A two-dimensional approximation of a floating fish farm in waves and current with the effect of snap loads

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Outline

- Introduction
- Floater in regular waves
- Net panel in uniform current
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- Floater, net and sinker in regular waves and uniform current
- Summary
Introduction

- Main challenges for offshore aquaculture industry
  - Fish escape from fish farms: mainly structural failure
  - Fish diseases
  - Environmental pollution

- Hydrodynamic effects
  - Wave forces
  - Current forces
  - Wave and current combination

→ Section of cage selected: simplified problem
  Experimentally and numerically analyzed
Floater in regular waves - Experiments

- Model test conditions:
  - Wave flume (2D flow conditions), MTS, NTNU
  - Deep water (h=1.0 m)
  - 10 wave periods
  - Wave steepness (H/λ=1/14)
  - Model scale 1:10
  - Rigid floater

- Measurements:
  - Accelerations of the floater
  - Forces in mooring lines
  - Wave elevation in the flume

Floater in regular waves - Experiments

- Sway and Heave Response Amplitudes; comparison with linear potential flow theory
  - Sway instability in both experiments at T=0.544 sec

Effects of viscous damping and pulley friction damping
Net panel in uniform current

- Screen Force Model (T.Kristiansen, O.M.Faltinsen (2012)): Constant solidity ratio, Constraint: length of the truss remains constant
- Hydrodynamic forces on the elements and tension in the elements

Small twine diameter; large KC

Cross-flow velocity at twines:

\[ U_n = \frac{U_{rel} \cos \theta}{1 - S_n}, \quad 0 \leq \theta \leq \pi/4, \]

Reynolds number:

\[ Rn = \frac{U_{rel} d_i}{v(1 - S_n)} \quad 10^{3/2} \leq Rn \leq 10^4 \]

\( S_n = \text{projected area of the net twines} / \text{total area of the net panel} \)

From T.Kristiansen, O.M.Faltinsen (2012)
Net panel in uniform current: Truss Model vs. Catenary Eq.

- Model verification in uniform current
  - Net shape
  - Tension in net twines
Sinkers tube in uniform current

- Morison equation is used.

- Experiments by *James and Truong (1972)* for spanwise tripping wire on a cylinder:
  - Ratio between net twine diameter and sinker tube diameter ($d/D = 3.2\%$, $6.3\%$)
  - Angle between net connection relative to the flow
    for angle 65 to 90 degree, $C_d = 1.6$ to $1.8$

- Unsteady lift force on the sinker tube due to vortex shedding
  - 3D effects of sinker tube and net connection can affect Strouhal number

\[ U = 0.2 \text{ m/s}, \quad S_n = 0.19, \quad W_s = 1.6, \quad f_v = 0.66 \text{ Hz} \]
Net panel in uniform current - Experiments

- Tension in net connection points to the bar
  - $W_s = 1.2$, 1.4, 1.6 kg
  - $U = 0.1$, 0.2, 0.3 m/s
  - $S_n = 0.16$, 0.19, 0.23
Floater, net and sinker in regular waves: Experiments

- **Model test conditions:**
  - 10 wave periods
  - Wave steepness \( \frac{H}{\lambda} = 1/14 \)
  - Solidity ratios (\( S_n = 0.16, 0.19, 0.23 \))
  - Sinker weights (\( W_s = 1.2, 1.4, 1.6 \) kg)

- **Measurements:**
  - Accelerations of the floater
  - Forces in mooring lines
  - Wave elevation in the flume
  - Net deflection
  - Tensions in net connecting points to the floater
• Net deflection in a wave period
  - Sn=0.23; Ws=1.6 kg
  - T=0.761 sec; H=0.065 m

 Floater, net and sinker in regular waves- Experiments

Time domain simulations

Very large snap loads in very short time; similar as risers, marine cables, equipment lowering devices, ...

Slack net

VIDEO
Time domain simulations: Floater Free-decay tests

- Accuracy of model by doing heave free-decay tests
- Time-domain equation of motion by including retardation function
  - Non-dimensional displacement and velocity of cylinder with radius R

\[
[m + a_{33}(\infty)]\ddot{z} + c_{33}z + \int_0^t R_{33}(\tau)\ddot{z}(t - \tau)\,d\tau = 0
\]
Floater, net and sinker in regular waves - Comparisons

- Snap loading prediction by considering net elasticity:
  Net modulus of elasticity is constant for 10% elongation

\[ T = K \Delta L, \quad K = \frac{AE}{L} \]

5~6 times T0

Snap Load Prediction: T=0.672 sec, amp=0.025 m

- Floater, net and sinker in regular waves - Comparisons

  - Snap loading prediction by considering net elasticity

  - $T=0.878$ sec, $amp=0.043$ m
• Net tensions for Sn=0.23 and Ws=1.6 kg

- Increase in maximum tensions for periods higher than T=0.601 sec

- Elasticity, length of net, sinker tube weight, wave excitation frequency and amplitude have effects on the loading
Floater, net and sinker in regular waves - Comparisons

- Sway and heave response amplitude operator, $S_n=0.23$, $W_s=1.6$ kg
  - No instability in sway
  - Less heave motion relative to floater only

Heave RAO

- Floater Only
- Numerical_snap
- Experiments

Sway RAO

- Experiments
- Truss_LPFT
- time_domain_truss

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Floater, net and sinker in regular waves and uniform current

- Net tensions for $Sn=0.16$ and $Ws=1.6$ kg
  - Opposite phasing of hydrodynamic forces on the floater and tensions due to netting on the floater $\implies$ cancellation of forces in the mooring lines
  - Calculation of $Cd$ for sinker tube is not straight forward
Summary

- Screen force model predicts hydrodynamic forces on the netting structure with very good accuracy,

- Time domain formulation used to solve floater motions, coupled with net and sinker tube,

- Snap forces in the netting predicted with good accuracy and should be of concern for net structure design,

- Floater, net and sinker tube have the same importance for the forcing on the model,

- Forces in mooring lines are measured and calculated for the wave and current combinations.
Thank You