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Time-Resolved PIV investigations of the flow field around cod-end net structures

Elkhadim Bouhoubeiny[a,b], Grégory Germain[a,c], Philippe Druault[b,*]

[a] IFREMER, Hydrodynamic & Metocean Service, 150 Quai Gambetta, 62321 Boulogne-sur-Mer, France
[b] University Pierre et Marie Curie-Paris 6, Institut Jean Le Rond d'Alembert, CNRS UMR 7190, case 162, 75252 Paris Cedex 5, France
[c] University Lille Nord de France, F-59000 Lille, France

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ABSTRACT

Flow field measurements past a fixed rigid cod-end structure and past a porous fishing net structure are conducted using Time-Resolved PIV method. The rigid cod-end is first used to characterize finely the wake flow. Proper Orthogonal Decomposition (POD) is then applied in order to extract the large scale energetic vortices of the flow from the measured velocity field. It is then observed that the first POD modes are associated to the Karman's type flow structure of vortex shedding. It is shown that the characteristics of the wake flow behind the rigid cod-end flow configuration compare quite well with previous ones obtained from bluff cylinder or sphere wake analyzes. Second, PIV measurements are performed around a non-rigid bottom trawl which is free to move. Preliminary analyses show that the frequencies associated with the oscillatory motion of the porous structure are the same as the ones detected in the near wake flow demonstrating the lock-in regime. It is then expected that these preliminary results provide some interesting informations about future investigations on the drag force acting on fishing net structure.

1. Introduction

The analysis of hydrodynamics of various types of fishing net structures, and especially of a trawl, has been of great interest for scientists for a long time. Such investigation has an impact not only on commercial fishing operations including the fishing vessel energy efficiency but also on biological and socio-economical environment. For bottom and pelagic trawls, the hydrodynamic turbulent flow has a great influence (i) on the stability of the movement of the fishing net structure; (ii) on the drag force of the fishing gear and (iii) on selectivity (the ability of fishing gears to prevent non-target fish catches). Due to its impact on fuel consumption, the second point is more and more crucial for fishermen and researchers (Dahm et al., 2002; Priour, 2009). The knowledge of these drag forces allows then the definition of the shape and the behaviour of the structure during a trawling process, and tension and loads in its threads and ropes (O'Neill et al., 2005). Globally, it is now well known that most of the fuel consumed during a fishing trip is used to tow the fishing gear and also that the trawls are responsible of the largest part of the fuel consumption during fishing operations. But, the determination of the drag force acting on net structures is a complex task. Even if the measurement of the whole drag force on the net structure with different size of catches (Pashen et al., 2002; Priour et al., 2006) may be possible, the determination of the drag contribution associated with each part of the trawl (net, catch, hydrodynamic forces...) remains today inconceivable. In this sense, we propose in this work to only focus on the hydrodynamic flow around the net structure hoping that a better understanding of the flow behaviour will provide some relevant information for future analyses of the drag force.

Porous structure poses challenging problem for the understanding of bluff body wakes. Indeed, porous structures are quite different to the usual classical rigid bluff bodies such as cylinders, spheres or disks which have been extensively analyzed in the past (see for instance the reviews by (Williamson and Govardhan, 2004; Govardhan and Williamson, 2005)). Furthermore, due to the flexibility of the net, there is a complex interaction between the flow, the shape of the net and its behaviour. In fact, the analysis of the hydrodynamic flow around (and also in) fishing net structures is extremely related to the strong influence of hydrodynamic fields on the shape of trawl elements, acting forces, fish behaviour and on catchability of fishing gears. The variations of incidence on the different part of the net (from 0° to 90°) induce different kind of behaviour of the flow, from laminar flow with a boundary layer development on the horizontal part of the net to separate flow through a porous structure for the higher panel angles or behind specific parts like the cod-end.

Despite its practical engineering application, there is almost no reported study dealing with the hydrodynamic flow analysis around porous structure and especially around realistic porous

* Corresponding author.
E-mail address: philippe.druault@upmc.fr (P. Druault).

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trawl free to move in the flow. Yet, it is clear that hydrodynamic flow has a very significant influence on the trawl moving process. To investigate the flow in presence of a net and a catch, Pichot et al. (2009) previously used Laser Doppler Velocimetry (LDV) measurements to study the mean flow field over a rigid cod-end with a closed and an open net entrance. Other previous works have focused on the analysis of different mesh sizes or numbers to improve the selectivity without taking into account the hydrodynamic flow. Instead of focusing on the hydrodynamic flow analysis, previous experimental works proposed to determine the total drag force using empirical formulations based on numerous assumptions (O'Neill and O'Donoghue, 1997). Besides, the complexity of the flow makes numerical simulations difficult, even if several authors made significant advances (Meyler, 2008). Today no effective model exists for such investigation (Patursson et al., 2010). An important work should be done on this area to improve the knowledge of the hydrodynamic flow past a fishing net structure.

It is important to predict the flow motion accurately: alternate shedding of vortices, which develops in the near wake, causes pressure forces which generate structural vibration and drag forces. In this sense, an experimental investigation is conducted to study the near wake of the flow around a cod-end, considered here as one of the more important part of a trawl (see Fig. 1). To simplify the issue, we firstly propose to investigate a modelled rigid cod-end net structure. Secondly, a 1/10 scaled bottom trawl is considered. In this last flow configuration, the fishing net structure is free to move. Particle Image Velocimetry (PIV) is implemented to access the instantaneous velocity fields in each flow configuration. To investigate the large scale flow structures around the cod-end, specific mathematical post-processing procedure such as Proper Orthogonal Decomposition is applied. Part 2 of the paper is devoted to the experimental set up and measurement method. Part 3 deals with the mathematical post-processing tool used to analyze PIV database. Then after presenting global flow results, the large scale flow structure characteristics in the wake of both rigid and free to move cod-end are examined.

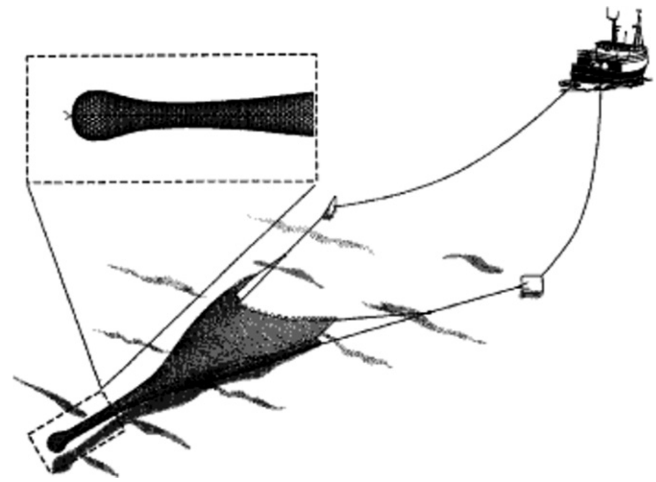

Fig. 1. Bottom trawl showing the position of the cod-end.

2. Experimental apparatus

2.1. Flume tank and fishing gear

Experimental campaigns are performed in the IFREMER (French Research Institute for Exploitation of the Sea) wave and current circulation flume tank shown in Fig. 2. The dimensions of the flume tank are 18 m (length) × 4 m (width) × 2 m (depth). A side observation window of 8 m by 2 m placed on one side of the tank allows users to observe the behaviour of the models during trials and to carry out video sequences. The bottom of the flume is a conveyor belt which can be synchronized with the water speed in order to simulate devices in contact with the bottom, like bottom trawls. The flow turbulence can be adjusted between 5 and 28% and the flow streamwise velocity range is 0.1–2.2 m s^{-1}.

The first flow configuration is the rigid cod-end given in Fig. 3. This rigid cod-end is used in order to avoid flow instabilities due to

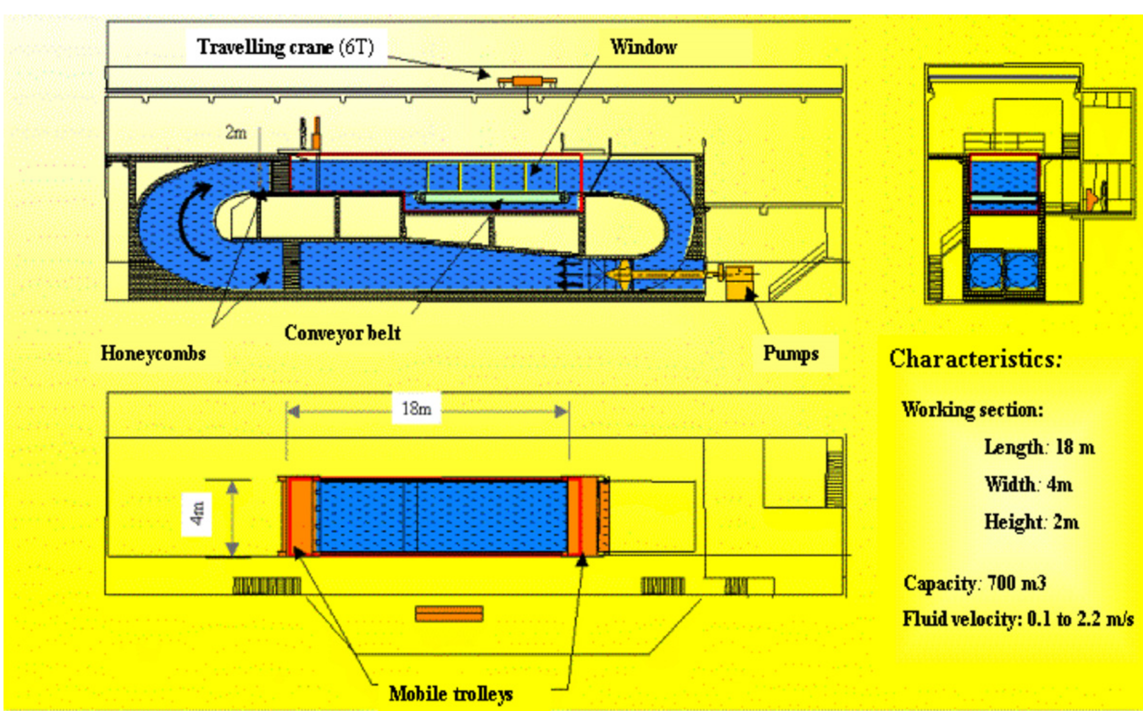

Fig. 2. Ifremer free surface hydrodynamic water tunnel.