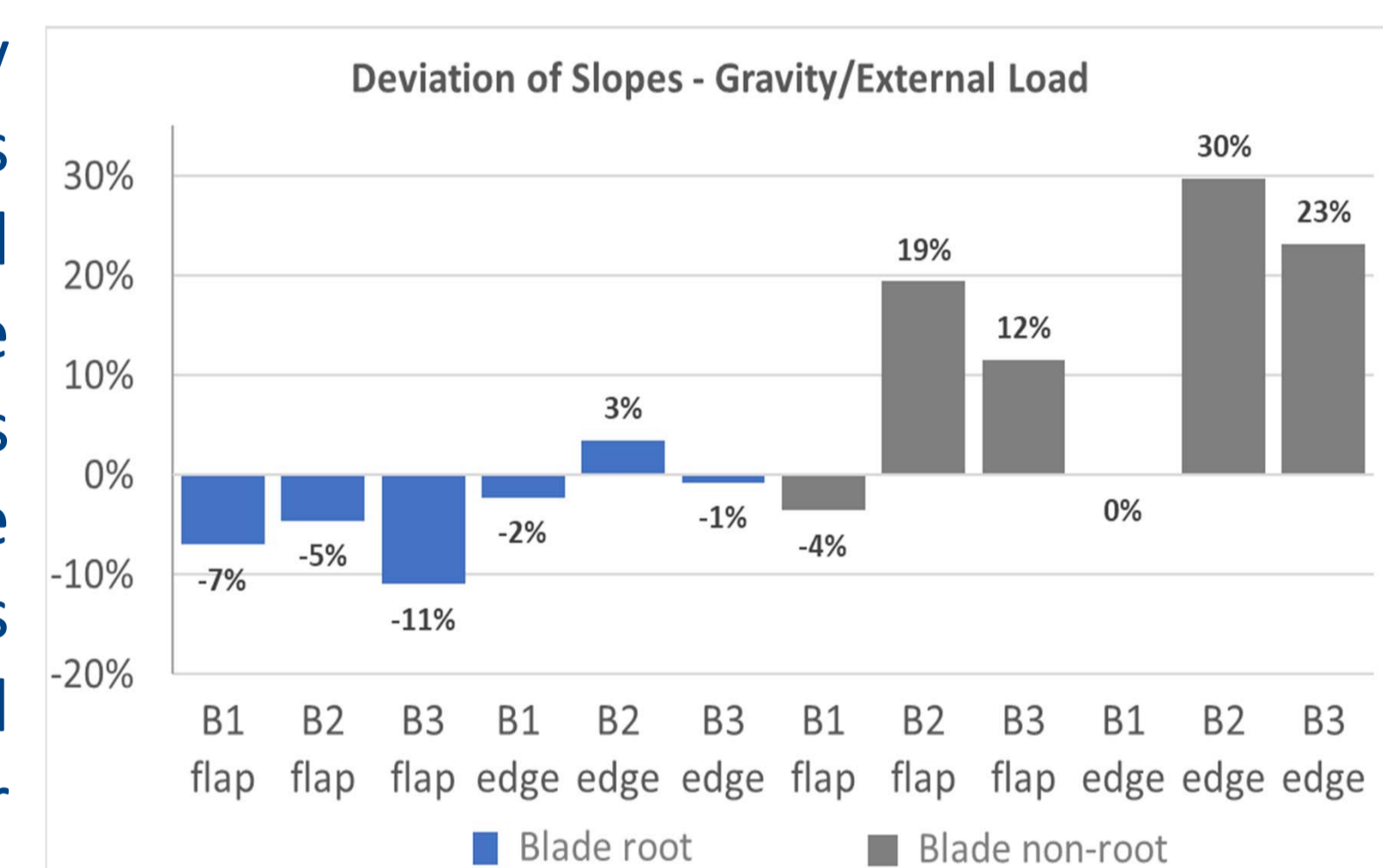
Gravity Calibration of Torsion

The results of the gravity calibration for both, measured and simulated, are shown on the right. Measured and simulated edge- and flapwise bending moments show a good agreement. However, for torsion, measurements show large discrepancies from the simulation. The influence of the cross-talk by the large bending moments overprints the torsion signal. Therefore, torsion strain gauge calibration by gravity seems to be difficult.



Bending Moments: Gravity vs. External Load Calibration

The deviation of the bending moments-slope between the gravity and external load calibration is depicted in the right diagram for all three blades (B1, B2, B3). In the blade root region the deviation of the slopes is smaller than for larger spanwise positions. The reason for that is unclear. Possible explanations could be amongst others a non-linear behaviour of the blade material or the non-cylindrical geometry of the cross section.



Conclusions

In order to measure the torsional moment of a rotor blade using strain gauges, it is highly recommended to use an external load for calibration.

Calibration of torsion using gravity loads seems to be impossible. **→ Improved calibration with external load has to be performed.**

There is a high influence of cross-talk by flap- and edgewise bending moments on the torsion signal.

Simulated blade bending moments could be validated by measurements.

References

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