Experimental and Numerical Investigation of Loads on Aquaculture Nets

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Introduction

The trend, nowadays, is to move the fish farms to more harsh areas where fish farms will suffer larger waves and stronger currents. Moreover, the dimensions of the fish farms are expected to increase. In this case, the hydrodynamic loads on fish farms are to be carefully predicted for design and assessment.

For traditional types of fish farms, loads on the nets contribute the most part. In particular, drag force is our main interest. Question is, how well the loads are modelled. In the past, loads are estimated using models without considering Reynolds effects. In experiments, Reynolds number is much smaller than in full scales while Reynolds effects are truly important when predicting the hydrodynamic loads. Thus experiments are carried out to test the loads on net panels. Numerical simulations are supplemented to make comparisons.

The hydrodynamic force model applied in this thesis is the screen type load model proposed by Kristiansen and Faltisen. The numerical simulation in this thesis is realized in the framework of the open source computational fluid dynamics toolbox OpenFOAM with version 4.1.

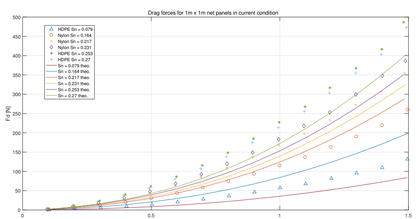
Objective and Structure

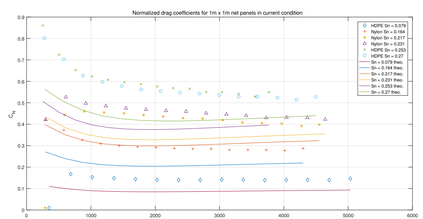
The purpose of this thesis is to investigate the drag force on the net panel with different size, material, solidity ratio and Reynolds number. This is realized by both experimental tests and numerical study supported by theoretical estimates. The results from experiments and numerical simulation will be used to check the validation of theoretical validation.

The thesis is organized as follows: First, an introduction of the topic will be presented; literature review is also included. Then, the hydrodynamic force model together with the porous media model will be introduced. Next the experimental and numerical investigation will be described respectively, and results and uncertainties are discussed. Finally conclusion and further work will be presented at the end of the report.

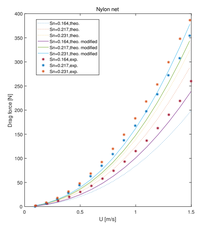
Experiment

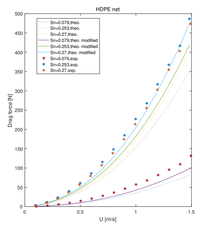
The experimental tests was carried out at Lilletanken, NTNU in January and February 2017, with the collaboration of Marintek and cooperation of Mael Moreau (NTNU, Trondheim). Tests are carried out in three situations: current only, wave only and current and wave. In current condition, the drag forces and the correspondingly drag coefficients are illustrated in figure below.

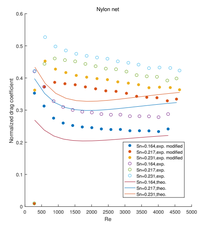


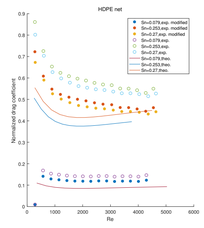


From figure we find that the deviation between the experimental and theoretical results are quite huge. This is mainly due to the non-linear steel frame effects (linear frame effects have been subtracted). The existence of the frame changes the original flow field and causes local speed-up near the frame. Once the local speed-up from the frame is included, the modified drag force and drag coefficient can be calculated. From figure below, one finds that the theoretical results after modification show better agreement with the experimental data now.



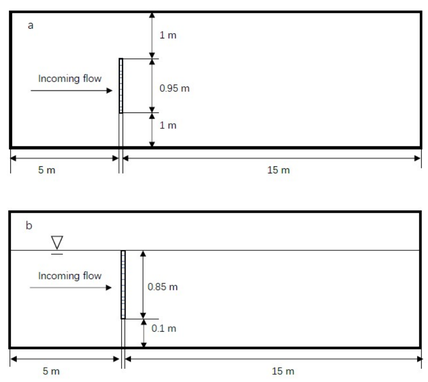


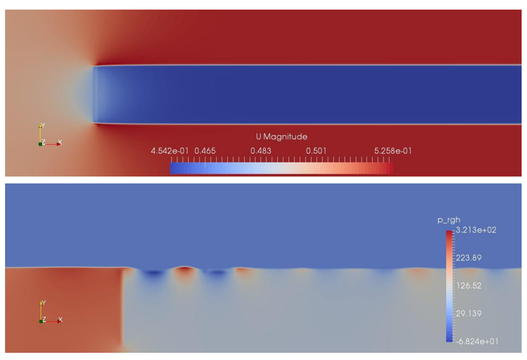




Numerical Simulation

The porous media model was proposed to solve the flow characteristics through and around a net panel. It was set up as porous media in single phase flow and two phase flow. The porous media in single phase flow was solved by a transient solver and the porous media in two phase flow was solved by a multiphase solver for incompressible, isothermal and immiscible fluids using volume of fluid (VOF) method. The sketches of the two cases are depicted below. The realizations in OpenFOAM are also presented below. The width of the porous media was set to be 0.05m, which is a commonly used value for porous media.





The top figure shows the velocity magnitude around the porous medium from a top view (incoming flow velocity is 0.5m/s in this case); the lower figure shows the pressure around the porous medium from the side view (incoming flow velocity is 1m/s in this case and gravity is included in two-phase flow simulation).

Acknowledgement Here I should thank my supervisor Trygve Kristiansen (professor, NTNU, Trondheim) for his guidance and instruction. I would also like to give my great appreciation to the guidance of Hao Chen (PhD student, DTU, Denmark) and the help from Mael Moreau (master student, NTNU, Trondheim) for the initiation of CFD simulation.

Screen Type Load Model

The hydrodynamic force model applied in this thesis is the screen type load model proposed by Kristiansen and Faltisen[1].
The hydrodynamic force is defined by:

$$F_N = \frac{1}{2}\rho C_N(\theta) A U_{rel}^2 \tag{1}$$

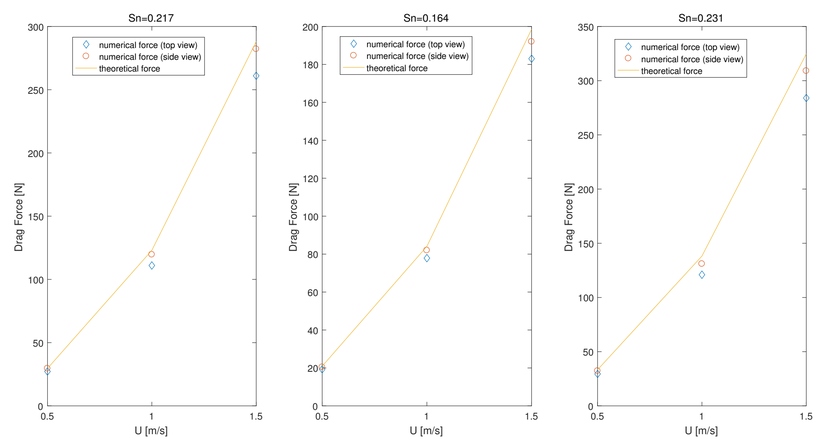
where ρ is the water density, A as the net panel area, and U_{rel} is the absolute value of the incoming flow velocity. The subscript N indicates the normal direction. The normalized force coefficient $C_N(\theta)$ in eq.1 is defined as:

$$C_N(\theta) = \frac{C_D^{circ.cly} S_n(1-2S_n)}{2(1-S_n)^2} cos^2\theta, \qquad 0 \le \theta \le \frac{\pi}{4} \tag{2}$$

where θ is the angle between the normal and inflow direction, S_n is the solidity ratio, and $C_D^{circ.cly}$ is the drag coefficient of a circular cylinder.

Reference [1] Kristiansen, T. and Faltinsen, O. M. (2012). Modelling of current loads on aquaculture net cages.Journal of Fluids and Structures, 34(218-235).

Conclusion



The theoretical prediction after applying the modified velocity profile shows a good agreement with the experimental data, which means the frame do have a significant effect on the net panel.
The figure above shows a good agreement between CFD results and theoretical prediction for nets with different solidity ratios. The CFD result from a two-phase flow simulation gives better fit with the theory.
More numerical results are coming out later and the comparison among the experiment,