Sub-structural testing of a wind turbine blade section with localized X-stiffener reinforcements

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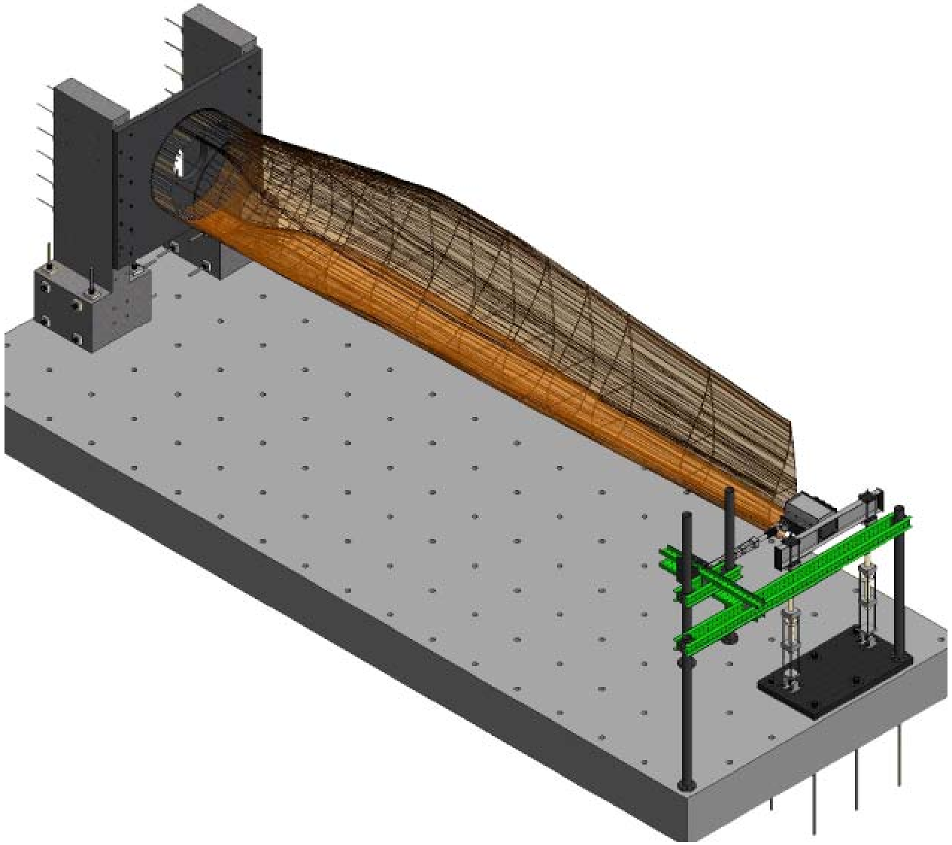
Sub-structural test of a 15 meters section of a wind turbine blade.

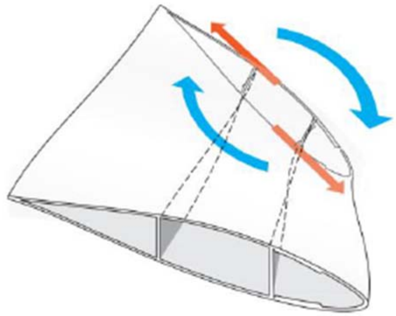


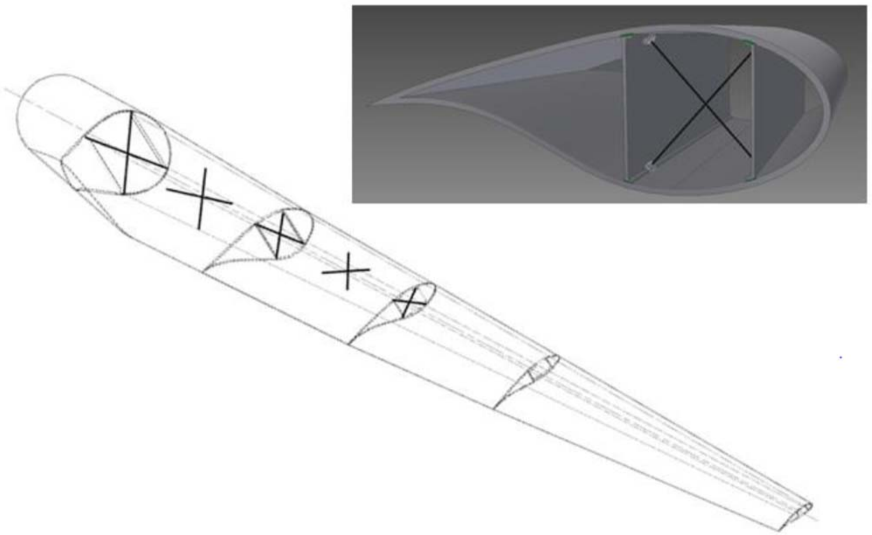
Sub-structural test of a 15 meters section of a wind turbine blade.

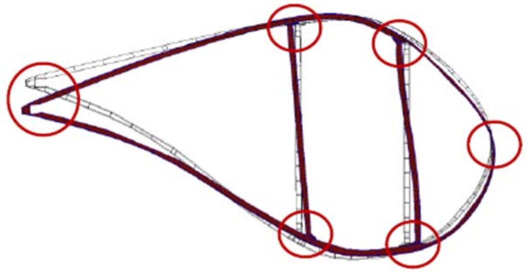
X-Stiffener retrofit reinforcement

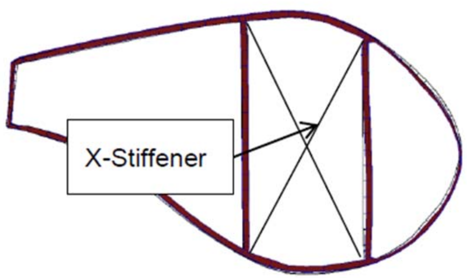
- **EUDP LEX Project** develop and demonstrate retrofit solutions for mitigating leading edge damages, caused by cross-sectional shear distortion.

- The **X-Stiffener** patented technology prevents the CSSD in cross-section areas by increasing the cross-sectional strength of the blade





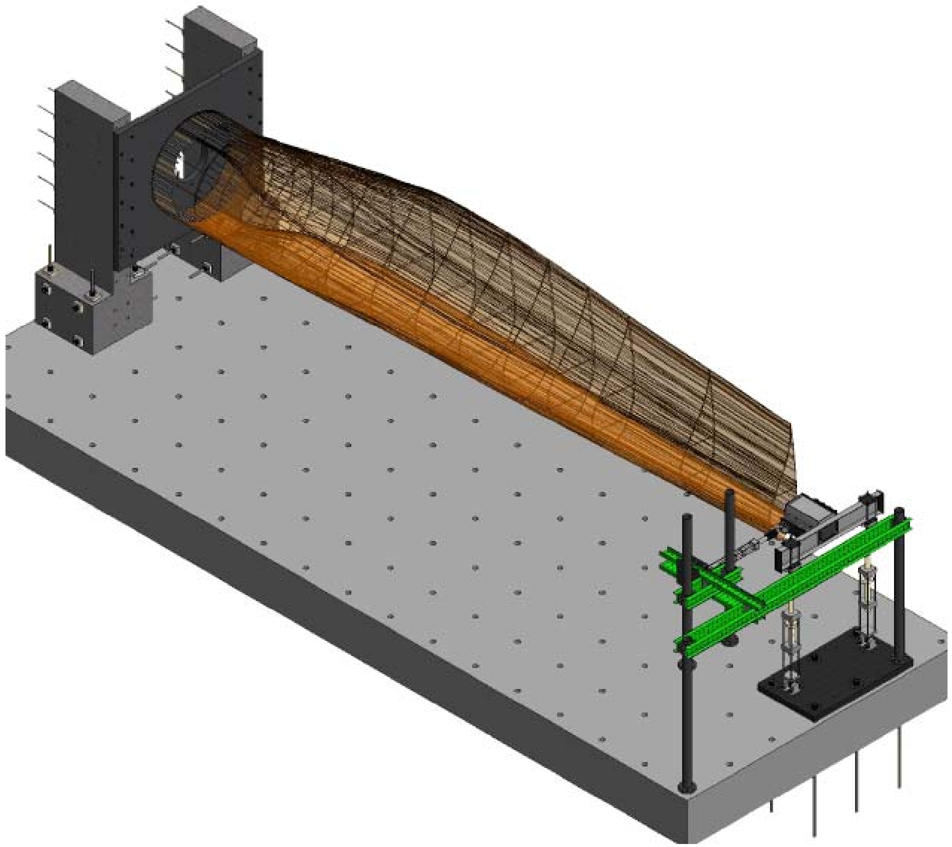




Illustrations from Bladena

The Test Rig developed at DTU Mechanical Engineering

Overview

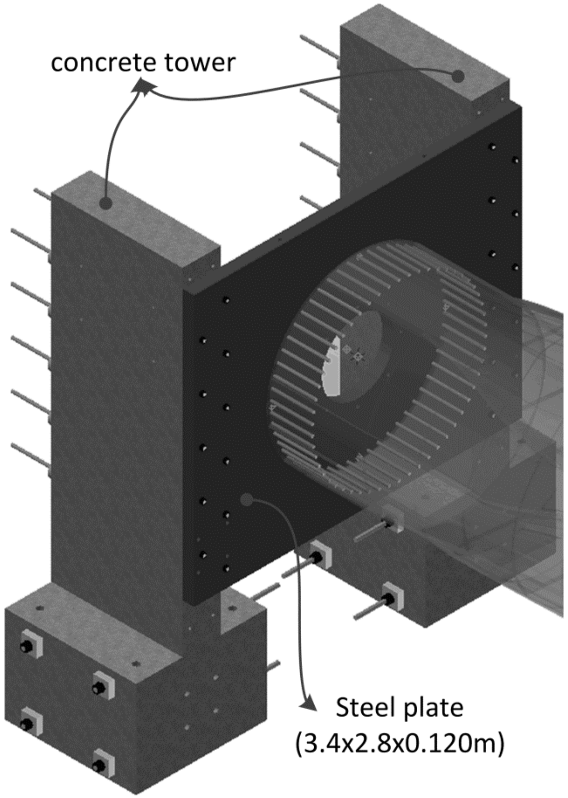


load and deformation capability:

- **flapwise**: ±50kN and 500mm
- **edgewise**: ± 100kN and 500mm
- **moment**: ±100kNm and 25 degrees

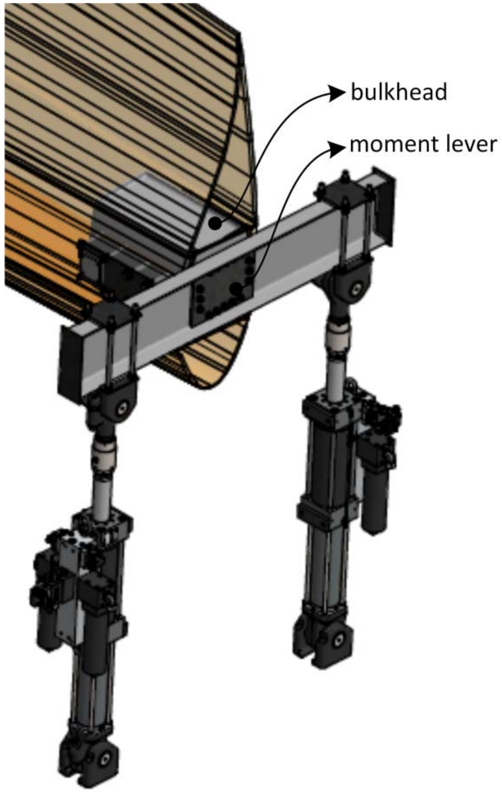
The Test Rig developed at DTU Mechanical Engineering

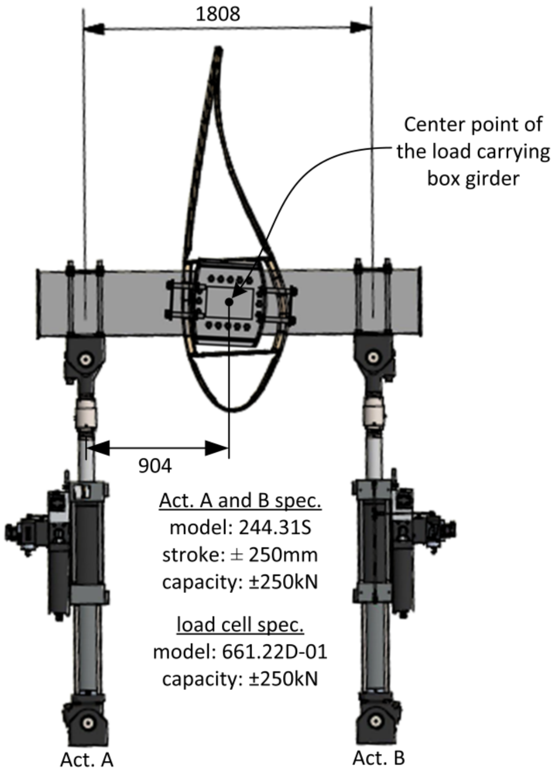
Clamping Support

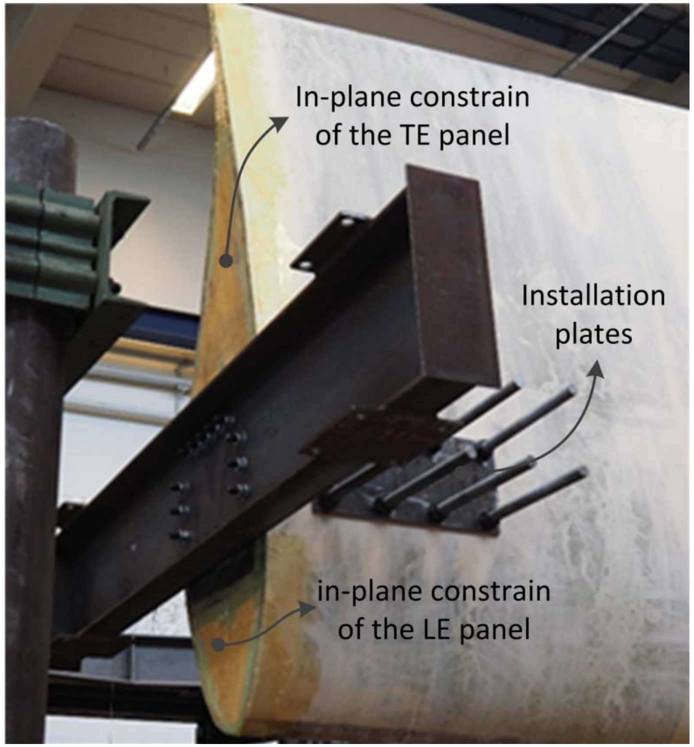


The Test Rig developed at DTU Mechanical Engineering

Load Train

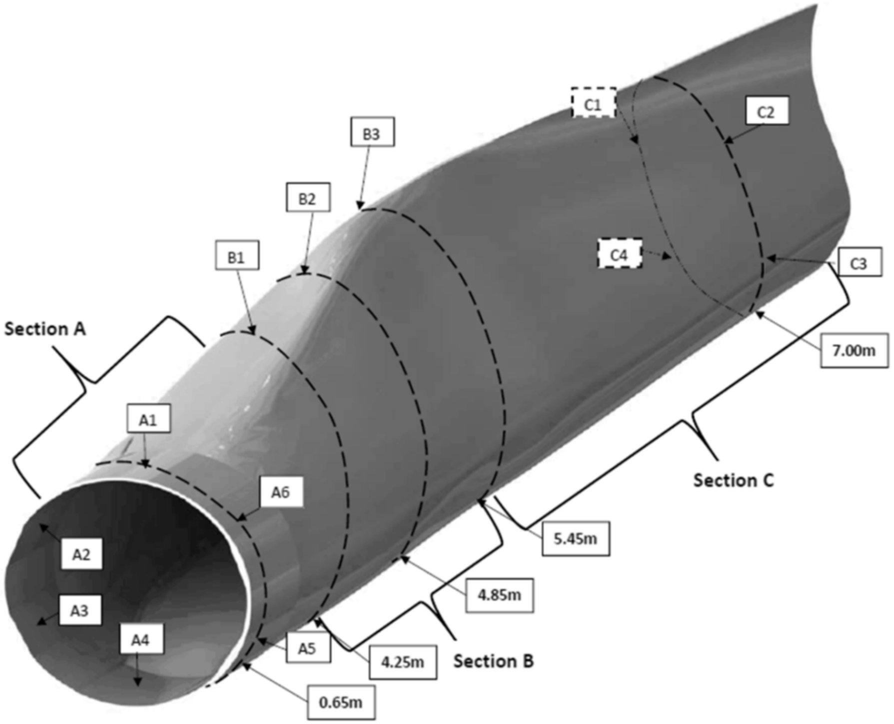






The Test Rig developed at DTU Mechanical Engineering

Measurement devices

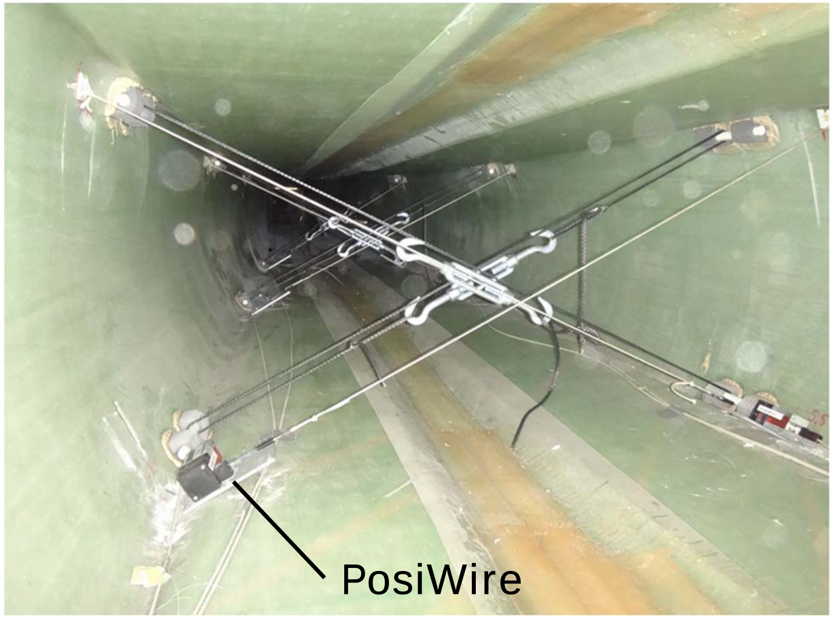


Strain gauges at 13 locations

Biaxial and rosette strain gauges

The Test Rig developed at DTU Mechanical Engineering

Measurement devices



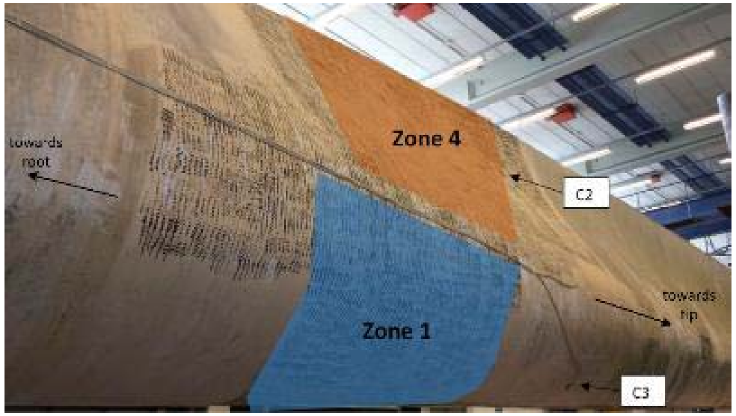
Wire potentiometers at 5 locations, from 5,5 meters to 11,5 meters from the blade root.

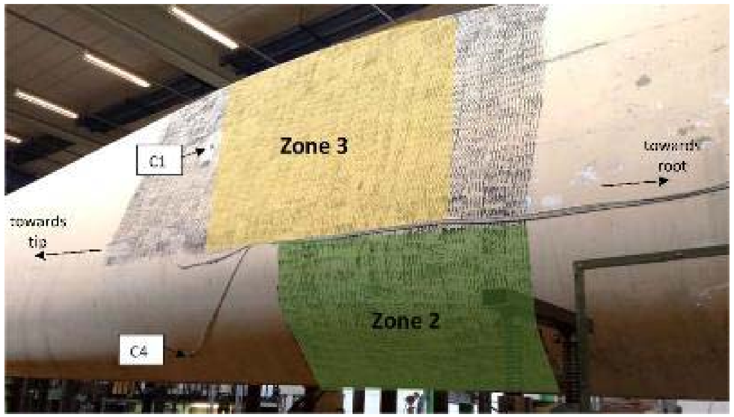
Measuring Cross sectional shear distortion.

Critical value for evaluation of X-Stiffener performances.

The Test Rig developed at DTU Mechanical Engineering

Measurement devices





DIC Measurements at 4 locations

Large scale system detecting strain and displacement field on the blade surface.

pumping/breathing behavior in the transition zone could be investigated in this configuration

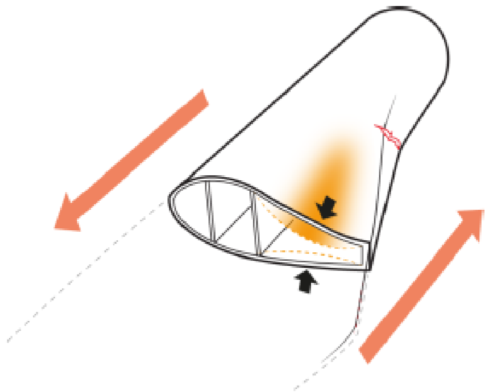


Illustration from Bladena

The Test Rig developed at DTU Mechanical Engineering

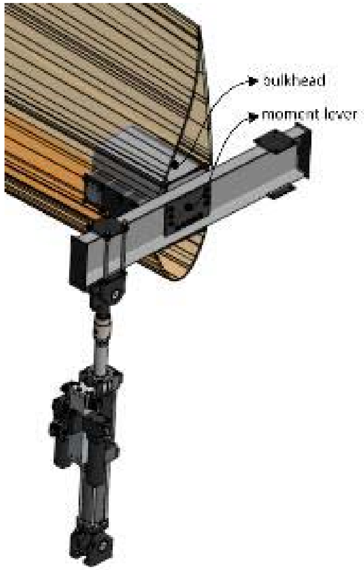
Control and Data Acquisition

The actuators are simultaneously controlled using an MTS FlexTest 100.

Data from PosiWire devices and straing gauges is collected using an MTS FlexDAC 20.

Static testing for LEX Project

Test Plan



1-Actuator configuration

Combination of Edgewise and Torsion loading

Displacement control until 75kN and back to 0kN

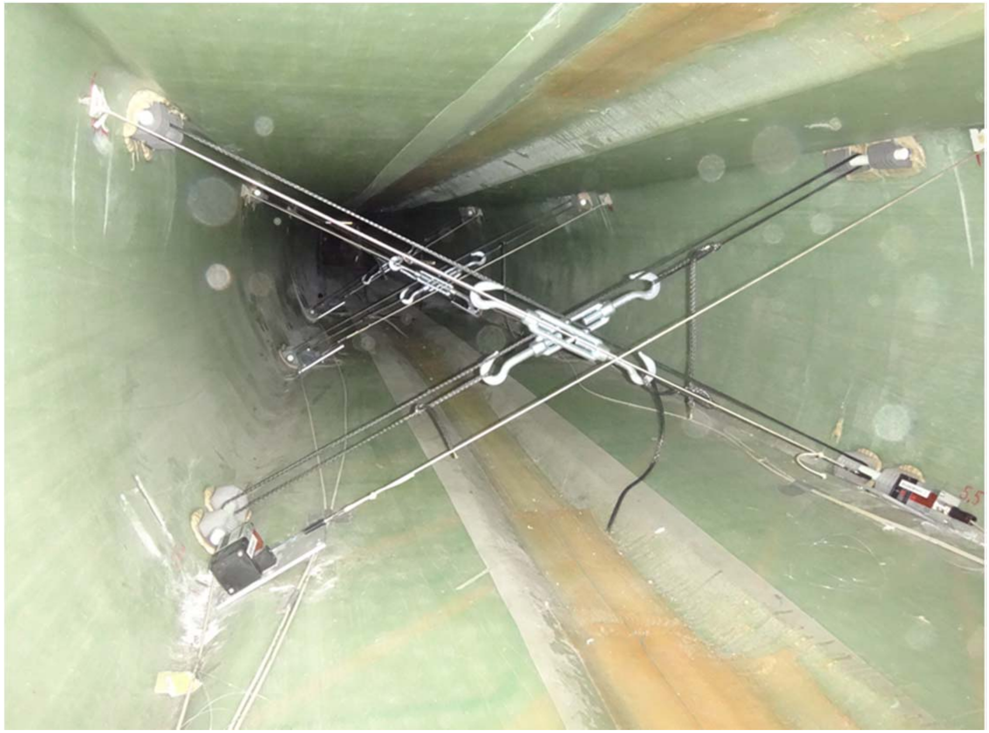
2-Actuators configuration

Pure Torsion loading

Maximum moment applied is 90 kNm

Static testing for LEX Project

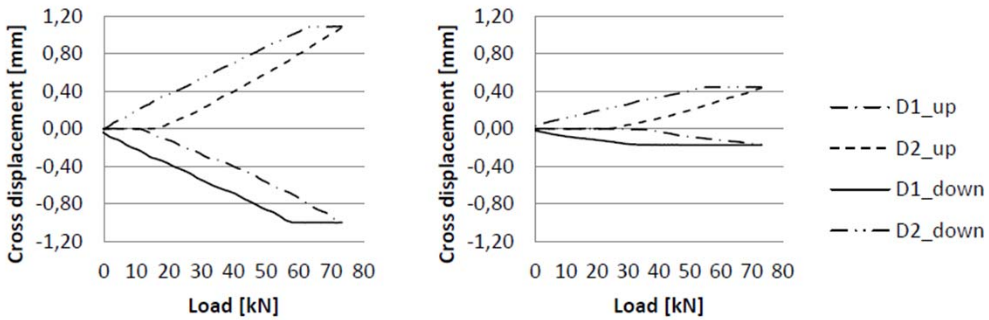
Test Plan



With and Without the X-Stiffener Cross reinforcement

Static testing for LEX Project

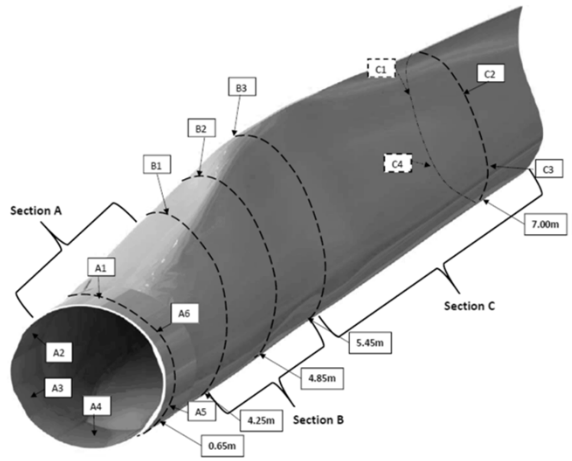
Results for 1-actuator configuration



Cross-sectional shear displacement at 8,5m from root, without and with the X-Stiffener.

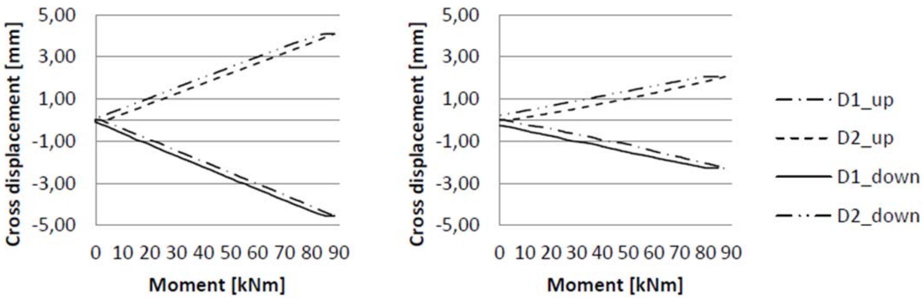
		Without X-Stiffener [mm]	With X-Stiffener [mm]	Div. [%]
5.5m	D1	0.790	1.145	-44.88
	D2	-0.145	-0.378	-159.7
7.0m	D1	-0.002	0.382	-100.5
	D2	0.207	0.001	99.34
8.5m	D1	-0.994	-0.172	82.70
	D2	1.081	0.435	59.77
10.0m	D1	-2.311	-0.972	57.91
	D2	2.155	1.143	46.94
11.5m	D1	-2.599	-1.659	36.15
	D2	2.705	1.699	37.18

	Without X-Stiffener	With X-Stiffener		Without X-Stiffener	With X-Stiffener		Without X-Stiffener	With X-Stiffener	
SG nr. [-]	Strain in 0 degree [με]		Dev. [%]	Strain in 45 degree [με]		Dev. [%]	Strain in 90 degree [με]		Dev. [%]
1	151.0	147.8	2.12	108.2	105.3	2.72	-14.6	-15.9	-8.93
2	461.9	470.6	-1.89	83.7	88.1	-5.29	-68.8	-67.6	1.81
3	-397.4	-402.2	-1.21	-314.5	-316.4	-0.60	90.0	92.9	-3.18
4	-85.7	-85.3	0.44	-45.2	-44.0	2.67	38.2	36.5	4.37
5	-439.6	-439.5	0.04	-18.6	-19.6	-5.40	63.1	61.3	2.87
6	-59.6	-60.0	-0.67	61.2	61.2	-0.06	368.0	371.1	-0.86



Static testing for LEX Project

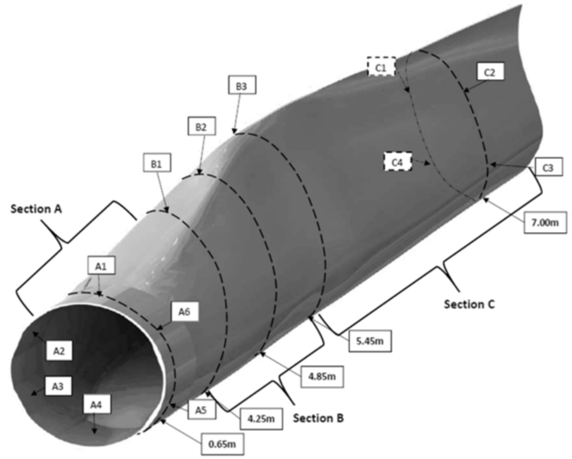
Results for 2-actuators configuration



Cross-sectional shear displacement at 8,5m from root, without and with the X-Stiffener.

		Without X-Stiffener [mm]	With X-Stiffener [mm]	Div. [%]
5.5m	D1	-3.028	-1.398	53.83
	D2	2.727	1.283	52.93
7.0m	D1	-3.947	-1.925	105.0
	D2	3.445	1.709	50.39
8.5m	D1	-4.516	-2.282	49.48
	D2	4.059	2.064	49.16
10.0m	D1	-4.698	-2.506	46.67
	D2	4.404	2.327	47.16
11.5m	D1	-3.995	-2.458	38.48
	D2	4.029	2.416	40.04

	Without X-Stiffener	With X-Stiffener		Without X-Stiffener	With X-Stiffener		Without X-Stiffener	With X-Stiffener	
SG nr. [-]	Strain in 0 degree [με]		Dev. [%]	Strain in 45 degree [με]		Dev. [%]	Strain in 90 degree [με]		Dev. [%]
1	12.9	10.4	17.6	-40.7	-38.7	4.89	-0.84	-1.37	-63.5
2	-49.2	-35.5	27.9	-58.4	-52.9	9.37	7.04	3.15	55.2
3	47.3	36.4	23.1	57.7	55.4	3.90	-14.1	-7.97	43.5
4	-7.25	-9.92	-36.5	33.8	30.0	11.2	10.6	12.11	-14.2
5	-42.7	-30.5	28.6	28.8	31.2	-8.52	13.9	8.24	40.8
6	-11.3	-6.38	43.7	-24.9	-28.0	-12.6	34.8	23.7	31.8

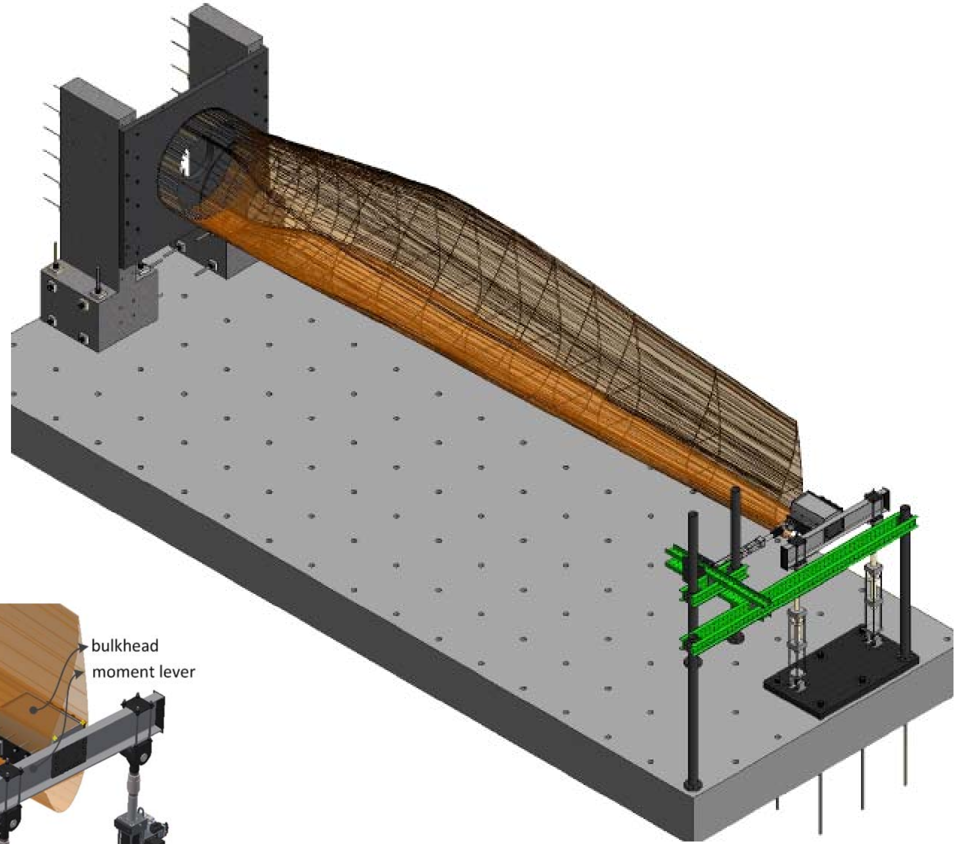


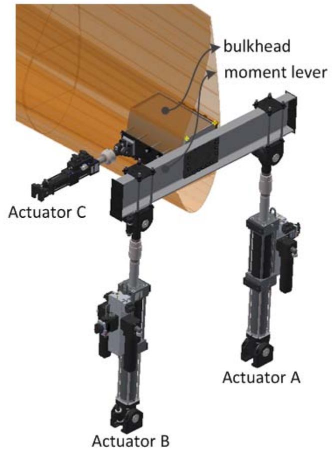
Future use of the test rig

Installation of a third actuator

The third actuator will enable the introduction of **Flapwise** loading to the blade substructure.

3 actuators are controlled simultaneously by the FlexTest 100 controller. Possible combinations of Edgewise, Flapwise and Torsion loading configurations.

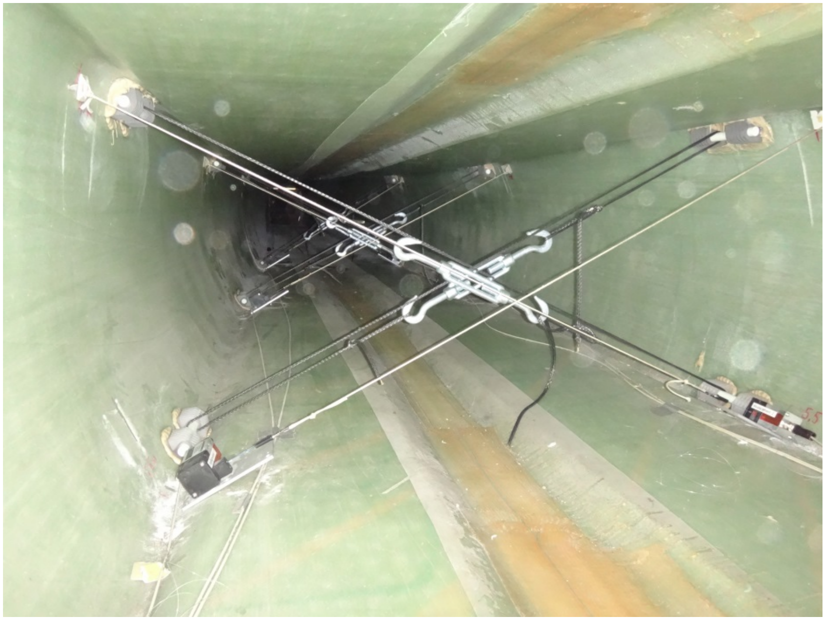




Future use of the test rig

Fatigue test of X-Stiffener reinforcement

- Fatigue validation of the test rig
- Evaluation of the performance of the X-Stiffener under **cyclic loading** conditions
- Fatigue testing using multiple actuators

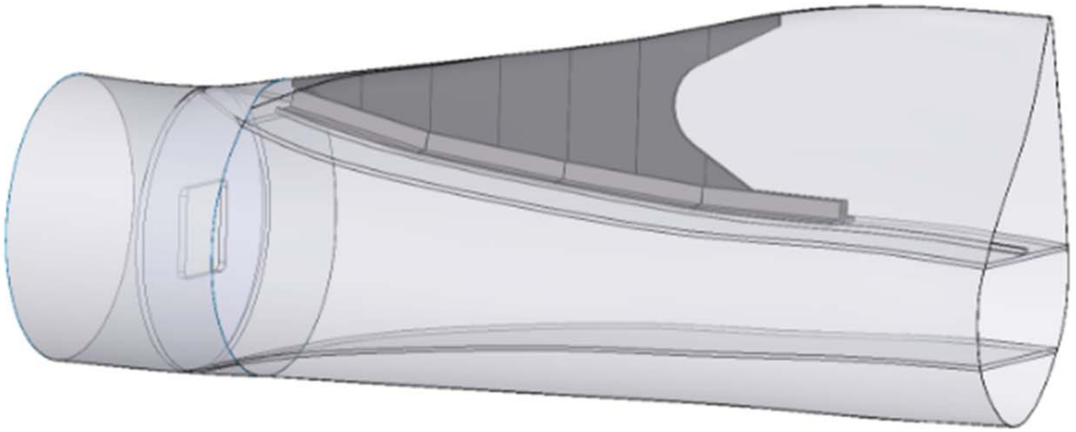


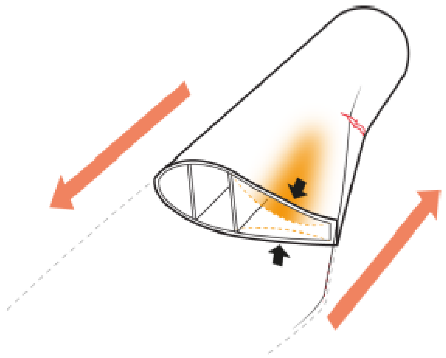
Future use of the test rig

EUDP RATZ Project

Root Area and Transition Zone and Reduction O&M cost of WT blades

The “Floor™” configuration makes it possible to transfer the edgewise loads smoothly to the root section and further into the hub. The Floor™ can be seen as a horizontal shear web and takes shear forces from the trailing edge and transfer them into the hub through the shear web.



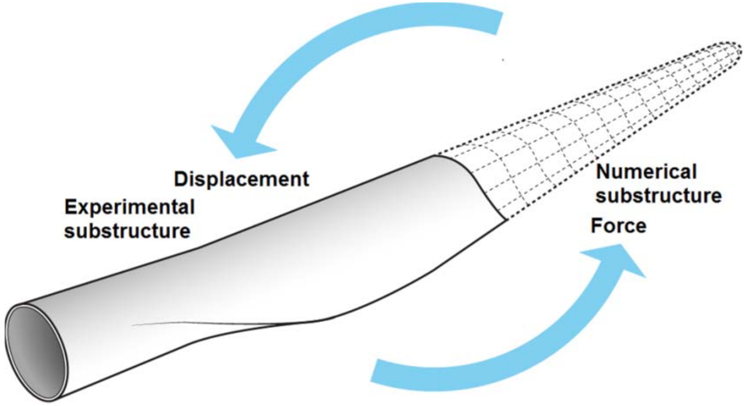


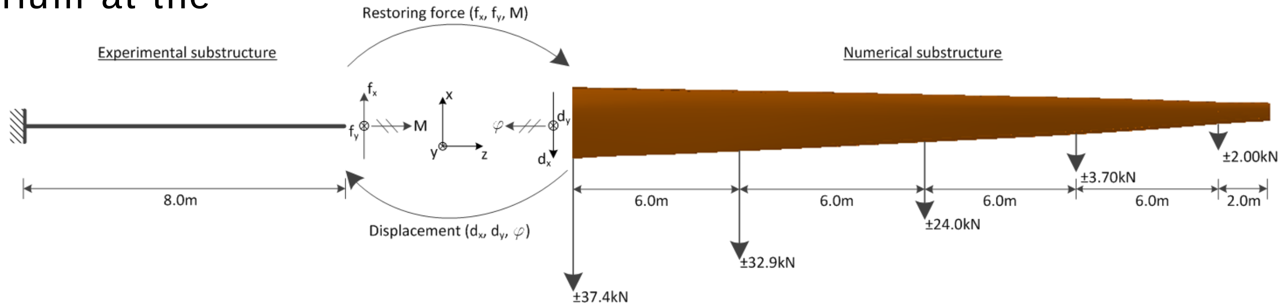
Illustrations from Bladena

Future use of the test rig

Hybrid Simulation

- Numerical substructure is discretized through a commercial FE-software
- A representative load configuration is applied the numerical substructure
- A displacement is fed from the numerical to experimental substructure
- The corresponding reaction force is returned to reveal the response of the experimental substructure
- A coupling is governed through the communication loop which ensures compatibility and equilibrium at the interface





THE END

Thank you for attention!