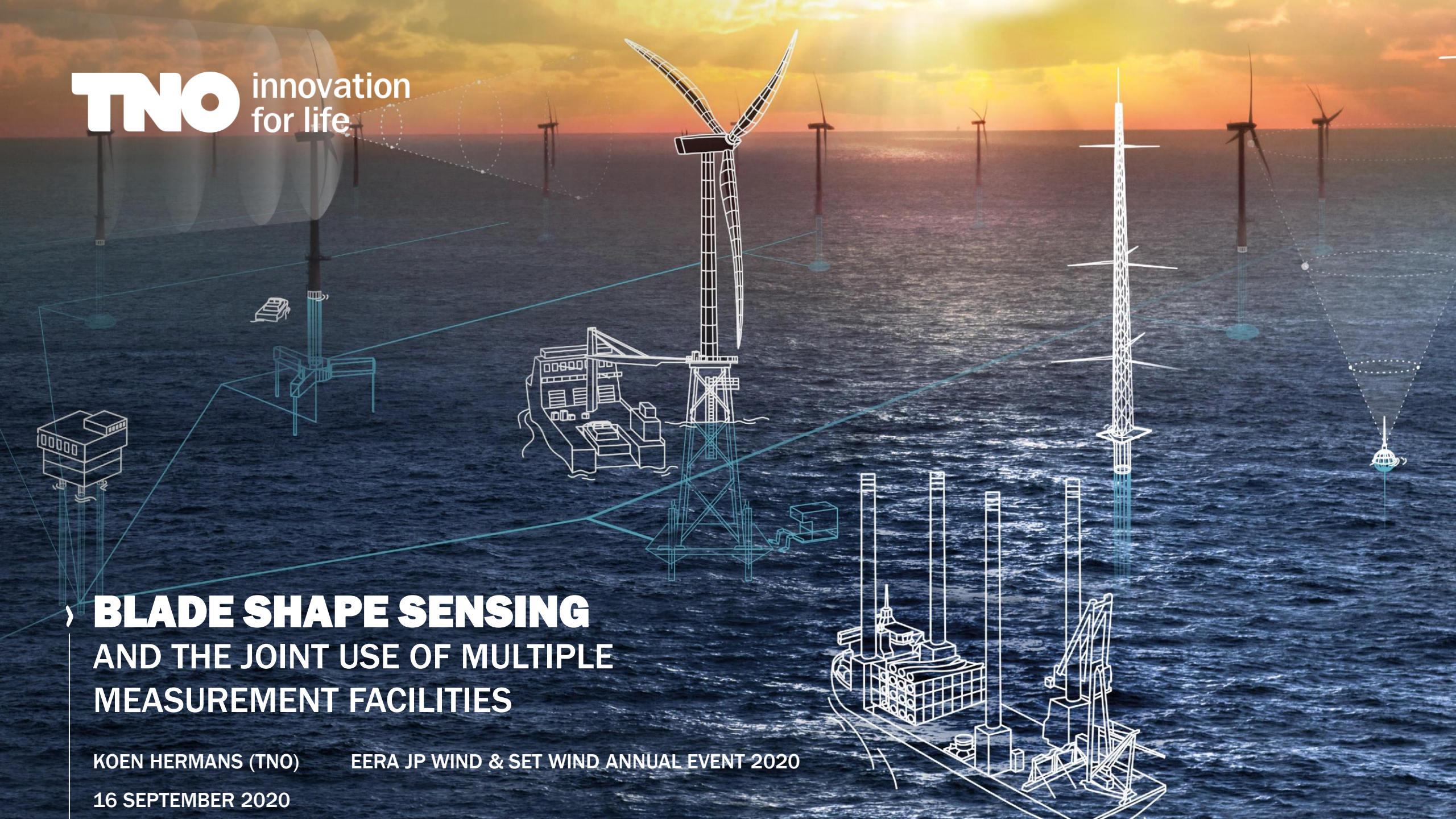


TNO innovation for life

BLADE SHAPE SENSING
AND THE JOINT USE OF MULTIPLE MEASUREMENT FACILITIES

KOEN HERMANS (TNO)

EERA JP WIND & SET WIND ANNUAL EVENT 2020

16 SEPTEMBER 2020

MOTIVATION

- For the design of large flexible blades, current structural models have insufficient accuracy. Investigations in an EU project showed large variations up to 17% in calculated torsional stiffness by using state-of-the-art tools.

- Power production, loads and aeroelastic stability (e.g. flutter margin) are heavily influenced by torsional behavior!

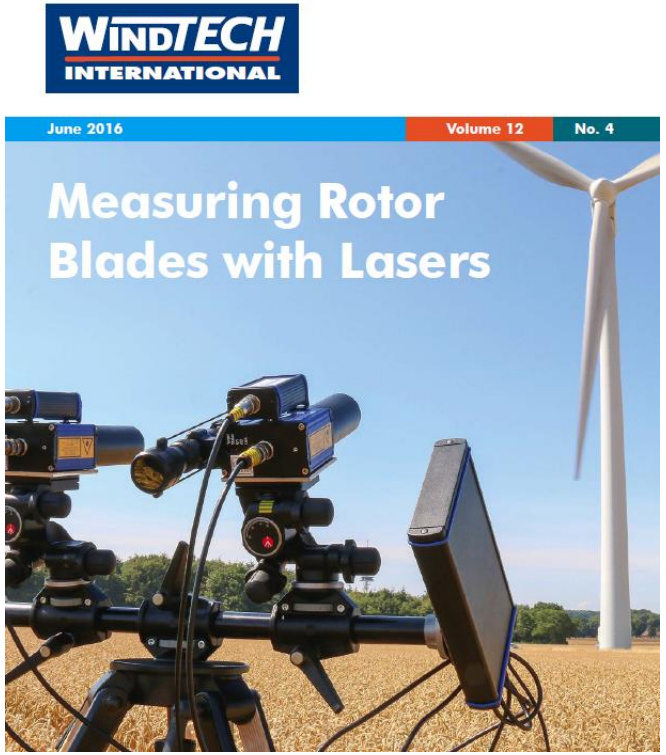
- Improvement of models and thus design is greatly hampered by lack of deflection measurements in the field

HOW TO MEASURE BLADE DEFLECTION IN THE FIELD

Goal: measure in-field torsional deflection with 0.1° accuracy

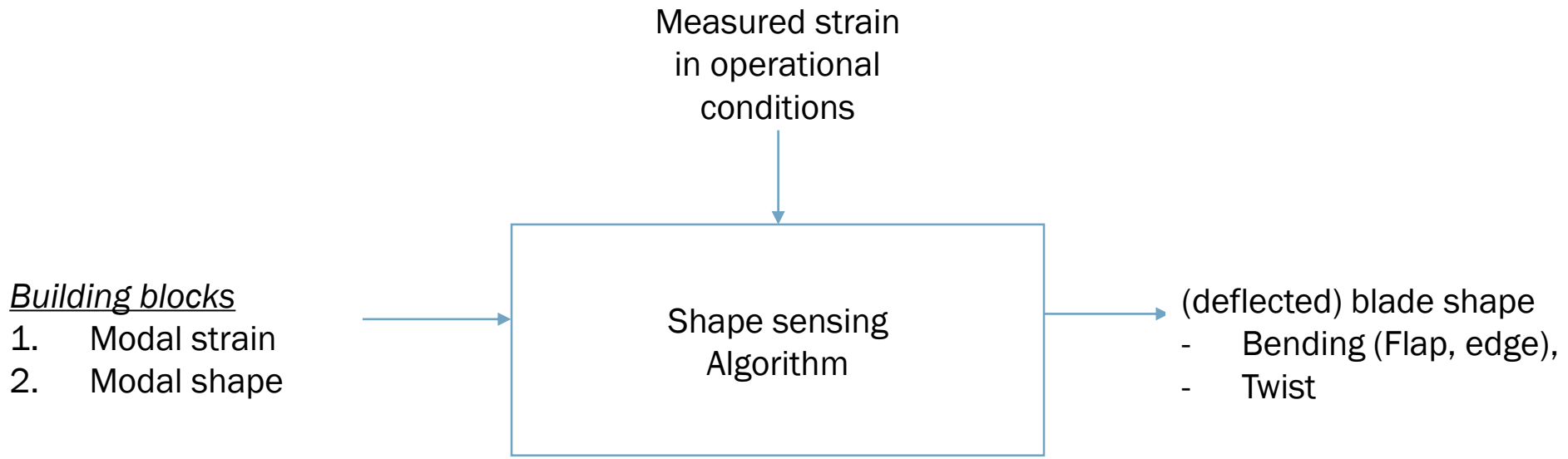
- Direct ‘optical’ methods (i.e. camera or laser systems)
  + Direct measurement
  + Industrial experience

  - Large data stream
  - Hard to process, (correction of bending, obstructed line-of-sight)
  - Accuracy of twist not fully there
  - Possible impact on aerodynamics (root mounted, volumetric markers)
  - Robustness for longer campaigns



SHAPE SENSING

- Use strain as an indirect measure of blade deflection



OVERVIEW OF BLADE TESTS

VaStBlades	Haliade-X
EWT 29 • Static torsion test (2017) LM WMC Technology Center	LM107 • Modal test (2019) • Static bending test (2020) • Fatigue test (2020) • Static torsion test (2020) OREC Blyth Wind Turbine Test Facility
LM 56.9P • Modal test (2019) • Static torsion test (2019) LM WMC Technology Center	
LM63.7 • Field test (2020-2021) EWEF Wieringermeer Tiade 3.8MW R&D Turbine	LM107 • Field test (2020 – current) Port of Rotterdam – 2e Maasvlakte GE Haliade-X 12MW prototype turbine

Source: LM

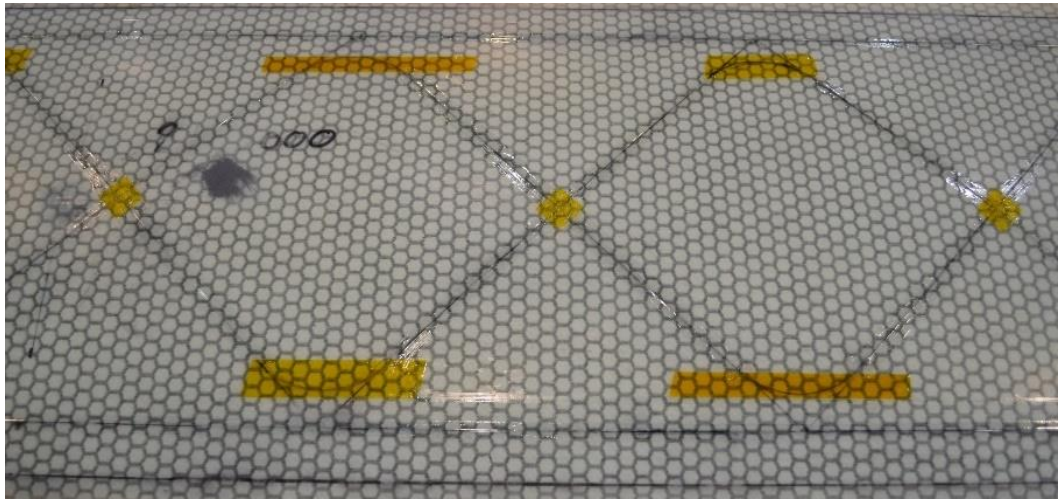

Source: LM

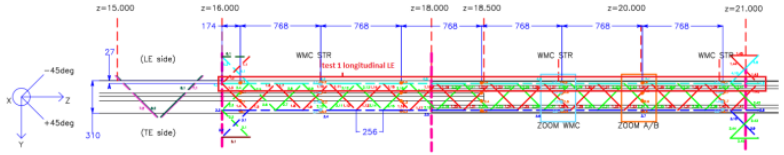

Source: GE

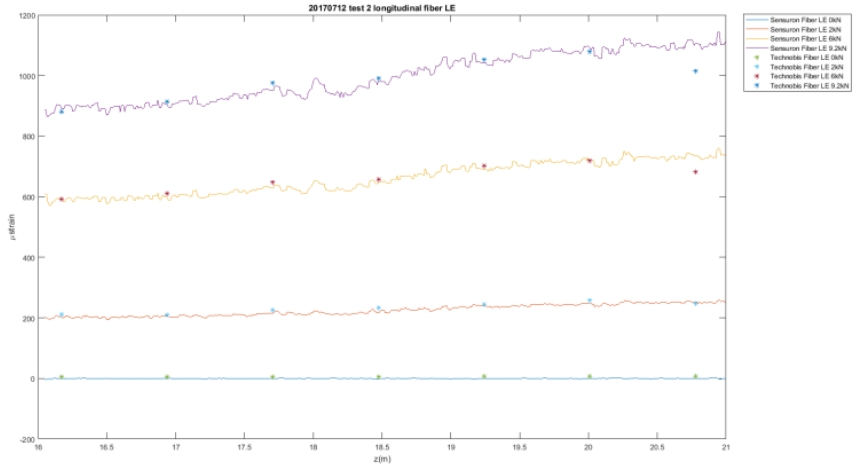
ECN Wind Energy Facilities B.V.

EWT29 TEST

- Blade designed by We4Ce-TRES4, tested at WMC Technology Center
- Goal: assess performance of optical strain gauges and fibre routing for torsion measurement
- Comparing discrete number of FBG positions (Technobis) versus distributed OFDR technology (Sensuron)

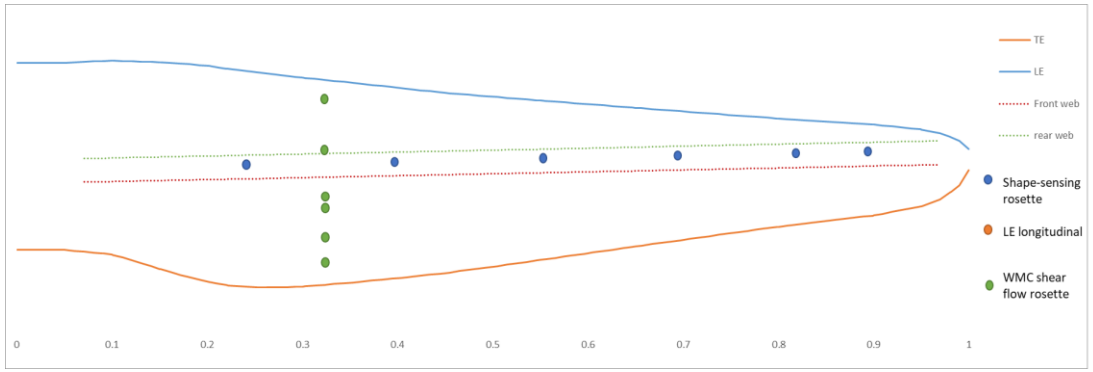


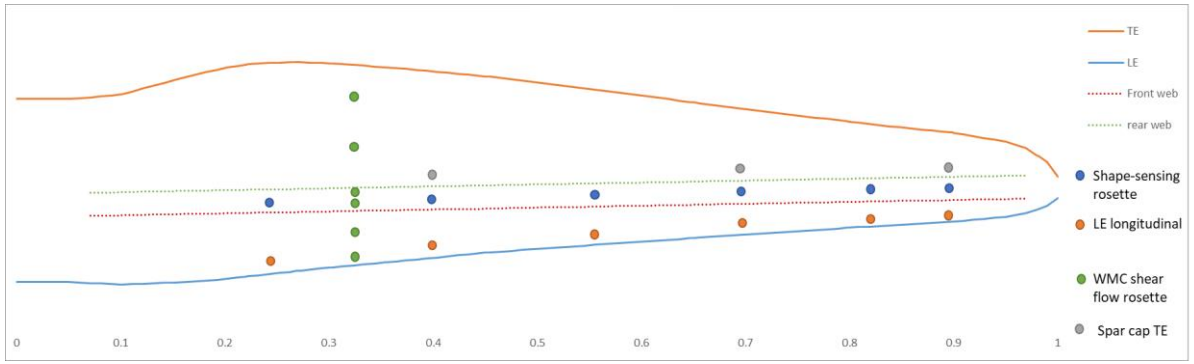




MODAL TEST – LM 56.9P

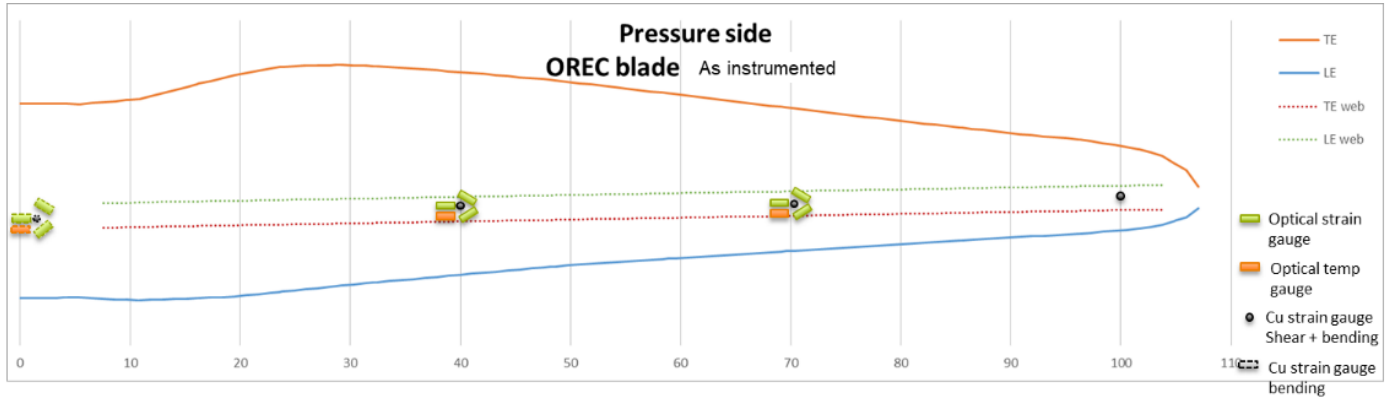
- Modal test performed by Hottinger Bruël & Kjaer at LM WMC
- Electrodynamic shakers to provide forced vibration at eigenfrequencies
- Strain gauge rosettes at 6 radial positions
- Accelerometers at LE and TE to capture mode shape

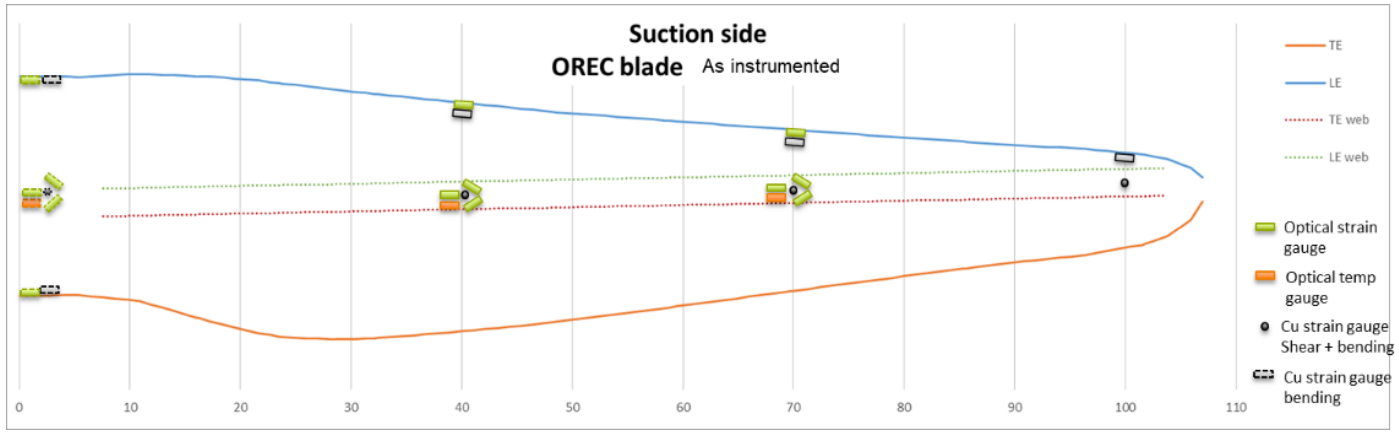




OREC BLADE TESTS LM107

- Modal test with impact hammer and by manual excitation
- Signal quality insufficient to derive modal strain
- Currently processing modal information from structural blade model

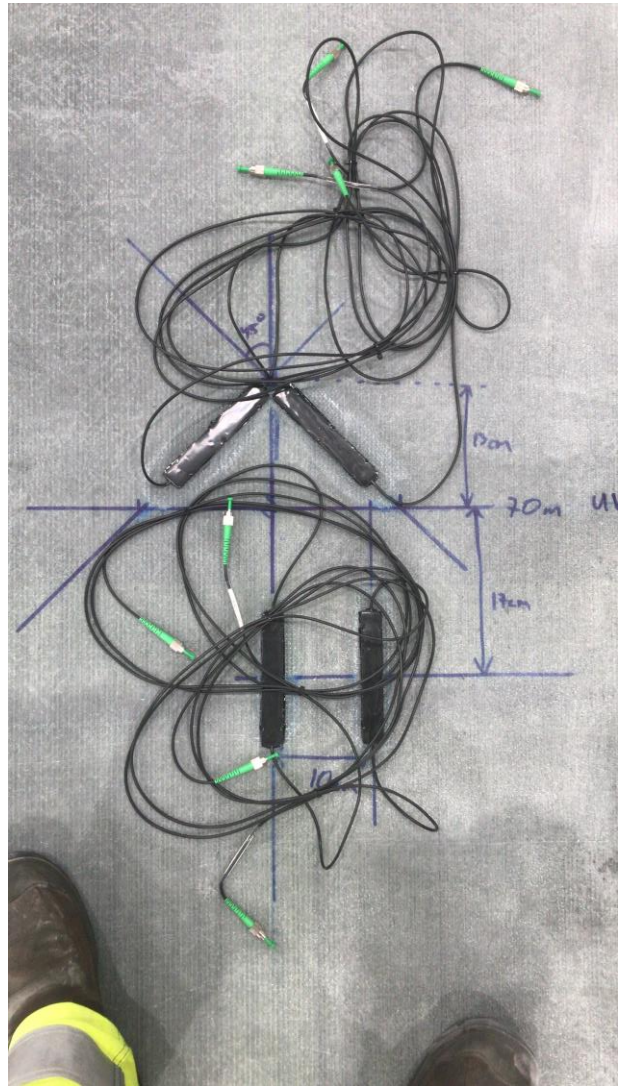




FIELD TESTING - OPERATIONAL DATA

- Blades at Haliade-X prototype Rotterdam are equipped with strain transducers similar to OREC blade

- VaStBlades field test on LM63.7
  - Tiade 3.8MW research turbine at EWEF Wieringermeer
  - Four radial positions up to 27m
  - Operating from end Q4 2020



CONCLUSION

- There are limited means to monitor the exact blade deflection in operational conditions
- Strain response could act as an indicator to estimate blade deflection when applying shape sensing techniques
  - A higher information density could be achieved when integrating fibres equipped with FBG strain into the laminate
- The blade tests at LM WMC, OREC Blyth blade testing centre, and the prototype turbine tests at EWEF Wieringermeer and Port of Rotterdam provide valuable input of realistic strain response using current measurement techniques
  - TNO to progress on this topic in the near future together with industrial partners

THANK YOU FOR YOUR TIME

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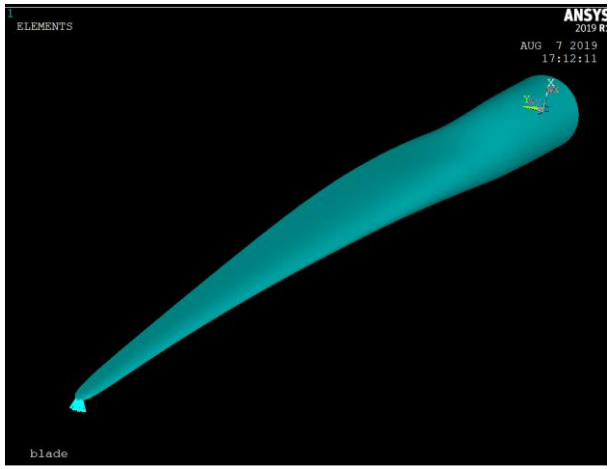
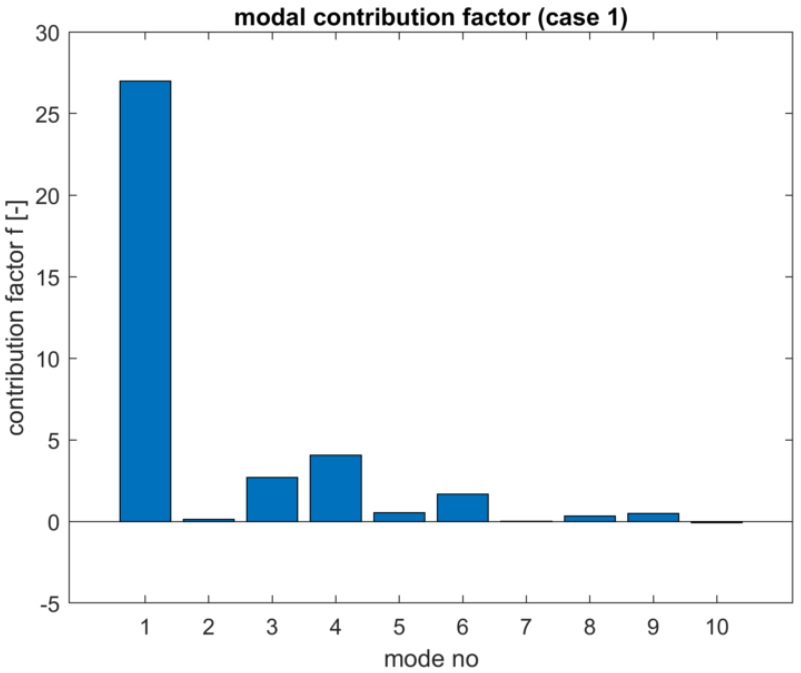
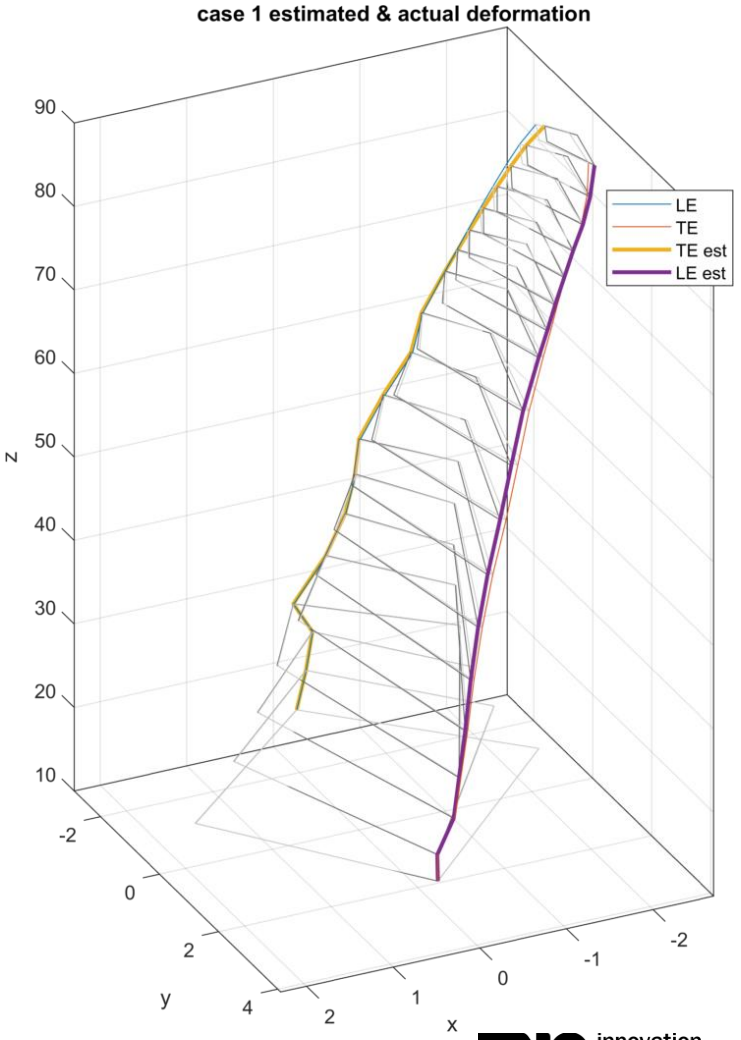
VERIFICATION USING FINITE ELEMENT MODELING
INNWIND 10MW BLADE MODEL

- Testing shape sensing algorithm







FLUTTER

- Flutter example

- Flutter speed (rpm) versus blade length