Water-Entry of Ventilated Structures

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Motivation:

The design of a structure is based on the strength requirements to sustain the operational as well as installation loads. An accurate estimation of such loads is also necessary for resource and mission planning of marine operations involving the deployment or installation of these structures. The hydrodynamic loads on a structure are often expressed as a summation of added mass and damping force components (as in Morison's equation) which can in-turn be calculated from analytically, experimentally or numerically determined added mass and drag coefficients. The purpose of this work is to experimentally determine hydrodynamic loads on ventilated structural components such as perforated plates and rod screens.

Additionally, in case of the water-entry loads on ventilated structures, it is observed that total hydrodynamic loads are drag dominated due to higher drag to added mass ratio. This effect becomes more prominent due to the small relative accelerations during constant velocity water-entry during the deployment of subsea modules. This indicates that a strong emphasis should be placed on the estimation of drag loads on such structures. In the current work, the drag coefficient for 2 different types of ventilated plates is determined from 3 different types of experiments.

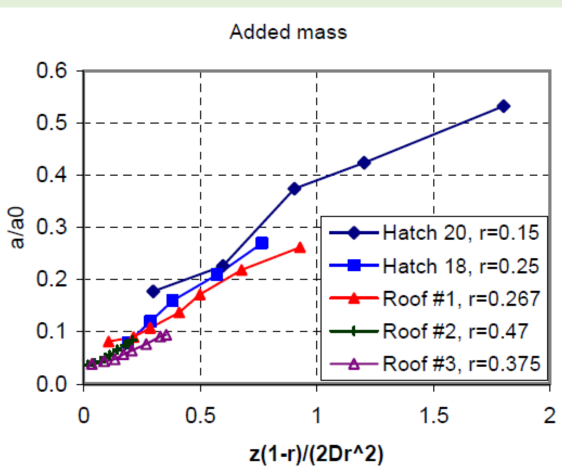
Ventilated Structure

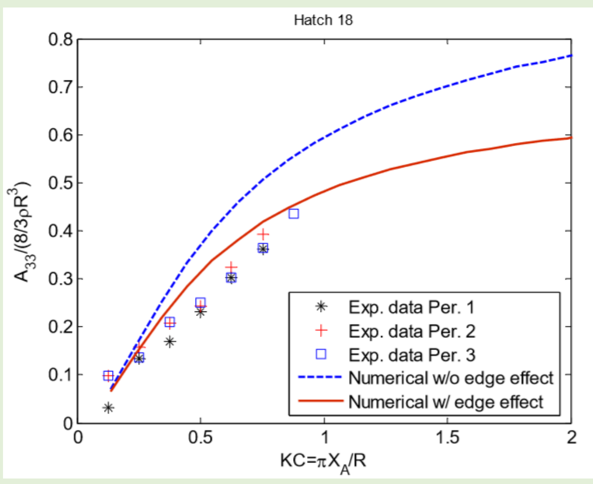
Introduction:

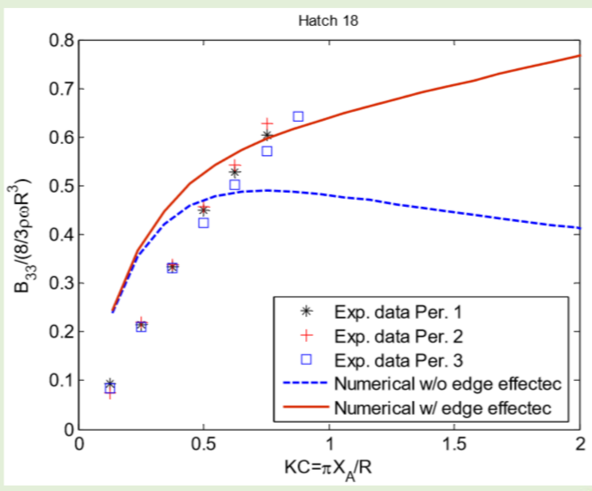
According to DNV-GL's recommended practice [1], ventilated structures comprises of structures where a plane normal to the oscillation direction is either arranged with holes or slots or consists of parallel slender elements. The results for a solid flat plate obtained by Newman, 1977 [2], cannot be directly used in case of a ventilated plate. Blevins, 1984 [3], presented a method to calculate the drag force on screens, grillages and perforated plates, using the principles of fluid dynamics, in terms of the total static pressure drop across the plate.

Molin, 2001 [4], suggested a method to calculate the added mass and damping of periodic arrays of fully or partially porous discs using potential flow theory. Sandvik, 2006 [5], conducted experiments to determine the hydrodynamic added mass and damping for ventilated plates with perforation ratio r.

Figures below shows the experimental results from [5] compared with the numerical method from [4]. Here, it should be noted that the added mass reduces due to edge effects (flow separation) whereas the drag force increases. This indicates that the hydrodynamic forces acting on a ventilated plate are drag dominated.





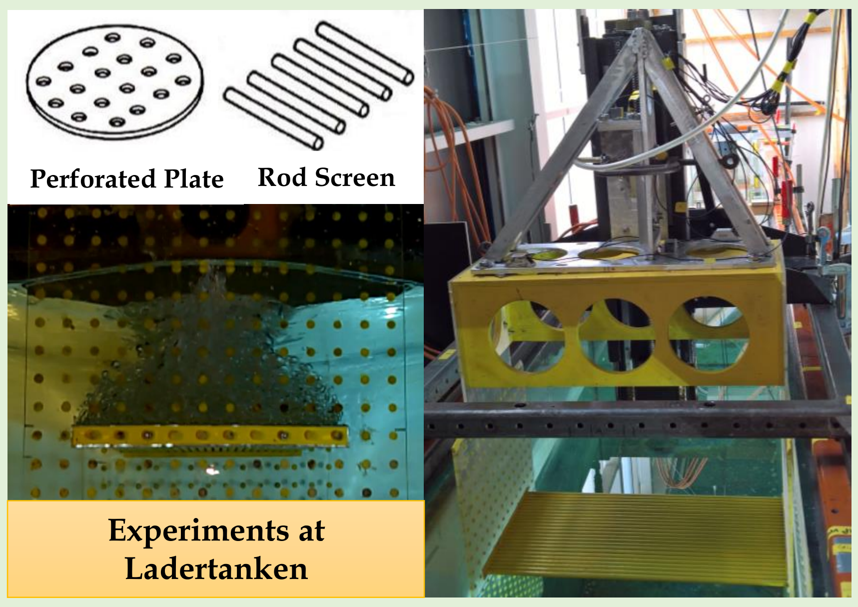


Experiments:

Experiments were conducted with 3 different plate models, 2 perforated plates (P19, r=0.186 & P28, r=0.278) and 1 rod screen (FING, r=0.189), in a 2D wave flume tank at Ladertanken, NTNU.

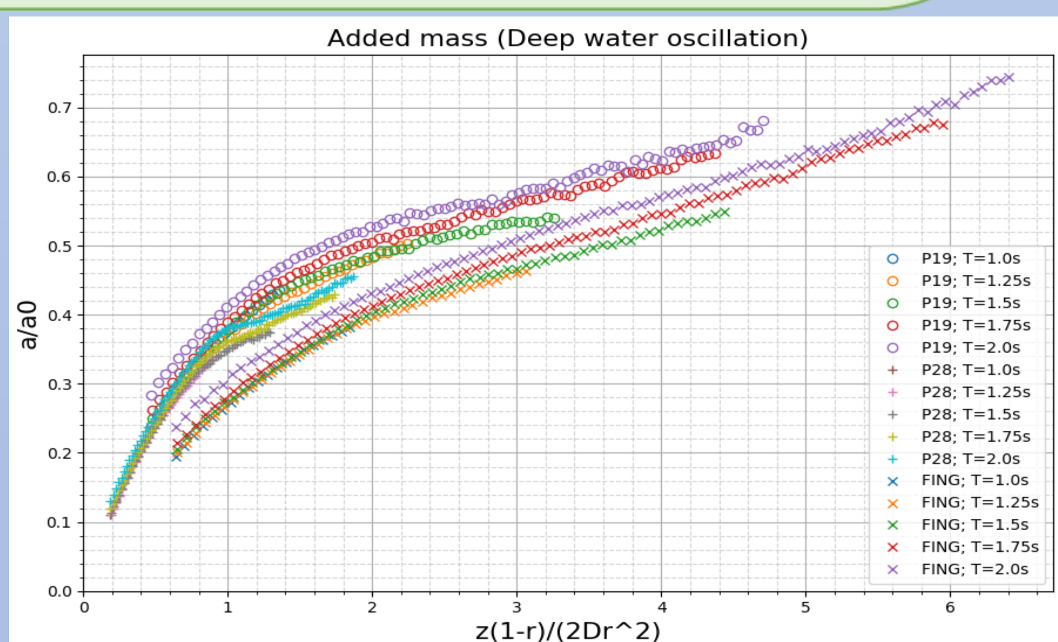
The aim of experiments was to determine the hydrodynamic force coefficients for the following test cases:

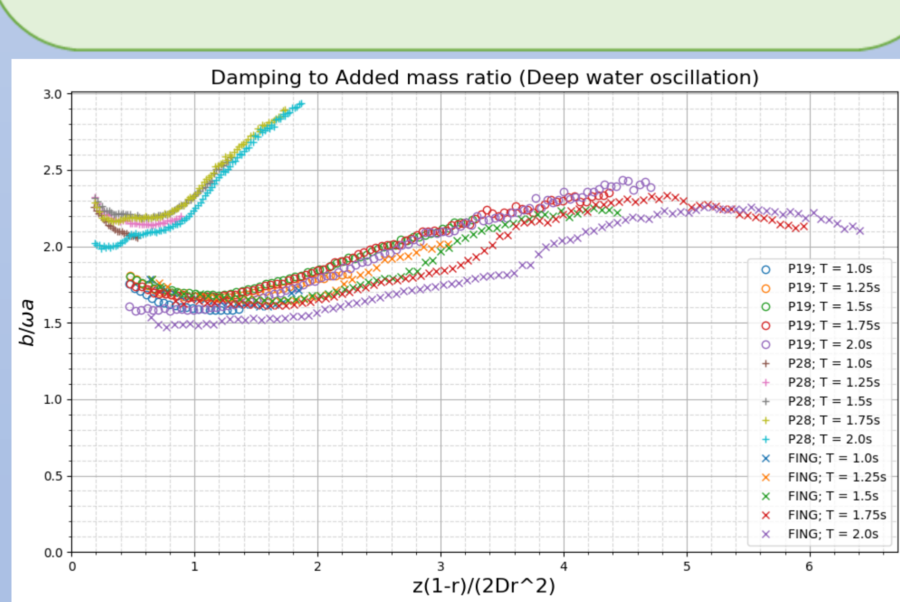
- Deep water oscillations
- Constant velocity water-entry
- Fully submerged plate in waves

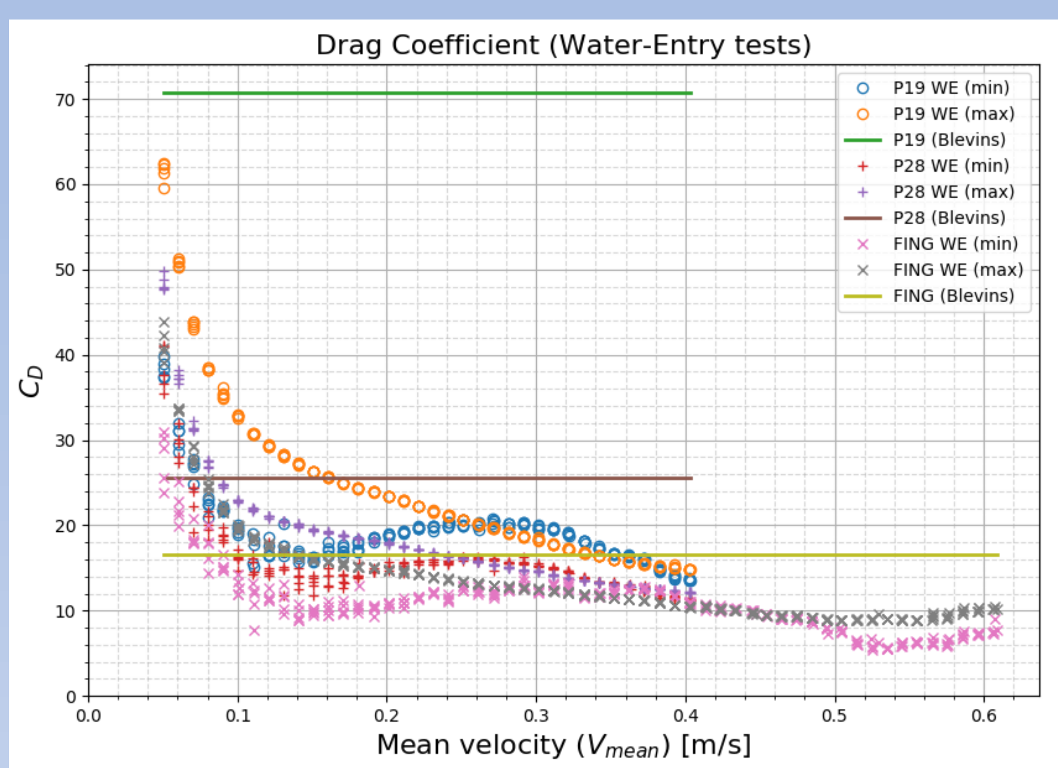


Results & Discussion:

- The experimental results for added mass and damping force coefficients follows similar trends as observed by Sandvik, 2006 [5].
- Damping to added mass ratio varies from 1.5 to 3.0. Thus, the total hydrodynamic force is drag dominated.
- Rod screen type plate experiences smaller hydrodynamic forces as compared to perforated plates. Here, it should also be noted that, in general, the ventilated structural members of subsea modules are rod screen type.
- Drag coefficients, calculated from the force impulse observed during the constant velocity water-entry, do not show very good agreement with the fluid dynamics estimates presented by Blevins [3], specially in the case of perforated plates.







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[1] DNV-RP-H103. Modelling and Analysis of Marine Operations. DNV, 2011.

[2] J.N. Newman and Knovel (Firm). Marine Hydrodynamics. Mit Press. MIT Press, 1977.

[3] R.D. Blevins. Applied Fluid Dynamics Handbook. Krieger Pub., 2003.

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