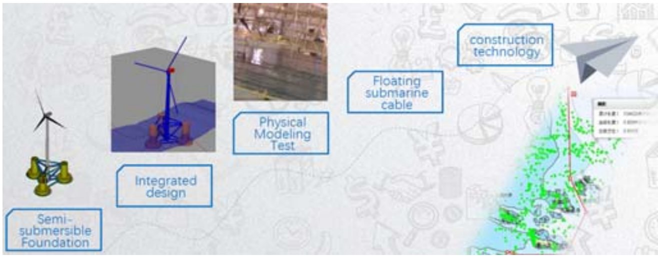
UK&CHN Centre for Offshore Renewable Energy

Joint UK-China Offshore Renewable Energy (ORE) call (2017)



General consideration / Goals and Objectives

The UK – China Offshore Renewable Energy programme aims to develop the next generation of offshore renewable energy (ORE) technologies to enable the safe, secure, cheap and efficient provision of clean energy.

As part of that programme, EPSRC and NERC have co-funded 5 UK-China Projects:

- **ResIn: Resilient Integrated-Coupled FOW platform design methodology; Lars Johanning** (EP/R007519/1)
- **FENGBO-WIND: Farming the Environment into the Grid: Big data in Offshore Wind; Mike Graham** (EP/R007470/1)
- **Extreme wind and wave loads on the next generation of offshore wind turbines; Tom Adcock** (EP/R007632/1)
- **INNO-MPP: Investigation of the novel challenges of an integrated offshore Multi-Purpose Platform** (EP/R007497/1)
- **MOD-CORE: Modelling, Optimisation and Design of Conversion for Offshore Renewable Energy** (EP/R007756/1)

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Objectives of UK – China “ORE network”

Sharing

This UK-China CORE program will help to develop the interface between researchers and the user community in government and businesses outside the programme membership, and to share research outcomes, data resources and best practice between the grants – all designed to maximise impact.

Knowledge

The ORE program ambition is to develop the next generation of technologies for the safe, secure, cheap and efficient provision of clean energy; building resilience against extreme events into ORE systems.

Innovation

The activities will be directly build into a ‘Research Bridge’ using the outcomes to exchanging the knowledge into the other themes, whilst using the bridge to inform the activities within this project to enable a joined-up interdisciplinary and international programme of work.

Impact

To develop a knowledge exchange strategy which incorporates a plan of co-ordinated activities and details how the research teams will work together to engage stakeholders and maximise impact through the establishment of the UK-China CORE programme

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OFFSHORE RENEWABLE ENERGY

Engagement activities

Key elements of Engagement plan:

i) 3 cross-country events,
ii) Summer Schools,
iii) Public School engagement,
iv) (internships), and
v) (flex funds).

All researchers will hopefully actively engage in this activities enabling a cross-country knowledge exchange and research collaborations.

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UK & China Centre for Offshore Renewable Energy

Publications →

Building a better future through a shared knowledge platform

A combined UK and China government initiative, the ORE International Impact Platform is a space where industry leaders and educational institutions' shared knowledge is brought together from across the world.

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www.ukchn-core.com

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Resilient Integrated-Coupled FOW platform design methodology (ResIn)

Prof. Lars Johanning
University of Exeter

SUPERGEN Wind General Assembly
Dundee, 08th November 2018

China-UK Offshore Renewable Energy

Resilient Integrated-Coupled FOW platform design methodology (ResIn)

Prof. Bing Chen
Dalian University of Technology

Prof. Lars Johanning
University of Exeter

2013


EXETER
EPSRC
Newton Fund
China-UK
llaborative
rkshop
Renewable Energy

2017

Project Overview

- Aim: “To enhance the design and development of floating offshore renewables, in particular offshore floating wind, as commercially viable electricity infrastructure through a risk based approach allowing building resilience against extreme events.”

- Duration: 3 years – 07/2017 – 06/2020

Academic Partners - UK

- University of Exeter (Prof Johanning, Prof Tabor, Prof Pavic, Dr Thies)
    - Hydrodynamic modelling and testing (WP2)
    - CFD modelling (WP3)
    - Structural Reliability assessment (WP4)
- University of Edinburgh (Prof Ingram, Dr Venugopal)
    - Environmental modelling (WP1)
    - CFD coupling (WP3)
- University of Bath (Dr Zang, Dr Blenkinsopp)
    - Particle-In-Cell (PIC) modelling method (WP3)

Academic Partners - China

- Dalian University of Technology (Prof Chen,)
  - Environmental conditions (WP1)
  - OWC damper, Experimental testing (WP2)
  - Hydrodynamic numerical modelling (WP3)
  - Concrete materials (WP4)
- Zheijang University (Dr Zhang)
  - Environmental conditions (WP1)

Industry Partners - UK

- DNV – GL
  - Attendance Knowledge Exchange Workshops
  - Input through Advisory Meetings
  - Review of technical project outcomes (floating platform innovation) to advise on suitable qualification and certification routes with increasing TRL.
- ITPEnergised
  - Participate in Knowledge Exchange Activity
  - Attendance of Industry Forum Workshops
  - Existing contacts/ network in China
- Offshore Catapult
  - Providing industrial guidance on the scope/outputs (Foundations / sub-structures)
  - Participate in Knowledge Exchange Workshop
  - Guidance on the Catapult Innovation processes
  - Host a postdoctoral researcher for 2 month secondment.

Industry Partners - International

- DSA
  - Participate in Knowledge Exchange activities
  - Guidance on industrial relevance of advanced coupled computational modelling
- EDF
  - Potential ‘end-user’ for technology and modelling outcomes
  - Participate in Knowledge Exchange activities
  - Provide guidance through Advisory

Industry Partners - China

- MingYang Wind Power
  - Participate in Knowledge Exchange activities
  - Offer Innovation Training to their Engineers
  - Participate in Industry Forum workshops
- Shanghai Investigation, Design and Research Institute
  - Participate in Knowledge Exchange activities
  - Participate in Industry Forum workshops

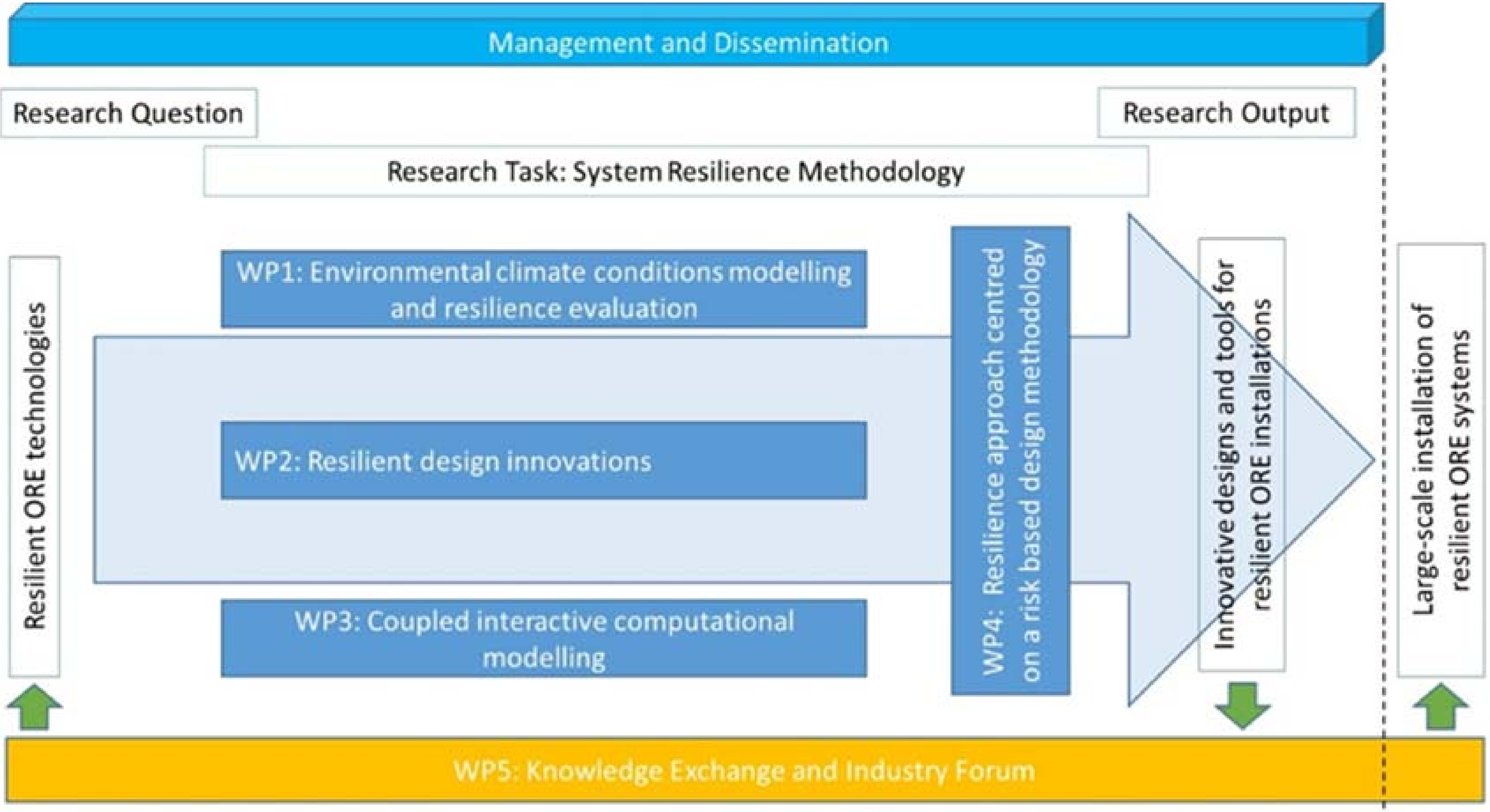
ResIn – 1st UK-China workshop

10th – 14th November 2017, Dalian University of Technology, Dalian, China

Dalian University of Technology International Convention Center, China,
Liaoning Sheng, Dalian Shi, Ganjingzi Qu, 凌工路 2 号

Work Packages

1. Enhanced environmental modelling to accurately determine extreme loadings;
2. Assessment of novel, porous floating offshore wind structures and active damping mechanisms;
3. Enhanced numerical modelling techniques to efficiently calculate the complex coupled behaviour of floating wind turbines;
4. Risk based optimisation of designs and engineering implications.



Management and Dissemination

Research Question

Research Output

Research Task: System Resilience Methodology

Resilient ORE technologies

WP1: Environmental climate conditions modelling and resilience evaluation

WP2: Resilient design innovations

WP3: Coupled interactive computational modelling

WP4: Resilience approach centred on a risk based design methodology

Innovative designs and tools for resilient ORE installations

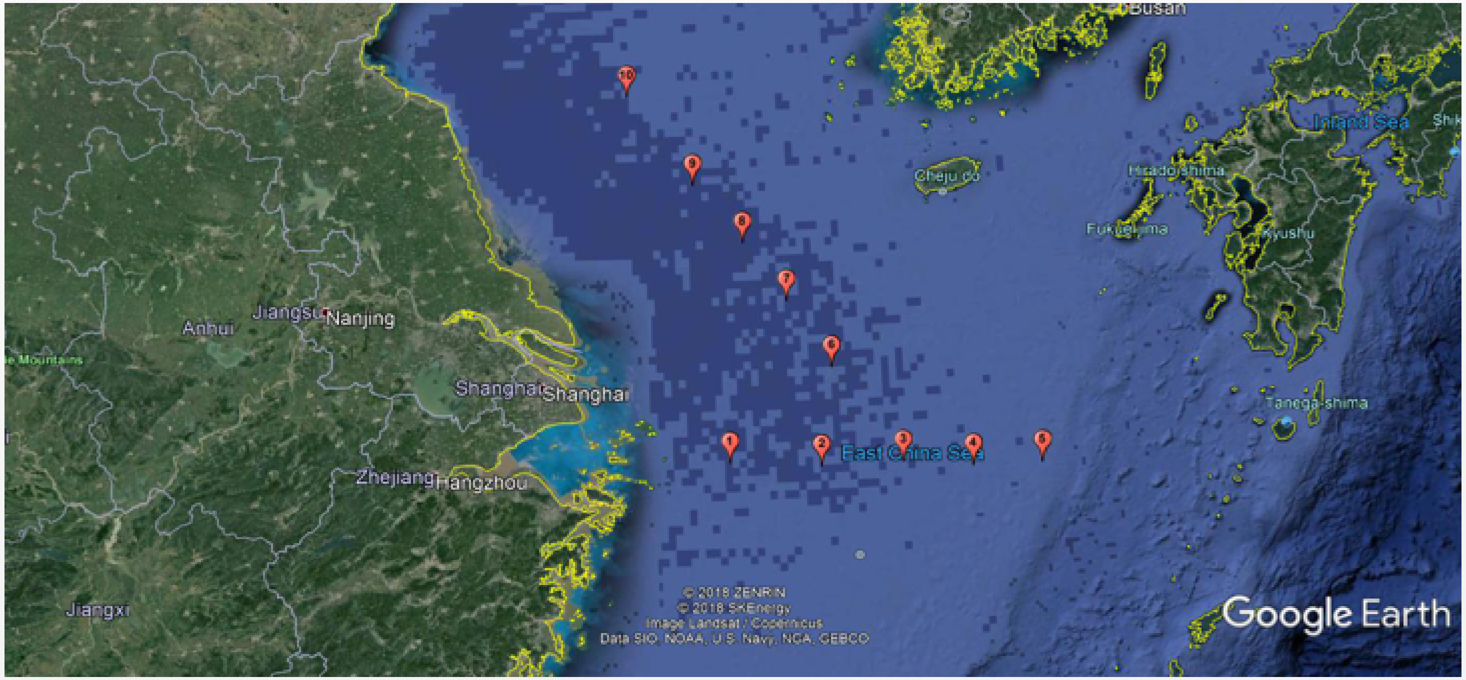
Large-scale installation of resilient ORE systems

WP5: Knowledge Exchange and Industry Forum

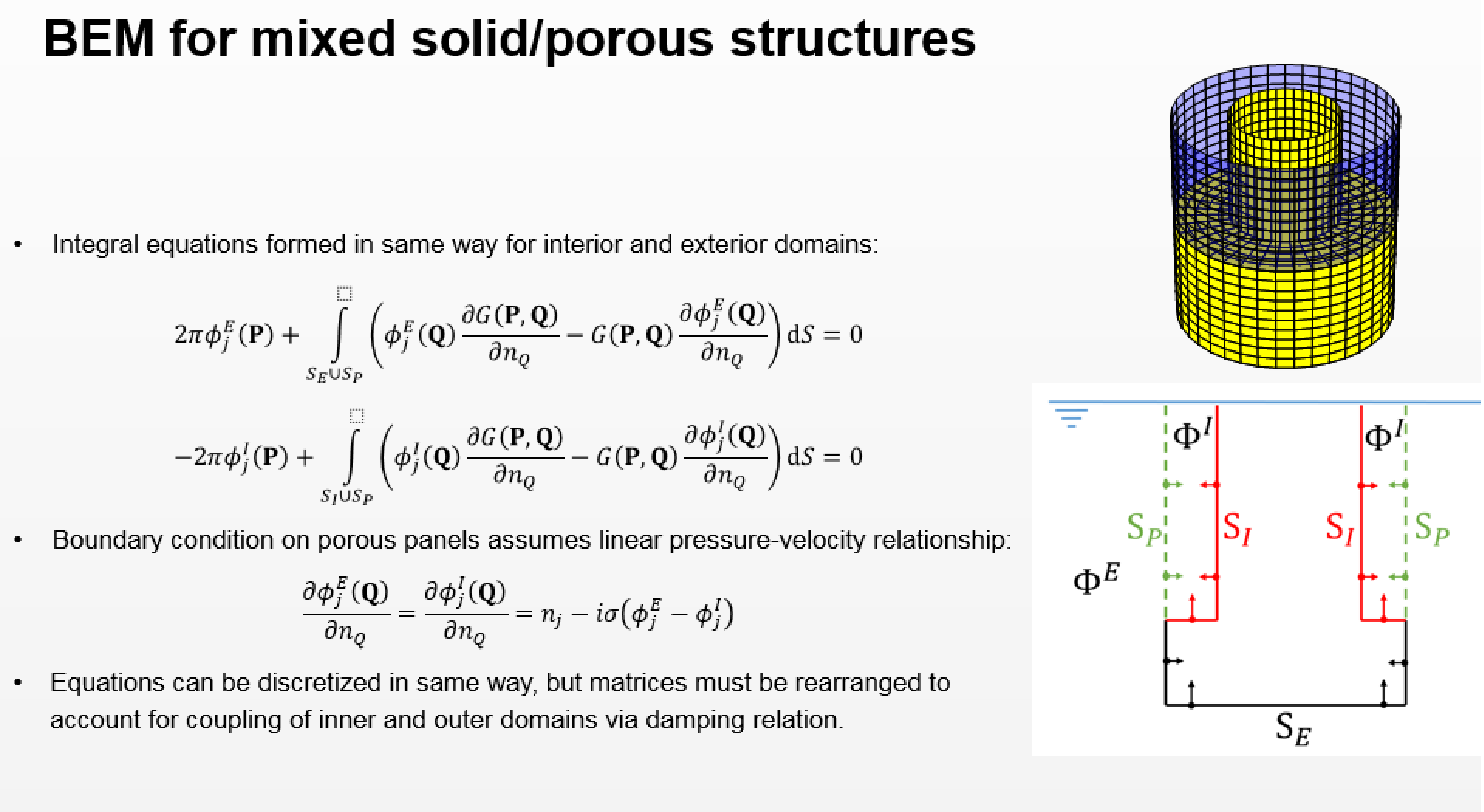
WP1 - Enhanced environmental modelling

Wind analysis

- Calculate return period values using annual maxima method
- PDF fitting



WP2 - Assessment of novel, porous floating offshore wind structures



BEM for mixed solid/porous structures

- Integral equations formed in same way for interior and exterior domains:

$$2\pi\phi_j^E(\mathbf{P}) + \overset{\square}{\int}_{S_E \cup S_P} \left(\phi_j^E(\mathbf{Q}) \frac{\partial G(\mathbf{P},\mathbf{Q})}{\partial n_Q} - G(\mathbf{P},\mathbf{Q}) \frac{\partial \phi_j^E(\mathbf{Q})}{\partial n_Q} \right) \mathrm{d}S = 0$$

$$-2\pi\phi_j^I(\mathbf{P}) + \overset{\square}{\int}_{S_I \cup S_P} \left(\phi_j^I(\mathbf{Q}) \frac{\partial G(\mathbf{P},\mathbf{Q})}{\partial n_Q} - G(\mathbf{P},\mathbf{Q}) \frac{\partial \phi_j^I(\mathbf{Q})}{\partial n_Q} \right) \mathrm{d}S = 0$$

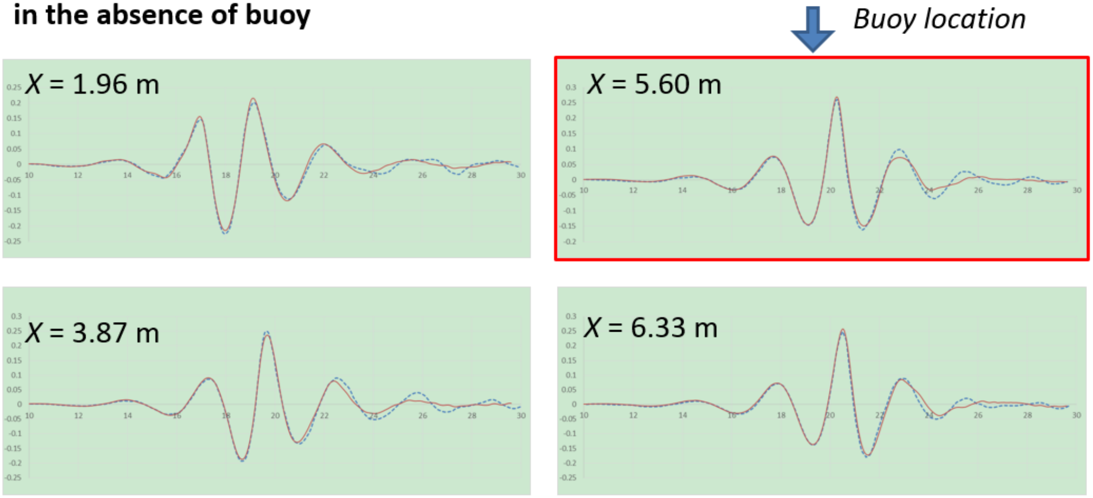
- Boundary condition on porous panels assumes linear pressure-velocity relationship:

$$\frac{\partial \phi_j^E(\mathbf{Q})}{\partial n_Q} = \frac{\partial \phi_j^I(\mathbf{Q})}{\partial n_Q} = n_j - i\sigma\left(\phi_j^E - \phi_j^I\right)$$

- Equations can be discretized in same way, but matrices must be rearranged to account for coupling of inner and outer domains via damping relation.

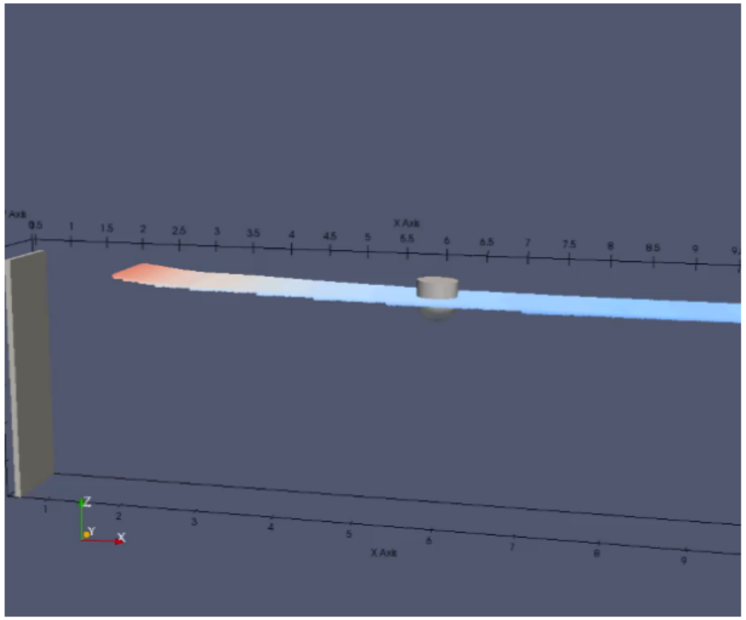
WP3 - Enhanced numerical modelling

Focused wave generation in the absence of buoy



Dashed line: experiment; Solid line: numerical

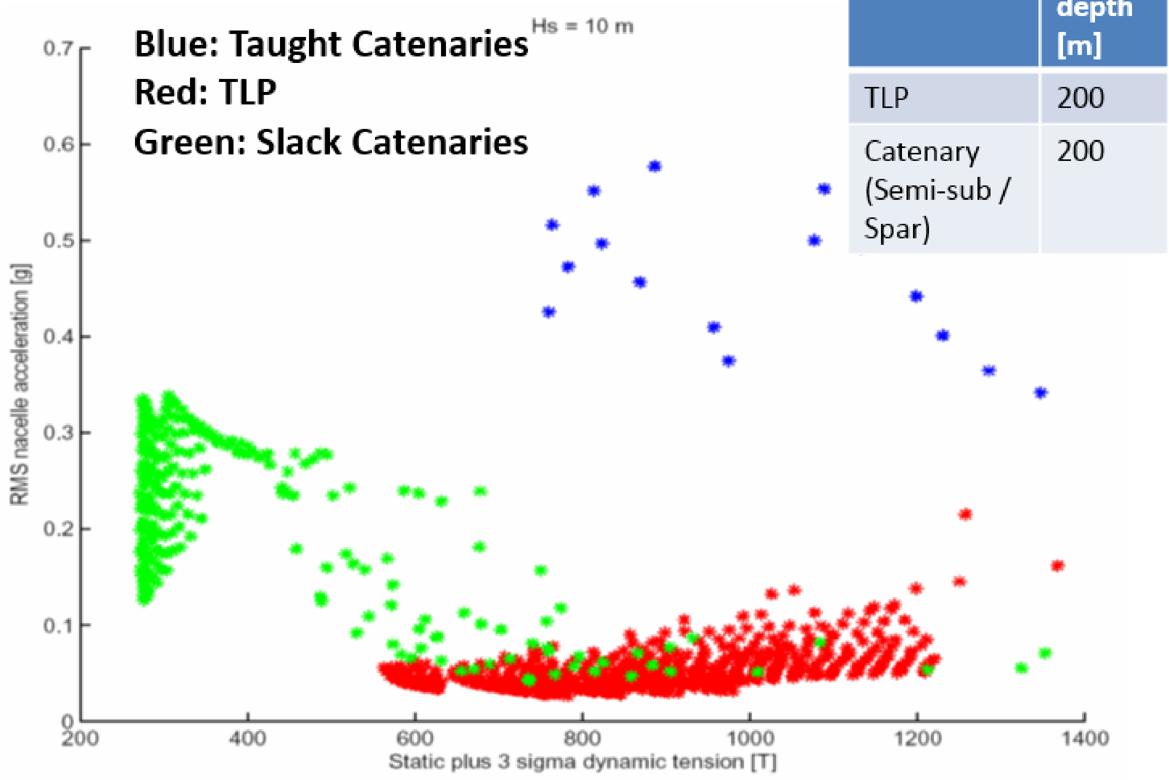
Wave-structure interaction



WP4 - Risk based optimisation of designs

Design Load estimation

Name	Water depth [m]	Sig. wave height, Hs [m]	Static + Dynamic tension [MN]
TLP	200	10	6.9 - 12
Catenary (Semi-sub / Spar)	200	10	2.5 - 6.5

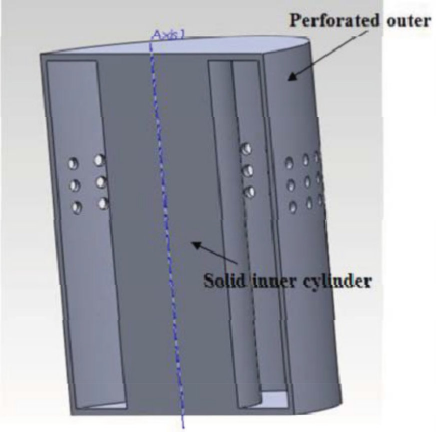


Blue: Taught Catenaries
Red: TLP
Green: Slack Catenaries

WP2 – porous elements for floating offshore wind structures

Why porous structures?

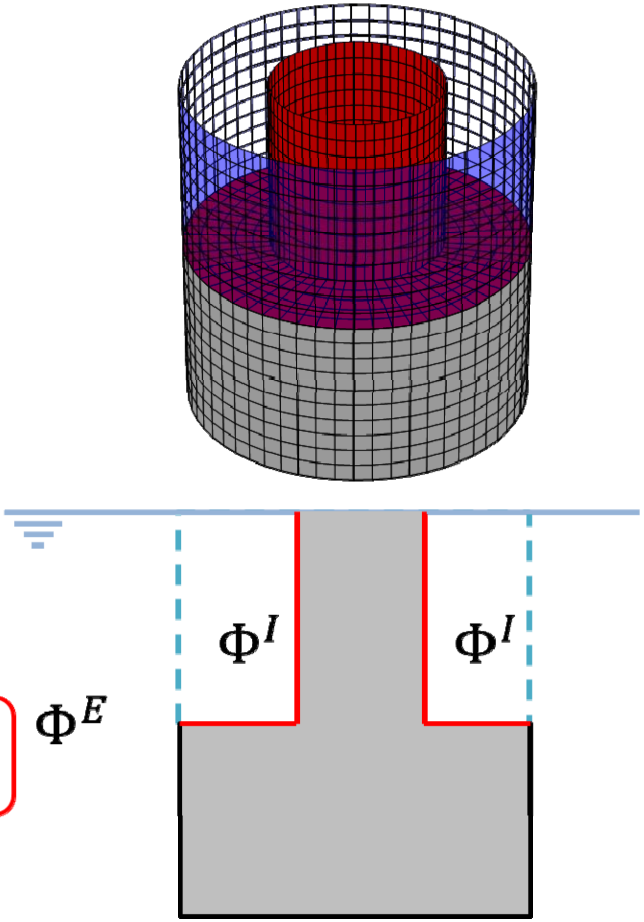
- Reduce wave loads on floating platform
- Increase motion damping
  - ▸ Reduce platform motions
    - → Reduce energy loss from turbine
    - → Reduce fatigue damage on structure and drivetrain
  - ▸ Reduce mooring loads



Problem formulation

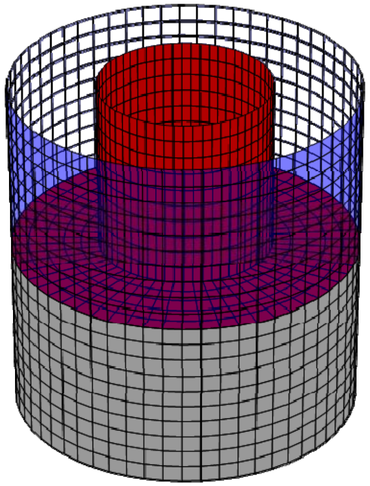
- Fluid divided into internal/external domains
- Standard decomposition of potential into radiation and diffraction components

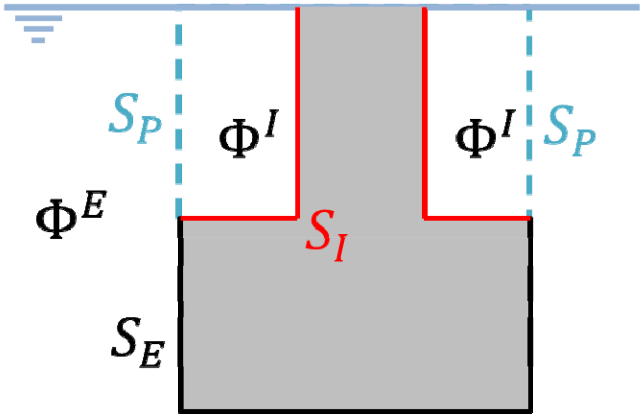
$$\Phi^{E,I}(\mathbf{x},t) = \mathrm{Re}\left\{ e^{i\omega t}\left[\underbrace{\frac{igA}{\omega}}_{\text{Wave amplitude}}\left[\underbrace{\phi_0(\mathbf{x})}_{\text{Incident potential}} + \underbrace{\phi_7^{E,I}(\mathbf{x})}_{\text{Scattered potential}}\right] + i\omega\sum_{j=1}^{6}\underbrace{\xi_j}_{\text{Motion amplitude}}\underbrace{\phi_j^{E,I}(\mathbf{x})}_{\text{Radiation potential}}\right]\right\}$$



Boundary conditions

- Standard boundary conditions on free-surface, sea bed and solid surfaces, S_E, S_I
- Additional boundary condition on porous surface, S_P:
  - Continuity of velocity: $\frac{\partial \phi_j^E}{\partial n} = \frac{\partial \phi_j^I}{\partial n}$
  - Pressure drop: $\frac{\partial \phi_j^E}{\partial n} = n_j - i\sigma(\phi_j^E - \phi_j^I)$
    - n_j = normal velocity of surface in jth mode
    - σ = porosity coefficient (0 if solid, ∞ if no porous wall)





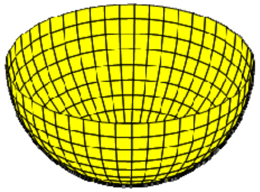
Pressure loss at porous boundary

$$\frac{\Delta P}{\rho} = \underbrace{\boxed{\frac{\nu}{l} U_n}}_{\text{Viscous loss: significant at low Re}} + \underbrace{\boxed{\frac{C_f}{2} U_n |U_n|}}_{\text{Turbulent dissipation: significant at high Re}} + \underbrace{\boxed{L \frac{\partial U_n}{\partial t}}}_{\text{Added mass: Dependent on size of openings}}$$

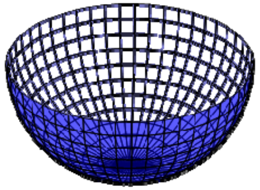
- ΔP = pressure drop
- ρ = fluid density
- ν = kinematic viscosity
- U_n = velocity normal to porous boundary
- l = friction coefficient (dimension length)
- C_f = dissipation coefficient (dimensionless)
- L = added mass coefficient (dimension length)

WP2 – porous elements for floating offshore wind structures

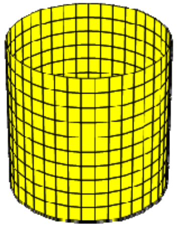
Verification and validation of BEM model



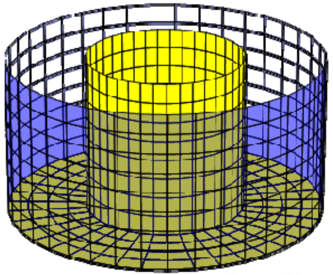
Solid hemisphere
(Deep water)



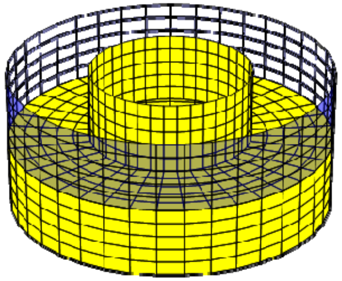
Porous hemisphere
(Deep water)



Bottom mounted cylinder
(Finite depth)



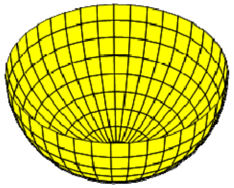
Bottom mounted cylinder
with porous outer cylinder
(Finite depth)

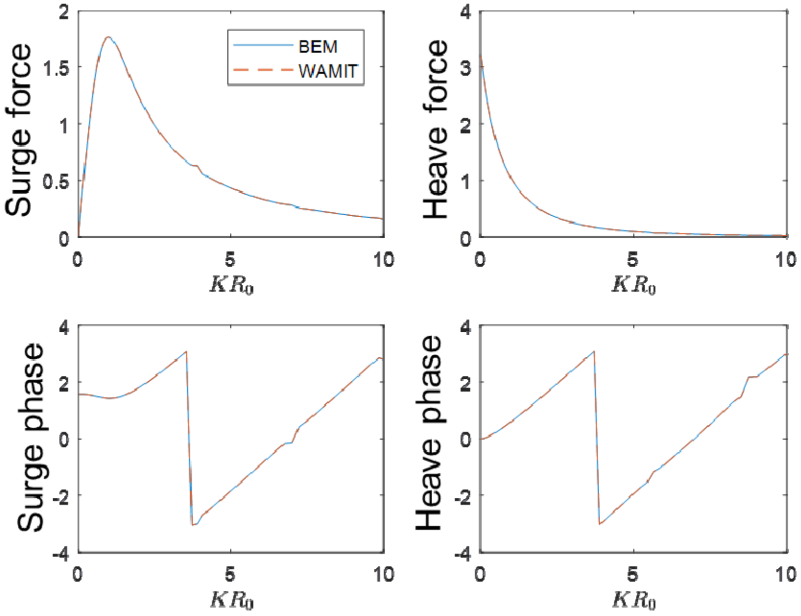


Truncated cylinder with
porous outer cylinder
(Deep water)

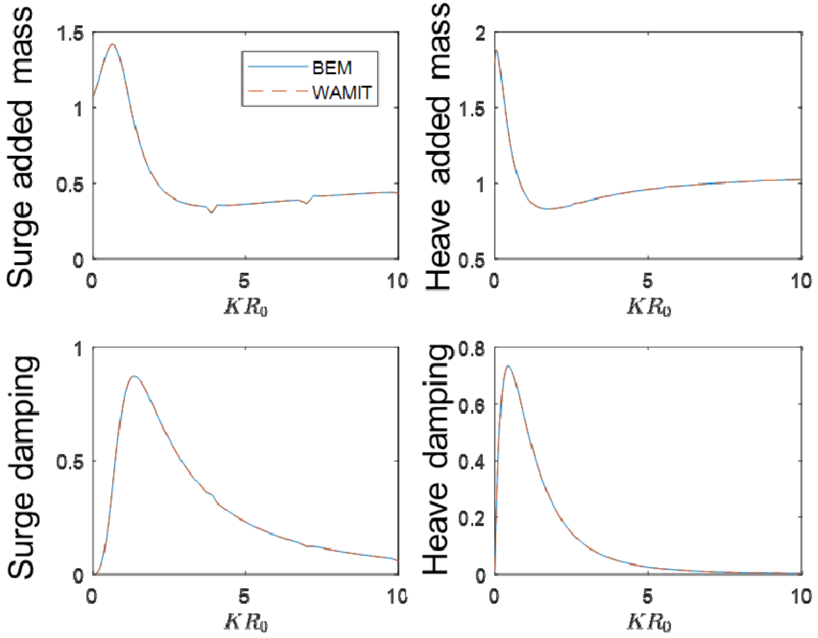
Numerical Comparison via WAMIT

Solid hemisphere (deep water)





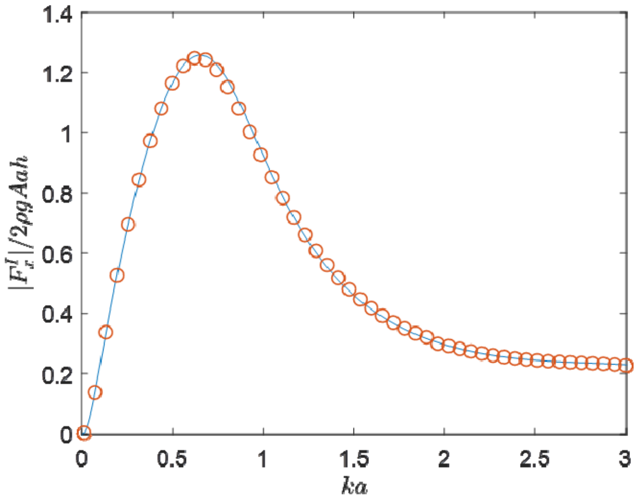
Non-dimensional excitation force vs. non-dimensional frequency



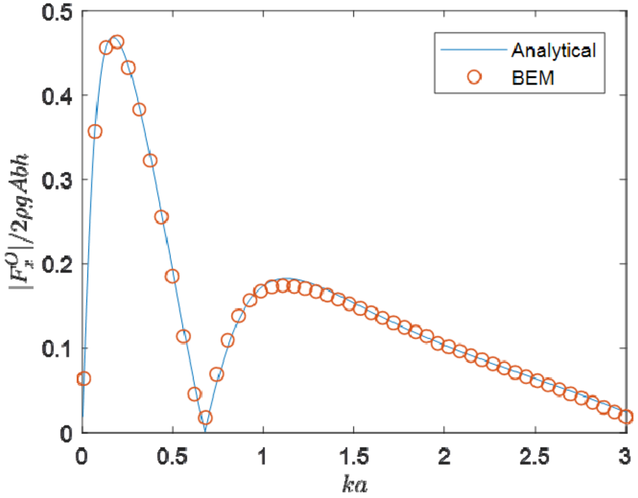
Non-dimensional added mass and radiation damping

Numerical Comparison via Analytic model: Wang & Ren (1994)

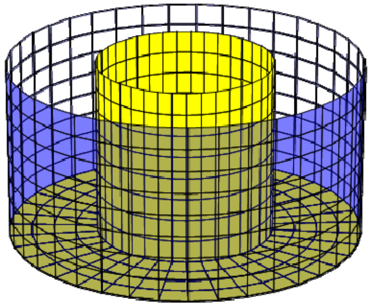
Concentric cylinder (finite depth)



Non-dimensional surge force on inner cylinder



Non-dimensional surge force on outer cylinder



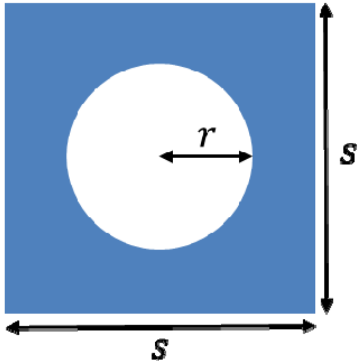
Water depth = h
Inner radius = a = h
Outer radius = b = 2h
Porosity coef. G = 2

WP2 – porous elements for floating offshore wind structures

Experimental Comparison

Tank tests at DUT, China

- Porous cylinder with / without solid inner cylinder
- Solid cylinder Ø250mm
- Porous cylinders Ø375, 500, 750mm
- Water depth $h = 1$ m
- Porosities $\tau = 0.1, 0.2, 0.3$
- 300 tests (29 regular waves, 4 irregular waves)



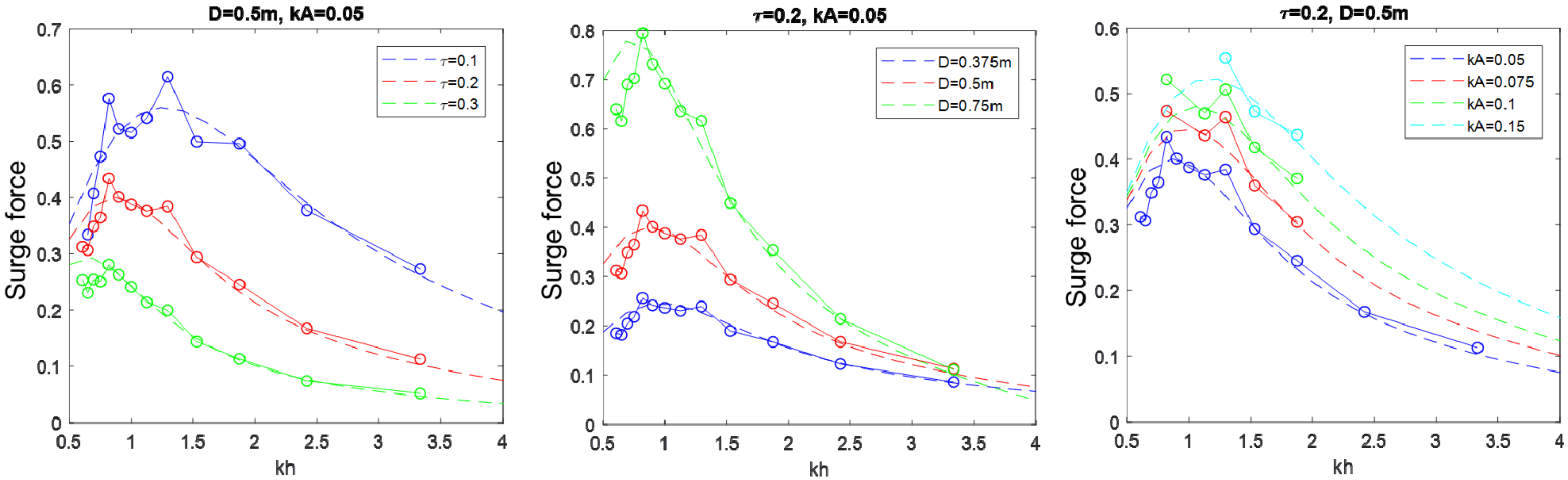
Porosity

$$\tau = \frac{\pi r^2}{s^2}$$

WP2 – porous elements for floating offshore wind structures

Experimental Comparison

Validation against tank tests (outer cylinder only)



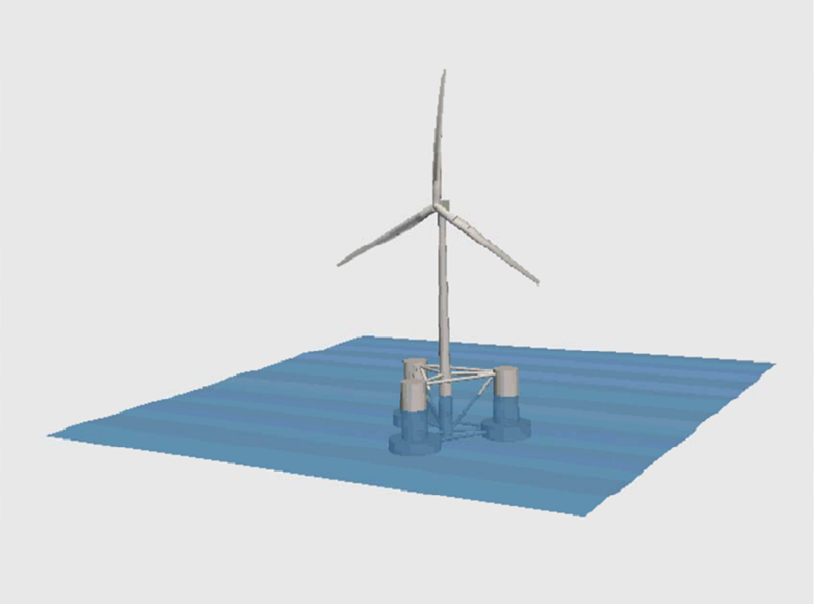
Non-dim. surge force vs non-dim. frequency

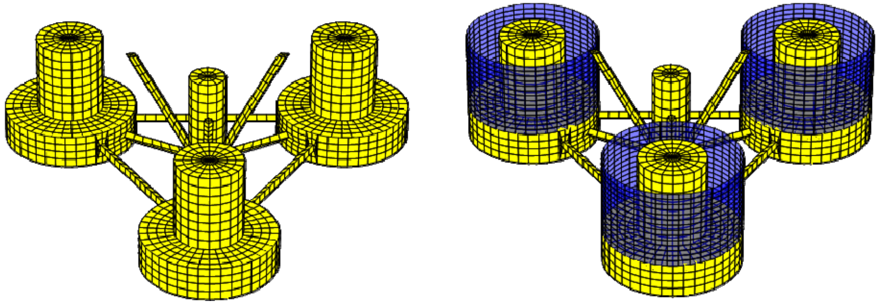
Circles: experimental. Dashed lines: numerical

WP2 – porous elements for floating offshore wind structures

Next steps

- Numerical investigations into effect of porous shroud in terms of:
    - Excitation force
    - Added mass & damping
    - Mean drift force
    - Motion RAOs
- Tests at FloWave & DUT to validate numerical predictions





Resin Publication to date

Journal papers:

- C. Yang, Y. Wang, S. Weller, De-Zhi Ning, L. Johanning; (2018). Experimental and numerical investigation on coupled motion characteristics of a tunnel element suspended from a twin-barge; Ocean Engineering 153 (2018) 201–214, doi: 10.1016/j.oceaneng.2018.01.112
- Mackay E, Johanning L. (2018) A generalised equivalent storm model for long-term statistics of ocean waves, Coastal Engineering, volume 140, pages 411-428, DOI:10.1016/j.coastaleng.2018.06.001.
- E. Mackay , L. Johanning (2018) Long-term distributions of individual wave and crest heights, Ocean Engineering, volume 165, pages 164-183, DOI:10.1016/j.oceaneng.2018.07.047.
- E.B.L. Mackay. "Approximation of the free-surface Green function in finite depth" J. Eng. Math. (Submitted)

Conference papers:

- E. Mackay, L. Johanning. (2018) A Simple and Robust Method for Calculating Return Periods of Ocean Waves. Proceedings of the ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering, OMAE2018, June 17-22, 2018, Madrid, Spain.
- E. Mackay, A. Feichtner, R. Smith, P.R. Thies, L. Johanning. (2018) Verification of a Boundary Element Model for Wave Forces on Structures with Porous Elements. RENEW 2018, 3rd International Conference on Renewable Energies Offshore, 8 - 10 October 2018, Lisbon, Portugal.

Thank you for listening - Questions

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Hai DU