The C-Tower Project
A Composite Tower for Offshore Wind Turbines

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Tjeerd van der Zee (WMC)

Marten Jan de Ruiter (WMC)

Ivo Wieling (Jules Dock Composites)

Knowledge Centre WMC
Wind turbine Materials and Constructions

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Project introduction

Photo: Quadell at Wikipedia

Photo: By Cacophony - Own work, CC BY 3.0

Photo: Jules Dock Composites

Project introduction


Photo: Wikimedia Commons


Photo: Rob Faulkner

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Project partners

- **Wind2020: co-ordination**
- **Jules Dock Composites: production expertise**
- **WMC: composite and tower design knowledge, design and analysis tools, material and full-scale testing**

Pros and cons of composite tower

- **Weight reduction compared to steel**
  - Lower installation costs
- **Material may better dampen vibrations**
- **Opportunities for increasing lifetime**
- **But:**
  - Complex production
  - Reduced stiffness (frequency issues)
  - End-of-life not clear
  - New technology – market is conservative

Project challenge

Design a composite offshore wind turbine tower which is:

- lighter
- more flexible but as strong
- more sustainable
- with better damping characteristics

compared to an equivalent steel tower.

Project goals

- **Design a composite offshore wind turbine tower to carry a 10 MW turbine**
  - Uses a steel monopile
- **Show by software analysis that the concept is feasible (strength and fatigue life)**
- **Select production techniques for such a design**
- **Build a (roughly) 1:10-scale prototype and test it**

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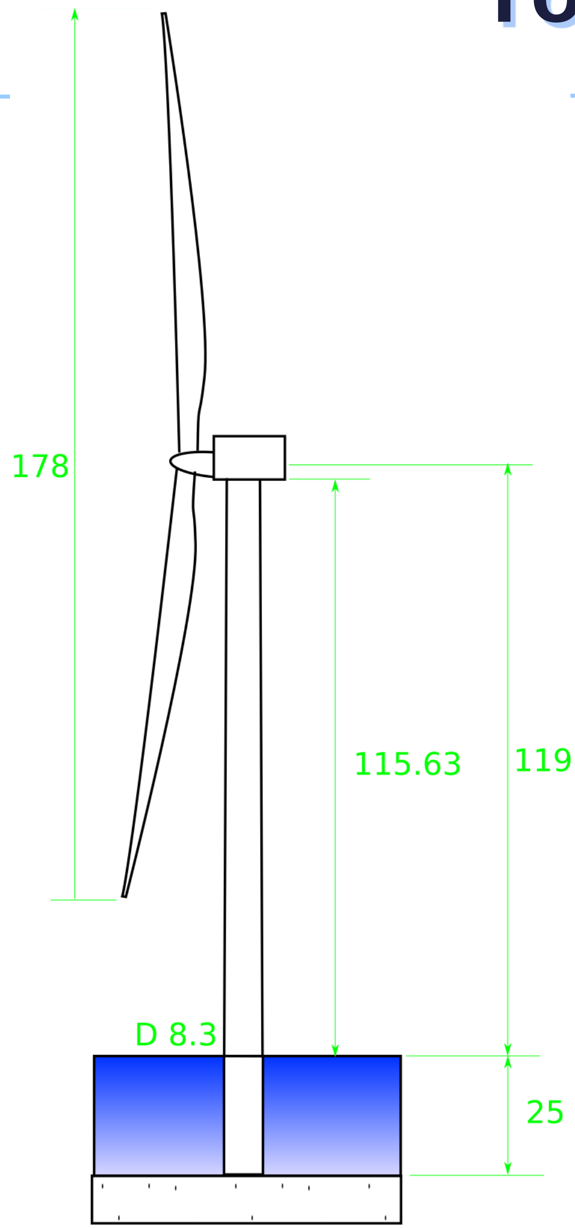
Tower geometry



Reference model:

- DTU 10 MW reference turbine

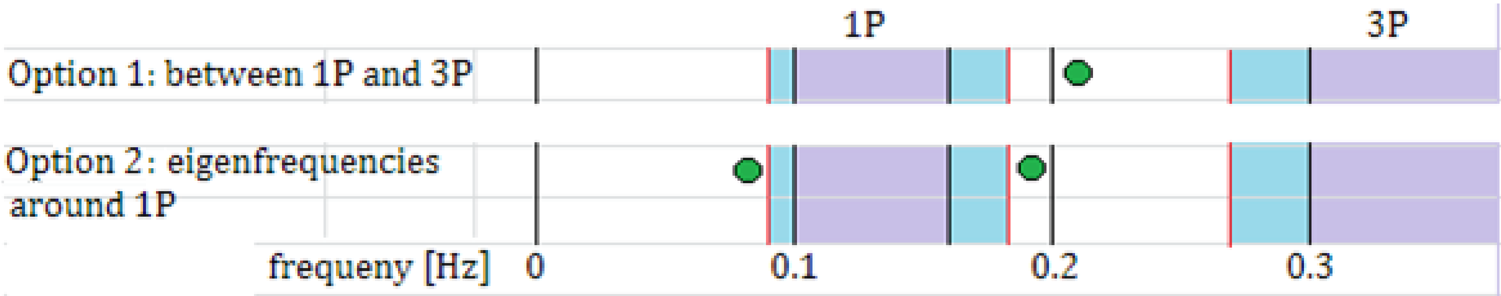
Tower model using:

- Steel (baseline)
- composite

Two composite designs:

- **Stiff: design has similar eigenfrequencies to steel**
- **Flexible: design has similar strength to steel, but lower eigenfrequencies**

Eigenfrequencies



	Stiff	Flexible
Top thickness (D 5.5m)	200 mm	10 mm
Bottom thickness (D 80m)	450 mm	32 mm
Tower weight	1191 ton	92 ton
1st frequency	0.199 Hz	0.065 Hz
2nd frequency	Not relevant	0.217 Hz
Maximum stress	168.7 MPa	330.2 MPa
Buckling SF	47.4	<< 1

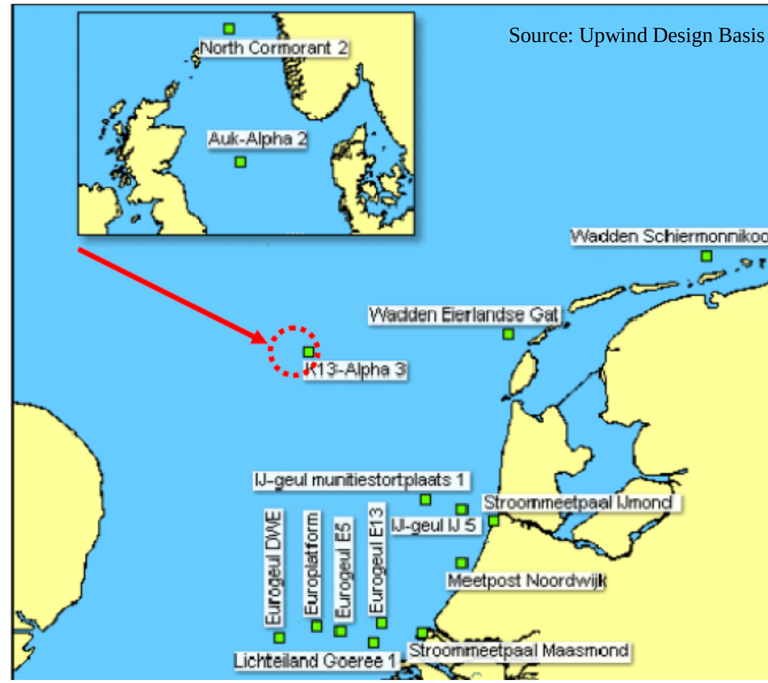
Optimization

- **Constraints:**
  - 1st side-to-side frequency: below 1P range
  - 2nd side-to-side frequency: over 3P range
  - Idem fore-aft frequencies
  - Buckling safety factor > 1
  - Stresses below critical value

- **Target: Minimization of tower mass**

Environmental conditions

- K13 North Sea location
- 25 m water depth
- Load cases defined according to IEC 61400-3



Ultimate strength analysis

- **Extreme load cases selected**
- **Parameters in optimization run**
  - Wall thickness distribution
  - Fibre orientation
  - Relative thickness of layers
- **Full FEM assessment at end of optimization loop**
- **Result: for a glass fibre reinforced epoxy stresses are below critical values**

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Fatigue analysis

- **Wind-wave directionality plays role in tower loading**
  - More aerodynamic damping by rotor for the tower motions when wave direction is aligned with wind
  - Results in large amount of load cases to consider
- **Slightly reduced set**
  - Maximum of 3 combinations of wave period and wave height per wind speed bin
  - 1824 load cases in total

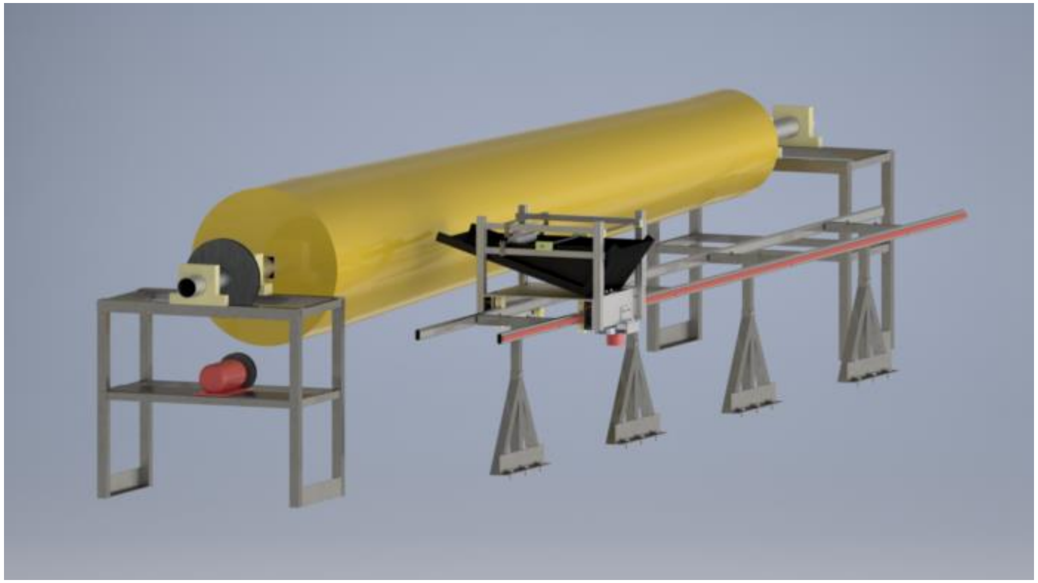
Fatigue analysis

- Values for Ultimate Tensile Strength (UTS) and Ultimate Compressive Strength (UCS) assumed
- Fatigue Reserve Factors determined at locations at 4 m intervals throughout tower
- 20 year fatigue lifetime possible with UTS = 132.7 MPa; UCS = 92.9 MPa
- All safety factors according to GL Guidelines taken into account

Manufacturing

Filament winding:

- Automation possible
- Consistent and highly controllable
- Angles close to 0 degrees



Manufacturing

- **Machine for manufacturing scale model being built now**

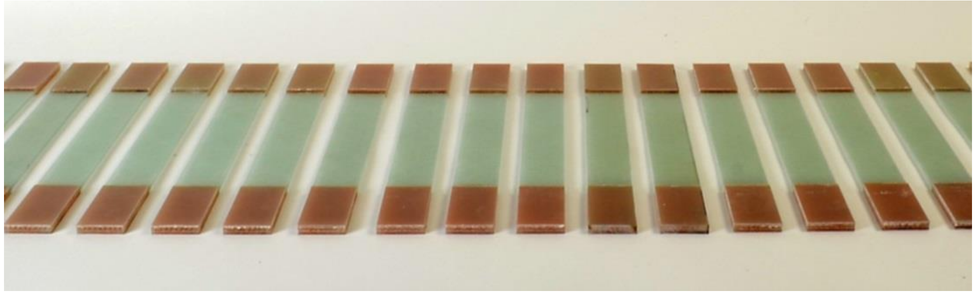
Photo: Jules Dock Composites

Conclusions so far

- **Calculations show that flexible composite tower is feasible**
  - 34% mass reduction compared to steel baseline tower
  - Tower top deflection of less than 3 degrees
- **For a real competitive design, an integrated approach including substructure and control strategy is required**

Next phase

- Completion of filament winding machine
- Material testing on small test coupons



- Production of the scaled model
- Testing of the scaled model at WMC

Thank you for your attention

Questions?

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