Hydrodynamics Facilities Newsletter

The evolution of the experimental facilities as well as the development of instrumentation and analysis tools are one of the key points in order to answer the new needs of the present scientific and industrial projects. Through the description of a few recent projects, we present in this newsletter some of the evolutions carried out in this way:

- the new capabilities of our flume tank in terms of combined trials under waves and current
- two offshore trials conducted to determine the behaviour of structures under waves
- the characterisation of a flow through flexible and porous structures with Proper Orthogonal Decomposition analysis
- a coastal project carried out to quantify the oyster tables impact on the flow from Laser Doppler Velocimetry measurements

Wave and Current Flume Tank

For a few months, the flume tank of Boulogne-sur-Mer has been equipped with a wavemaker and a damping beach. This new wave-current circulation facility offers unique features to study the behaviour of marine devices submitted to the combined effect of waves and current. This new equipment will also be useful to increase the knowledge of wave/current interactions in deep or shallow water and also to study the behaviour of mid-deep or coastal structures submitted to wave and current impacts.

The wave generator is composed of 8 independent displacement paddles of 0.5 m wide and 300 mm deep. It can be easily moved between an upstream or a downstream surface position in order to create waves propagating with or against the current. Without current, the capabilities of the wave generator enable the production of regular waves with a period range between 0.5 to 2 seconds and a maximum peak-trough height of 280 mm.

Measurements revealed that the resulting reflexion coefficient was less than 12 % for all the usual periods and amplitudes. Wave spectrum models like Pierson-Moskowitz, JONSWAP, Bretschneider and others can be used for the generation of random waves.

A series of tests was carried out for measuring the mean vertical profiles of axial velocities on wave-current interactions. Some results of this campaign are presented below, for a current of 0.4 m/s and waves of 150 mm height and 0.6 Hz frequency. The profiles without waves are different from the one with pure current because of the disturbances produced by the wavemaker or the damping beach at the upstream location in the free surface: the mean-velocity is decreasing near the surface and is increasing in the bottom region. Current profiles in combined flows show that when waves propagate against the current, an increase in the current intensity is achieved near the mean water level, while a reduction is obtained for waves following current. This phenomenon is a consequence of nonlinear effects along the whole water column.

The generation of waves modifies the turbulence intensity level of the flow only on the upper part. The possibility to adjust the turbulence level of the flow (between 5 to 28%) which is of great interest for the study of wakes interaction and turbulence effects on marine current turbines can then be used for combined trials under waves and current.

Mean velocity profiles: pure current (left), with waves following and opposing current (middle) and amplitude of the corresponding orbital velocity of waves (right)
Steel Catenary Riser and Vertical cylinders in interaction

Within the frame of the European Program METRI for transnational access of facilities in Ocean Engineering, National Technical University of Athens was offered a contract to test a model of Steel Catenary Riser (SCR) and a model of a group of four vertical cylinders in the Ifremer ocean wave tank of Brest. These experiments concern all typical in-plane directions of the external excitation, namely, vertical, horizontal, axial and normal to the tangent at the top terminal point.

Steel Catenary Riser and Vertical cylinders in interaction

The steel catenary riser model at scale 12.5 was a glass reinforced plastic pipe for bending stiffness and with an internal steel wire cable for weight adjustment. The system was fitted in order to avoid parasitic motions of the cable inside the pipe. The top end of the riser model is connected to a planar motion mechanism able to induce heave and surge motions in the plane of the model. The other end of the model lays on the tank bottom, the touch down point is located approximately at 55% of its total length from the top end.

The measurements for the dynamic bending moments are obtained using four strain gauges in five locations distributed above the touch down point allowing in- and out-of-plane measurements. Three accelerometers are attached along the structure. The measurements for the dynamic tension at the top of the structure are taken by activating the tension gauges on the oscillator.

Various harmonic motions with amplitudes and frequencies are applied and the most energetic case at the equivalent full scale is 1.5m amplitude and 1.5rad/s frequency. Comparison of measurements results to numerical computation run by NTUA including high order harmonics in the signals shows a favorable agreement.

The experimental campaign carried out to test a model of a group of four vertical cylinders includes measurements of 6 components loads on the restrained four cylinder configuration in regular waves as well as under the combined action of regular waves and low-forward speed.

First and second order wave loading including mean drift and time-dependent second order components are extracted from the signals. In addition the wave elevation is measured in the gap between the cylinders or wave run-up along their wetted surface at a total of 8 specific locations. Two wave angles are considered at 0° and 45°. Results of measurements were successfully compared to numerical prediction from NTUA.
HydroPêche Project

The analysis of hydrodynamics of various types of fishing net structures, and especially of a trawl, has been of great interest to 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. Due to its impact on fuel consumption, the second point is crucial for fishermen and researchers. One of the issues that remains unresolved concerns the origin of the drag on the net structure. In order to find some elements of answer, it is necessary to analyse the hydrodynamic flow around a fishing net structure, which is one of the main goals of the HydroPêche Project*.

The final objective of this project is to develop tools for an automatic optimisation of trawl in order to minimize the consumption for the towing process. For that purpose, different aspects are studied in order: a/ to extend the basis of experimental data on flow characteristics governing the hydrodynamic behaviour of different porous structures ; b/ to develop numerical tools to simulate more realistic flow around porous structures taking into account fluid / structure interactions; c/ to develop automatic optimisation tools to design efficient trawls in terms of energy consumption.

Due to the flexibility of the net, there is a complex interaction between the flow, the shape of the net and its behaviour. The analysis of the hydrodynamic flow around fishing net structures is then extremely related to the strong influence of hydrodynamic fields in the shape of trawl elements, acting forces, fish behaviour and on catchability of fishing gears.

Porous structure poses challenging problem for the understanding of bluff body wakes. The variations of incidence on the different part of the net (from zero to ninety degrees) induce different kinds 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. So the origin of the drag is various and the contribution of each part is not well known (alternate shedding of vortices, which develops in the near wake, causes pressure forces which generate structural vibration and drag forces).

Flow field around a bottom trawl are conducted using Time Resolved Particle Image Velocimetry (PIV) method. Based on these measurements, the characteristics of the resulted wake flow are investigated. Proper Orthogonal Decomposition (POD) is applied in order to extract the large scale energetic vortices of the flow from the measured velocity field. Such application allows a low dimensional description of the wake which demonstrates the effectiveness of the POD procedure to isolate the large scale flow structures (containing the most kinetic energy) from the background incoherent fluctuations. Indeed, it is observed that the first and the second POD eigenfunctions are associated to the vortex shedding flow structures in the wake of a cod-end. Different flow instability mechanisms are also detected. POD is shown to be robust to act as a filter for the frequency analysis. Indeed, a low order representation composed of the mean flow and the first POD eigenfunctions provides a good description of the coherent wake motion, enabling the identification of the major characteristics of the vortex shedding process. To investigate the drag force acting on fishing net structure in the future, it is necessary to control these flow instabilities and also the one associated with the boundary layer developing onto the porous structure.

* Project supported by the French Ministry of Agriculture and Fisheries and the European Community, conducted by Ifremer in partnership with: Ecole Navale, Ecole Centrale de Nantes, University of Paris 6 and University of Rennes 1

http://www.ifremer.fr/hydropeche
## Oyster Tables Impact on the flow

The lack of knowledge about the impact of an oyster farm on the wave propagation and on the flow remains a significant difficulty for the comprehension of sediment transport processes in coastal zones. This can be harmful for the production in case of strong siltation. To highlight this problem, a fine description of the hydrodynamical phenomena (velocity fields, turbulence levels) is needed. In order to study these phenomena, both experimental and numerical works have been carried out. The experimental part is done to analyse the flow perturbations in the field of one or two tables with a reduced length while the numerical work is conducted in order to study the impact of more realistic table lengths on the flow. Velocity and turbulence fields obtained by this kind of modeling could be put into large scale hydrodynamic coastal models in order to reproduce the effects of an oyster farm on hydrodynamics and sediment dynamics on the scale of a bay or a basin. Then, these results obtained by a wide-extension hydrodynamical model can be used to simulate the disturbance produced by a whole oyster farm. This could help to define the best configuration for the limitation of the siltation phenomenon.

In the field, an oyster table is typically 100 m long by 1 m wide and 0.7 m high. A good understanding of the current-table interactions led to the choice of a 1/2 scaled model. Representing the whole table lengthwise would require a much greater scale. However, preliminary trials show that a length of 7.20 m gives a good knowledge of the flow interaction with the structure: the length is sufficient for the upper boundary layer establishment. These dimensions were also chosen so as to allow multi-orientations in the tank, with a low blockage ratio. The oyster table model is made of 8 mm diameter galvanized iron rod. The oyster bags are manufactured with the same plastic nets as used in the field, but with a 7 mm meshes, while the size ratio between reality and experiments is preserved. The bags are filled with pebbles used to simulate oysters.

Shear stresses measurements reveal that there is no consistent modification on the bottom, i.e. no direct impact on the bottom sediment but there is an increase in the total shear stress which leads to energy dissipation by turbulence. This energy dissipation involves an overall flow decrease, and in turn modifications of sediment transport patterns at a greater spatial scale. The effect of the succession of tables is an increase of the total shear stress and hence of energy dissipation.

In order to reach more realistic table lengths and to model the impact of a whole oyster farm on the flow, a porous model has been developed. After validation work from experimental results on reduced table length, the extension of the model to real size of oyster tables allows the investigation of the hydrodynamic behaviour of the flow around several tables at real scale. So, the wakes interaction and bottom shear stresses of the tables are now numerically reachable for a part of an oyster farm in different configurations of the mean flow incidence.

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**Experimental and numerical studies for the characterisation of oyster tables impact on the flow, B. Gaurier & al., 2010**

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