HydroPêche: experimental and numerical developments for fishing devices optimisation

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HydroPêche Project

Goal of the project:

to develop tools for trawl optimization in order to minimize the drag of the gear.
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A work in three areas:

- to extend the basis of experimental data on flow characteristics governing the hydrodynamic behaviour of different porous structures

- to develop numerical tools to simulate more realistic flow around porous structures taking into account fluid / structure interactions

- to develop optimisation tools to design efficient trawls in terms of energy consumption.
Experimental flow characterization around trawls

Goal of this task:

- to extend the basis of experimental data on flow characteristics governing the hydrodynamic behaviour of different porous structures (sheets of net, trawls)

- to identify the areas where the drag is generated

Wave – Current flume tank

Characteristics:

- Working section:
  - Length: 18 m
  - Width: 4 m
  - Height: 2 m
- Capacity: 700 m³
- Fluid velocity: 0.1 to 2.2 m/s
Experimental flow characterization around trawls

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- to identify the areas where the drag is generated

Three kinds of trials:

- Flow characterisation around a 1/10 bottom trawl
- Flow characterisation around a rigid cod-end
- Flow characterisation around a large rectangular piece of net
Experimental flow characterization around trawls

Flow characterisation around a 1/10 bottom trawl

to perform velocity field measurements around a moving bottom trawl
to develop post-processing tools aiming at characterizing the unsteady flow
to provide measurement benchmark for numerical modeling
Experimental flow characterization around trawls

Flow characterisation around a 1/10 bottom trawl

Representation of mean flow field along the transverse direction at a fixed streamwise location and for two different instants

Boundary layer evolution

Time evolution of the bottom trawl during measurement
Experimental flow characterization around trawls

Flow characterisation around a 1/10 bottom trawl

Mean flow streamline topology

Kinetic energy

Power spectrum of the vertical motion

Power spectrum of Ux
Experimental flow characterization around trawls

Three kinds of trials:

- Flow characterisation around a 1/10 bottom trawl
- Flow characterisation around a rigid cod-end
- Flow characterisation around a large rectangular piece of net

LDV measurements on a rigid cod-end
Experimental flow characterization around trawls

Flow characterisation around a rigid cod-end

- mean flow field
- mean kinetic energy
- vortex shedding frequency

Mean velocity field

Turbulent kinetic energy
Experimental flow characterization around trawls

Three kinds of trials:

- Flow characterisation around a 1/10 bottom trawl

- Flow characterisation around a rigid cod-end

- Flow characterisation around a large rectangular piece of net
Experimental flow characterization around trawls

Flow characterisation around a large rectangular piece of net

- mean flow field
- comparison with bottom trawl results
- flow behavior over the curved part
Experimental flow characterization around trawls

Flow characterisation around a large rectangular piece of net

$\delta =$ function of: porosity, Reynolds number, and ??
Experimental flow characterization around trawls

Boundary layer evolution on both sides of the rectangular piece of net
Experimental flow characterization around trawls

Flow characterisation around a large rectangular piece of net

Mean velocity at a upper location

Mean velocity at a lower location
Numerical simulations for trawl behaviour modelisation

Goal of this task:
- to develop numerical tools to simulate more a realistic flow around porous structures taking into account fluid / structure interactions

State of the art:
- use of Landweber / Richtmeyer law to calculate the fluid forces on the net:
  \[ F = \frac{1}{2} \rho C_d D L (V \sin \theta)^2 \]
  \[ T = f \frac{1}{2} \rho C_d D L (V \cos \theta)^2 \]
- no fluid / structure interaction
Numerical simulations for trawl behaviour modelisation

First step of development:

experimental velocity profil integration in FEM model:
- in the turbulent boundary layer zone

Flow velocity in the TBL

- around curved parts: in progress
Numerical simulations for trawl behaviour modelisation

3D integration in progress:

- Source terms from structure code to represent a rectangular piece of net
- Integration to Navier-Stockes code
- Coupling in progress
Numerical simulations for trawl behaviour modelisation

3D integration in progress:

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Numerical simulations for trawl behaviour modelisation

3D developments:

for a complete fluid/structure modelisation
Energy optimisation of bottom and pelagic trawls

Goal of this task:
- to develop automatic optimisation tools to design efficient trawls in terms of energy consumption and to adapt the numerical code for the routine used by an optimiser

Optimisation tool based on:
- Finite Element Method 3D model of the net
  no fluid/structure interaction but with the rigging, headline, wings…
- Successive search per parameter method
- Specific target for bottom trawl and pelagic trawl
Energy optimisation of bottom and pelagic trawls

Optimisation of a bottom trawl:

Objective: optimised the drag over swept width ratio

Results:
- improvement of 17% on fuel consumption
- optimised swept width 27m (22.3m for the reference one)

potential increase of fishing catch
Energy optimisation of bottom and pelagic trawls

Optimisation of a pelagic trawl:

Objective: optimised the drag over the mouth surface

Results:
- improvement of 39% on fuel consumption
- conservation of the mouth surface (~200 m²)
Energy optimisation of bottom and pelagic trawls

Optimisation of a bottom trawl:

Front view of a trawl. The fish caught is expected to be the intersection of the trawl mouth and the fish repartition (here 3 m height between the two lines).

Presentation of the different cables used on a bottom trawl (warps, doors, foot-rope).
Energy optimization of bottom and pelagic trawls

Conclusion:

- specific data analysis carried out from PIV measurements around a bottom trawl, a rigid cod-end and a large rectangular piece of net
- unsteady mean boundary layer flow filed
- unsteady wake flow vortex
- numerical tools to simulate the flow around trawls
- developments of optimisation tools

Perspective:

development of a complete fluid/structure model to simulate the behavior of bottom and pelagic trawls usable by the optimization tools