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Passive Control of Wave Induced Platform Motions for Semi-submersible FOWTs

Ling Qian, Yang Zhou and Wei Bai

Centre for Mathematical Modelling and Flow Analysis
Department of Computing and Mathematics
Manchester Metropolitan University

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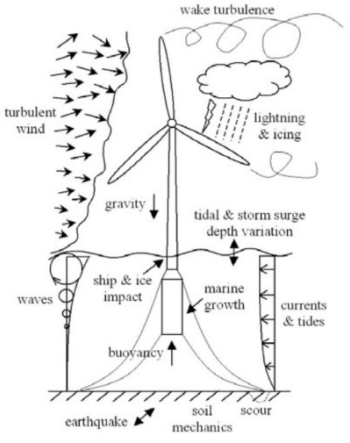
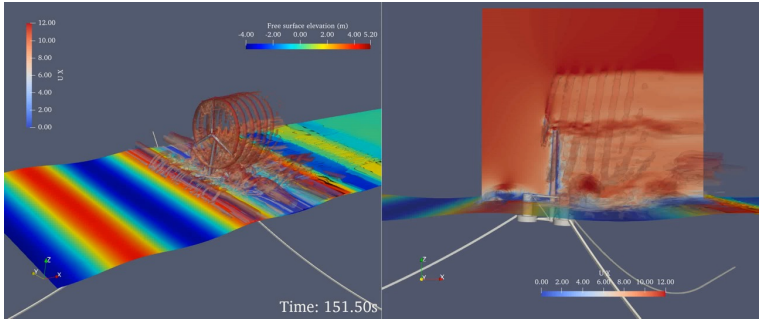
Background

- Floating offshore wind – a promising future ORE technology
- Operating in deep water and harsh marine environment
- For safe/efficient operation and survivability, FOWT platform motions due to waves and wind must be limited
- The project aims to evaluate the effectiveness of a novel Tuned Liquid Multi-Column Dampers (TLMCDs) for mitigating wave induced rotational motions of semi-submersible FOWT platforms



Environmental loads on offshore floating turbines



Dynamical response of floating offshore wind turbines

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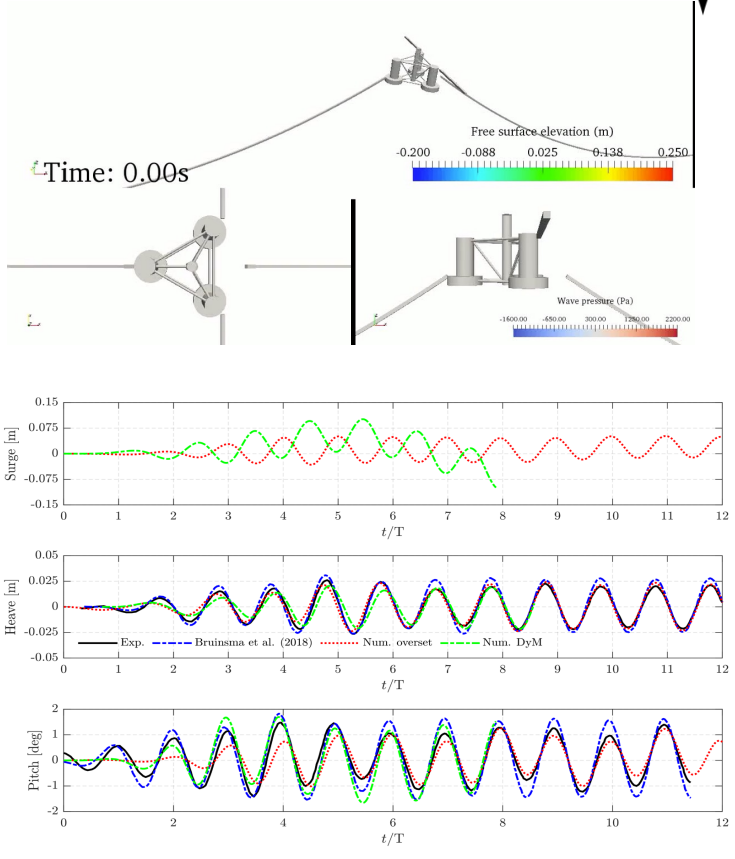
Numerical Approach

- OpenFOAM CFD tool box
  - Multiphase Navier-Stokes solvers
  - Overset and Dynamic mesh for 6DoF body motions
  - Wave generation and absorption based on relaxation zone approach (IHFoam)
  - Catenary/Quasi-static/Lumped Mass models for mooring line dynamics
  - Both wave and wind loads are included.
  - Good parallel scalability
  - Extensively validated



Responses of a FOWT floater under regular waves

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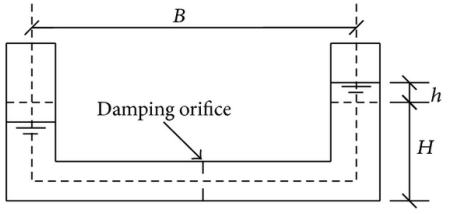
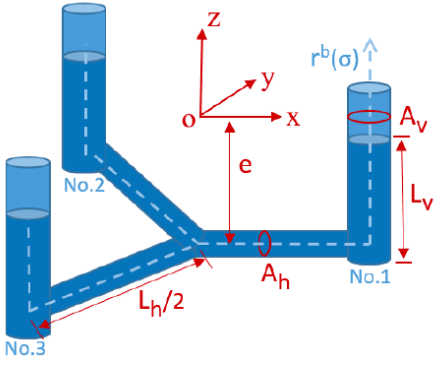
Design of TLMCDs

- Extended from traditional U-tanks (anti-roll tanks)
- Multiple inter-connected columns for better response to changing wave directions
- To be effective, the natural frequency of the internal sloshing needs to be tuned to the dominant frequency of pitch (roll) motion

$$\omega = \sqrt{\frac{2*g}{L_h*\frac{A_v}{A_h}+2L_v}}$$



Classic tuned liquid column damper (TLCD)



Tuned liquid multi-column damper (TLMCD)[1,2]

A semi-sub support structure

[1] W. Yu and P-W Cheng, Proceedings of 30th International Ocean and Polar Engineering Conference, 2020.
[2] Christophe Coudurier, Olivier Lepreux, Nicolas Petit, Ocean Engineering, Volume 165, 2018, Pages 277-292.

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Validation of the Numerical Approach

- A U-shaped TLCD under prescribed roll motion (Roll amplitude: 2 deg)

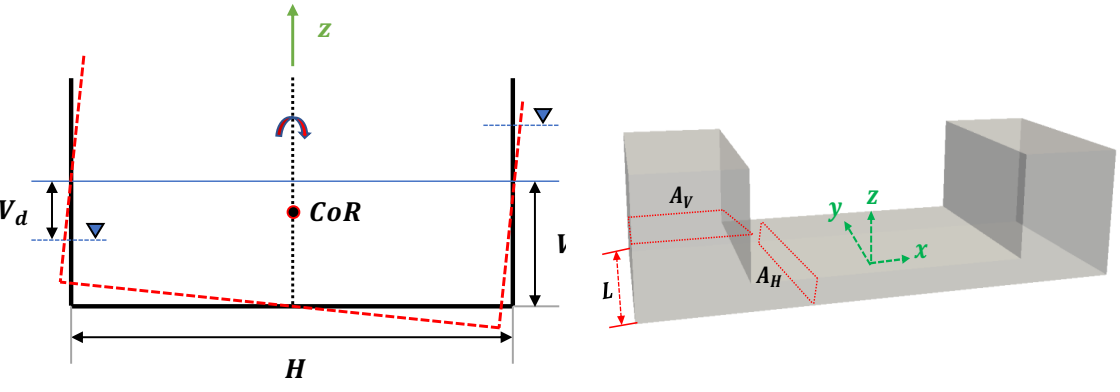
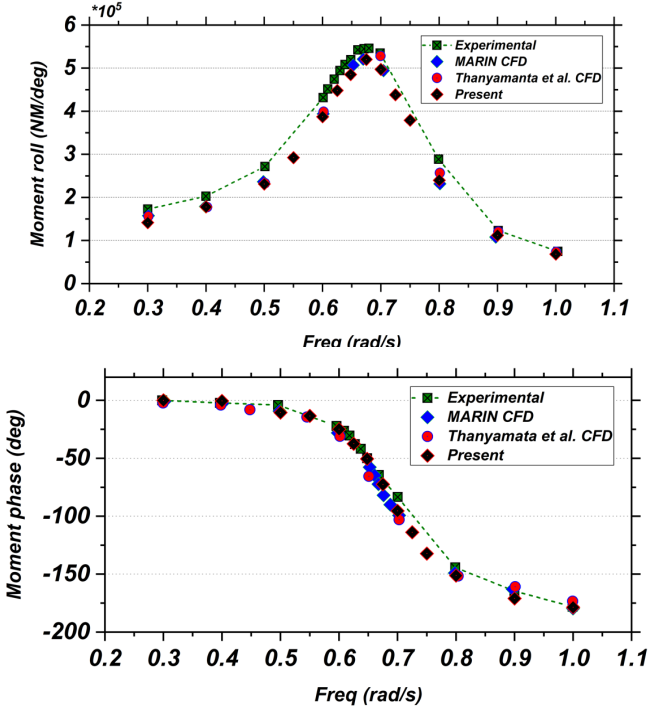


Table 1 Dimensions of the U-shaped TLCD water tank

H (m)	V_{CoR} (m)	V (m)	V_d (m)	A_H (m^2)	A_V (m^2)	L (m)
12.800	1.372	1.524	0.160	3.254	14.631	5.334

The U-shaped TLCD



Predicted roll moment and phase lag

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Sloshing under pitch only and surge only motion

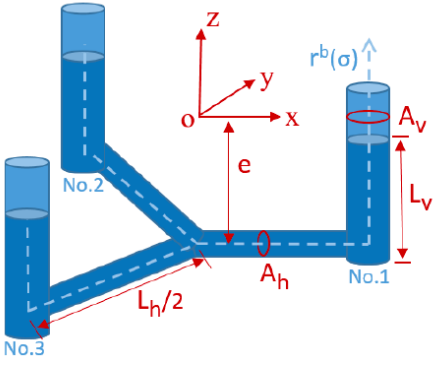
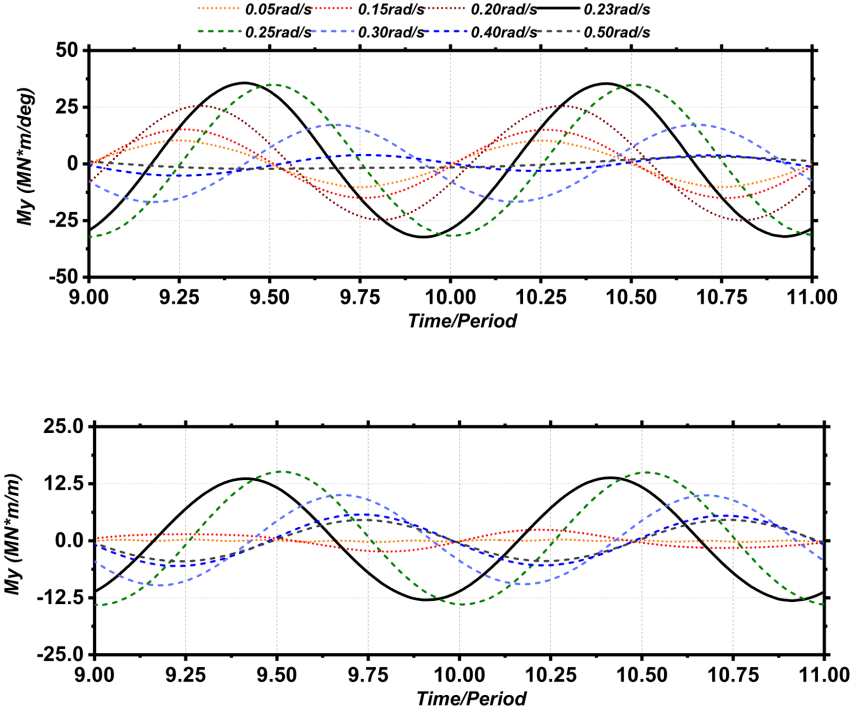


Table 2 Dimensions of the star-like TLMCD

L_h (m)	V_{CoR} (m)	L_v (m)	A_h (m^2)	A_v (m^2)
56.10	4.50	6.00	8.04	50.24



Predicted pitch moments under prescribed motions. top: pitch (2 deg); bottom: surge (4 m)

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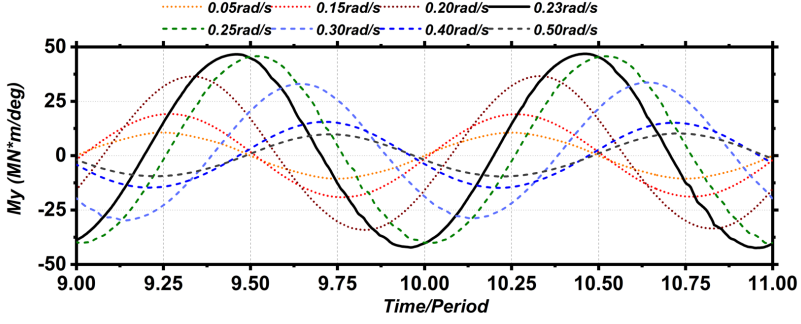
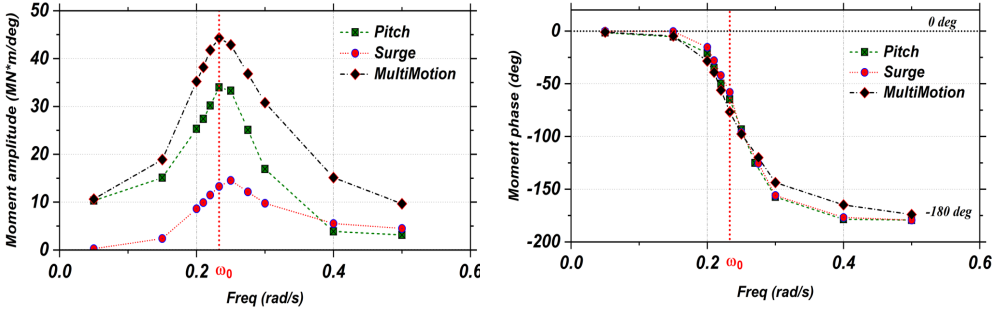
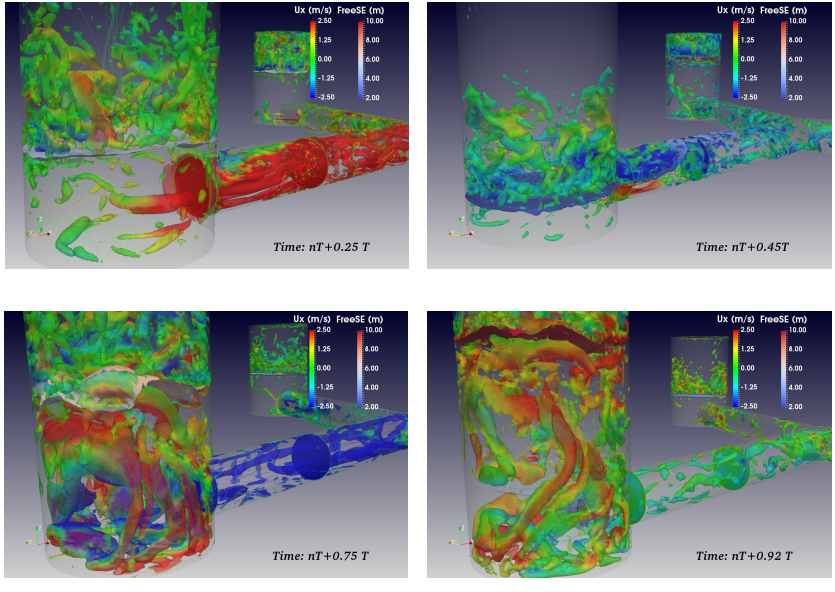
Sloshing under combined surge and pitch motion



Pitch moment under combined surge and pitch motion



Amplitude and phase lag of the predicted pitch moments under surge, pitch and combined motions



Vorticity plots of the side column under four time instants

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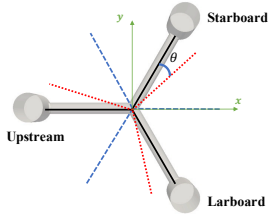
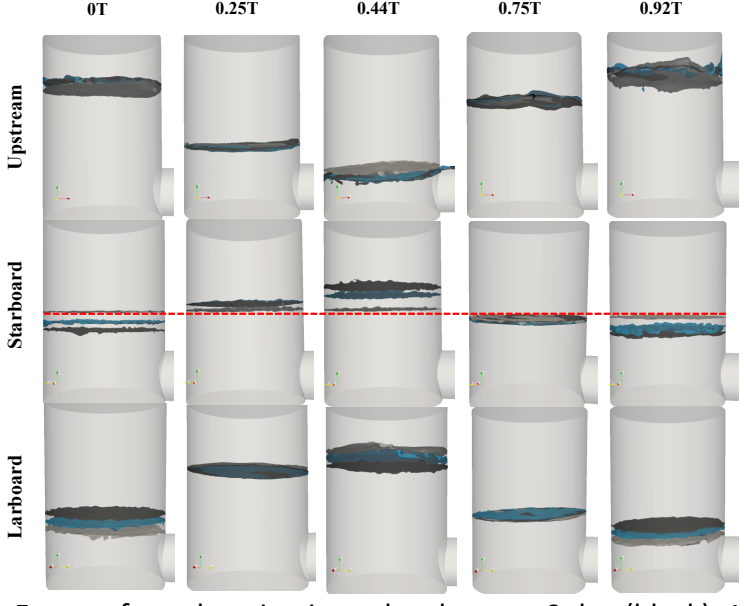
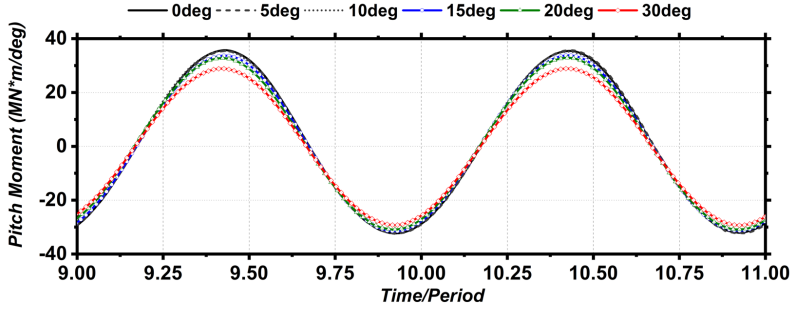
Sloshing under combined pitch and roll motions



Sketch of the TLMCD under different rotation angle around z axis



Free surface elevation in each column at 0 deg (black), 15 deg (blue) and 30 deg (grey)



Pitch moment under combined pitch and roll motion

- Combined pitch and roll motion is added on the TLMCD by rotating the TLMCD to a prescribed angle (<30deg)
- The three-column star-like TLMCD is a better option than U-shape TLCD to reduce the platform motion, it is more robust under different inflow directions indicated by the pitch moment is not significantly changed

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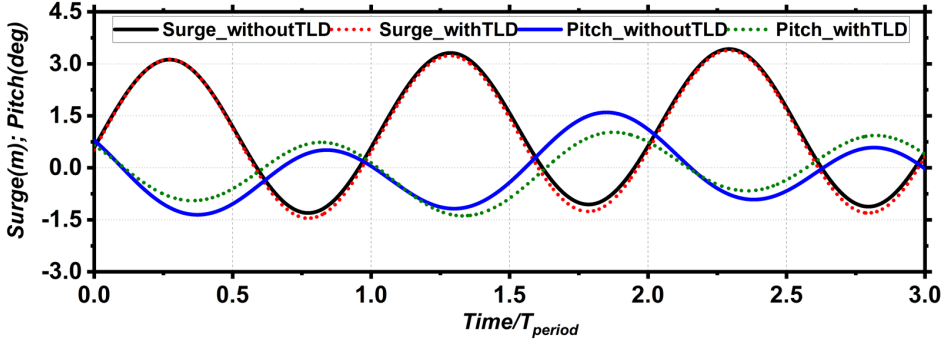
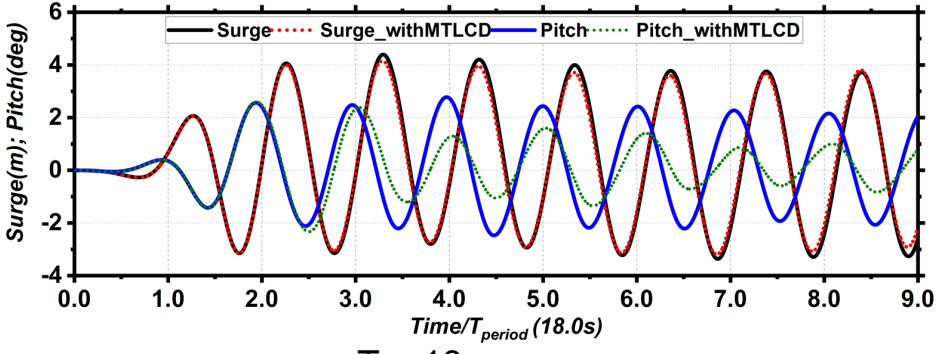
Dynamic Response of the floater with and wihtour a TMLCD

- Wave parameters:
  - 2nd Stokes waves; H:7.58 m T: 12.1 s and 18 s
- Surge motion not affected much with the TLMCD
- Reduction in pitch motion due to internal liquid sloshing of the TLMCD observed



T = 12.1 s



T = 18 s

Summary and Next Step

- Sloshing dynamics of a novel tuned liquid multi-column damper has been analysed numerically
- It was found that the pitch moments induced by the internal sloshing have the right phases to counter-balance the wave induced pitch moments on a FOWT floater
- A multi-columned liquid damper is robust than a traditional TLCD with two vertical columns for FOWTs
- From project, 2 journal and 2 conference papers have been published
- In the future work, the effectiveness/performance of TLMCDs on a FOWT under realistic marine environments will be evaluated and a parametric study for the optimal design of TLMCDs for FOWT applications will be conducted.