CLOSED CAGES IN WAVES

Marin Byggteknikkdagen 19. April 2018

David Kristiansen, SINTEF Ocean

Outline

- Introduction
- Model tests of closed cages in waves
  - Wave induced rigid body motions
  - Sloshing
  - Mooring loads
- Summary
- Ocean Space Centre

Introduction

- Closed cages vs. conventional net-cages
  - Contained water separated from the ambient
  - Controlled water exchange system
  - Large displacement (large volume structure)
  - Internal free surface and sloshing
- Motivation for use of closed cages
  - Control of water quality
  - Protect fish against sea-lice
  - Collect waste
  - Improved growth rates
  - Access to new licences for production

Photo: NRK. (Aquafarm Equipment AS).

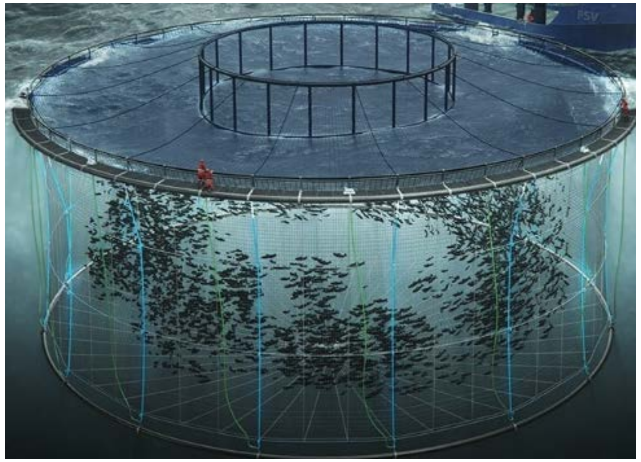
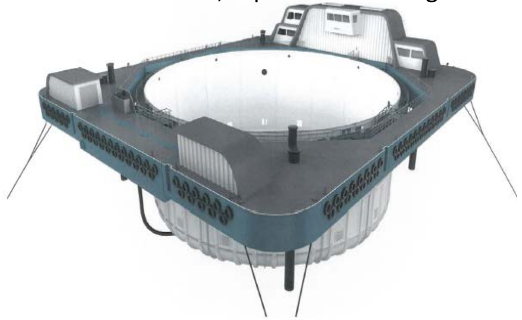


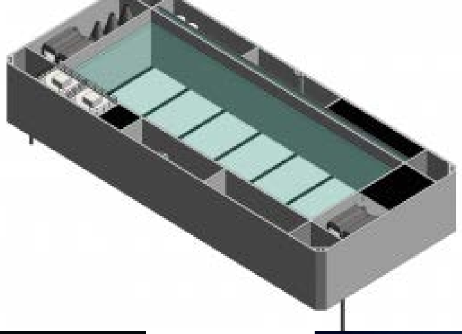
Illustration: Aqualine AS.

Development licences…

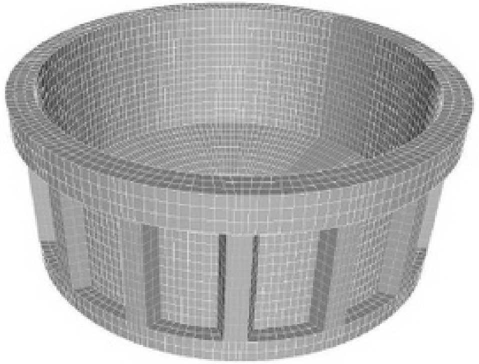
Marine Harvest , Aquafarm Utvikling

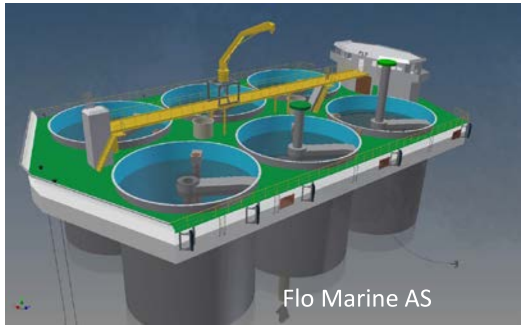


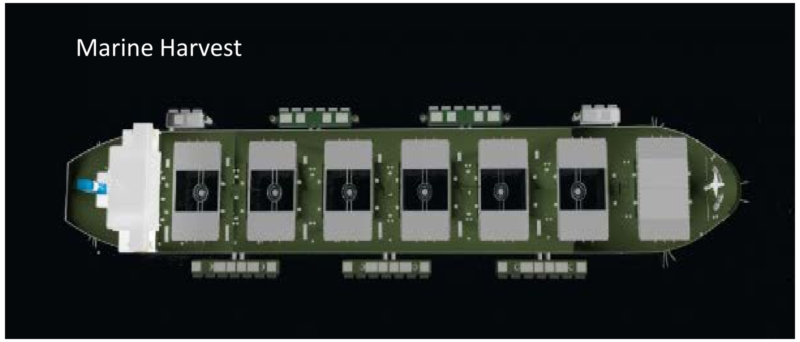
Engesund Fiskeoppdrett

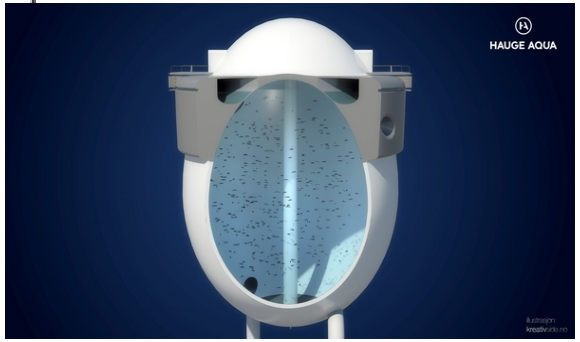


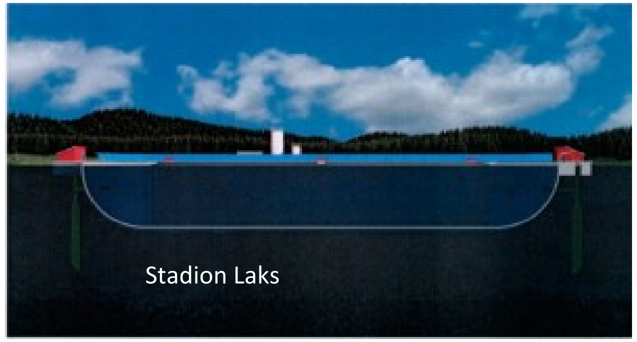
Fish Farming Innovation /Dr. Techn. Olav Olsen

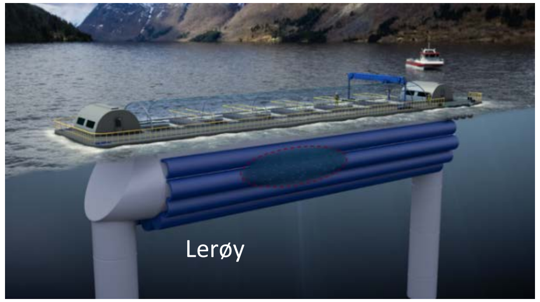


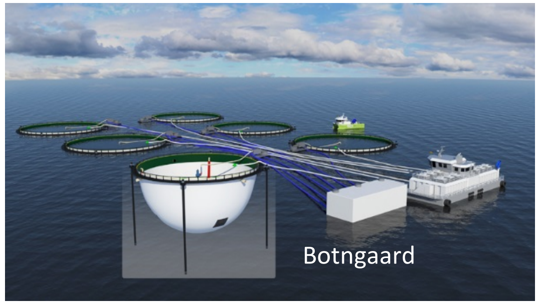


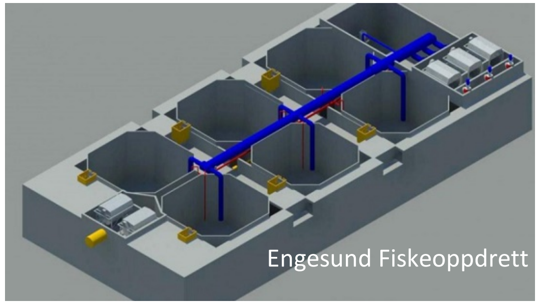












Three main types of closed cage structures:

- Rigid type (negligible deformations)
- Elastic type (deformations and bending stiffness matter)
- Flexible bag-type (negligible bending stiffness)

Photo: www.nrk.no

Results from recent research projects at SINTEF Ocean:

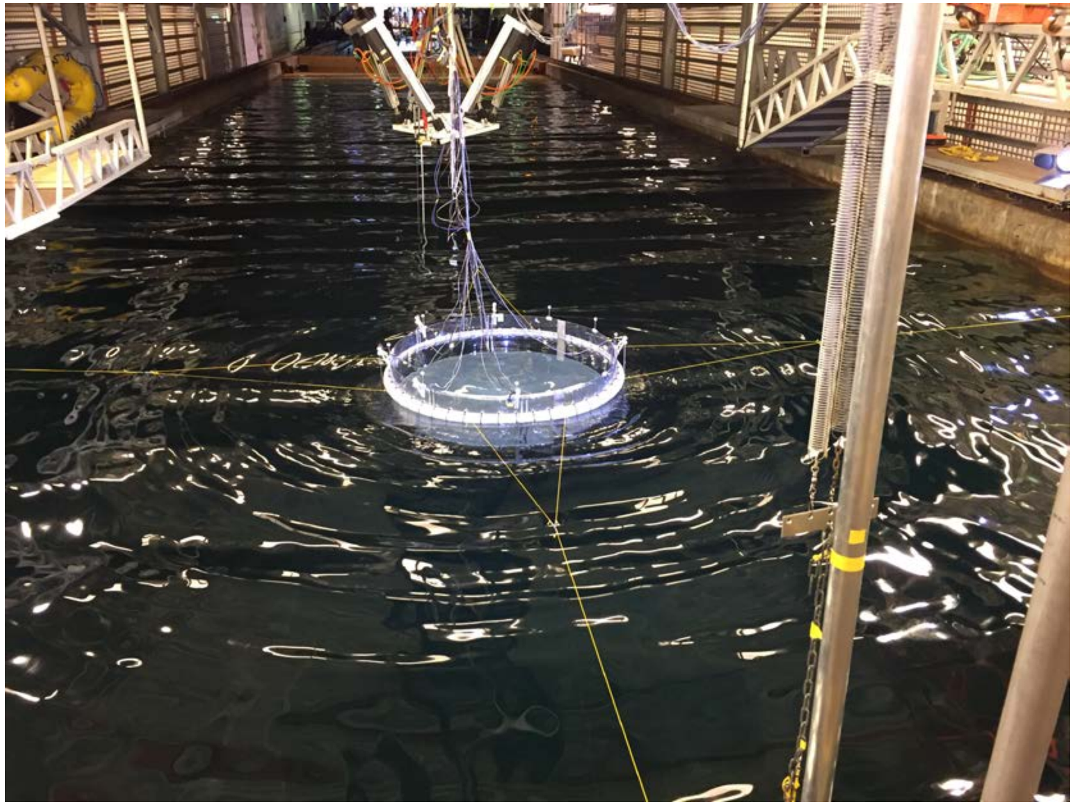
- SJØFLO (2016-2018) – "Seakeeping behavior and moorings of closed fish farms" (FHF)
- CCW (2017-2020) - "Safe Operation of Closed aquaculture Cages in Waves" (RCN, MAROFF-KPN)

Model tests with closed cages in waves

Scaled model tests at SINTEF Ocean, March and Nov./Dec. 2017.

Laboratory: Towing Tank (Extension)

L x B x H = 85 m x 10.5 m x 10 m



Objective:

- Study seakeeping behavior of generic closed cages in waves
- Study effects of internal free surface and sloshing

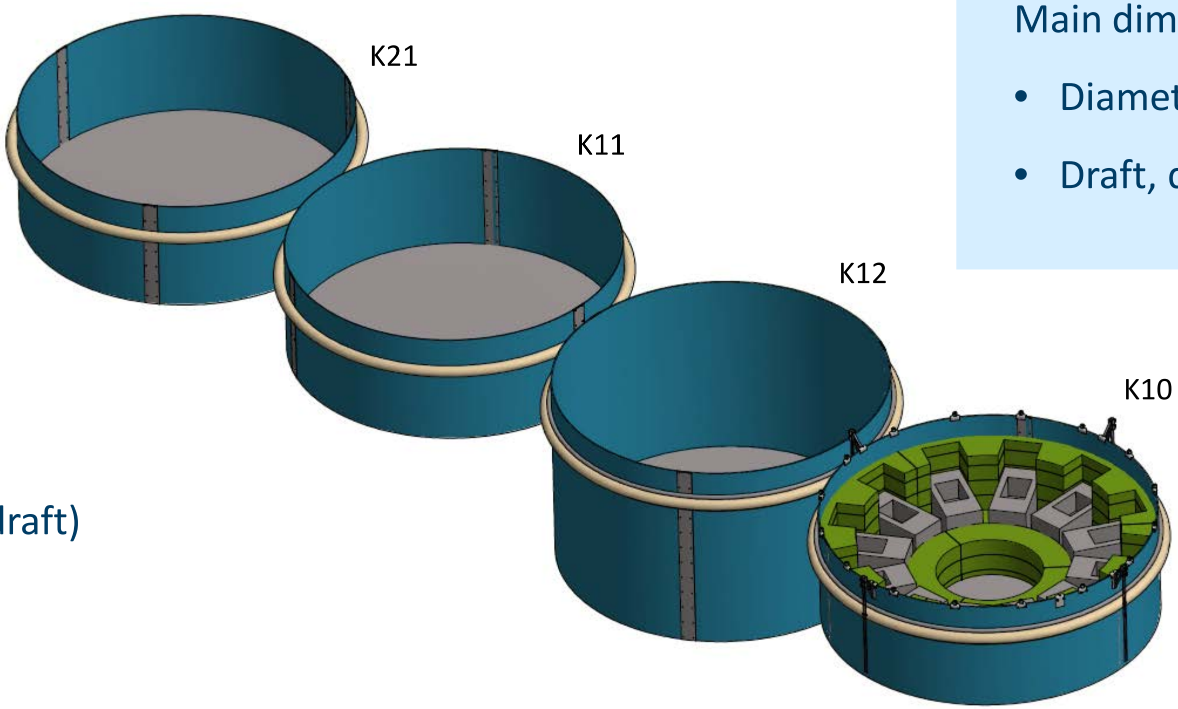
SINTEF

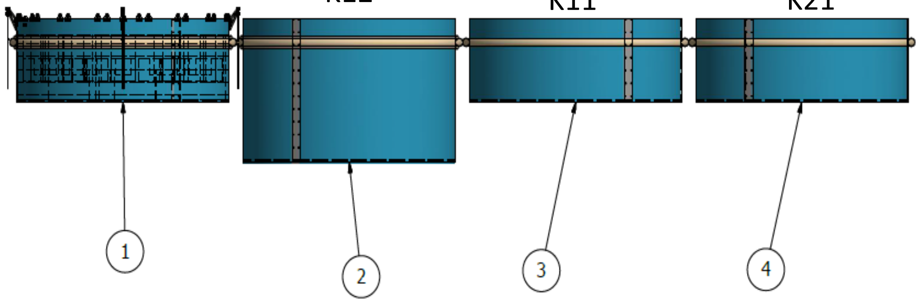
Models

- Model scale factor 1:27
- Five model configurations
    - Rigid type (wet/dry, increased draft)
    - Elastic type
    - Flexible bag type

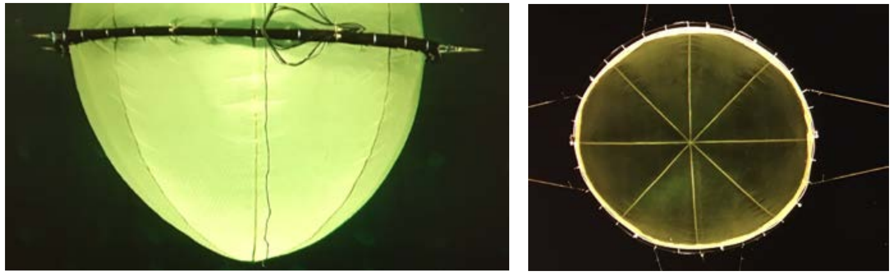
Main dimensions:

- Diameter, D=1.5 m
- Draft, d/D = 0.25 and 0.5



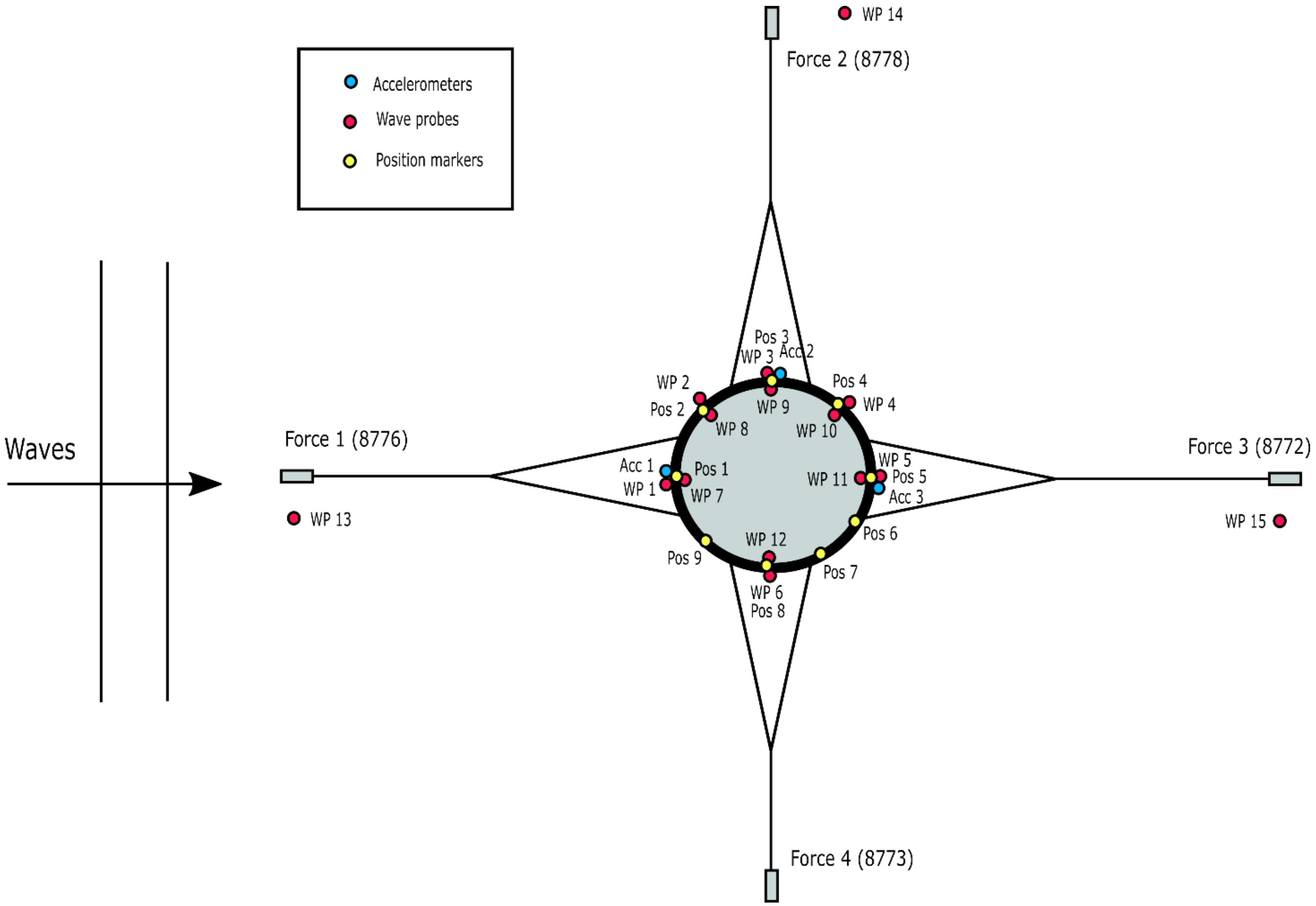


K51



SINTEF

Measurements and wave conditions



Wave conditions:

Regular waves:
- 23 periods (λ/D = 0.5 – 6.5)
- 3 steepnesses

Irregular sea:
- JONSWAP (Hs = 1.5 m, Tp=4.7 s)
- Broad band (pink noise)

SINTEF

Effects of sloshing on rigid body motions

- Tests with and without water inside
- Fixed weights resembles weight of "frozen water"

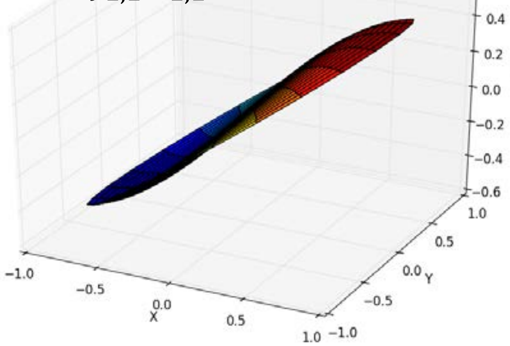
Dimensions:
- Diameter D=1.5 m
- Draft d = 0.375 m
- d/D = 0.25

Model with fixed weights

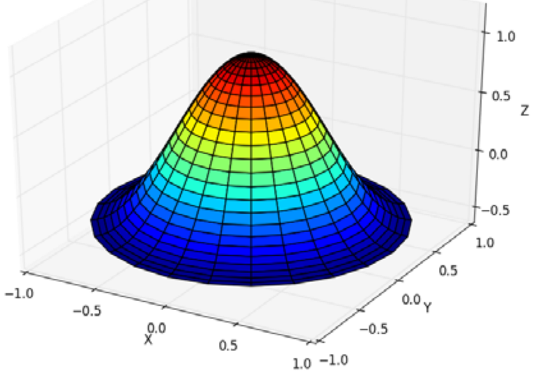
Model with contained water

Sloshing modes

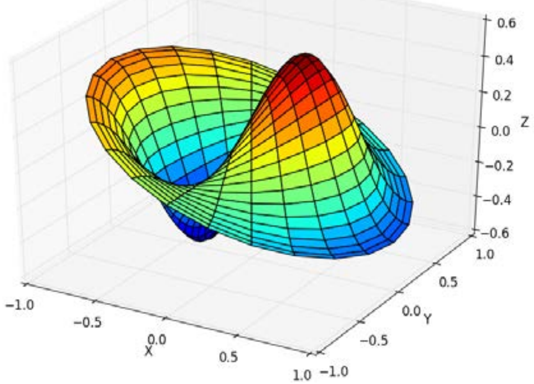
$f_{1,1}\ T_{1,1} = 1{,}50$ s



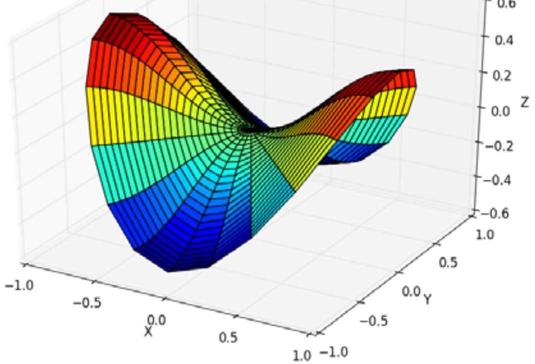
$f_{0,1}\ T_{0,1} = 0{,}91$ s



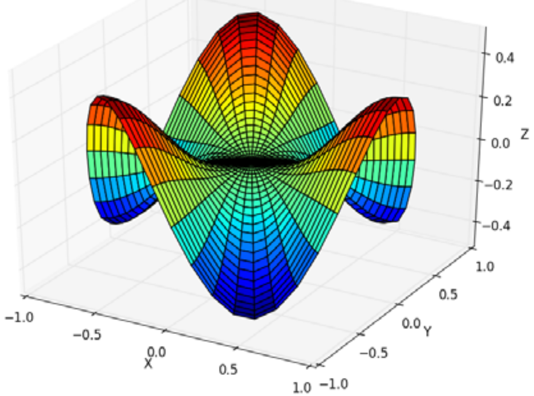
$f_{1,2}\ T_{1,2} = 0{,}76$ s



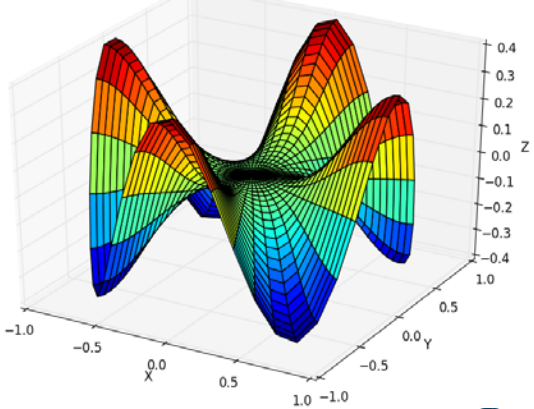
$f_{2,1}\ T_{2,1} = 1{,}04$ s



$f_{3,1}\ T_{3,1} = 0{,}86$ s



$f_{4,1}\ T_{4,1} = 0{,}76$ s



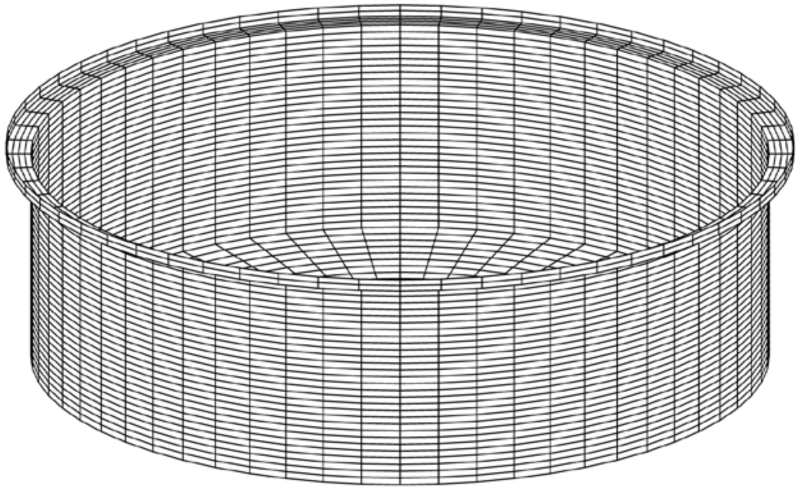
Numerical calculations

Numerical model:

- WAMIT - Potential flow theory in frequency domain
- Simplified and rigid model geometry
- Low order panel method

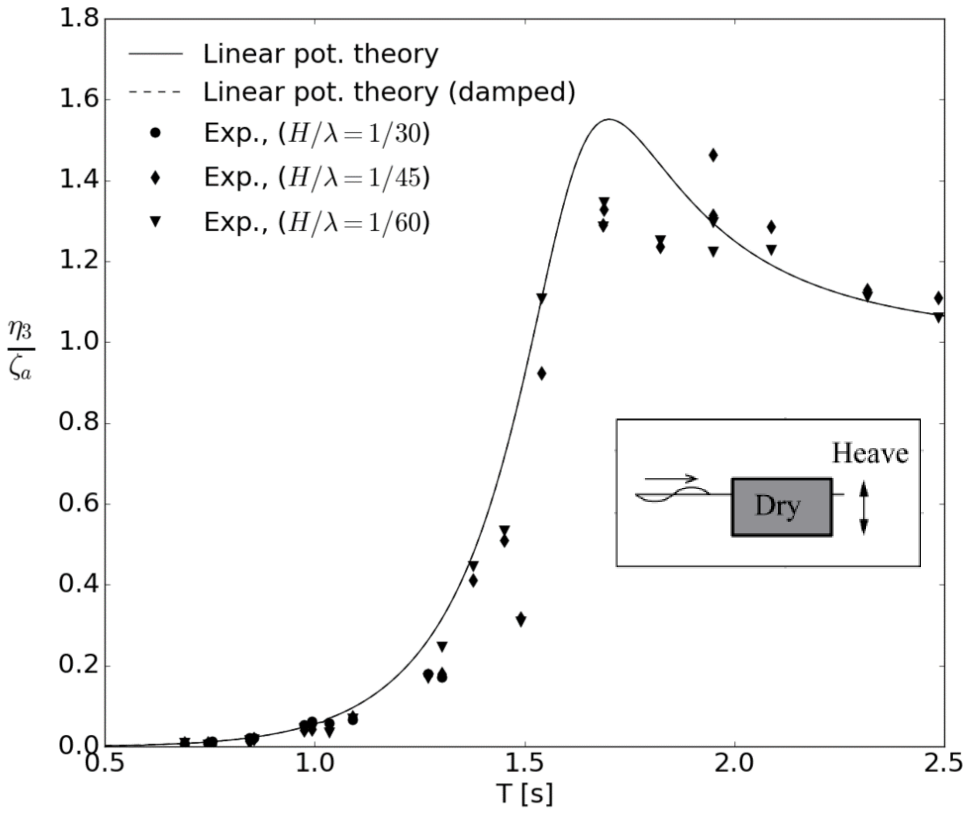
Simulations:

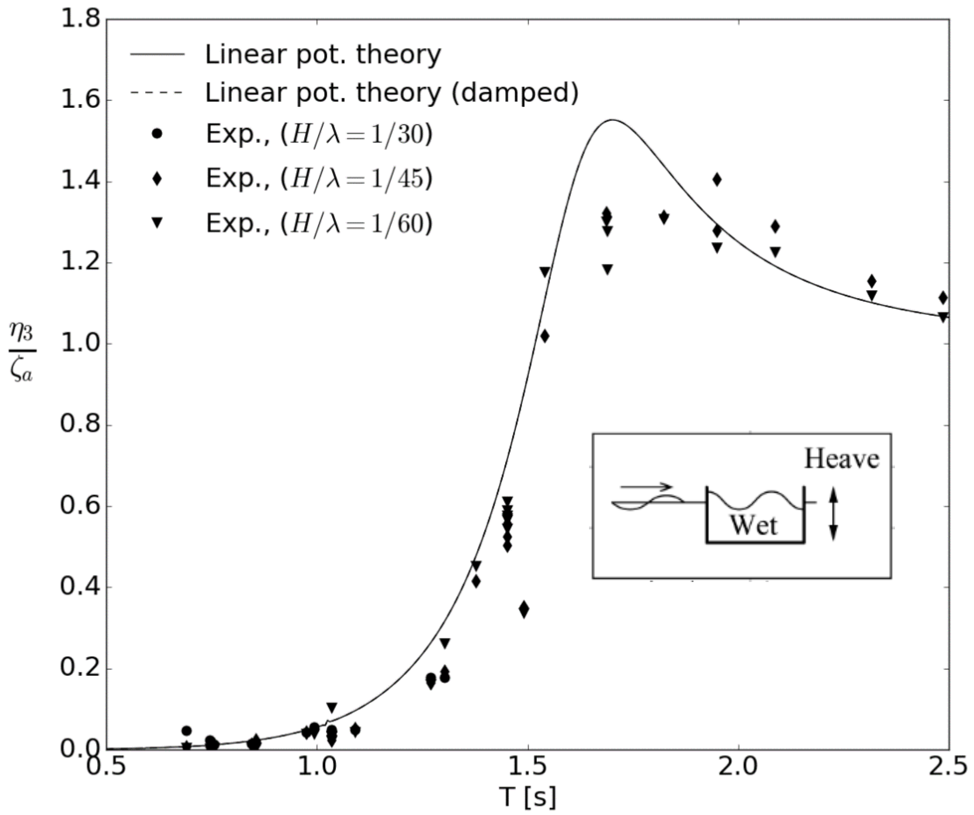
- Rigid body motions in regular waves
- With and without internal tank
- Effect of wall reflections in the experiments



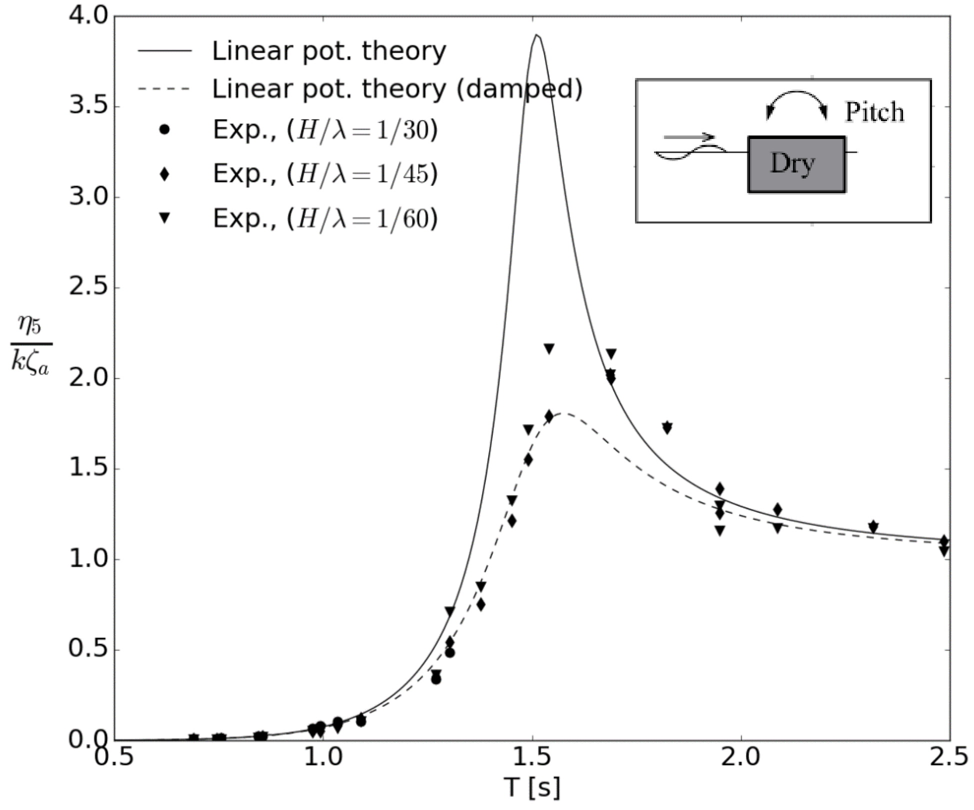
SINTEF

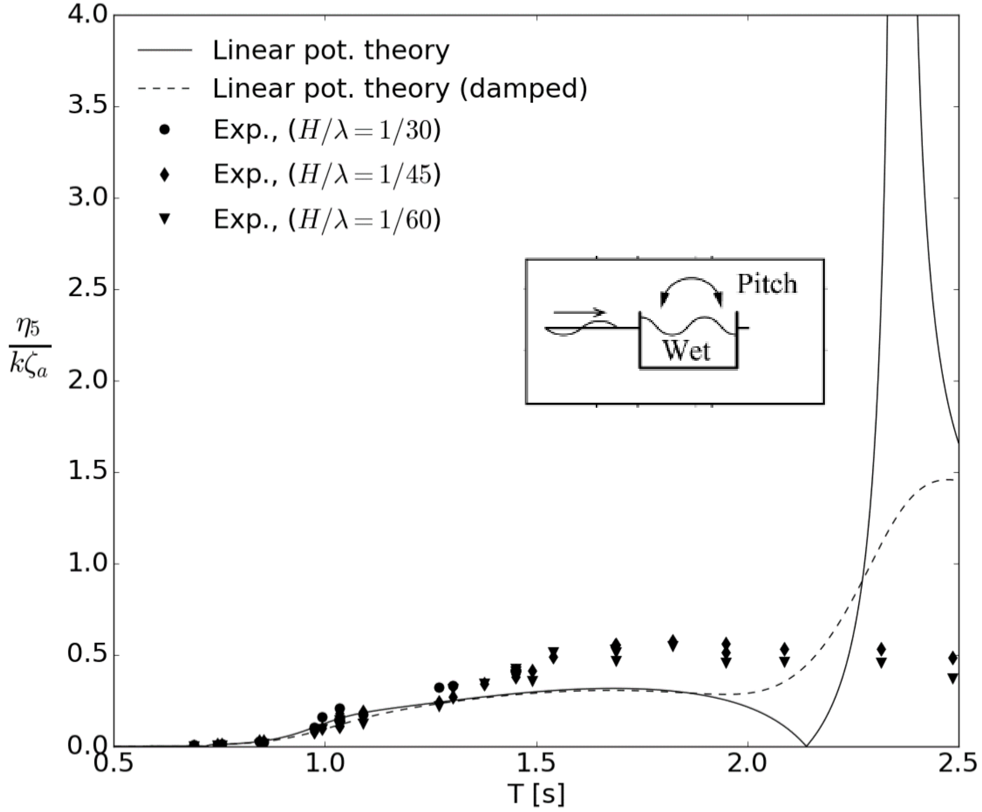
Results – heave motion





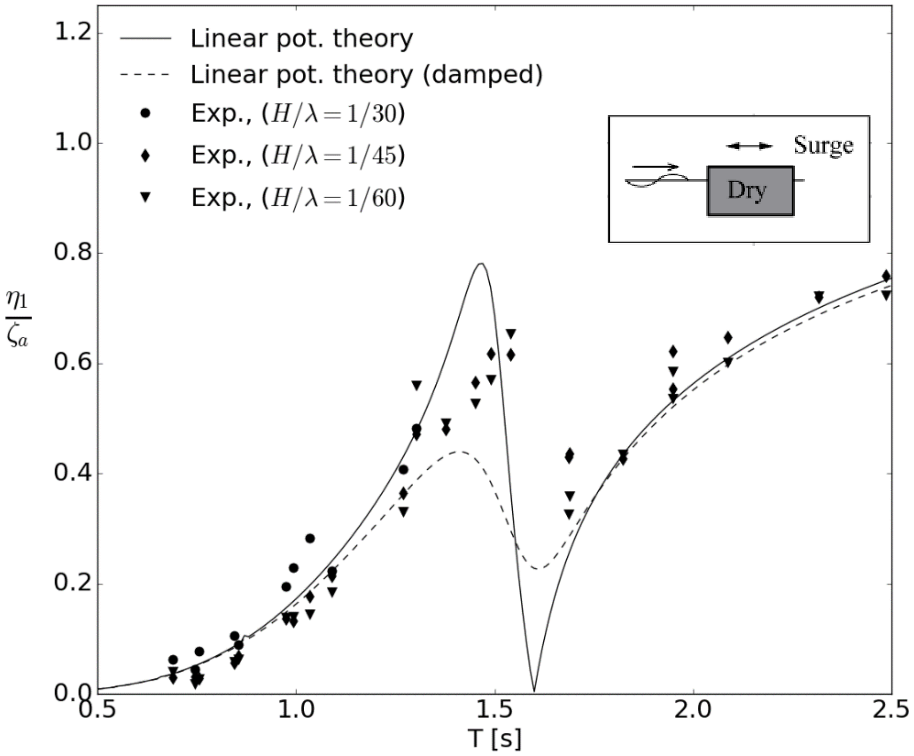
Results – pitch motion

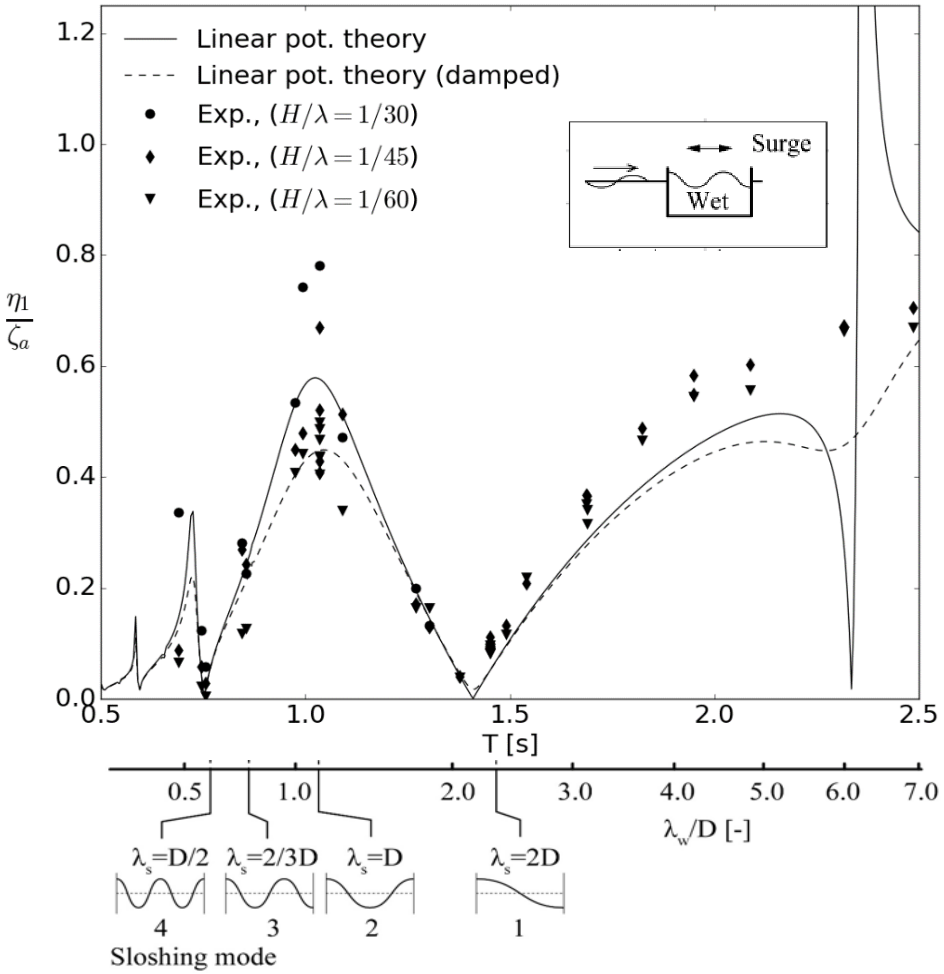




SINTEF

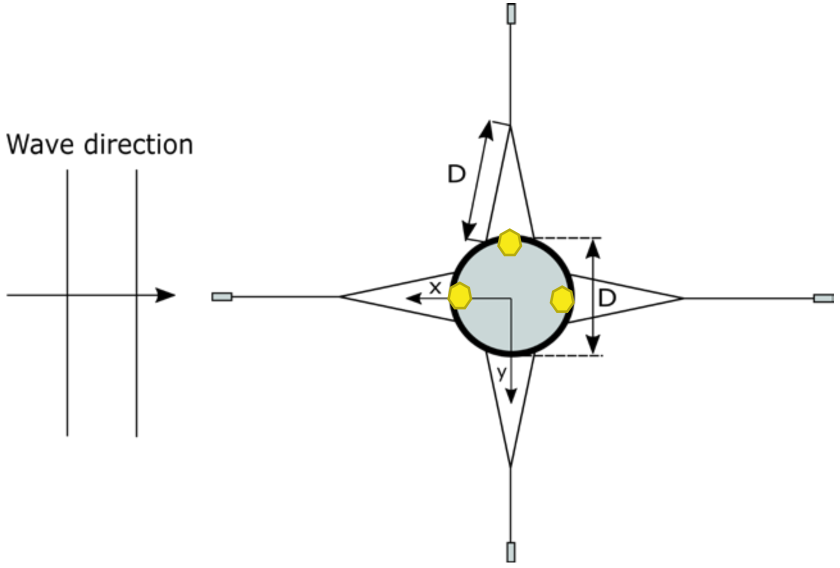
Results – surge motion

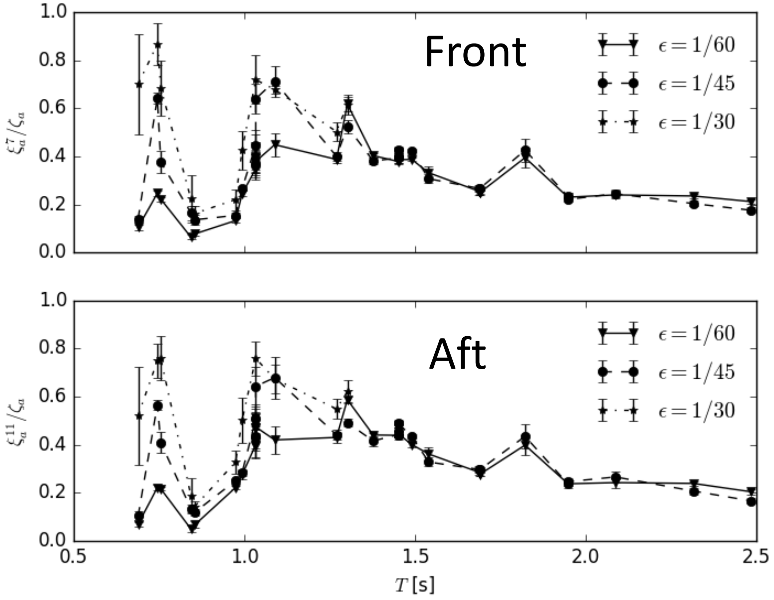




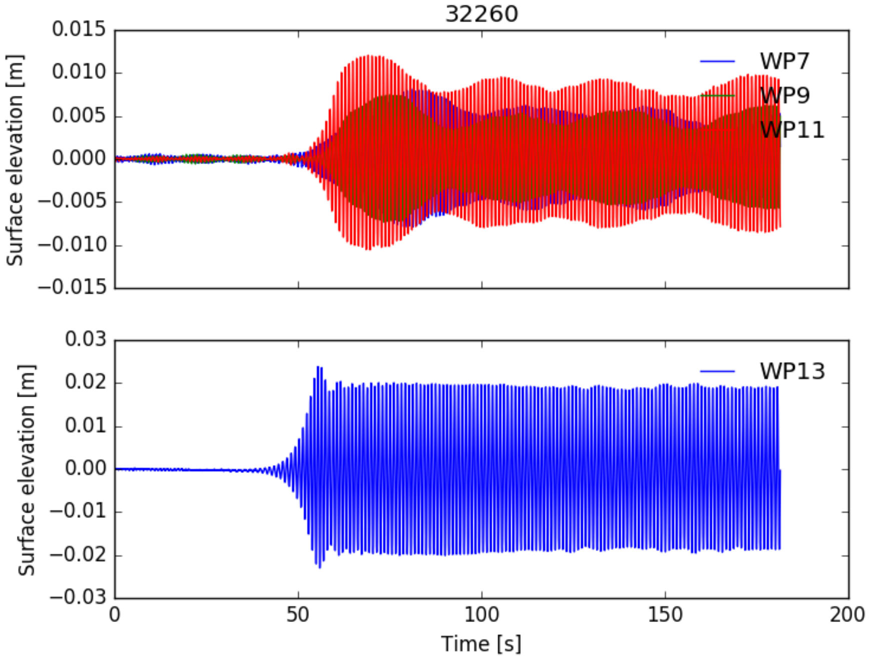
Measured sloshing

- Non-stationary sloshing – beating
- Coupling of sloshing modes
- Nonlinear sloshing at natural sloshing peropds





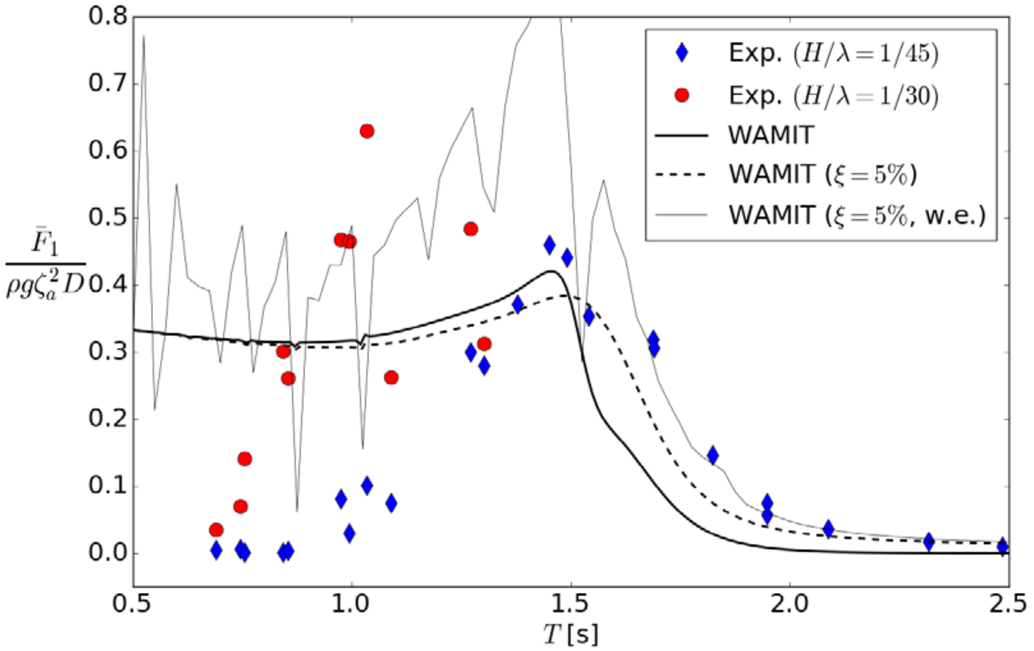
Rigid model



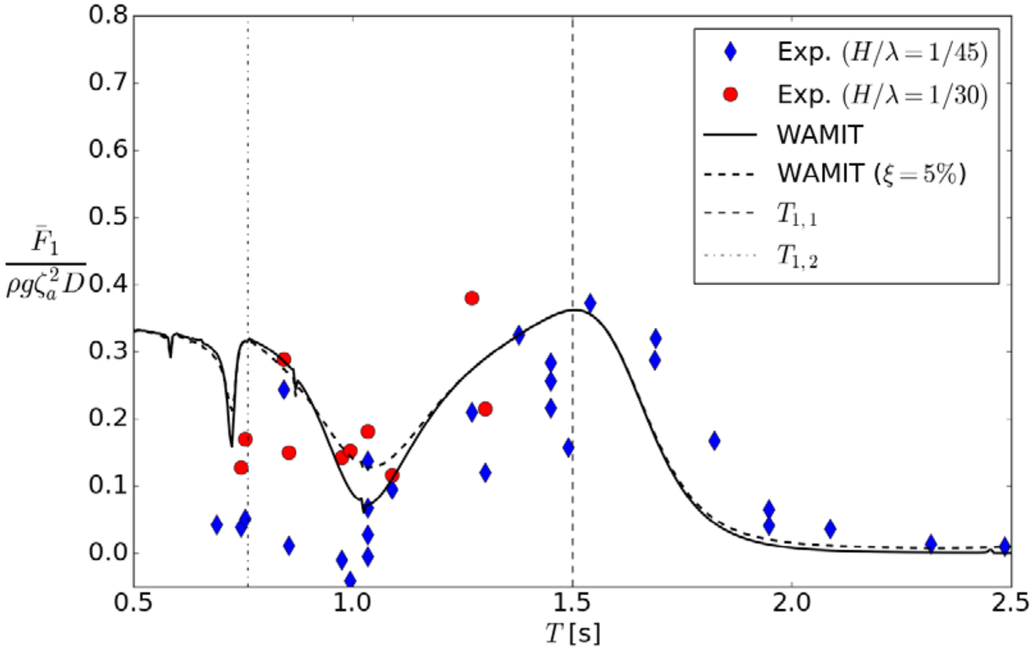
SINTEF

Mean wave drift forces

K10 - Dry

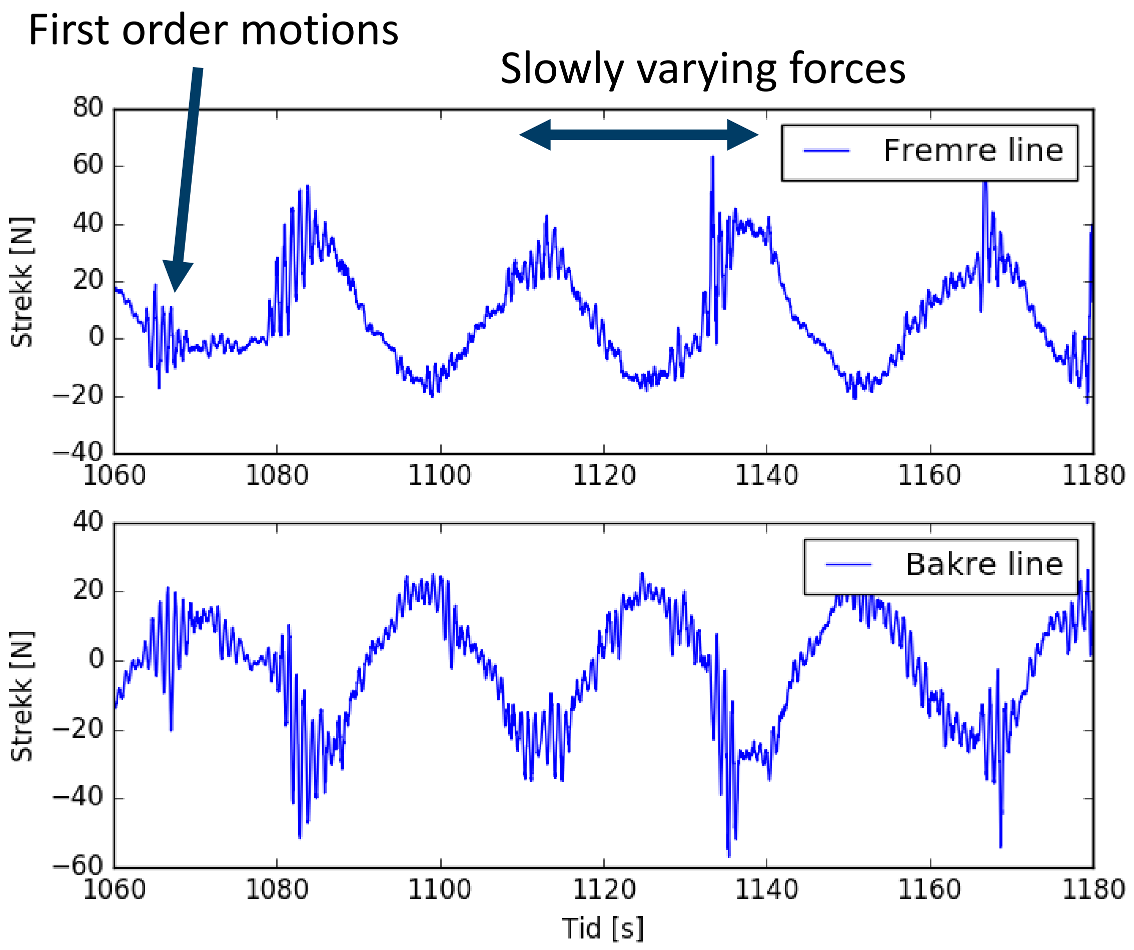


K11 - Wet



Slowly varying wave forces

- Tests with flexible bag model
- Irregular waves – JONSWAP
  Hs=1.5 m, Tp=4.7 s, γ=3,81
- Dynamic mooring line forces
  - First order motions and sloshing
  - Slowly varying forces and motions

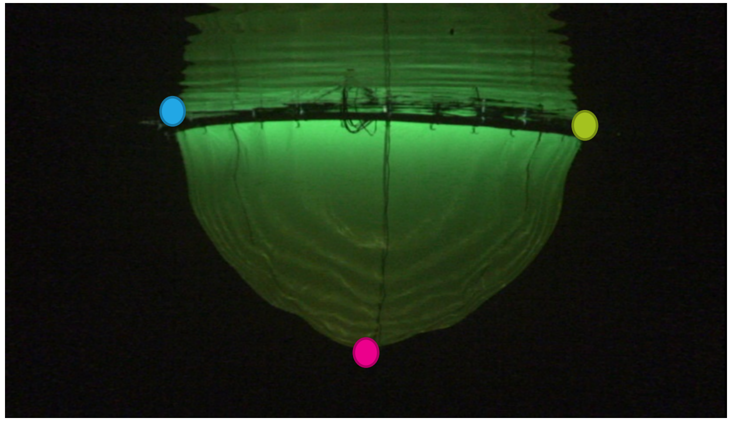


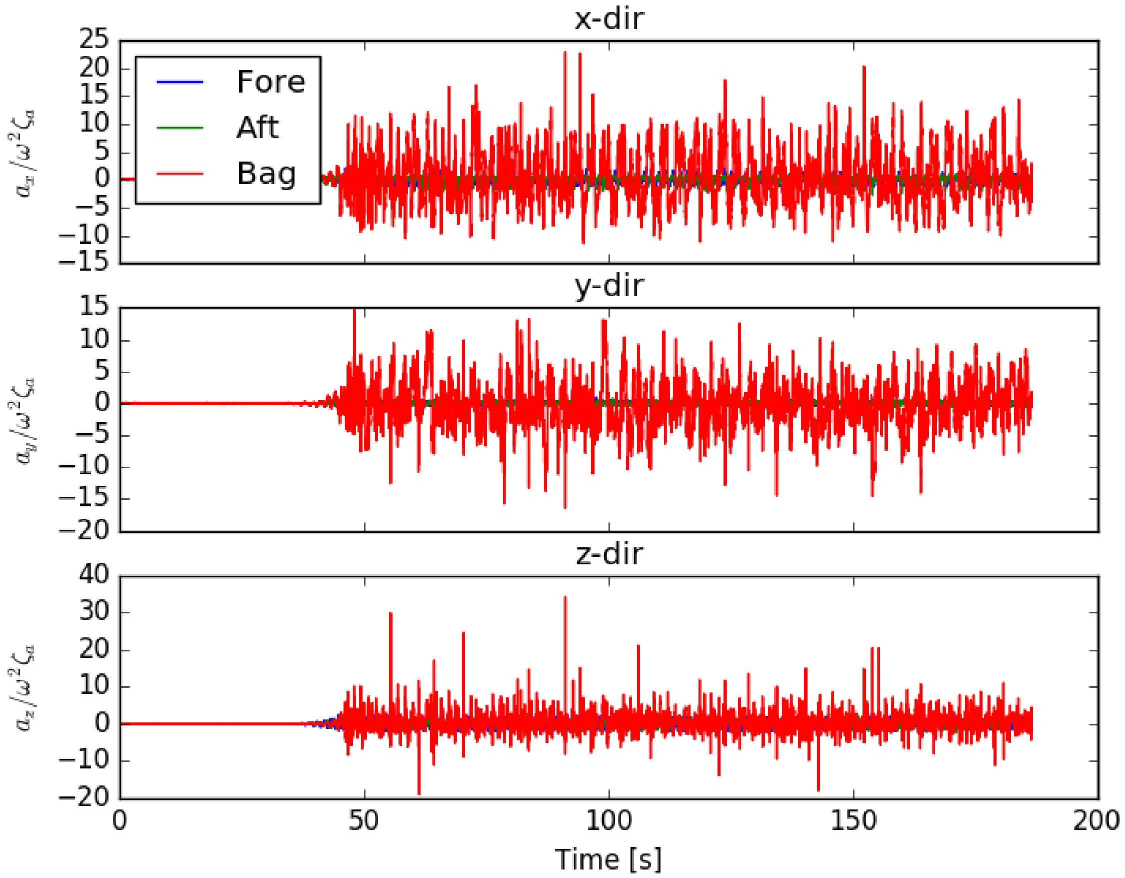
SINTEF

Wave induced motions of flexible bag structure

Flexible dynamic motions of bag observed

- Flutter-like behavior
- Large bag accelerations at bottom
- Scale effects of structural elastic properties





SINTEF

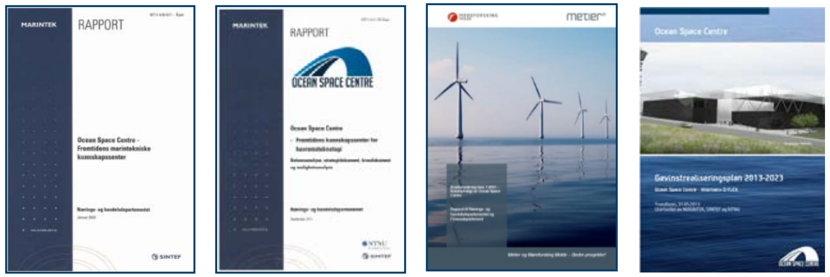
Summary

- Coupled motions in surge and pitch strongly affected by sloshing
- Particular amplification of surge motion for wave periods corresponding to natural period of 2. sloshing mode
- Heave motion not affected by sloshing
- Slowly varying wave forces can be significant
- Large accelerations of flexible bag structures in waves can cause high tensions

Ocean Space Centre

Time line

Lansering av ”Visjons-prosjektet” World Ocean Space Center



Forstudie

KVU

KS1

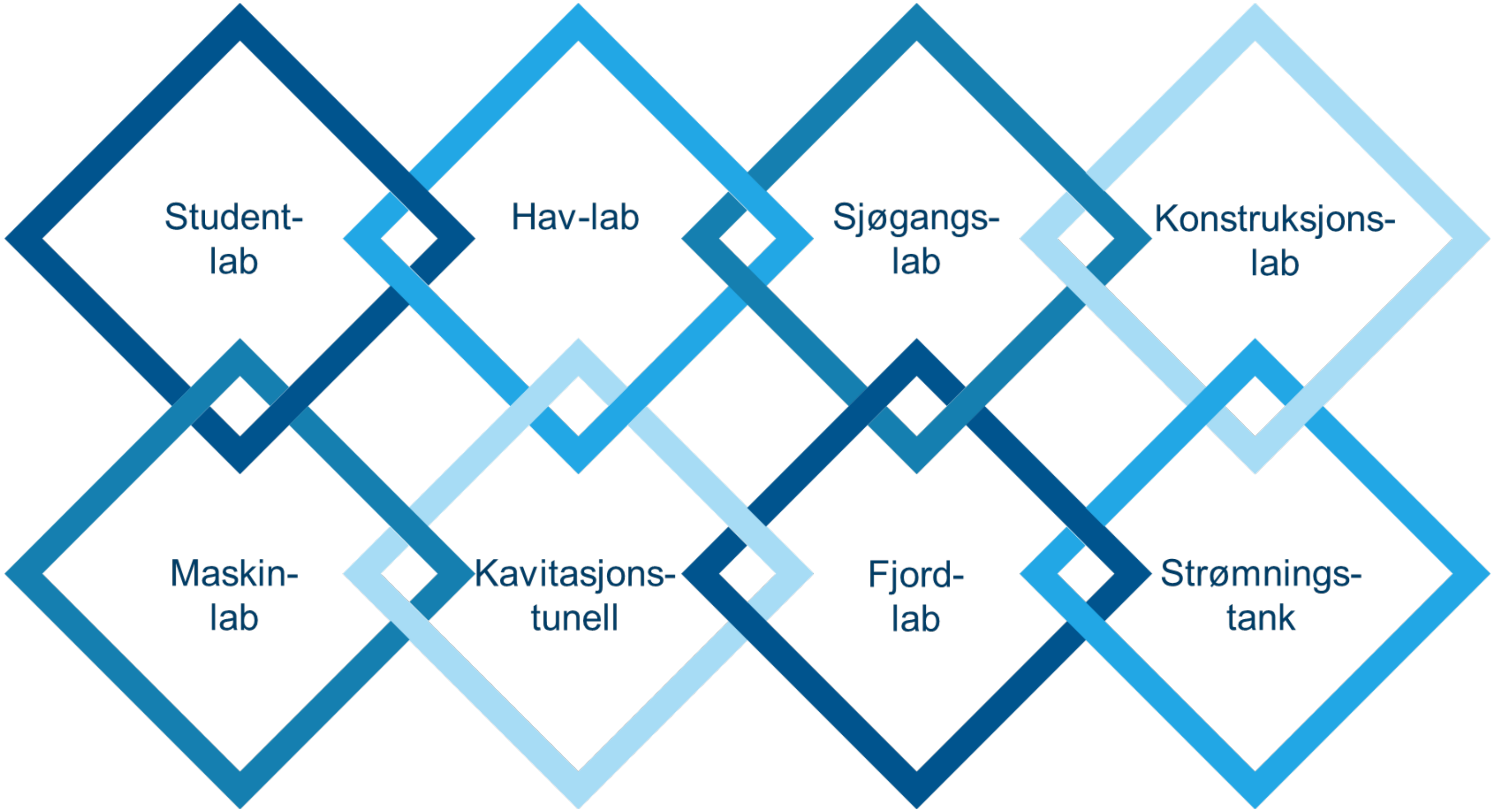
Gevinst-realisering

Tilpasset KVU

KS1

2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017

Laboratories of the new concept

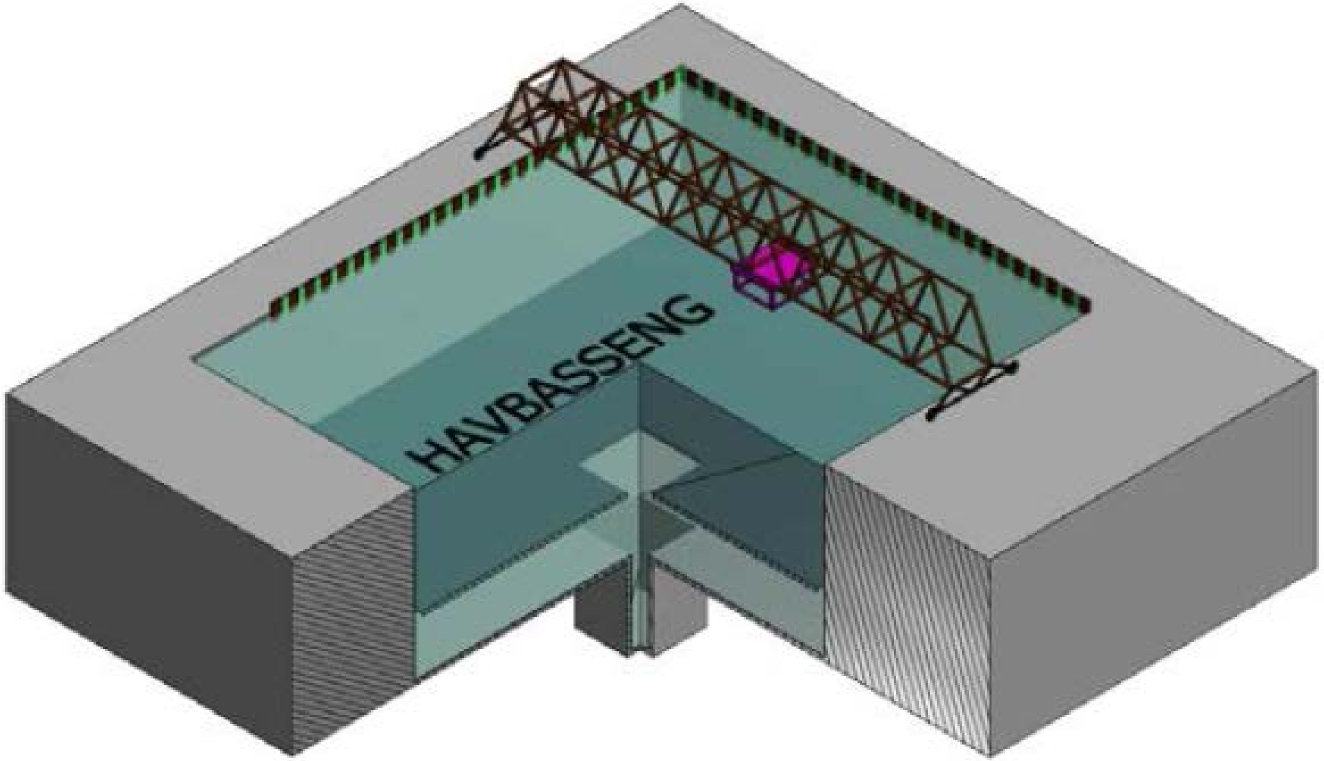


SINTEF

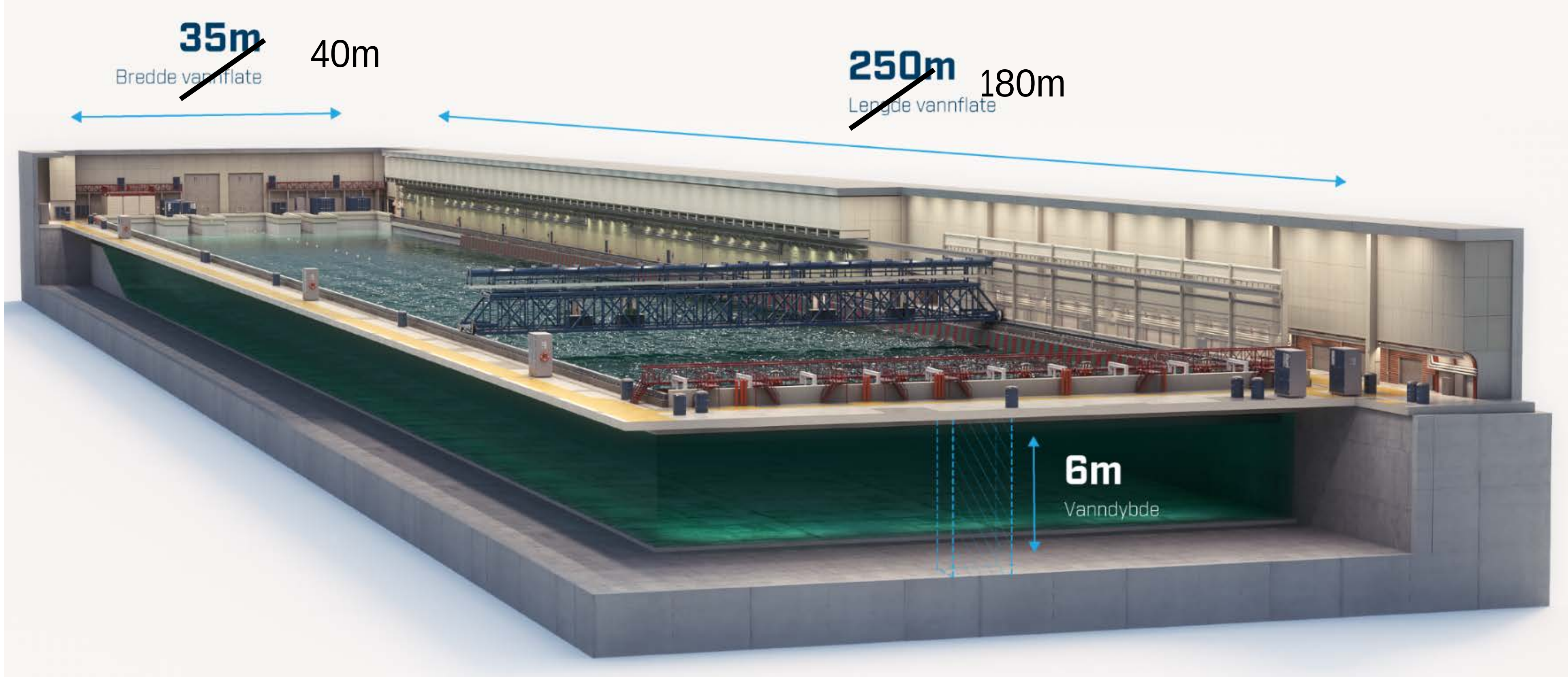
Ocean basin

50x60x20m

Center pit: 7,5x7,5x10 m



Sea-trial basin



Fjord (field) laboratories

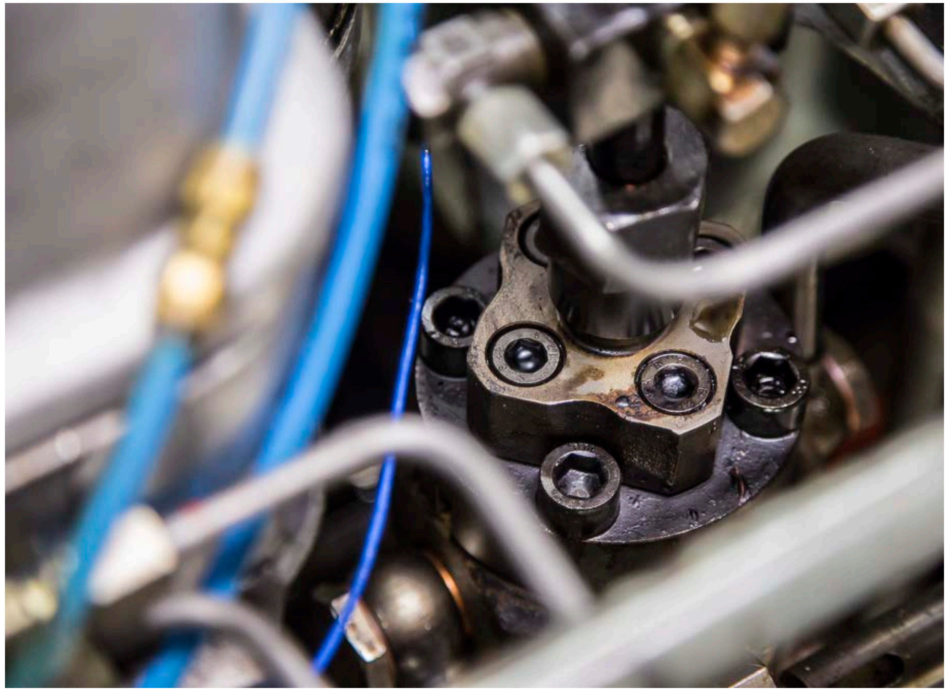
Trondheimsfjorden
- Autonomy and interventions
- Monitoring technology
- Digitalisation

Hitra/Frøya
- Fish farming technology
- Monitoring technology

Ålesund
- Full scale maritime testing
- Simulation center
- Monitoring technology

Flume tank

M-lab and K-lab



OCEAN SPACE CENTRE

SINTEF

NTNU

SINTEF

Teknologi for et bedre samfunn