Kim Branner, Head of Section – Structural Design & Testing
Member of IEC 61400-5 & 61400-23

Developments in blade tests and the work in IEC 61400-23

Outline

- Recent failures and learning from them
- How to test blades better and faster
- How it is reflected in the new IEC blade test standard
- How digital twins of blades can help to make them more reliable

Super Typhoon Yagi in the Hainan province of China

September 7, 2024




Violent winds and heavy rain caused
widespread devastation in the country



The turbines destroyed were reportedly new ones that were under construction

https://www.msn.com/en-au/news/other/super-typhoon-yagi-flattens-storm-resistant-wind-turbines-in-china/

offshore-mag.com/renewable-energy/article/55135538/second-ge-vernova-turbine-blade-reportedly-fails-at-uks-dogger-bank-wind-farm

Offshore SUBSCRIBE MAGAZINE VIDEOS WEBCASTS EVENTS ABOUT US EXCLUSIVE CONTENT BEST PLACES TO WORK LOGIN JOIN

REGIONAL REPORTS GEOSCIENCES DRILLING & COMPLETION FIELD DEVELOPMENT SUBSEA PRODUCTION PIPELINES VESSELS RIGS RENEWABLE ENERGY ENERGY TRANSITION

RENEWABLE ENERGY

Second GE Vernova turbine blade reportedly fails at UK's Dogger Bank wind farm

Incident would represent third Haliade-X turbine blade failure this year.

Aug. 23, 2024

Related To: GE Vernova





initiated an investigation into the cause of the incident. Initial findings indicate that the circumstances surrounding the incident are isolated to the single blade affected.

Press releases

BLATIGUE - Fast and efficient fatigue test of large wind turbine blades

A project supported by EUDP and VILLUM FONDEN

Project partners:

- DTU Wind Energy
- Siemens Gamesa Renewable Energy A/S
- R&D A/S
- Blade Test Centre A/S (BLAEST)
- Olsen Wings A/S
- DNV GL
- Zebicon A/S
- Ørsted A/S



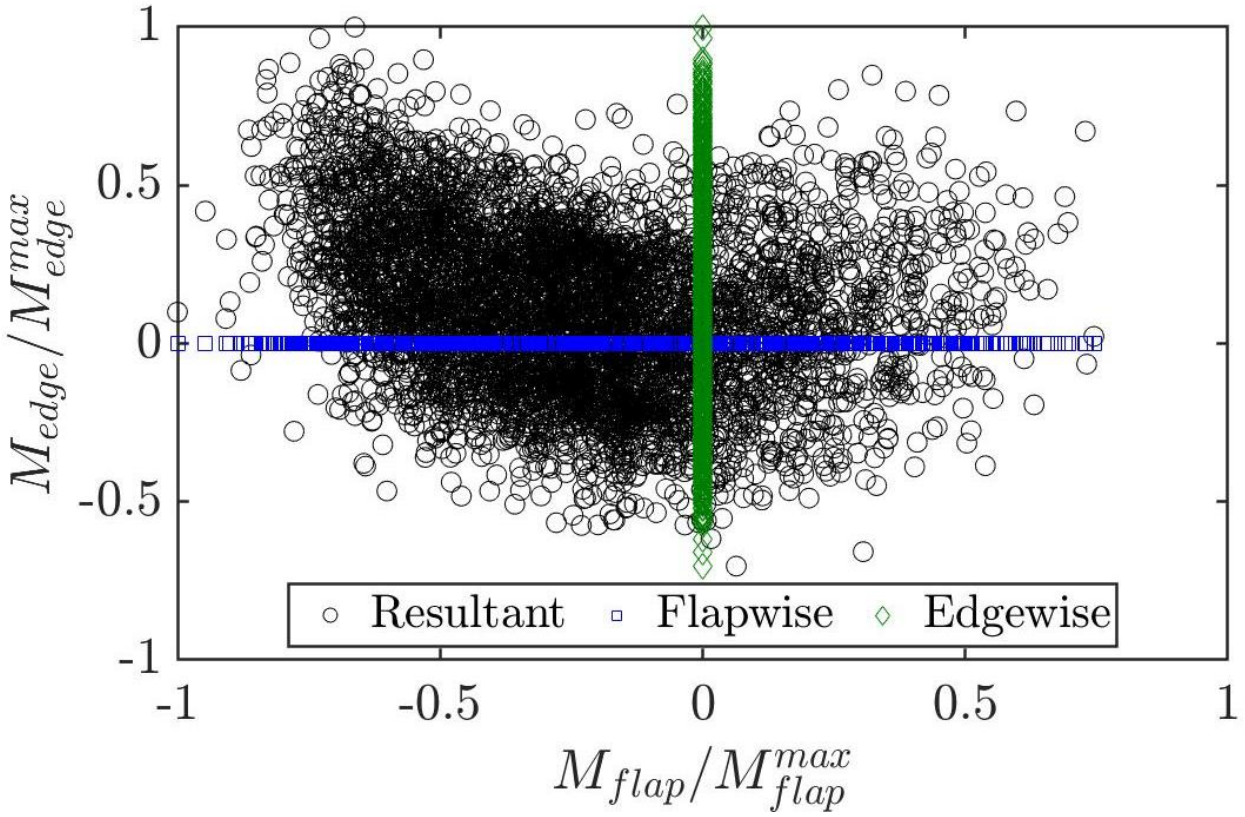
The objective of BLATIGUE is to develop **fast and efficient fatigue test methods** for large wind turbine blades and to develop **equipment to excite the blades** under such tests.

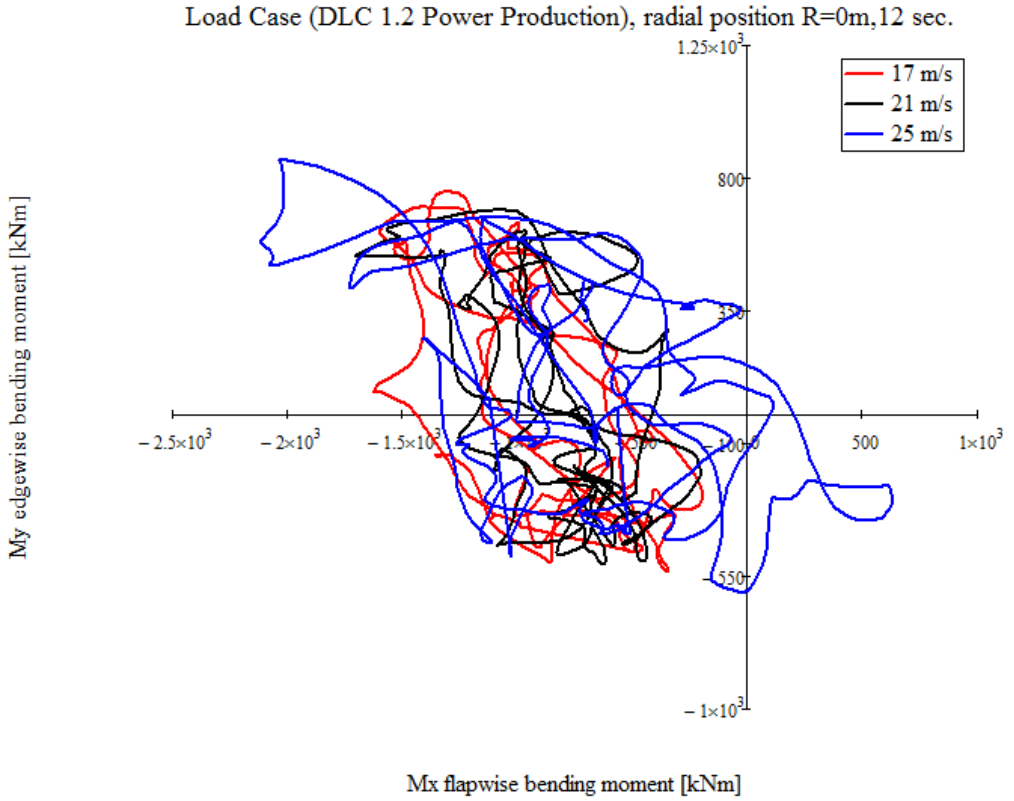
- Period: Dec. 2016 – August 2021
- Total hours: 30730 h

EUDP

Fatigue testing

- According to IEC61400-23 blades shall be tested in fatigue:
  - In flapwise direction
  - In edgewise direction





A 12s sample of load cloud at 17m/s, 21m/s and 25m/s at the SSP 34m blade root section

Current standard fatigue tests

Edgewise test



Flapwise test



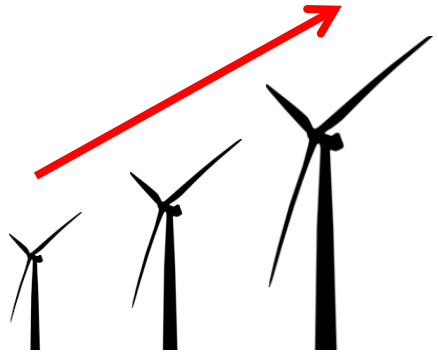
* frames from LM's YouTube video

Full-scale fatigue testing of large blades - test time and loads



Full scale testing is currently the only way to check how the blade structure works as a "whole".

- How to reduce the total test time?



150-meters blade → about 1 year for standard fatigue test

- How to ensure that the applied loads represent the real loads?

IEC 61400-23 new edition 2.0 status

- The committee draft (CD) was submitted to all IEC Members: those who participate actively in IEC work, and those who have observer status only for comment and approval.
- Comments are currently being processed
- Next step is then Committee Draft for Vote (CDV). The CDV is submitted to all national committees for a 12 week voting period

- Convenor: Peter Quiring, LM Wind Power

6.2 Areas to be tested

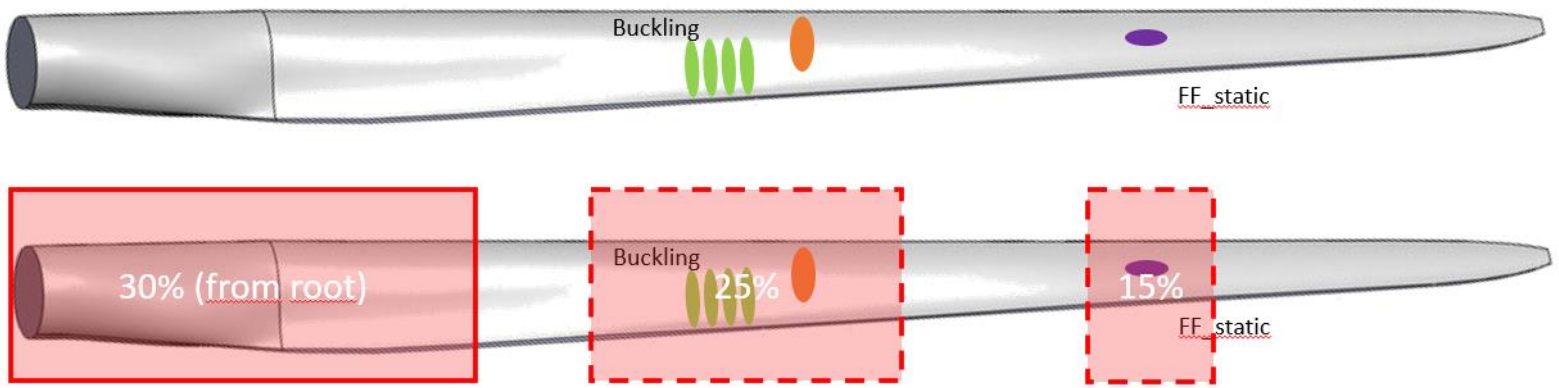
- The areas of the blade or component to be tested according to the requirements in this document shall be defined.

- The areas shall be defined based on all the following criteria
  - Spanwise segments
  - Areas with minimum design safety margins
  - Design details

- Areas that physically cannot be tested due to conflicting requirements for areas to be tested, may be represented by similarity with other areas on the same blade or blade design.

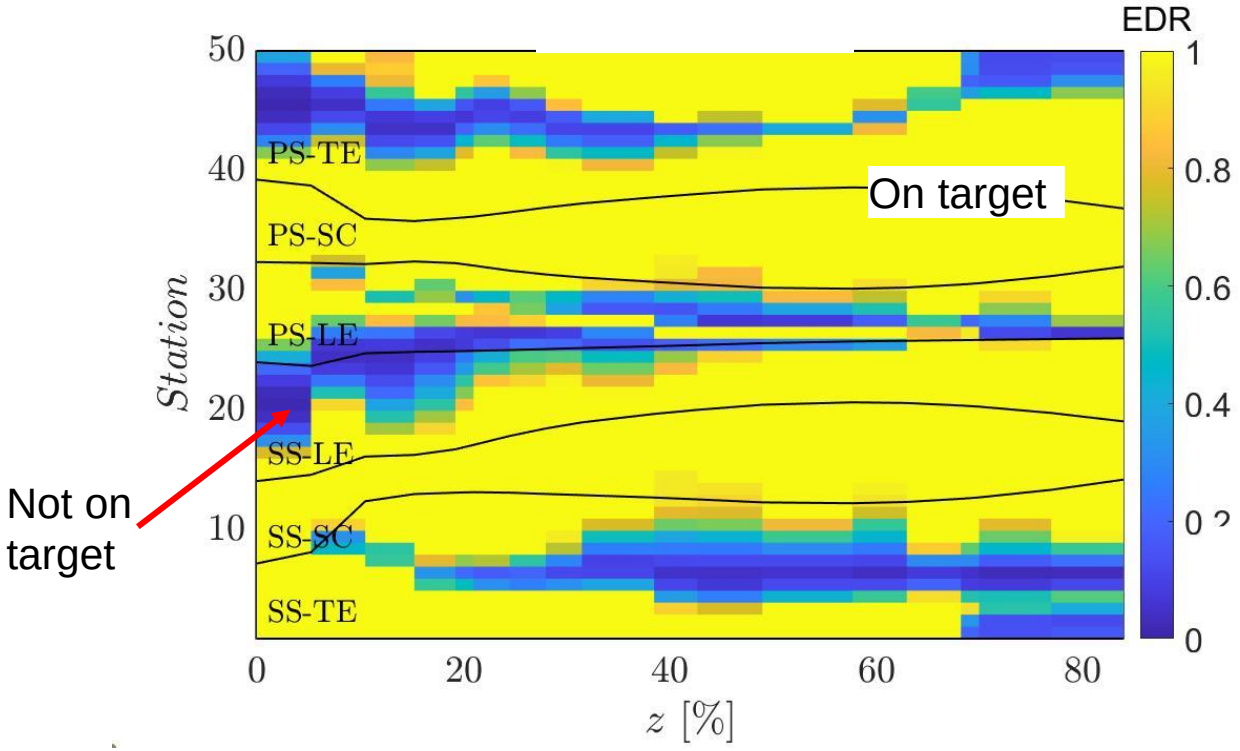
6.2.1 Spanwise segments to be tested

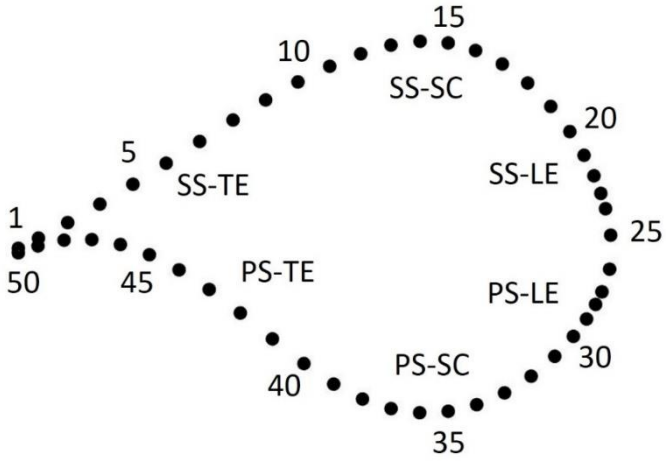
- The spanwise segments of minimum 70% of the total blade length shall be loaded with minimum the target loads in static and fatigue testing.
- The spanwise segments from the blade root at 0 % to 30% of the total blade length shall be loaded with minimum the target loads.
- The spanwise segments loaded with target loads outboards from 30% blade length can be distributed.



Simulated standard test

- Total test time: 15.8 days
- Points where target is reached: No all
- Tuning mass configurations: 2



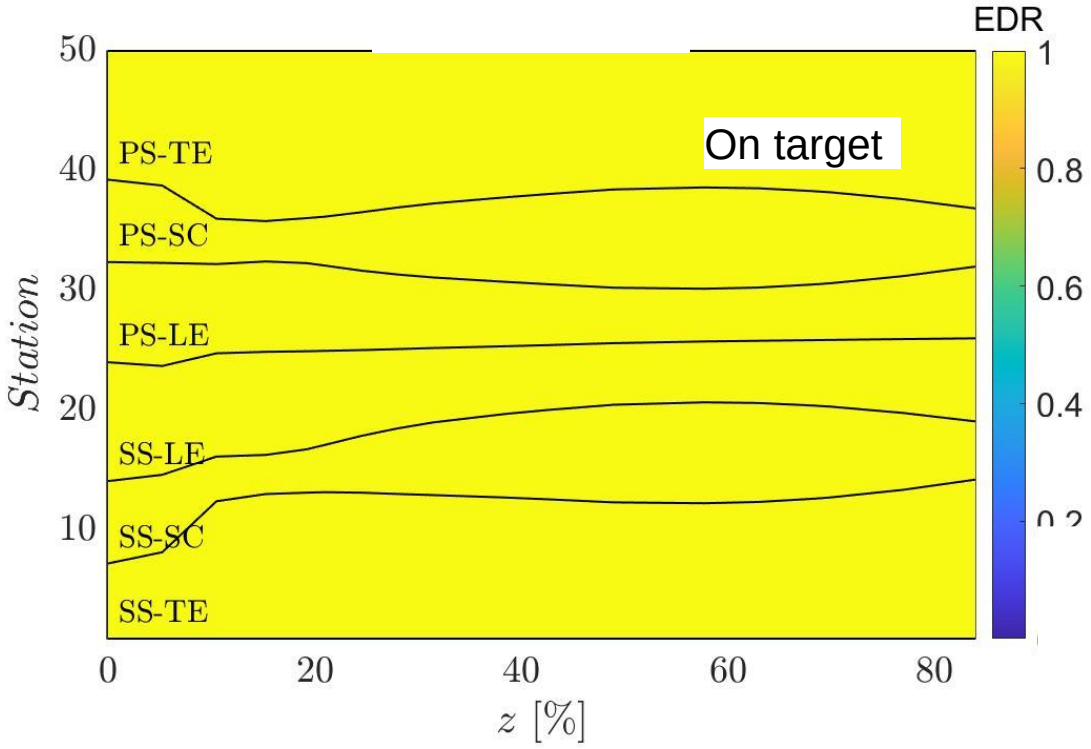


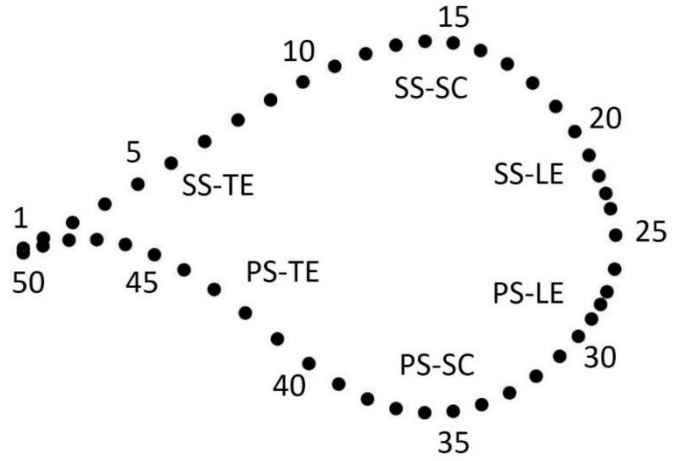
$$EDR = \frac{D^{test}}{D^{tgt}}$$

Tuning Mass Conf.	Flapwise force (N)	Edgewise force (N)	Time (days)
1	6020	0	10.21
2	0	700	4.69

Simulated optimized test

- Total test time: **7.83 days** (half of the standard test)
- Points where target is reached: **All**
- Tuning mass configurations: 6





$$EDR = \frac{D^{test}}{D^{tgt}}$$

Tuning Mass Conf.	Flapwise force (N)	Edgewise force (N)	Time (days)
1	0	490	0.22
2	0	490	0.24
3	7000	490	3.79
4	7000	385	2.32
5	7000	385	0.15
6	7000	385	0.45

Experimental demonstration

- Two blades were tested at the DTU LSF, one based on the standard test and the other based on the simulated optimization results.
- Total experimental test time (standard): 15.8 days;
- An update of the optimized test campaign was performed during the test to decrease deviations.
- Total experimental test time (BLATIGUE): **8.0 days;**



Castro et al., Compos. Struct., under revision

Successful final demonstration in BLATIGUE





Fatigue test of wind turbine blade to trigger damage growth.

ReliaBlade – Improving Blade Reliability through Application of Digital Twins over Entire Life Cycle

- Digital twins make it possible to improve the design, optimizing manufacturing and move the operation from fixed scheduled intervals with reactive maintenance to predictive maintenance.

Danish part:

- Budget of 88 mio. DKK, with 44 mio. DKK funding by EUDP at Danish Energy Agency

German part:

- Budget of 9.3 mio. EURO (69 mio. DKK)

Supported by:

Federal Ministry for Economic Affairs and Energy

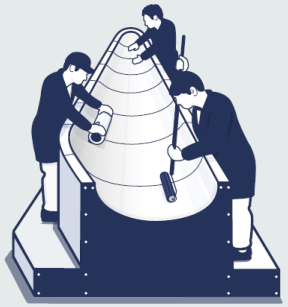
Total budget: 21.1 mio. EUR

ReliaBlade project vision

ENTIRE LIFE CYCLE



Design



Manufacturing



Operation

PHYSICAL

DIGITAL

1 Design and model

2 As-built blade

3 Imperfection characterization

4 Sensor deployment

5 Damage identification

6 Physical implementation of proposed repairs

Communication and Interaction

Numerical model

0101101

Imperfection modeling

Numerical implementation of physical damages

Virtual testing (the current performance)

0101101

Virtual testing (the performance with repairs)

ReliaBlade

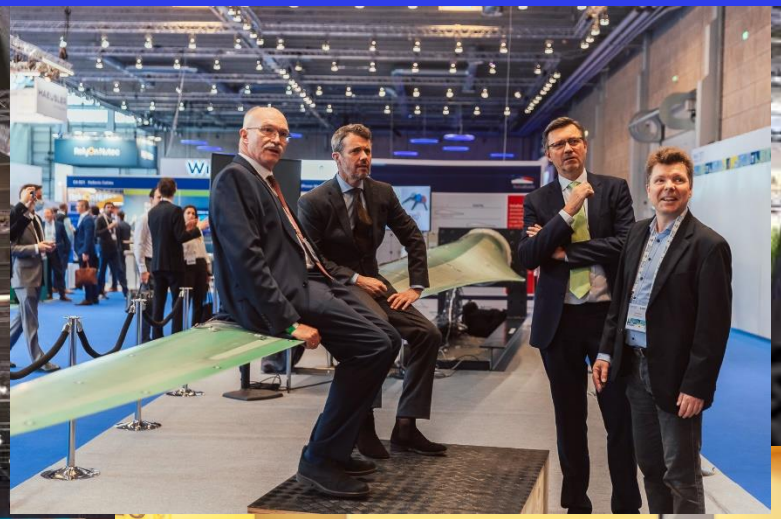


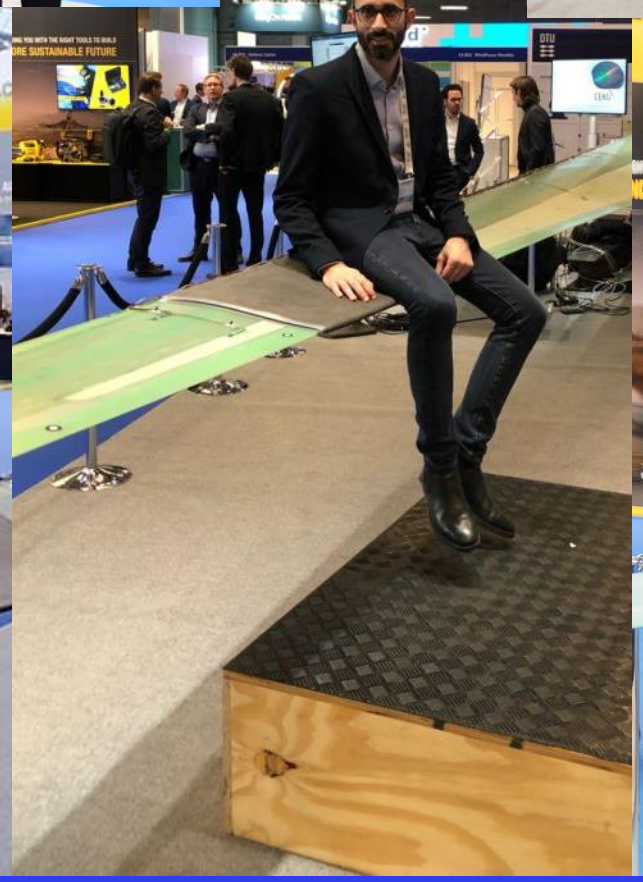
Executable digital twin of wind turbine blade

- Presented at WindEurope Electric City last week
- The physical twin is a DTU designed and manufactured 12.6m blade
- The digital twin is developed by Siemens Digital Industries Software based on a structural model developed by DTU
- Augmented reality visualization is developed by Siemens Digital Industries Software and InPro








Winner of JEC Composites Innovation Award 2024

- Category Digital, AI & Data





The awards ceremony was live transmitted online from Paris on February 8th, 2024

Takeaways and discussion points

- The wind energy industry currently have big challenges with upscaling and quality.
- Our research gives independent knowledge and arguments for development of standards towards new technology and improved methods.
- More public funds could accelerate this further.
- My experience is that standards tends to be behind the technology development and seldom accelerate the technology development.
- Should standard push more for quality, monitoring and digitalization?
- The wind industry is missing a structured way of learning from failures and mistakes like in aerospace.



Questions?