Investigation of Moonpool Resonance as a Vessel Damping Device

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Problem

1. Experimental investigation of two moonpools on a floating marine bridge pier as a pitch damping device
2. Verify the numerical hybrid scheme, Potential Viscous Code 3D(PVC3D), through forced oscillation experiments

Background

The E39 highway is approximately 1100 km from Kristiansand to Trondheim, crossing seven fjords along the way. By commissioning the Coastal Highway E39 project, the Norwegian Public Roads Administration has set aim on "a ferry free E39".

Due to the large widths and depths of these fjords, bridge crossings will depend on concept innovations and technological development. Multiconsult has proposed a chained floating bridge with a moonpool damping device to reduce pitch-and modal resonance motions.

Governing Equations

The hydrodynamics inside a moonpool are described either by potential or viscous flow theory. Potential theory is evaluated by Laplace′s equation, which implies that there exists a velocity potential in the fluid domain that satisfy following equation,

$$\nabla^2\phi = 0 \quad (1)$$

The viscous effects around the moonpool are better explained by the continuity-and Navier-Stokes equations,

$$\nabla u = 0 \quad (2)$$

$$\frac{\partial u}{\partial t} + u\cdot\nabla u = -\frac{1}{\rho}\nabla p - g\hat{j} + \nu\nabla^2 u \quad (3)$$

Methodology

The problem is inspected through 2D experiments on different moonpool configurations:

- Verification analysis of PVC3D for forced geometry motions in heave and pitch
- Corresponding forced oscillations experiments in heave and pitch
- Freely-floating tests in incoming waves

The experimental setup is given below:

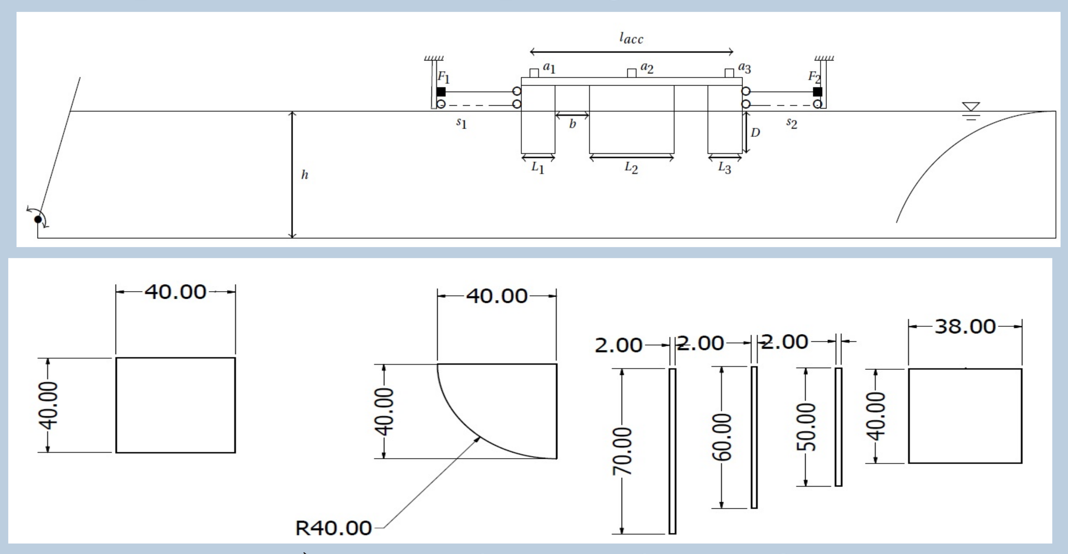

Figure 1: Fig a) setup for the freely-floating experiment, fig b) moonpool inlet configurations.

Acknowledgements

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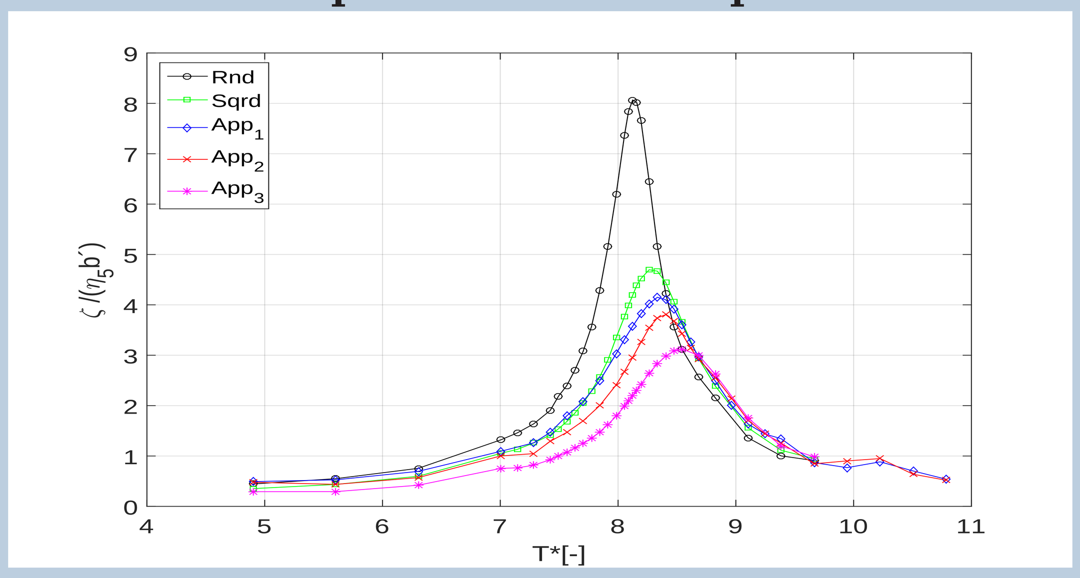
The experiments are assisted by Torgeir Wahl, Ole Erik Vinje and Trond Innset.

Physical Domain

Numerical & Forced Oscillation Experiments

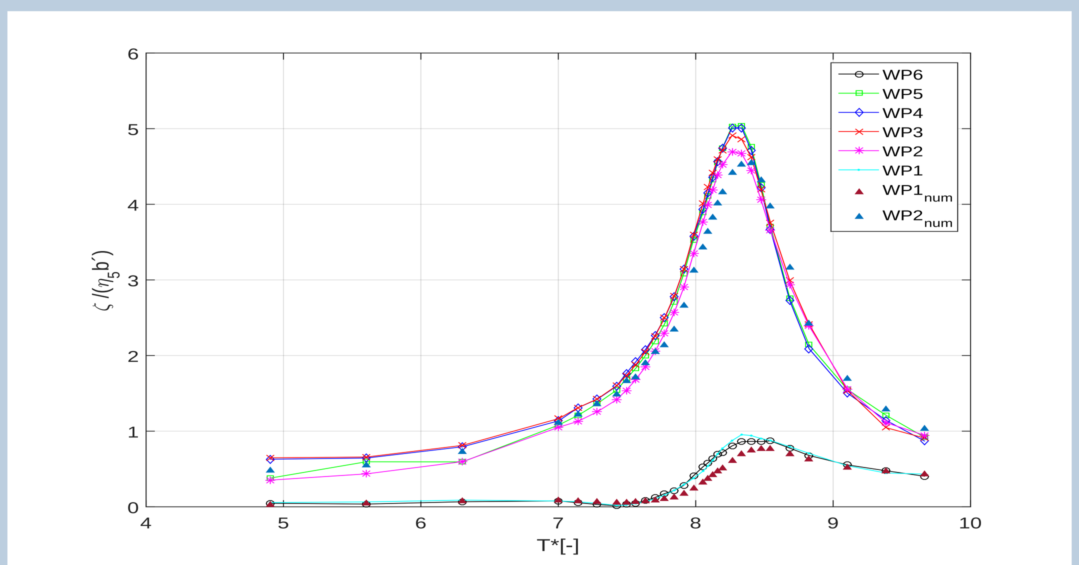
Forced oscillation experiments are carried out for five different inlet geometries; rounded, squared and three appendage configurations. The rounded corners gave rise to potential flow, while viscous effects of different degrees were apparent for the other inlets.

Moonpool Inlet Comparison



a

Verification of Numeric scheme



b

Figure 2: Figure a) is a RAO comparison for different moonpool inlets, with $\eta_5 = 0.79^o$ Figure b) display a verification study of the numerical scheme for a moonpool geometry with squared inlets and $\eta_5 = 0.79^o$. Turquoise, black and burgundy lines are outside the structure, the rest display wave elevation inside. The y-label is done dimensionless by, b', which is the distance between geometry center to moonpool center and $T* = \sqrt{\frac{g}{b}}$, g is the gravity and b is moonpool width.

Freely-floating Experiments & Discussion

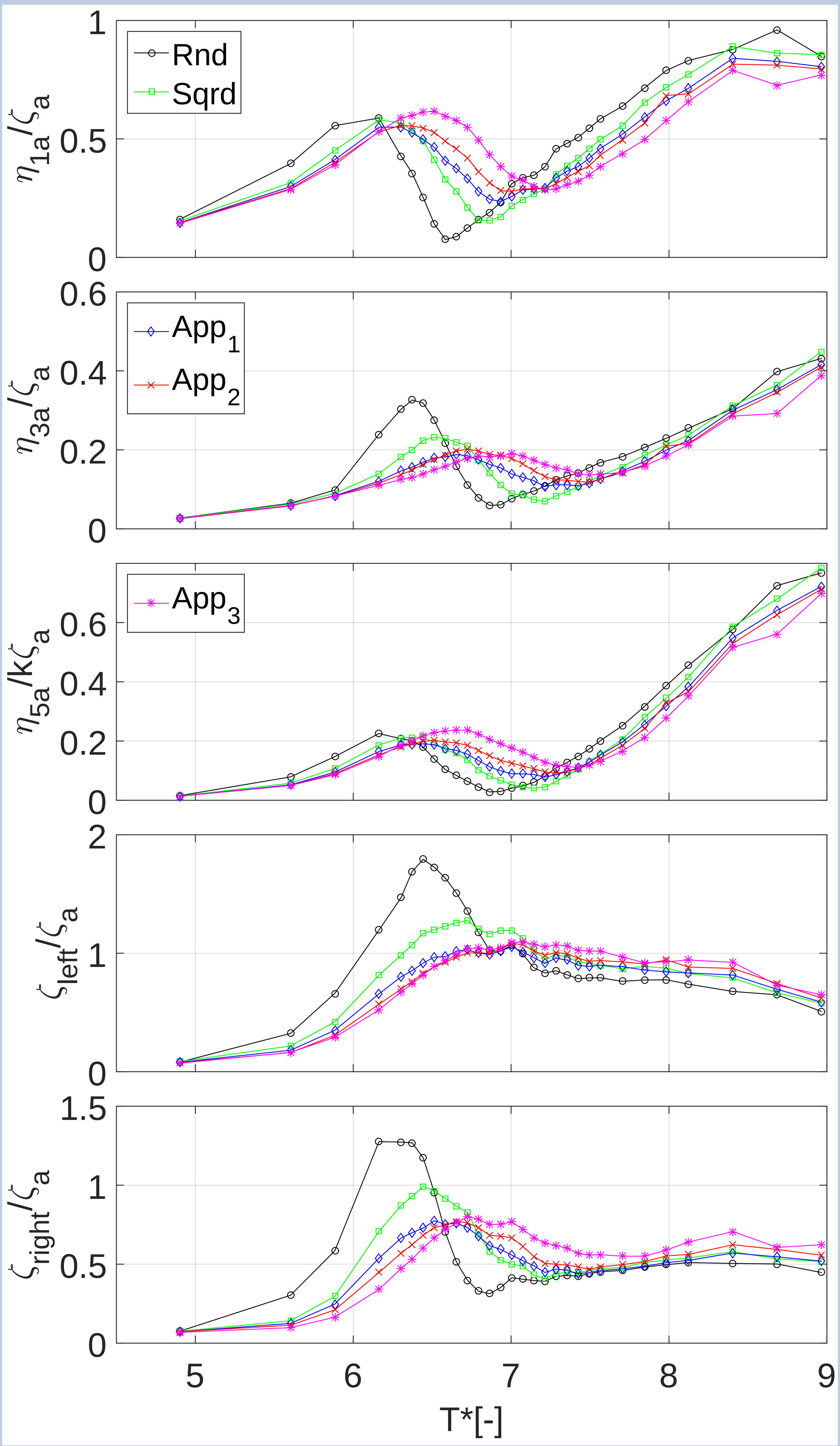


Figure 3: The figures display respectively surge, heave, pitch, left moonpool and right moonpool RAO's for the five different moonpool inlet configurations. The pitch RAO is done dimensionless wrt. the wave number k, and $T* = T\sqrt{\frac{g}{b}}$

The graphs for the forced oscillation experiments display following trends:

- The inlets affect the hydrodynamics inside the moonpools(Fig.2a): Potential flow is valid for rounded inlet, and no shed vortices are apparent. It reduces the damping, i.e. higher resonance peak. Vortices appears for the other inlets, and increases with increasing appendage size
- The effective moonpool draft change the resonance period. Rounded inlets which have the smallest effective draft has the lowest $T*$
- The numeric scheme is in compliance with experiments(Fig.2b)

The trends from the freely-floating experiments are as follows:

- The RAO cancellation of geometry motion is apparent in surge, heave, and pitch, which indicates advantageous effects of the moonpool installation
- Rounded and squared corners have most advantageous pitch cancellation effects, around $T* \cong 7$, while the appendages appears less advantageous
- The length of cancellation interval in pitch for rounded and squared corners are of similar magnitude
- A high resonance peak close to the cancellation periods for rounded inlet. This configuration could be sensitive for variations of the incoming wave periods wrt. heave resonance.