

Supergen ORE Hub - Annual Assembly, Tackling the research challenges:

Resource and environment characterisation & Survivability, reliability and design

LOADTIDE

FULL SCALE FATIGUE TESTING FOR
IMPROVED COMPOSITE DESIGN





LoadTide Project Partners



THE UNIVERSITY
of EDINBURGH

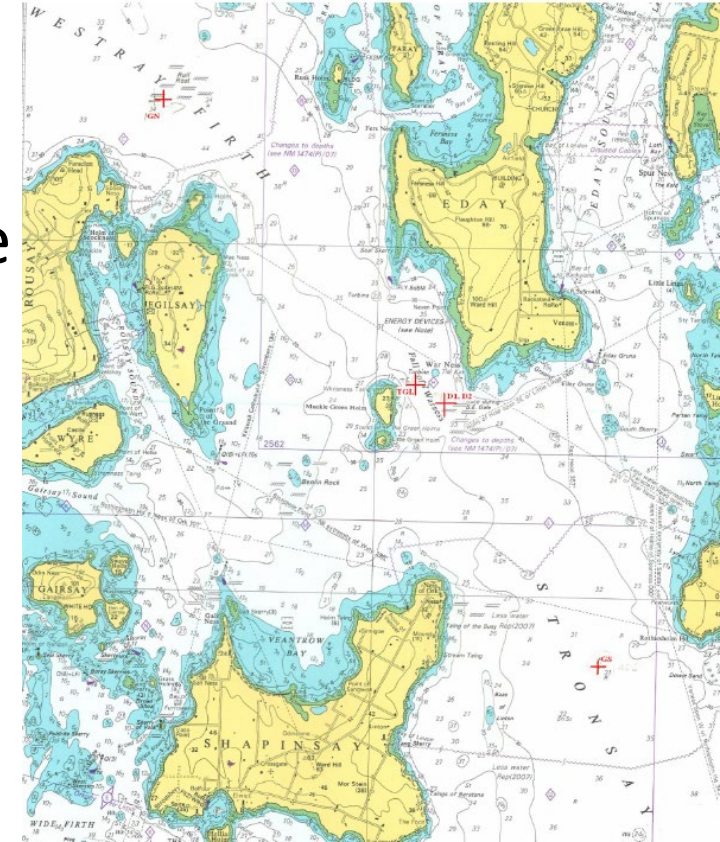
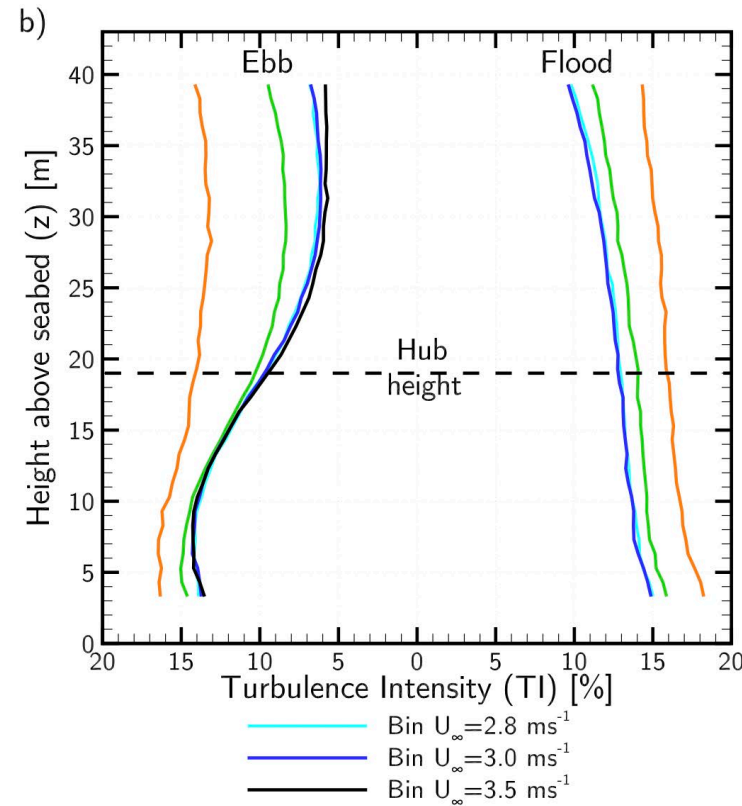
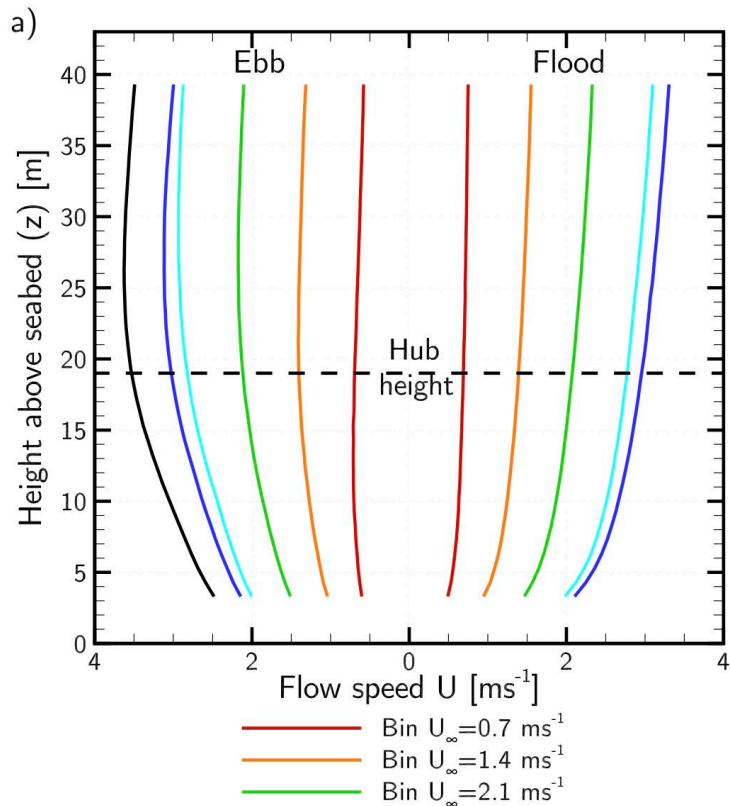


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OXFORD



Environmental Conditions

- Data sourced from the ReDAPT project for Falls of Warness
- 1/6th power law flood tide, 1/5th power law ebb tide

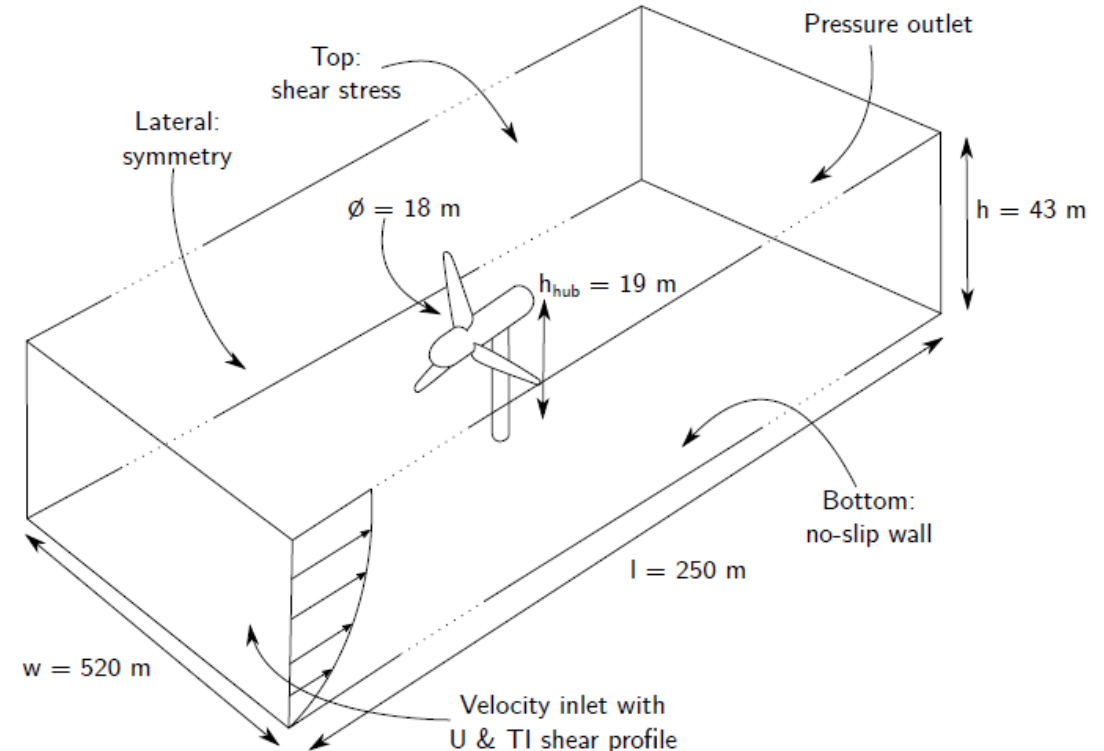


Computational model

- URANS simulations performed in OpenFoam with k- ω SST turbulence closure
- Turbine represented with an actuator line model with Shen et al. tip losses
- Lift and drag coefficients from Qblade

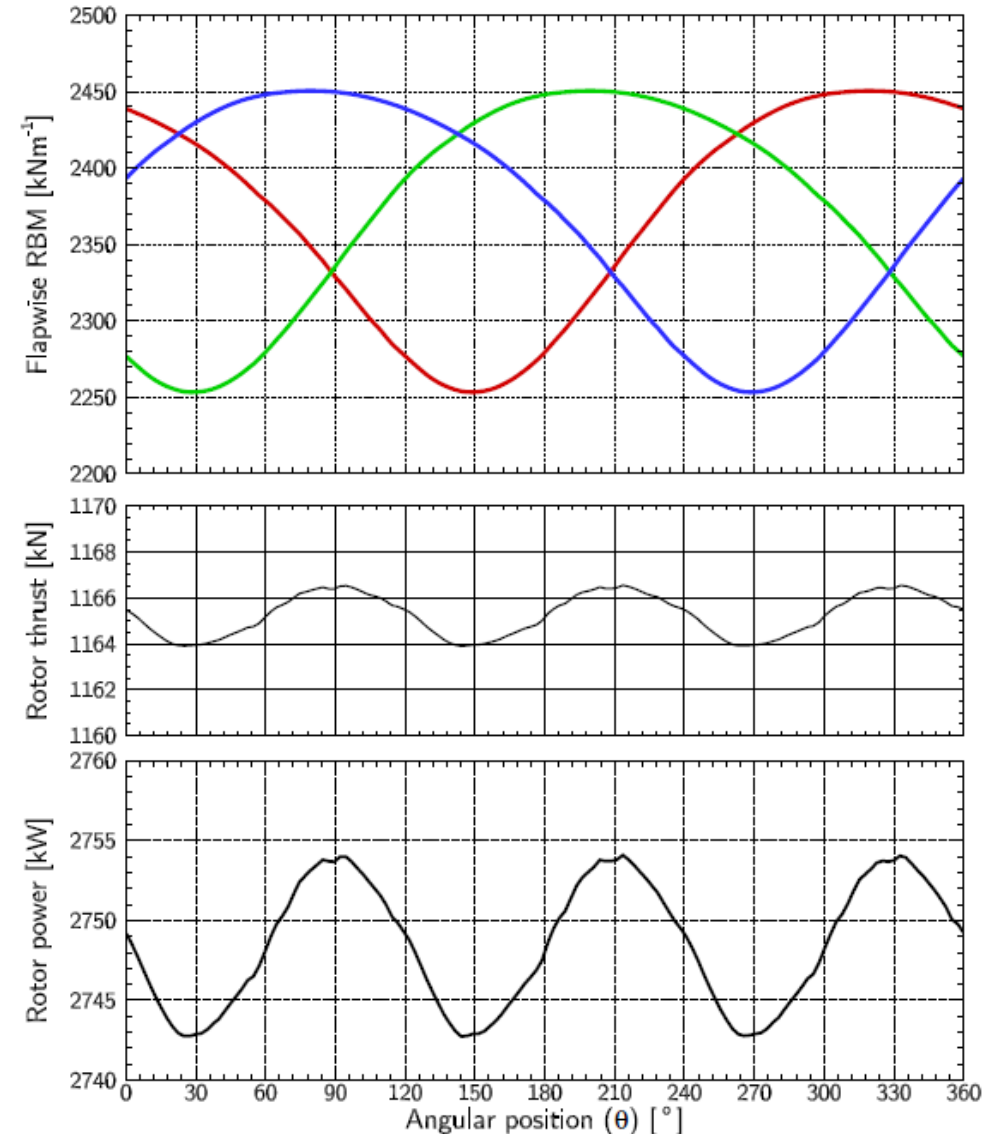
Mesh

- Octree mesh with extra resolution at top and bottom to capture variation in flow profile, approx. 2.8×10^6 elements
- Blockage ratio: 1.14%
- Time step $dt < 2.5^\circ/\text{step}$

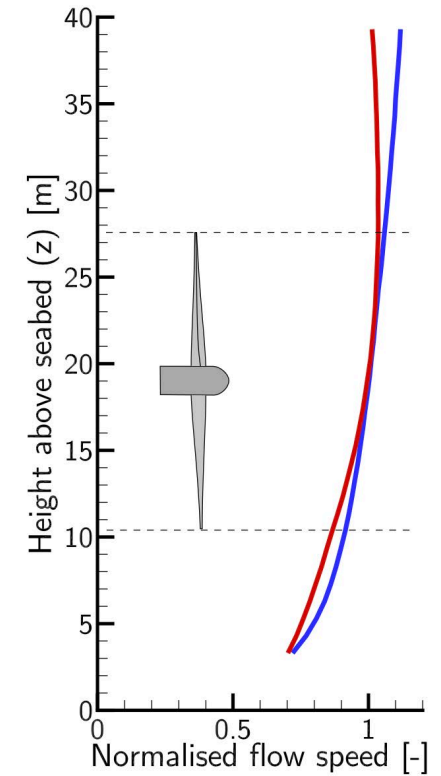
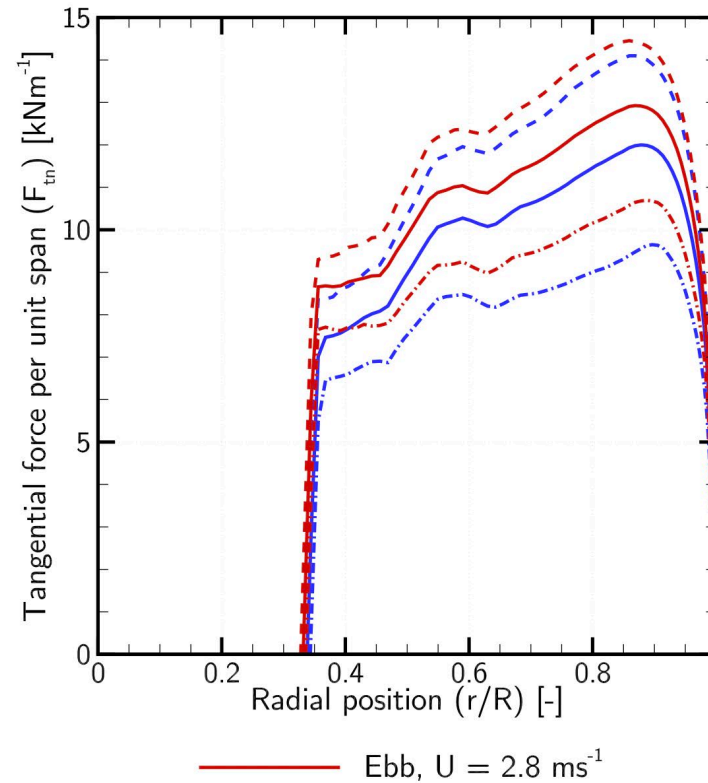
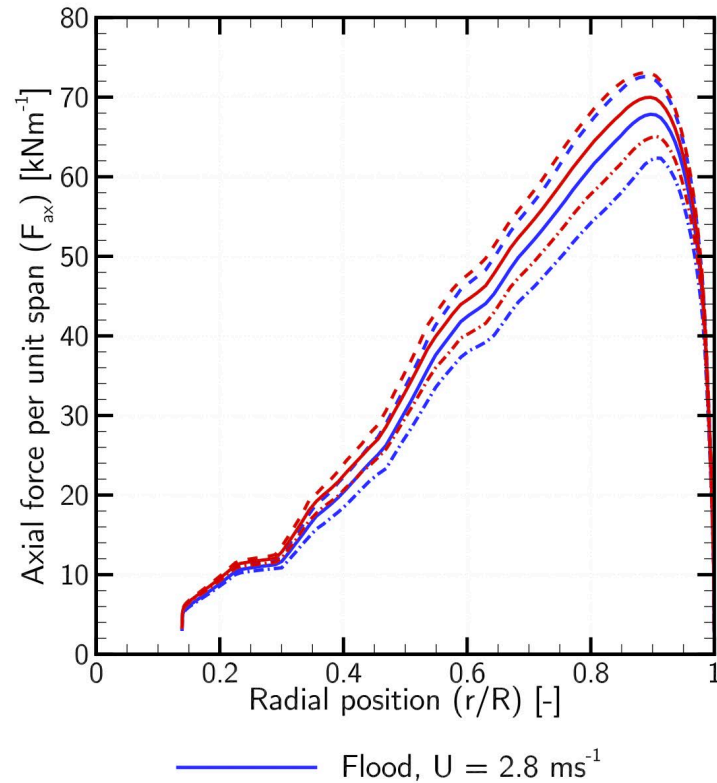


Turbine performance

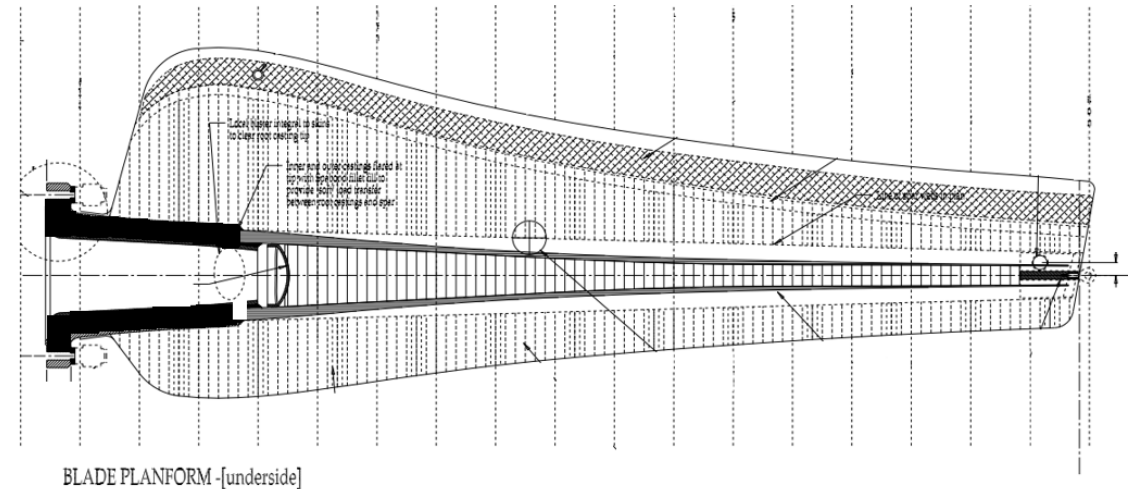
- Ebb tide, 3.5 m/s hub-height flow speed
- 1p fluctuations in individual blade RBMs observed
- 3p fluctuations in rotor thrust and power
- RBM asymmetry between top and bottom of rotation due to flow profile – dependent on tide
- Higher 2p component in ebb vs. flood tide due to shear profile



Turbine performance

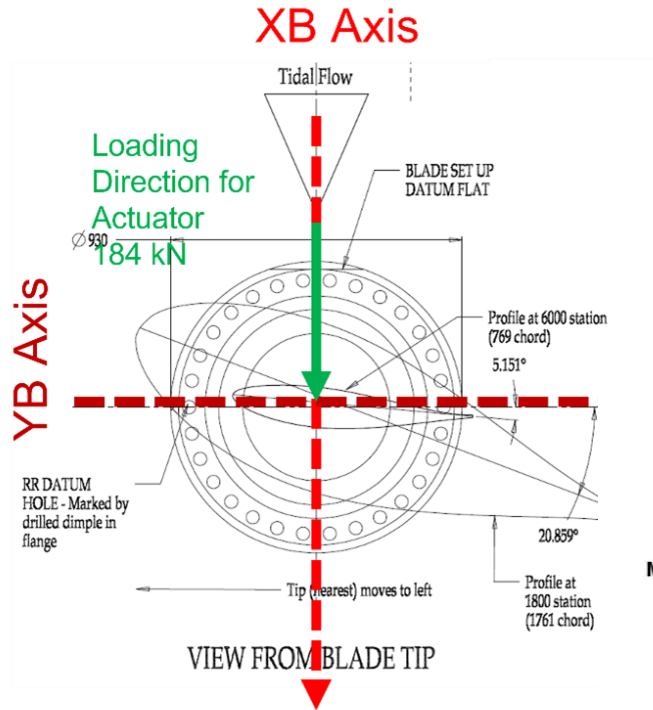


Test Specimen

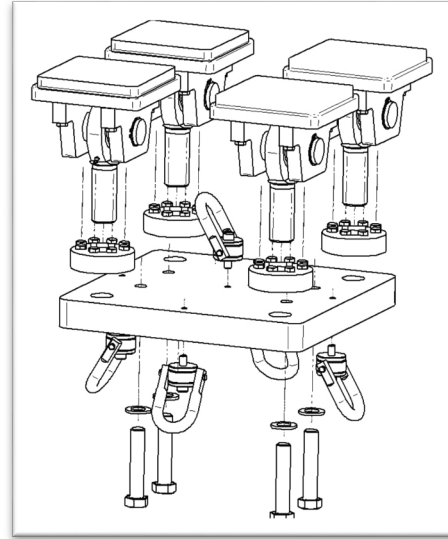


Test Plan & Load Introduction

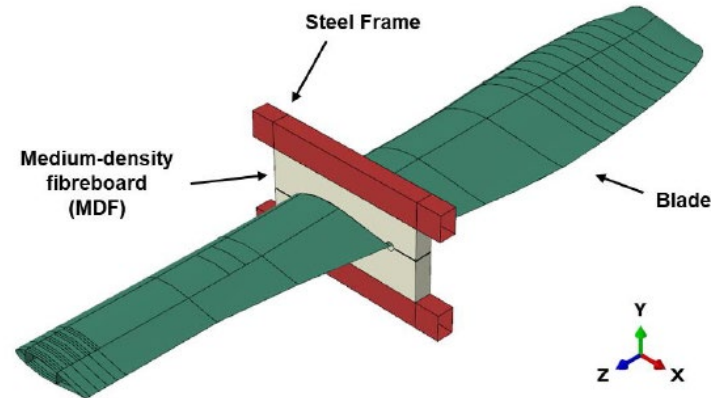
- Natural Frequency
- Static Testing at 273.3 kN
- Fatigue at 183.7 kN



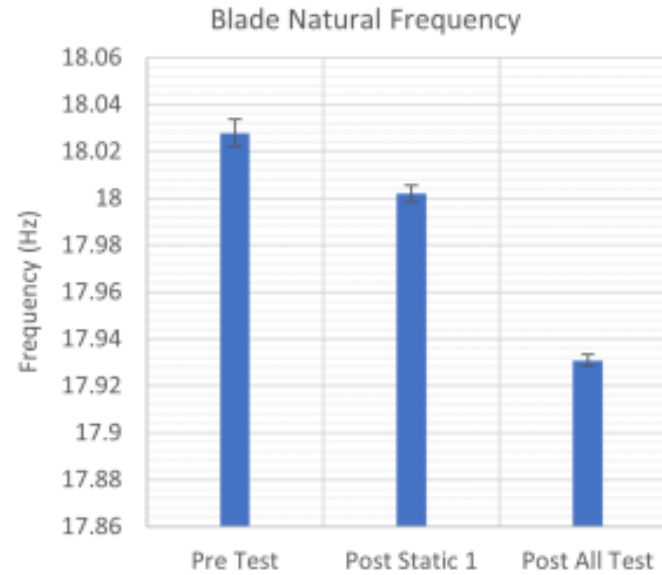
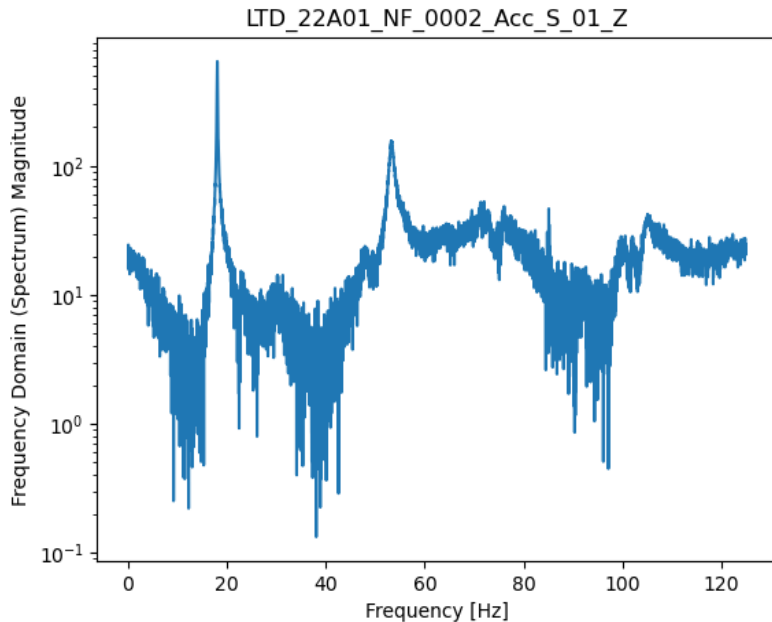
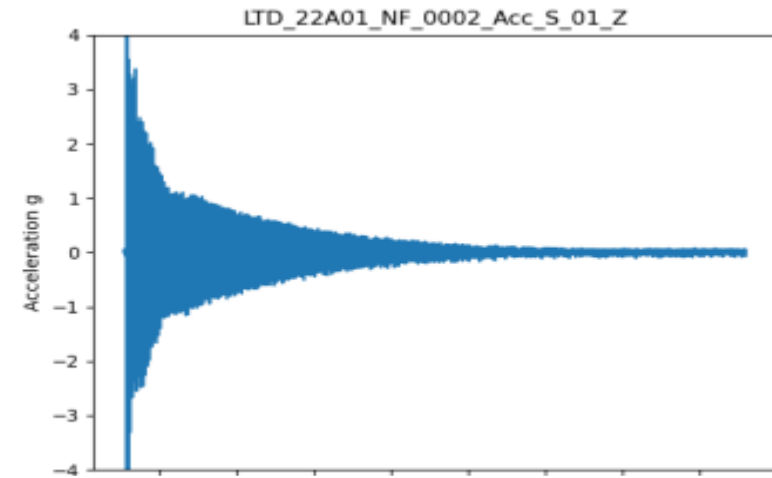
Saddle Design 1



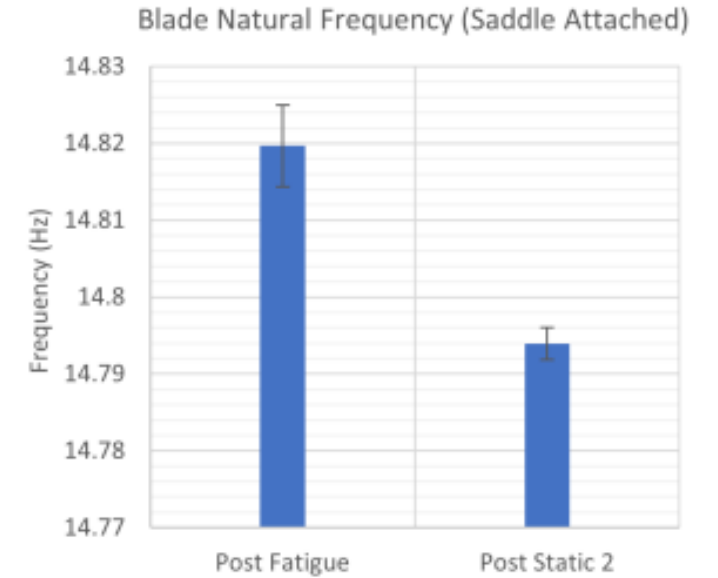
Saddle Design 2



Natural Frequency



(a) Natural Frequency changes



(b) Natural Frequency changes (Saddle Attached)

Figure 6.2: Natural Frequency changes of the blade

	Natural Frequency (Hz)	Standard Deviation
Pre Test	18.0278	0.0057
Post Static 1	18.0019	0.0035
Post All Test	17.9308	0.0026

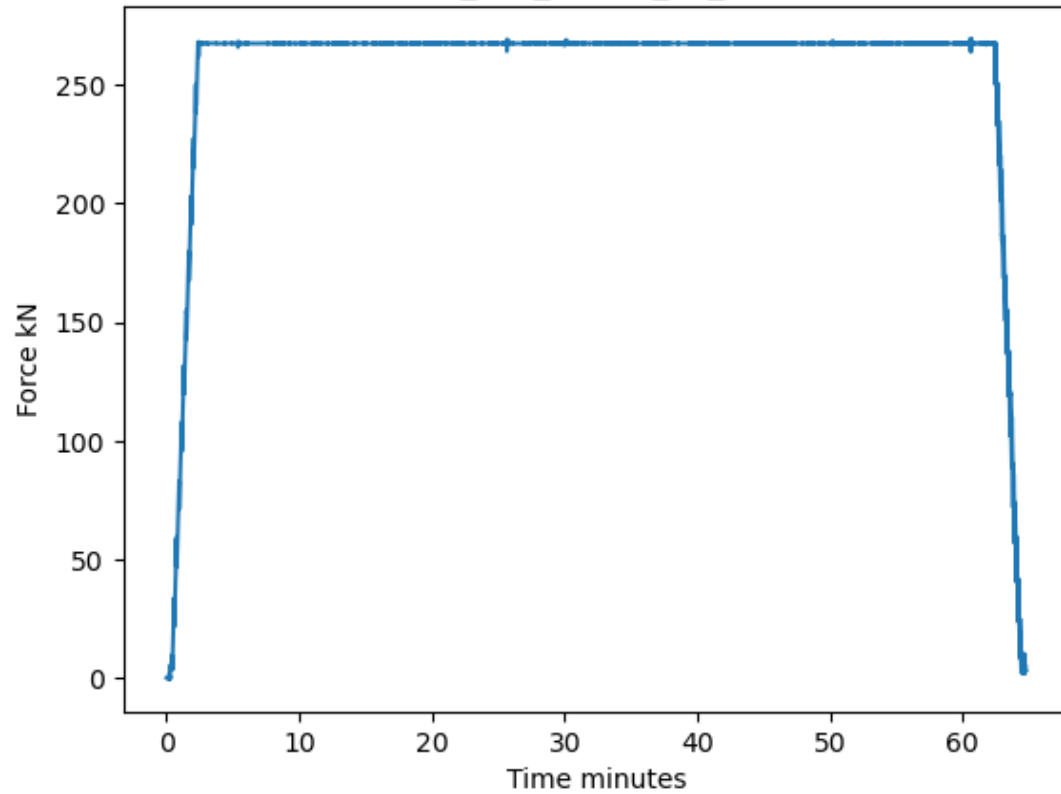
(a) No Saddle Attached

	Natural Frequency (Hz)	Standard Deviation
Post Fatigue	14.8196	0.0053
Post Static 2	14.7939	0.0021

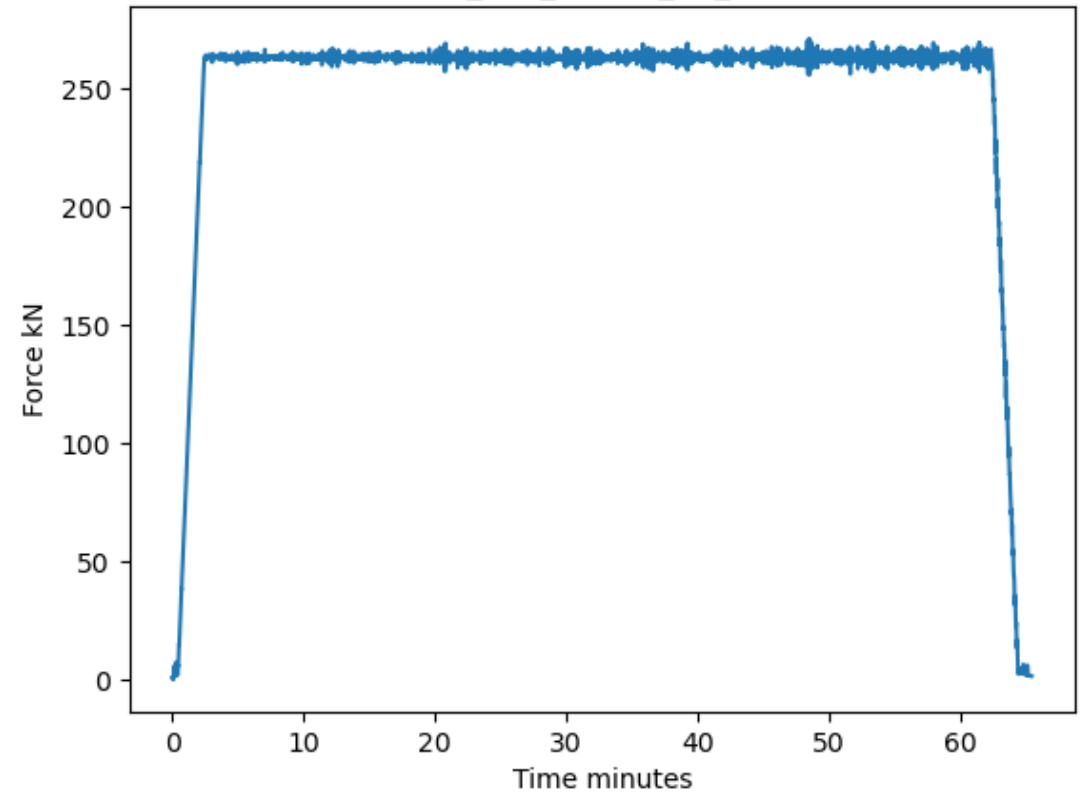
(b) Saddle Attached

Static Test 1-2 Load

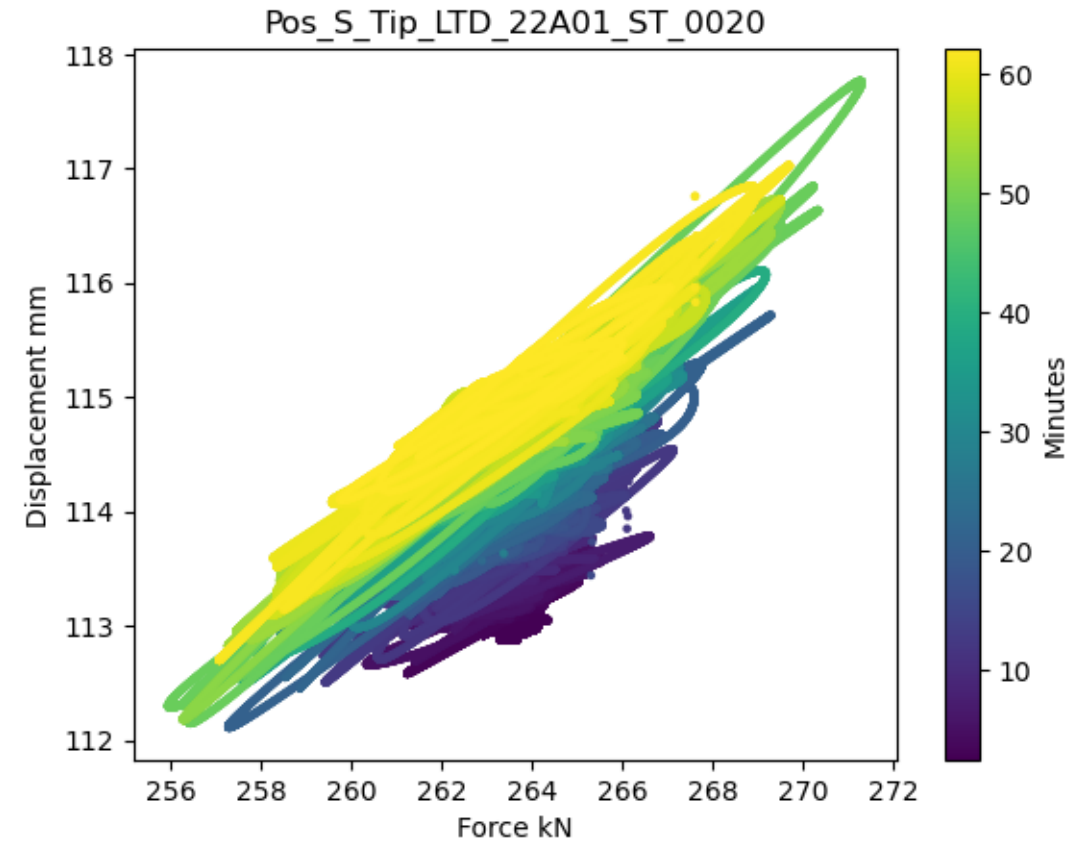
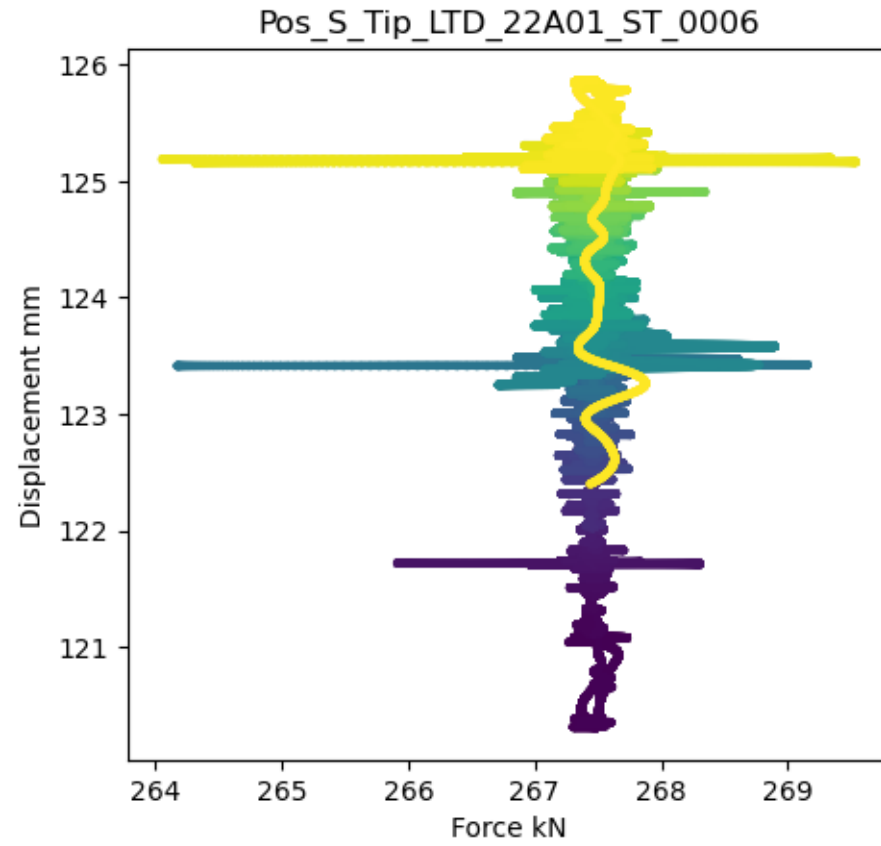
Load_LTD_22A01_ST_0006



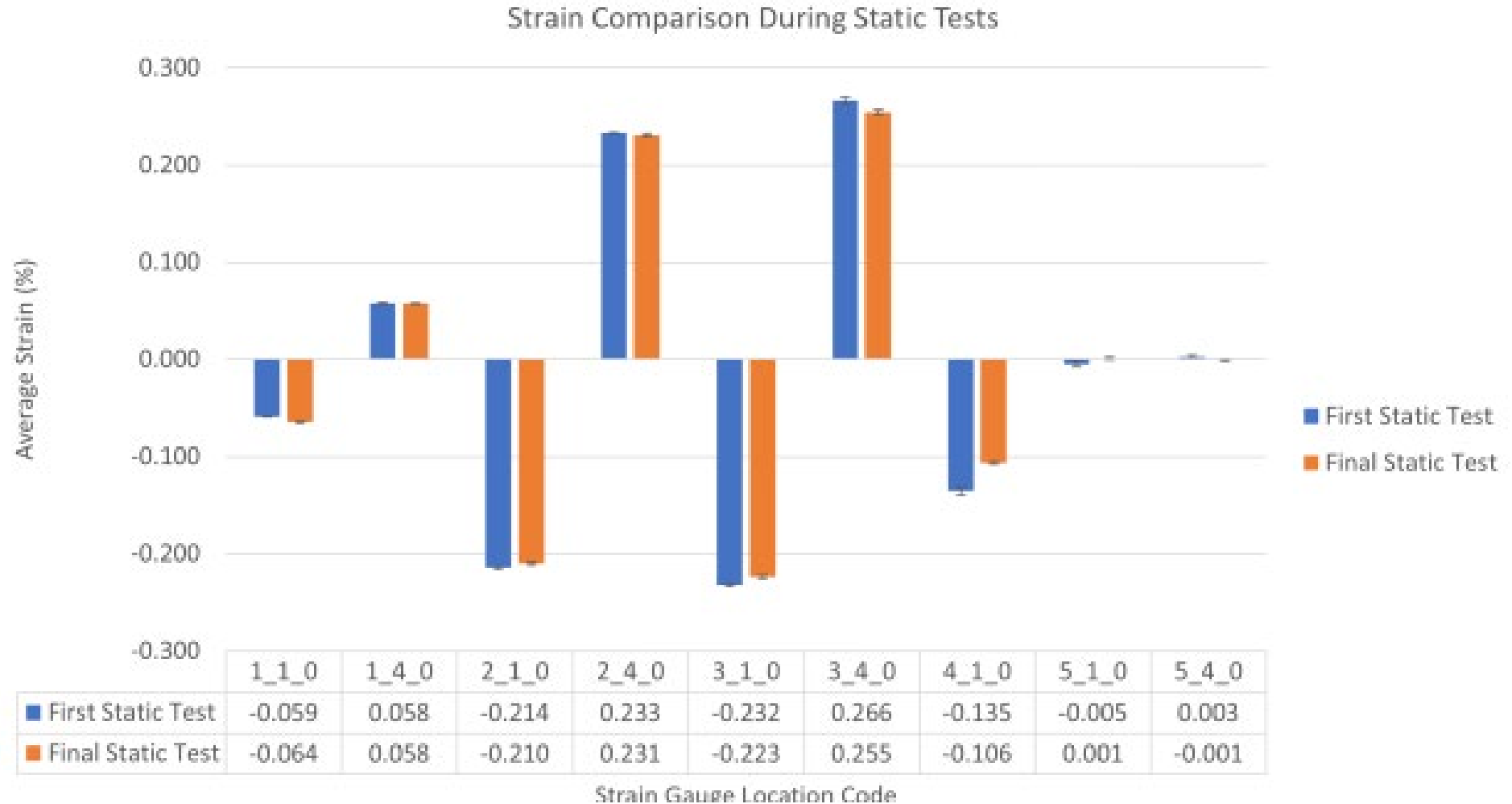
Load_LTD_22A01_ST_0020



Static test, Load-displacement tip

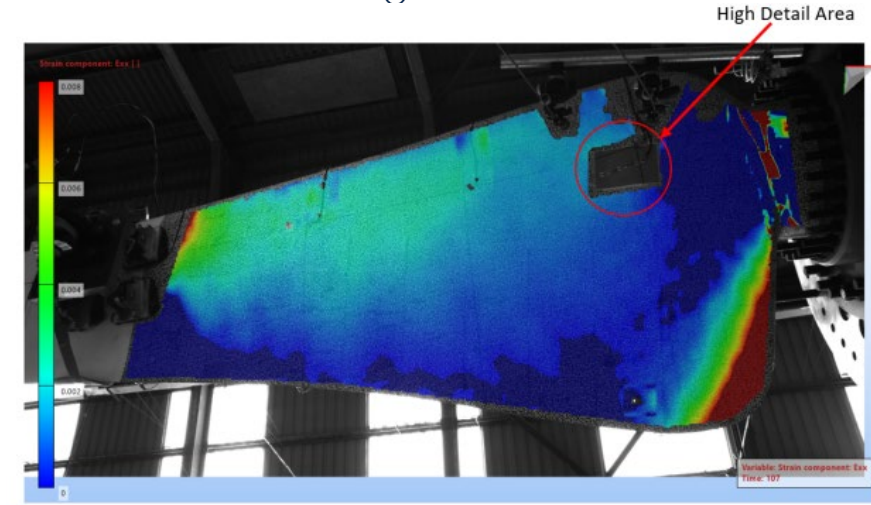
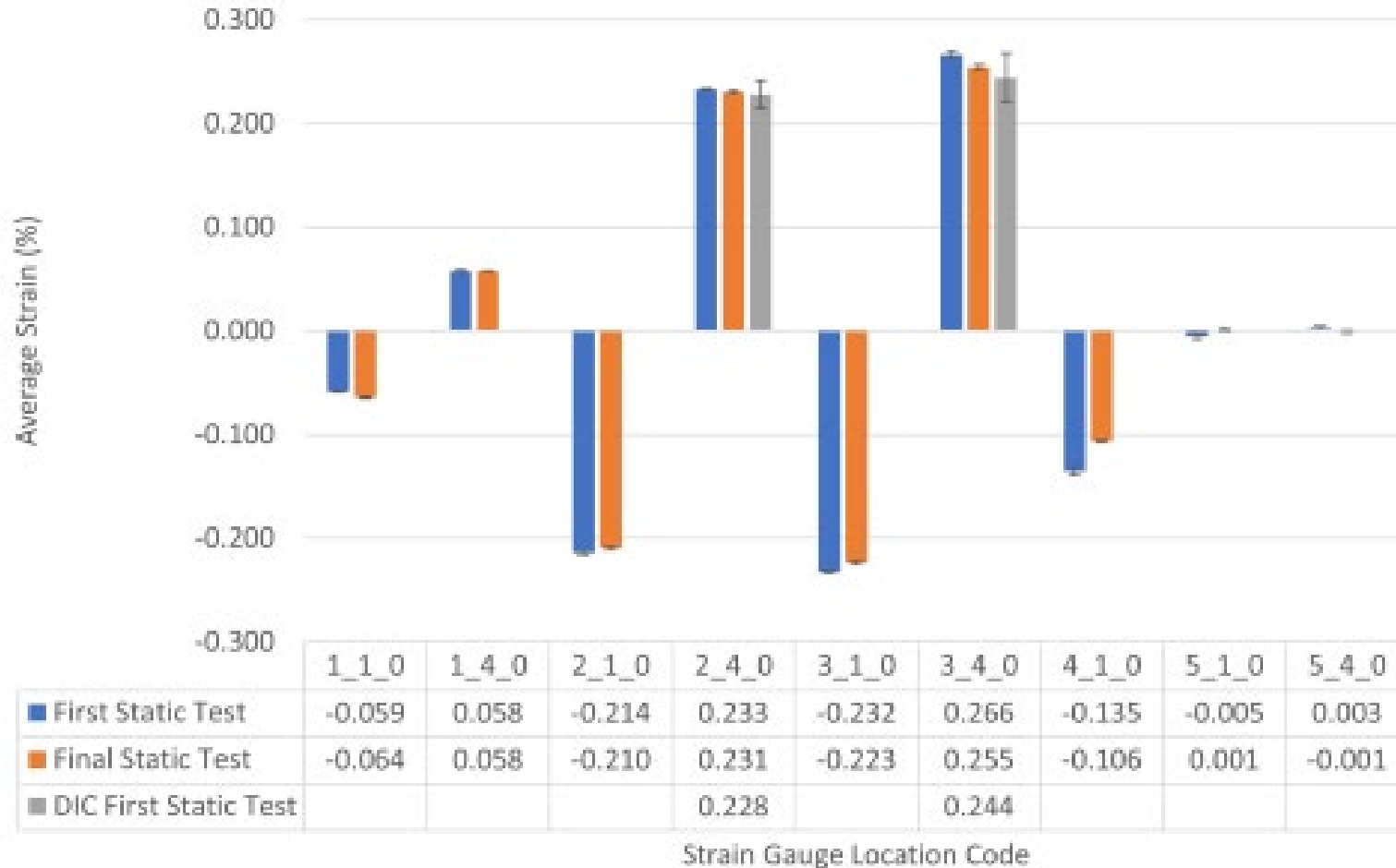


Static Strain comparison



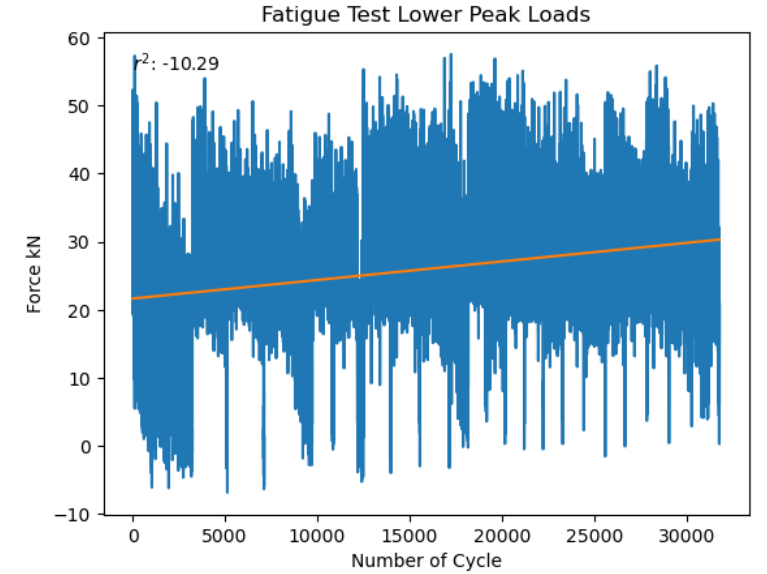
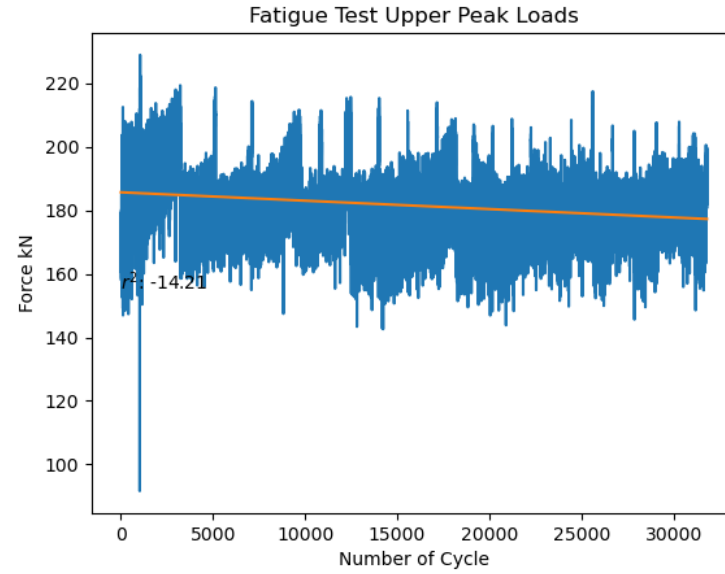
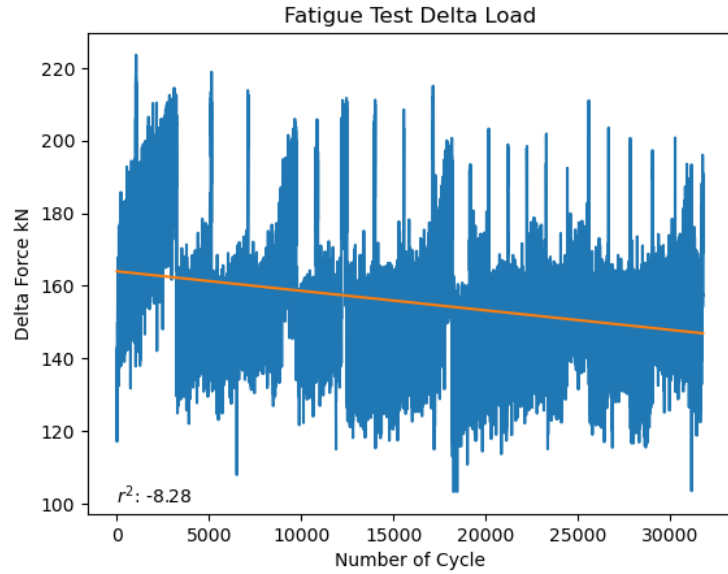
Static DIC

Strain Comparison During Static Tests



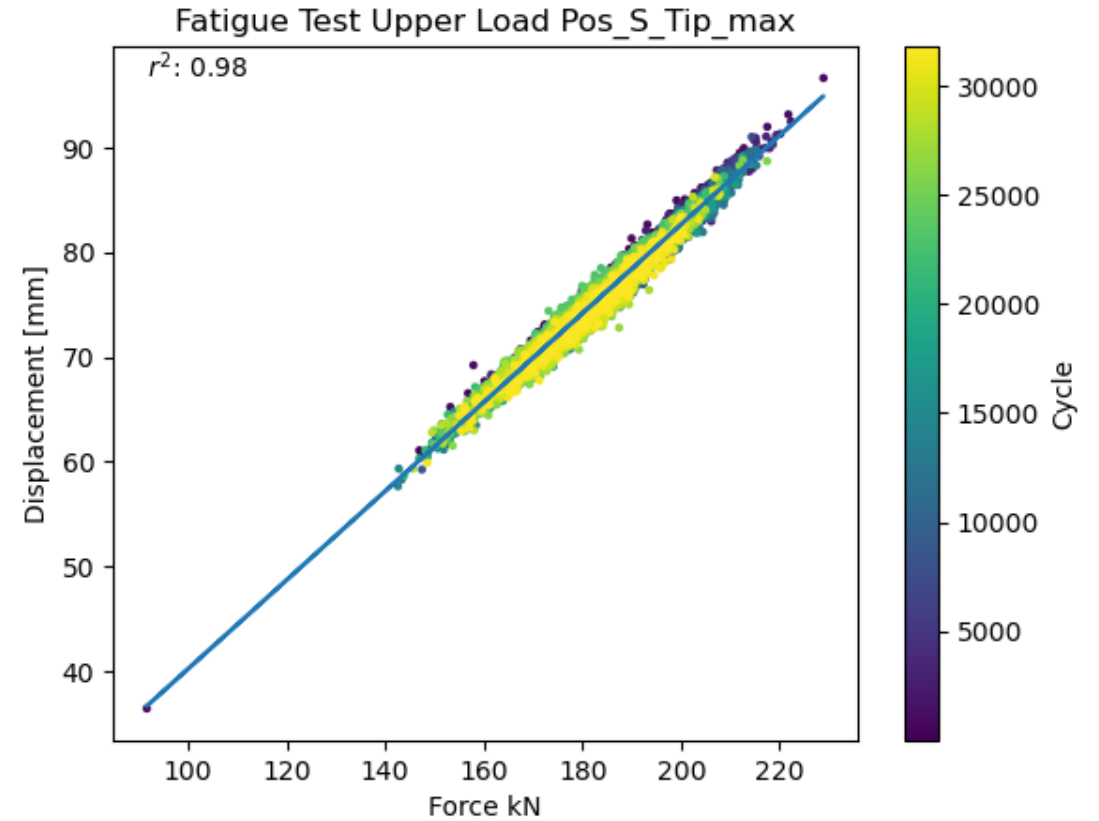
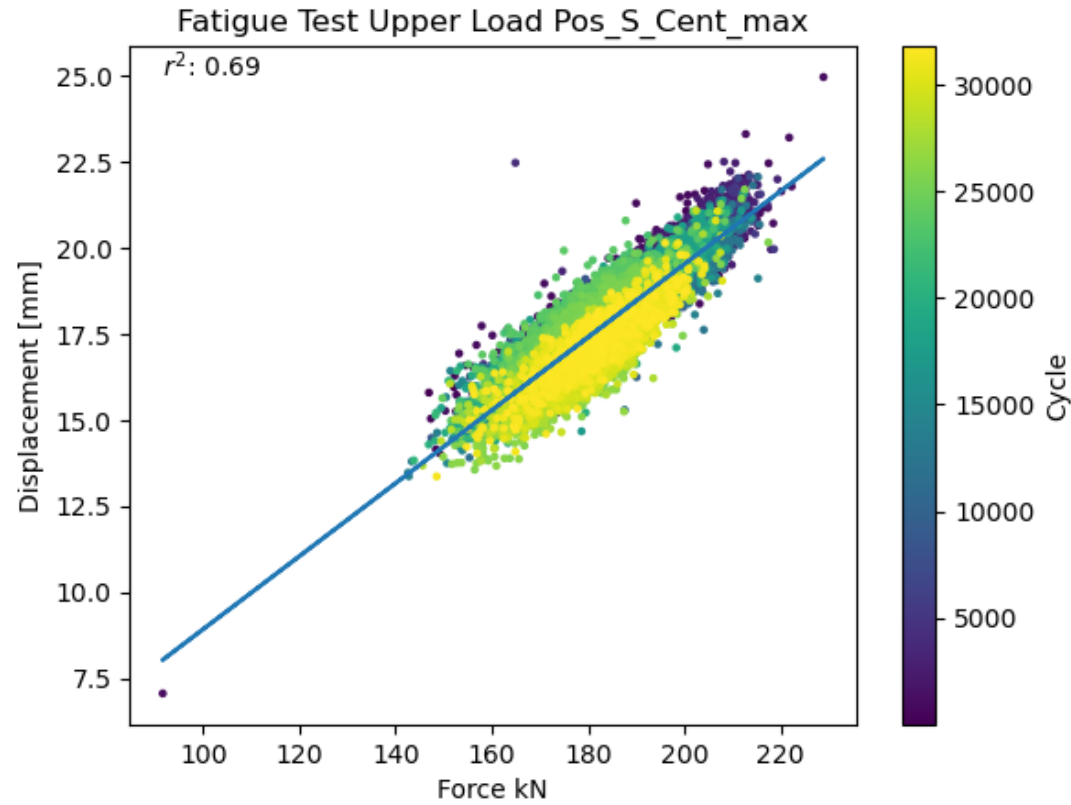
- First Static Test
- Final Static Test
- DIC First Static Test

Strain Comparison During Static Tests with DIC Results

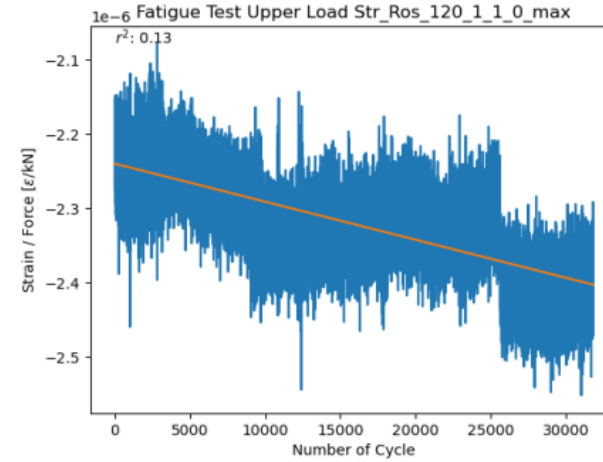


Fatigue Test Loads

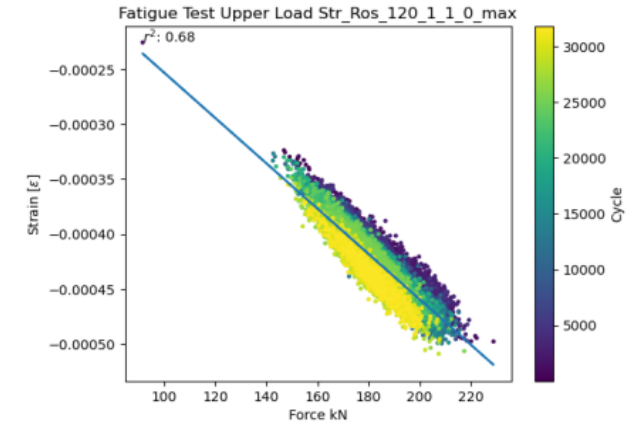
Fatigue Load-Displacement Max Load



Fatigue Test Strain Results Maximum Load

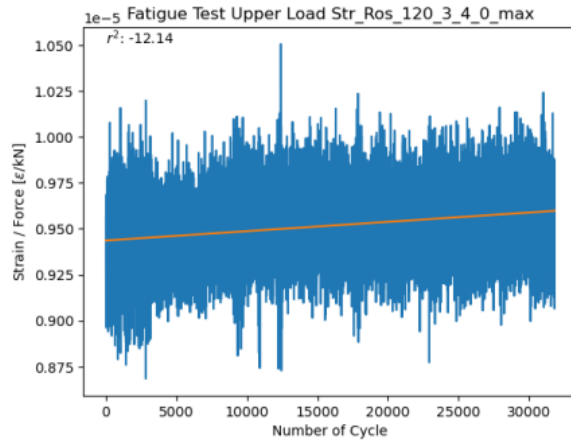


(a) Strain/Force

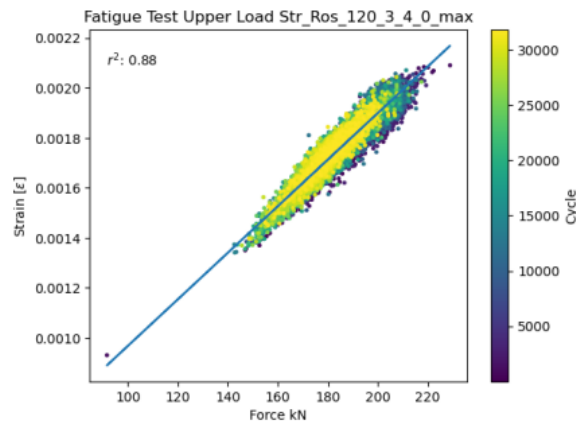


(b) Strain vs Load

Figure 6.25: Blade top surface strain 900mm from root

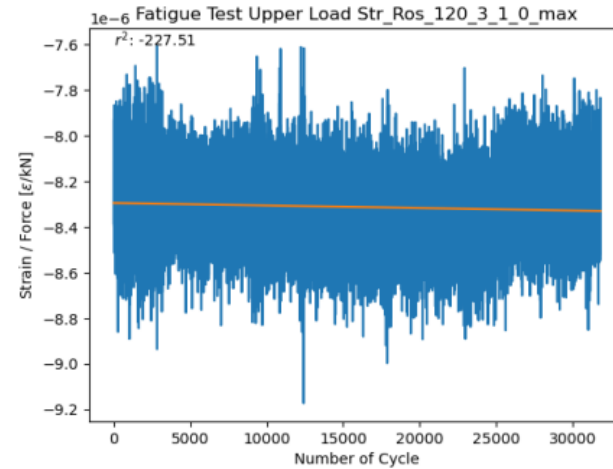


(a) Strain/Force

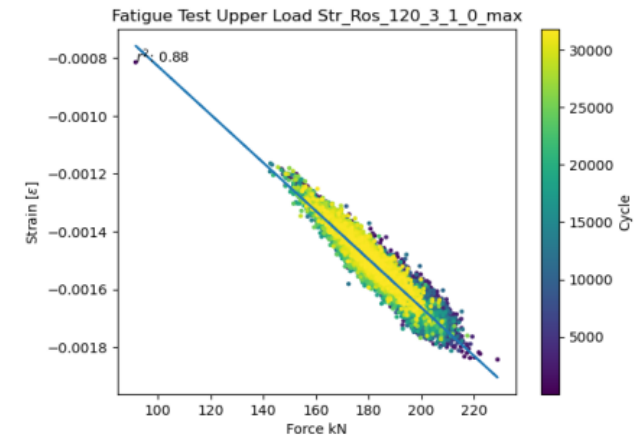


(b) Strain vs Load

Figure 6.27: Blade bottom surface strain 2500mm from root



(a) Strain/Force



(b) Strain vs Load

Figure 6.26: Blade top surface strain 2500mm from root

Blade Stiffness Results

Test	Location	Displacement (mm)	Load (kN)	Stiffness (kN/mm)
Static 1	Tip	120.2	272.83	2.26
	Centre	28.8	272.83	9.47
Fatigue	Tip	68.67	169.64	2.47
	Centre	18.91	169.64	8.97
Static 2	Tip	114.53	275.99	2.41
	Centre	31.24	275.99	8.83

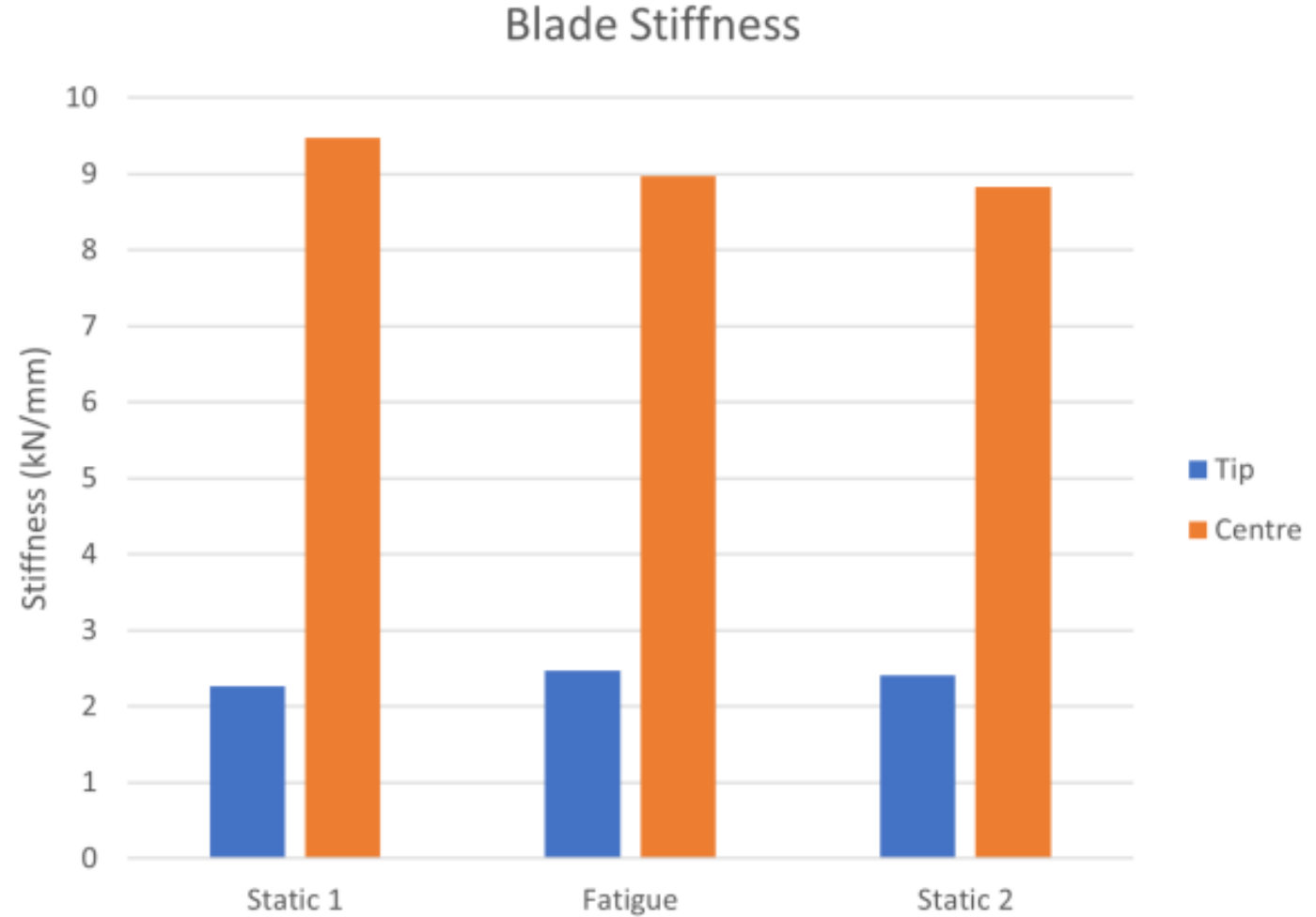


Figure 8.2: Blade stiffness at centre and tip

Conclusions

- FastBlade successfully performed a mechanical fatigue test of a tidal blade.
- The blade survived the worst-case static load criteria as defined by the blade developer.
- The blade withstood 20 years (equivalent) of accelerated fatigue loading without catastrophic failure.
- No specific failures were observed throughout all testing. No audible sounds of failure were detected, and no sudden changes in position or load. The DIC system did not detect any areas of exceptionally raised strain. The highest strain measured with strain gauges was 0.266% on the bottom surface of the blade, near the loading saddle.
- FastBlade identify possible improvements to the testing procedures, i.e., control strategies, load introduction, instrumentation layout, instrument calibration, and test design.

LOADTIDE

Thanks for listening

