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Proceeding Paper

Simulation of the Fluid–Structure Interaction in Fishing Nets †

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Abstract: The main objective of this work is the development of a Computational Fluid Dynamics model coupled with a structural code for the simulation and optimization of fishing gears. As fishing nets are highly deformable structures under the influence of incident water, the use of merely empirical correlations for hydrodynamic forces, such as those used in many structural codes, does not provide precise predictions for their behaviour. The coupling between the structural problem and the hydrodynamic effects makes it necessary to tackle the problem through a new "fluid–structure interaction" approach, which is described here. Preliminary results obtained with the CFD model are also presented.

Keywords: computational fluid dynamics (CFD); fluid–structure interaction (FSI); porous media; trawl nets

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1. Introduction

The fishing industry involves activity that is fundamental to supplying quality food to the world's population, and it constitutes a very important livelihood in coastal areas. Industrial fishing is carried out mainly by trawling gear, which consists of a bag-shaped net, towed by one or more boats, that captures the species that are in its path.

Currently, the fishing industry faces two challenges: the improvement of its energy efficiency and the elimination of discards. The best way to face these challenges is to reduce the drag coefficient of the nets and improve their selectivity.

Designing selective fishing gear is a very complex process, and it is mainly based on the expertise of fishermen and marine biologists, together with expensive tests in the open sea or in towing tanks. Nowadays, the design of gear cannot rely on Computational Fluid Dynamics (CFD) simulations of complete fishing nets because of their complex geometry and the high computational power required. With the idea to develop a simplified approach with a reduced computational cost, Patursson et al. [1] and Zhao et al. [2] propose the idea of modeling a net as a porous medium to simulate the hydrodynamic behaviour of the water flow in the structure using CFD computations.

On the other hand, the deformation of fishing nets during their operation affects their hydrodynamic behaviour. Therefore, the accurate simulation of a trawl also needs to account for structure deformation. Two-way coupling between hydrodynamic and structural models requires the implementation of a co-simulation method between a CFD model and a Finite Element Method (FEM) model of the net, following a fluid–structure interaction (FSI) approach. Zou et al. [3] propose a first approximation with one-way simulations, in which the net deformation is computed based on the hydrodynamic forces applied to the flat net. In this work, we simulate the implementation of two-way coupling between the net structure and the fluid by establishing data communication between a CFD and an FEM model. It is carried out in two steps:

- The development of a CFD model based on the use of porous surfaces for the simulation of the hydrodynamic behaviour of a fishing net.

- The implementation of co-simulation between the CFD and FEM models of a net.

2. Methodology

For the hydrodynamic model, open-source CFD libraries OpenFoam are used, which are based on the finite volume method. As for the FEM model, the choice of data is still pending further tests. The development of the final two-way coupled tool involves a series of milestones:

- The development of a CFD model based on the use of porous surfaces for the hydrodynamic behaviour of fishing net modeling, which includes the estimation of the appropriate porosity coefficients and validation of the results with experimental and numerical data.
- The implementation of co-simulation between the CFD model and an FEM model providing two-way solutions:
  - The implementation of a communication protocol between the CFD model and the FEM model.
  - The establishment and implementation of a calculation strategy based on a computational cost/accuracy ratio.

3. Preliminary Results

We are currently working on the development of the CFD model. The idea is to firstly simulate a net sample with highly detailed geometry, and validate the predictions in terms of drag and lift forces with data from the literature. This step requires a long testing procedure, in which the solver parameters are calibrated, and the minimum level of geometric details is determined in order to obtain precise results. Once the numerical results are available, we will start to develop a method to obtain the porosity parameters that lead to the same drag and lift forces as the complete net. This methodology allows the number of experiments to be reduced, leaving them only for the final validation stage.

In the first simulations, the net was idealized as a set of cylinders and spheres arranged in the shape of a cross, as described in the study by Lader et al. [4], and shown in Figure 1. Currently, two of the five configurations studied experimentally by Lader et al. [4] were simulated for a single flow velocity (0.6 m/s). The results are shown in Figure 2, where configuration 1 refers to a net without knots, and configuration 3 to a net with medium-sized knots. According to Figure 2, the CFD predictions are in good agreement with the experimental results for configuration 1. In contrast, the drag forces generated by the knot and the upper cylinder are underestimated for configuration 3. We intend to improve the numerical results by refining the mesh and adjusting the turbulence models with different wall roughnesses.

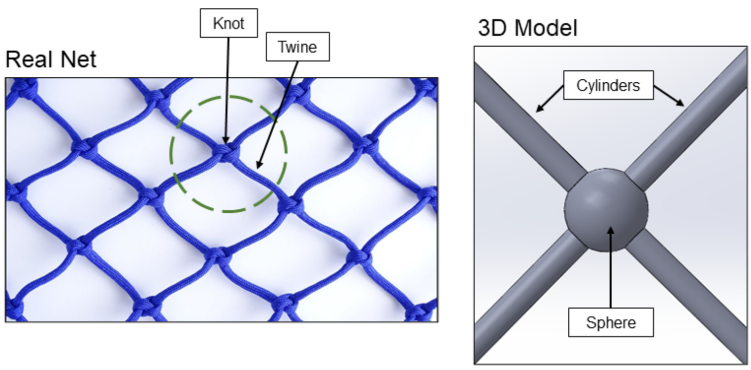

Figure 1. Real net (**left**) and idealization with cylinders and spheres (**right**).

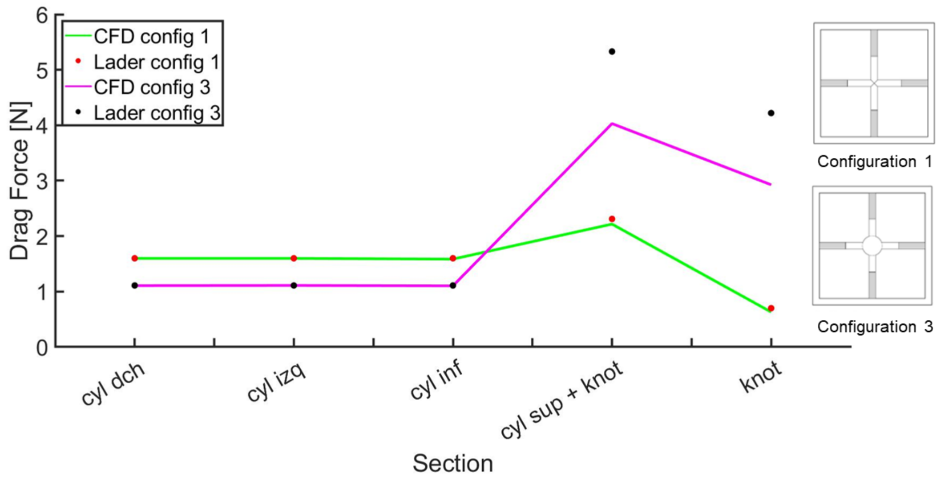

Figure 2. Results obtained by numerical simulations based on the experiments carried out by Lader et al. [4].

These simulations will be refined until a consistent relationship is achieved between the complexity of the net geometry and the accuracy of the data, since it is essential to obtain a reliable numerical model that provides the correct drag and lift forces of the net. These forces are essential data in order to obtain the porosity parameters that will allow the geometry of the net to be replaced with a porous surface.

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