BOHEM – Blade Optical Health Monitoring

18/01/2018 | Paul McKeever

CATAPULT Offshore Renewable Energy

Agenda

- Project partners
- Project objectives
- How BOHEM works
- BOHEM initial results
- Latest BOHEM results
- Summary

About the BOHEM Partners

WideBlue Ltd is multi-disciplinary product design and product development consultancy based in Glasgow. WideBlue's team of product, mechanical, electronic and software engineers, physicists and optical designers have years of experience of taking products from design through to successful manufacture and commercialisation.

The Offshore Renewable Energy Catapult is the UK's flagship technology innovation and research centre for advancing wind, wave and tidal energy. ORE Catapult participates in large-scale collaborative R&D and innovative commercial and public funded projects, amassing vast technical knowledge and know-how.

ORE Catapult

Our Vision:

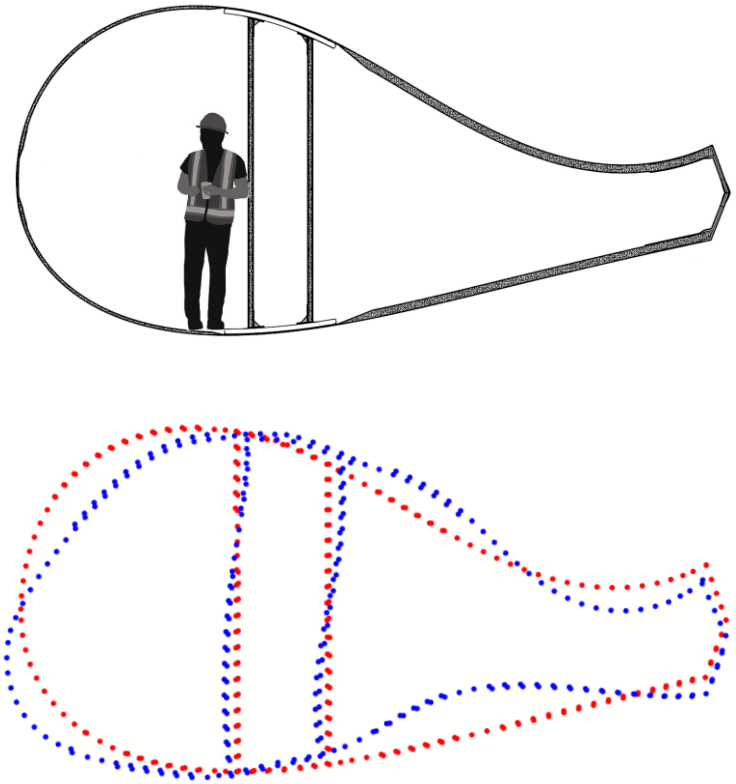
Abundant, affordable energy from offshore wind, wave and tide

- Reduce the cost of offshore renewable energy
- Deliver UK economic benefit
- Engineering and research experts with deep sector knowledge
- Independent and trusted partner
- Work with industry and academia to commercialise new technologies

80+ technical experts

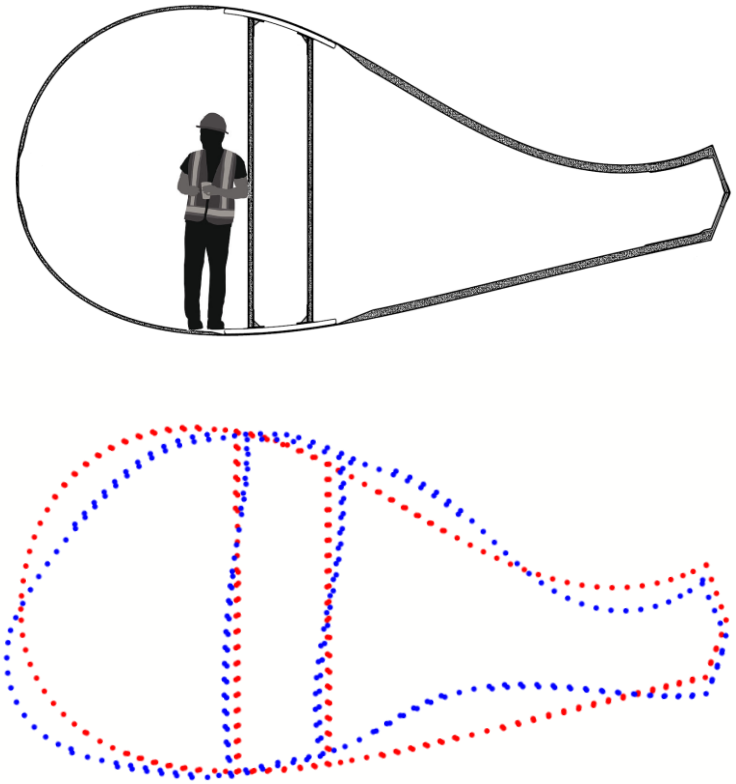
Blade Cross-Sectional Deformation

- The current generation of large wind turbines have blades in excess of 80m long, with a typical chord length of 6m
- This means that there are extremely large unsupported panels around the max chord region of the blade which can deform out of plane when the blade bends
- These deformations stress the panels in the transverse direction (potentially causing delamination and create peeling stresses at the trailing edge bond line)

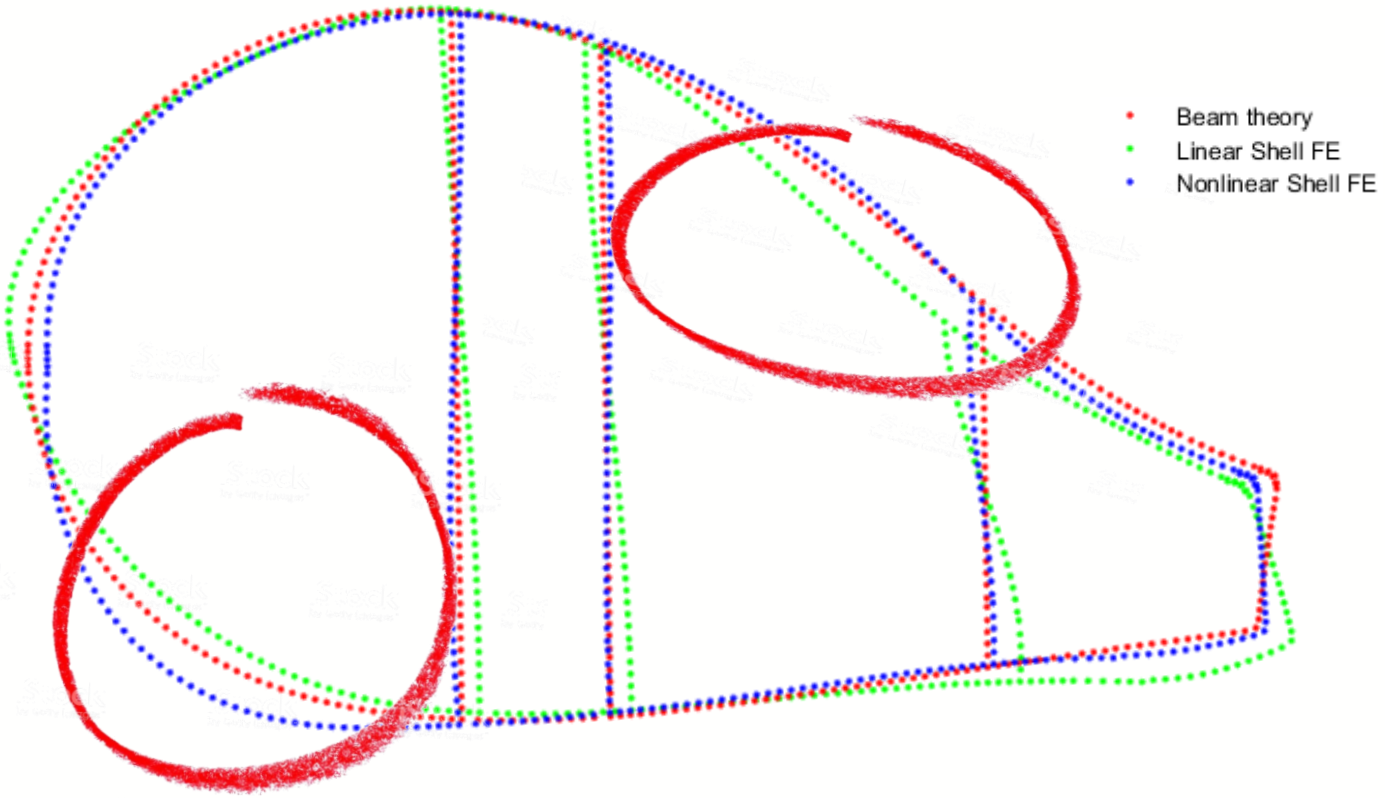


Blade Cross-Sectional Deformation

- In addition to this phenomenon of panel deformation, the whole blade cross-section can shear as a result of combined torsional and shear loading, which generates stresses at the bond between the shear webs and the spar cap or the blade shell, depending on blade architecture.
- The use of large flatback aerofoils further compounds this issue.

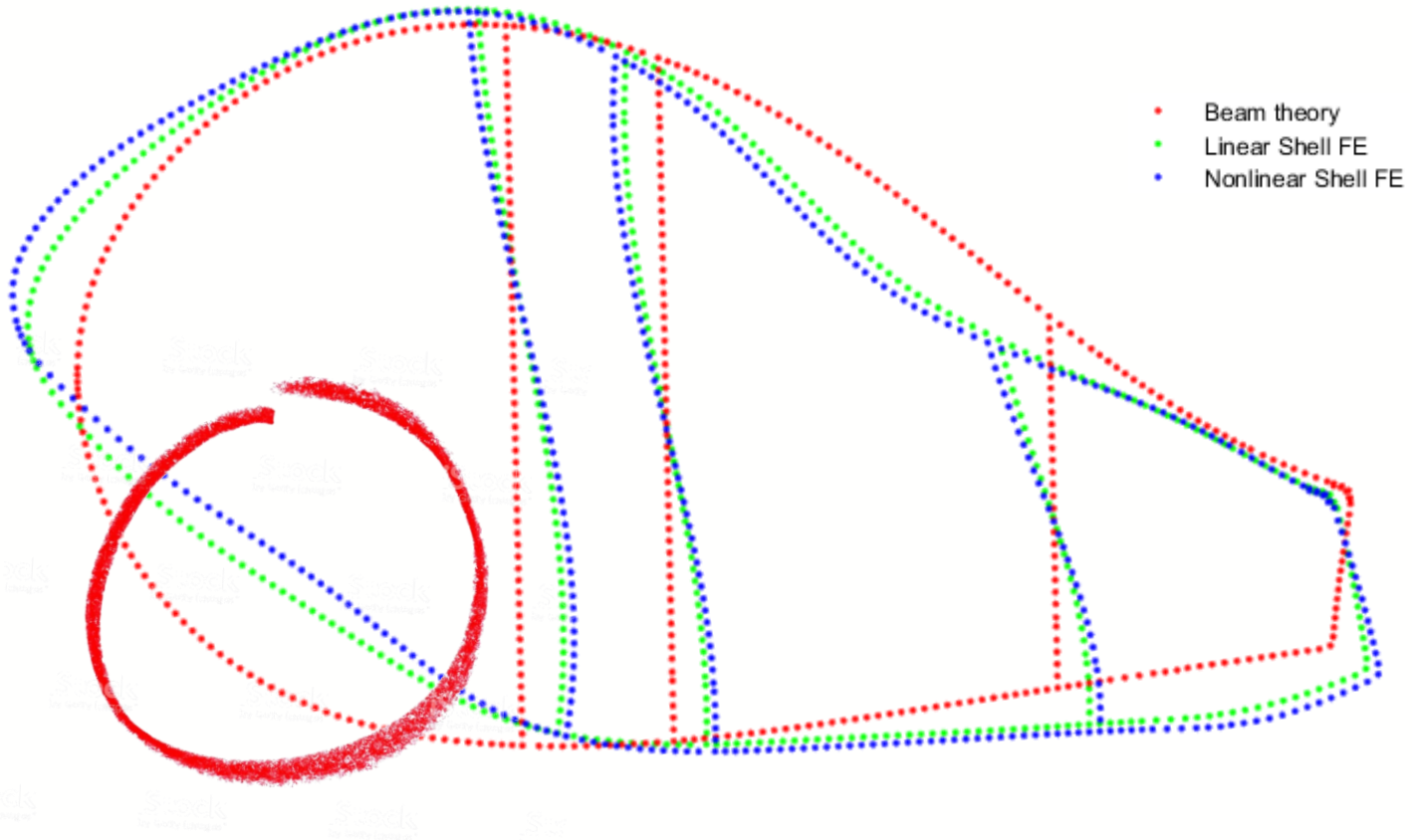


Blade Cross-Sectional Deformation (Flap Max)



Nonlinear and linear deflections are in opposite directions!

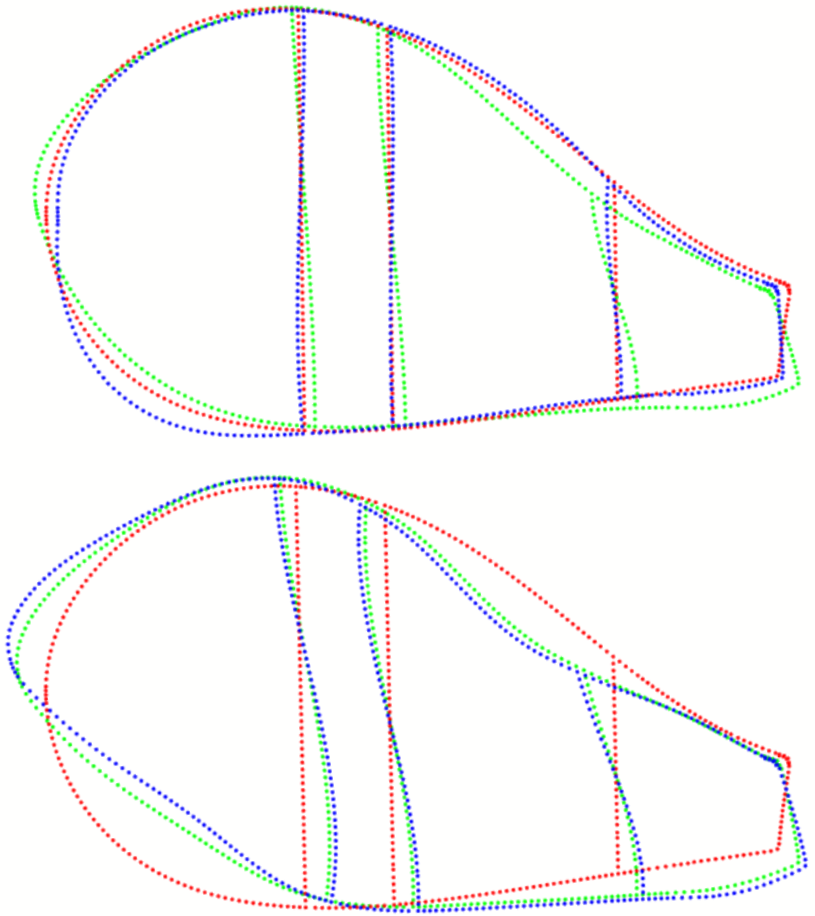
Blade Cross-Sectional Deformation (Edge Min)



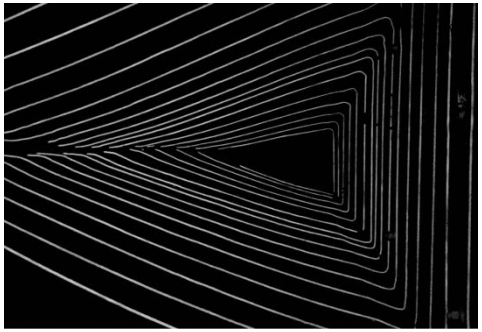
Nonlinear deflections are much larger than linear

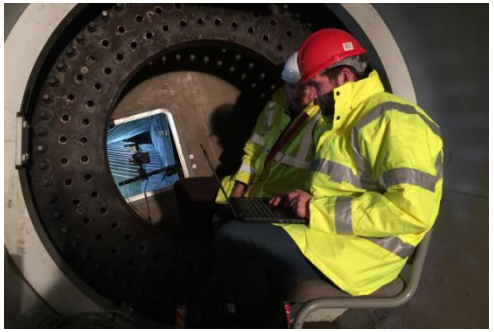
Blade Cross-Sectional Deformation

- It is clear that, whilst blades are beam like structures, their hollow structure means that the cross section can deform and the assumption of 'plane sections remaining plane' cannot be used. The structural designer must use nonlinear shell or brick based 3D FE (finite element) models to characterize how panels deform, and these models must be validated.
- ORE Catapult and Wideblue Ltd have developed the BOHEM system to monitor blade cross-sectional deformation

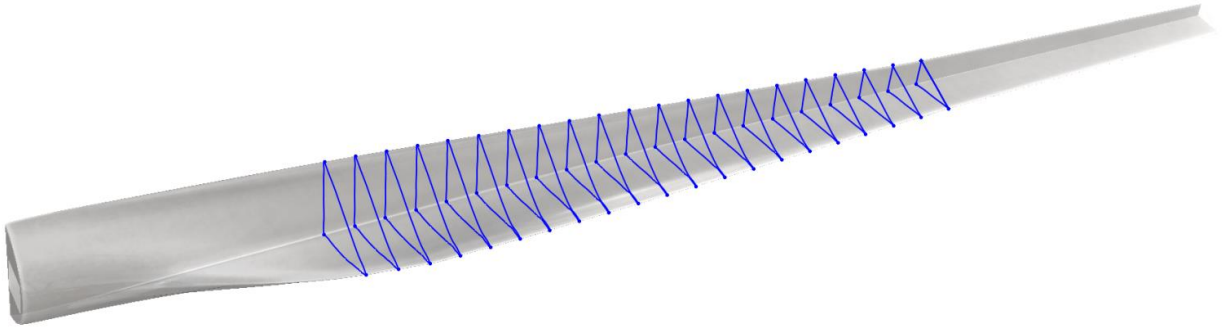


BOHEM Concept



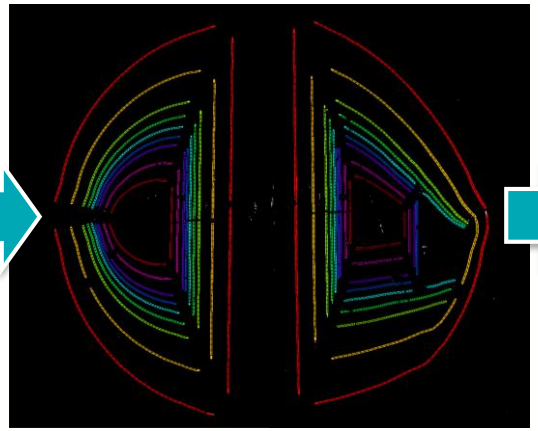


BOHEM's robust root mounted vision system tracks the displacement of a series of reflective markers installed in the blade's most critical areas. The reflective markers are passive, low cost, easy to install and can be removed without damage to the blade.



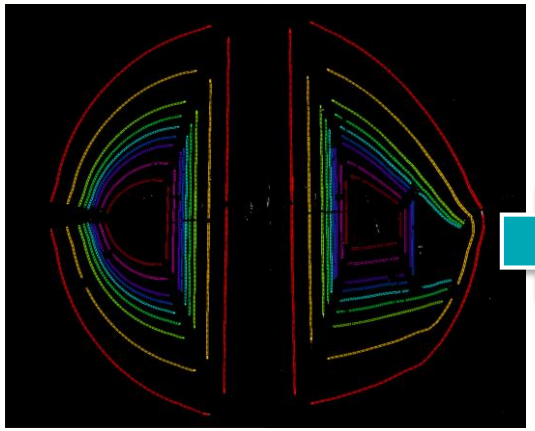
BOHEM Process

Illuminate markers and acquire image in reference state

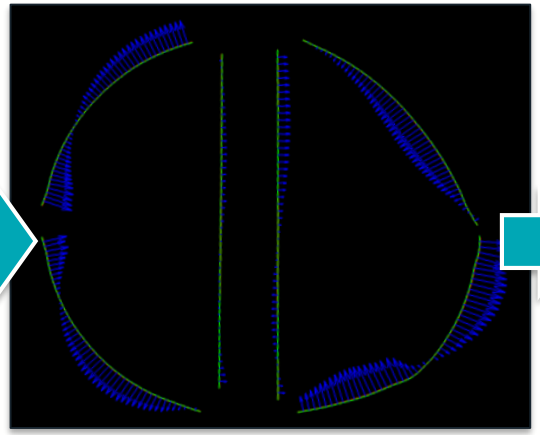


Isolate markers in reference image

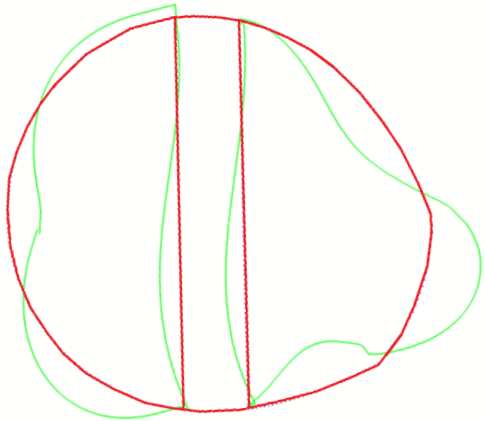
Illuminate markers and acquire footage as blade deforms



Isolate markers in each frame

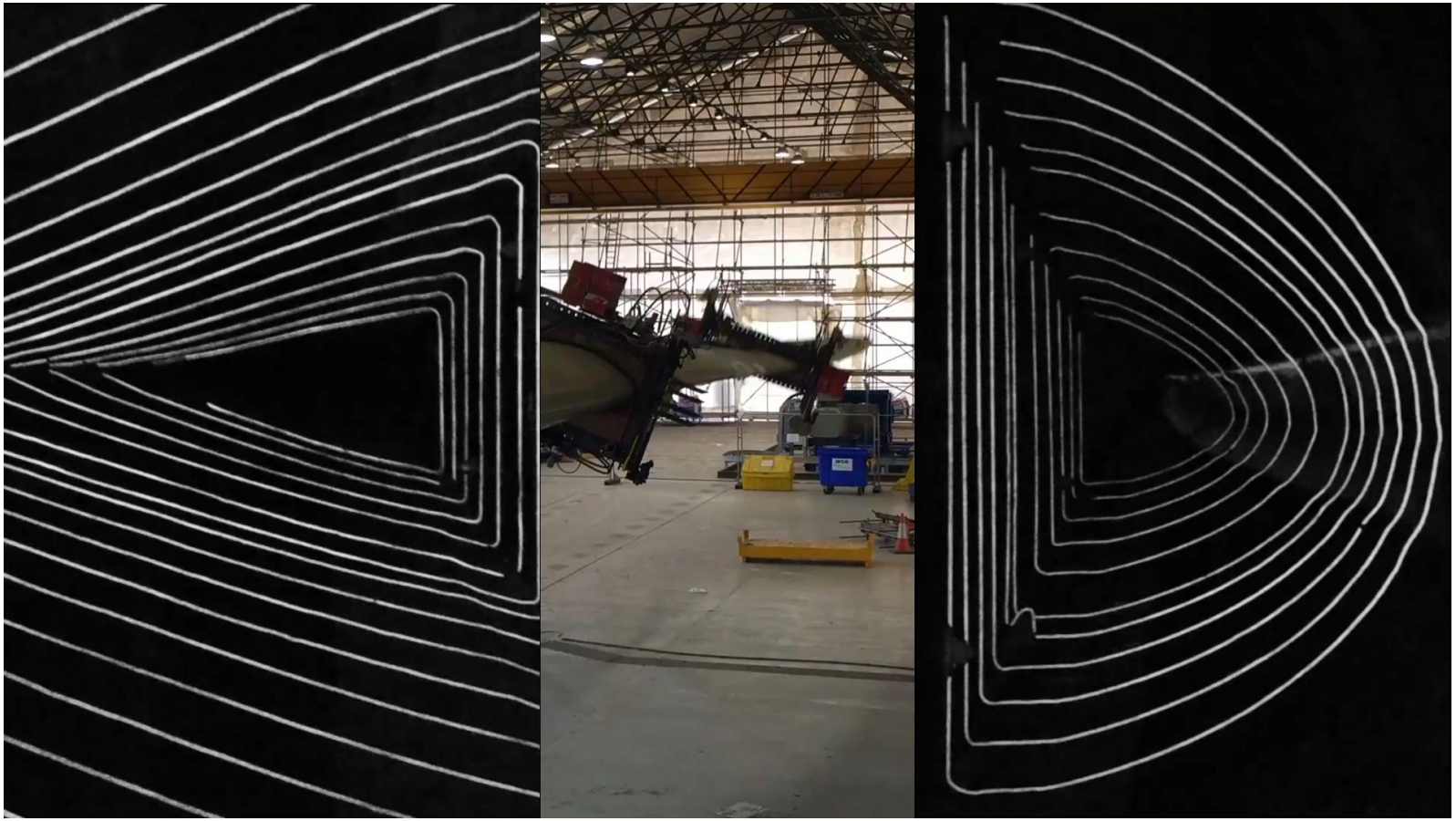


Remove global translation and rotation to map each section to reference state for each frame, then display scaled deformation

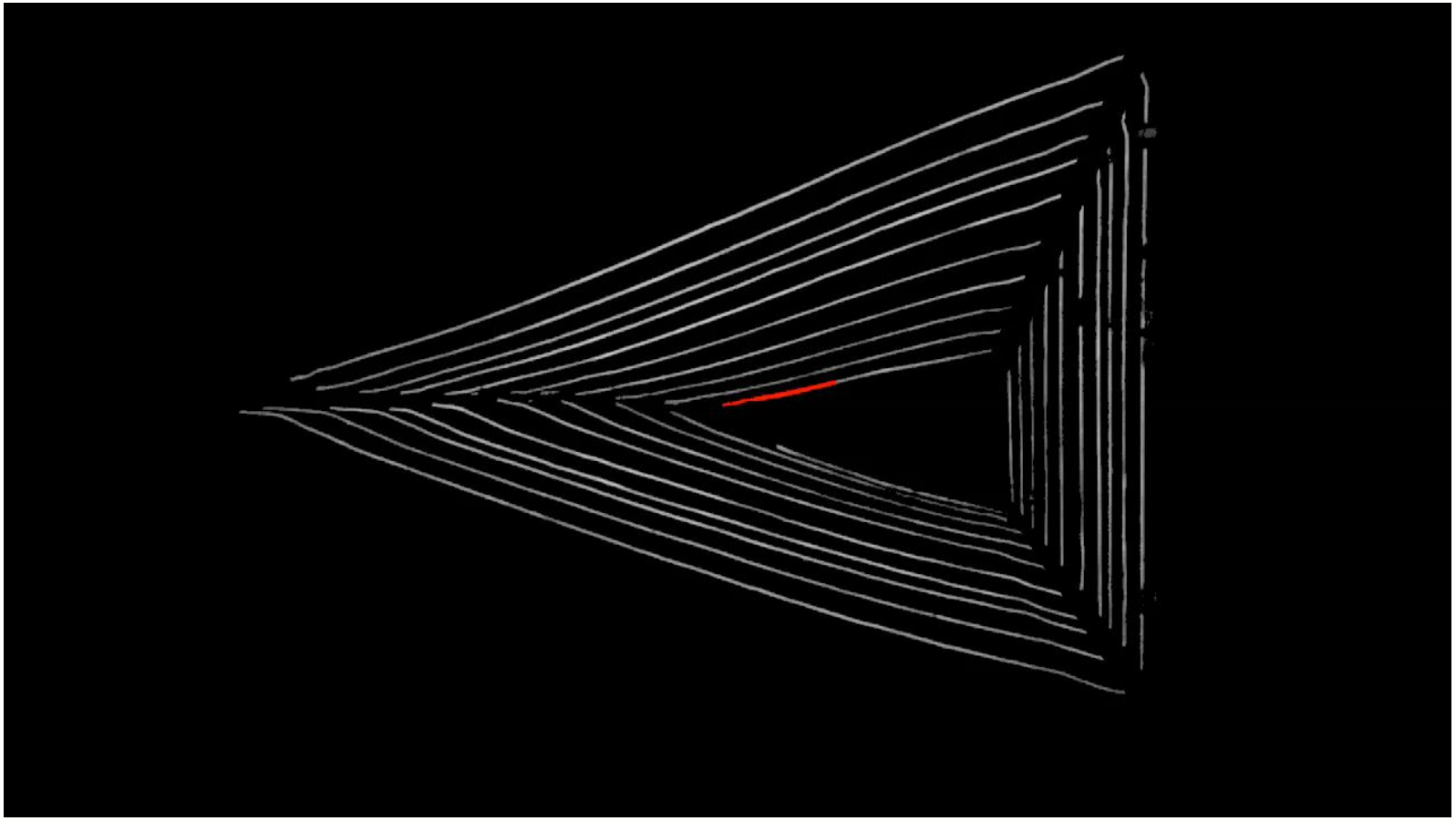


Compare to finite element model

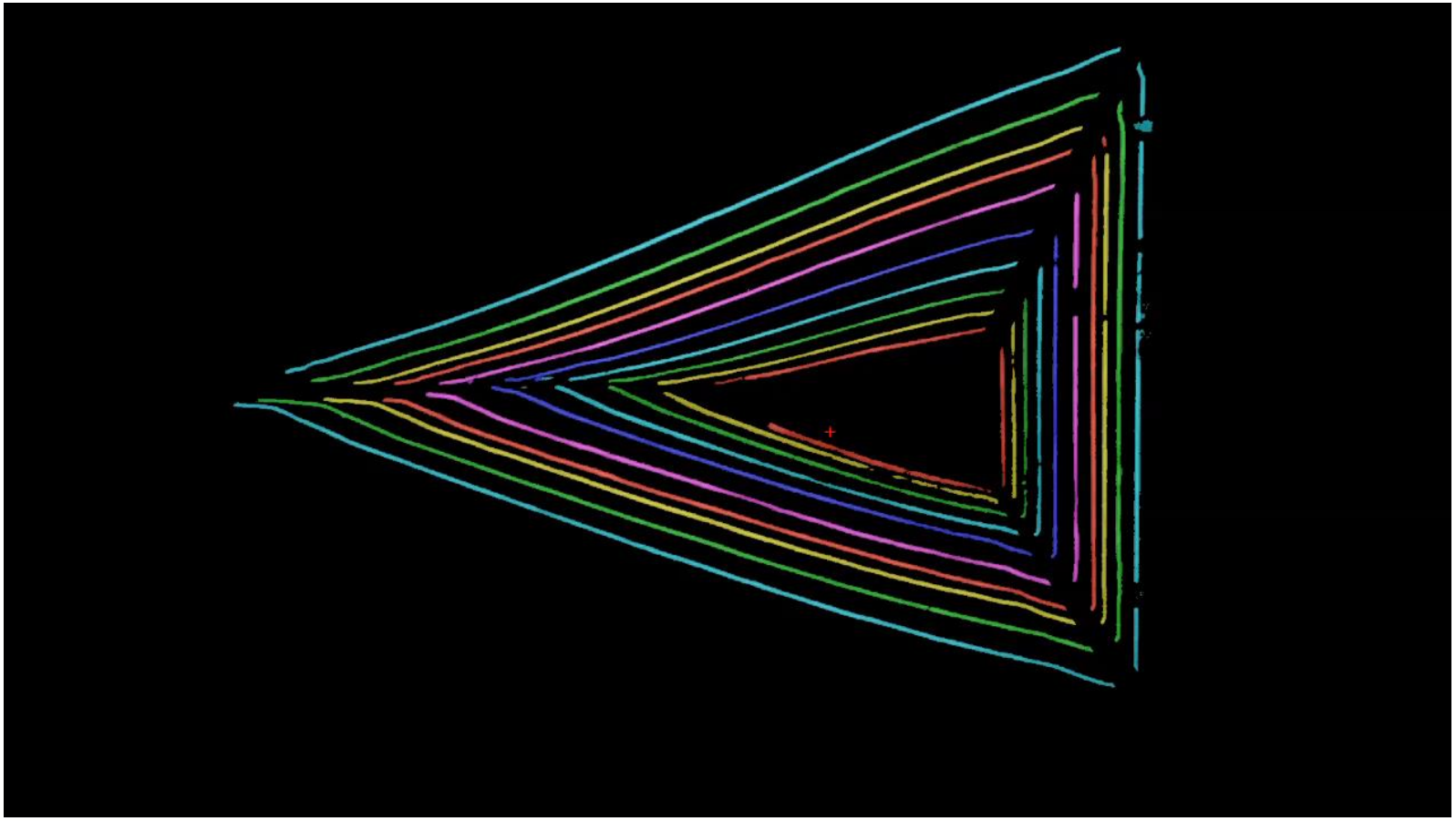
Raw Footage
Reflectors 5m - 20m in a 40m Blade



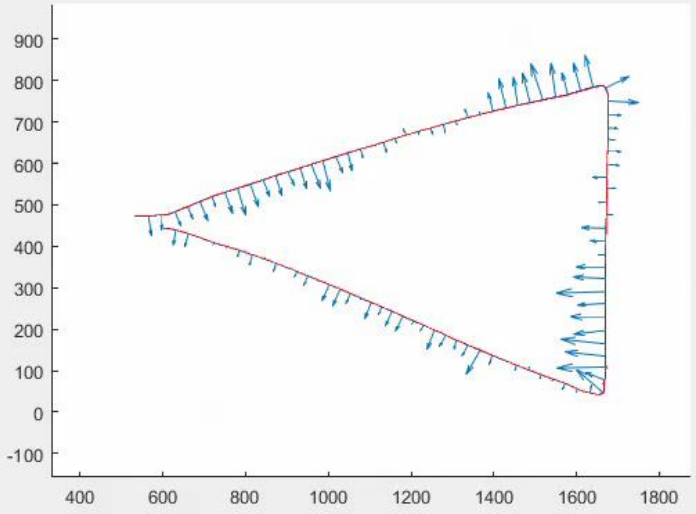
Footage Processing

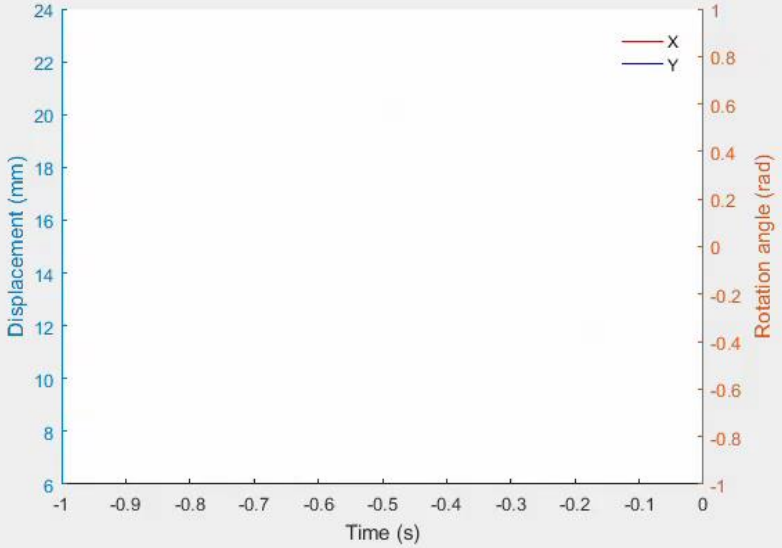


Footage Processing



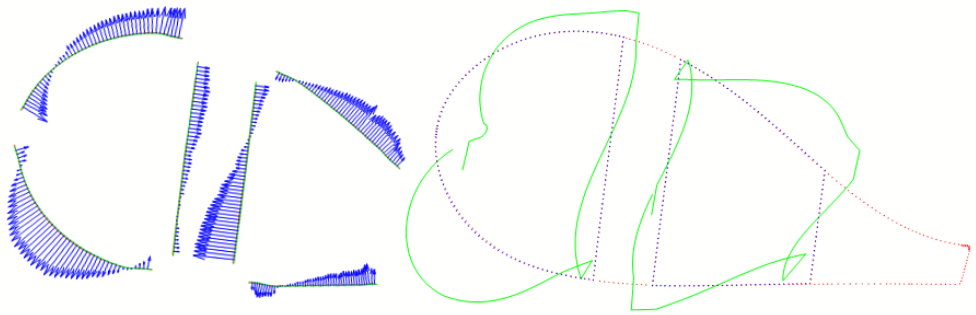
Post Processing





BOHEM Validation

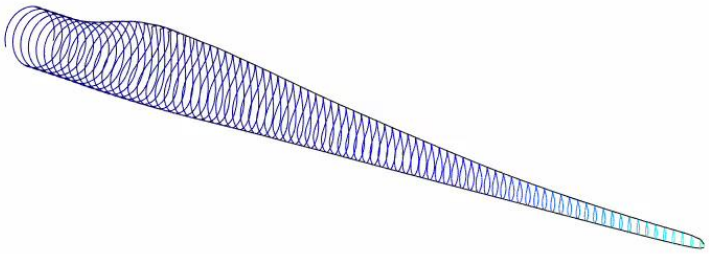
- BOHEM can be used as a 'virtual stringpot' to measure the displacement between two points
- It has been validated against stringpot measurements during static blade testing
- Unfortunately, the stringpot measurements were not reliable so in the final test laser measurement mounted on telescopic poles was used
- Overall, good agreement was achieved but it is hard to say whether measurement inaccuracy is responsible for discrepancies…
- A lot of lessons have been learnt for next time!

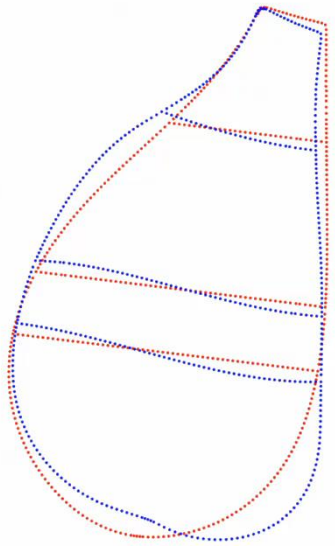


	Measurement Location	BOHEM Prediction (mm)	FE Prediction (mm)	Test value Stringpot (mm)	Test Value Laser (mm)
Test 1	Leading edge 11m	100%	108%	81%	
	Trailing edge 8m	100%	114%	91%	
Test 2	Leading edge 11m	100%	186%	-17%	
	Trailing edge 8m	100%	186%	110%	
Test 3	Leading edge 11m	100%	87%	71%	103%
	Trailing edge 8m	100%	254%	181%	181%

Summary and Further Work

- BOHEM is a novel method of monitoring cross-sectional deformation based on acquiring images of reflective markers
- It has been proven to give useful results during full scale blade tests
- The long term goal of the BOHEM project is to develop a low cost health monitoring mechanism for blades in service
- By tracking the deflection envelope and how it changes over time for a given wind speed (known from SCADA data) BOHEM could act as an early warning system for panel delamination or trailing edge debonding





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