Title of the offer: Fixed-term contract Doctoral researcher: Experimental and numerical studies of boat-waterways interaction with analogous experiments and in towing tanks (M/F)

Title of the offer: CDD doctoral researcher: (M/F)

Number of Positions: 1
Place of work: CHASSENEUIL DU POITOU
Publication date: mid-May 2024
Type of contract: Fixed term doctoral researcher/doctoral contract
Contract duration: 36 months
Post-doctoral start date: October 1, 2025
Work shift: Full time
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Description of the subject of the doctoral work

The Curiosity team at the Pprime institute wishes to recruit a doctoral student as part of a collaboration with the Voies Navigables de France (VNF) and the Laboratory of Mathematics and Applications (LMA) of Poitiers in order to study the navigation in a confined environment with a view to fluid-structure interaction. In addition to a post-doctoral project in progress on a revisit of theoretical work on the effects of hydraulic and undulatory confinement for a river boat interacting with the structure (typically a trapezoidal canal), we now wish to feed the theoretical studies by experiments to screen the models as well as to guide modelers towards the relevant models due to gaps in the understanding of the phenomena as revealed by the analysis of the literature and which the experiments could fill.

For example, one of the challenges consists of determining the critical speed of a river boat corresponding to the appearance of hydraulic confinement phenomena which result in a return current around the hull of the ship, a variation in the level of the plane of water, a modification of the resistance to the advancement of the ship depending on the geometry of the waterway, its roughness of the slope or the presence of a current, the naval architecture characteristics of the boat such as the block coefficient or friction on the hull [1,2].

The work of the theoretical post-doctoral student in support of the future thesis was first bibliographical on the basis of a state of the art provided by VNF of the scientific theories available in the field of waterways. The consortium thus formed between Pprime, the LMA and VNF has since then worked to extend the theories on navigation in confined environments from the literature by removing simplifications and inaccuracies and, by attempting to unify them in a complete theory integrating practical knowledge as well as as engineering type formulations with work in applied mathematics on the calculations of resistance to the progress of the ship to arrive at an analytical formulation of the whole which can serve as an operational basis.
An analogy between the theoretical behavior of a flow above a bottom obstacle occupying the entire width of the channel and the so-called energetic approach to navigation in a confined environment was also discovered independently by the Pprime team in the framework of

another study of an experimental nature on the hydrodynamic regimes (hydraulic + dispersive) of inhomogeneous subcritical and transcritical flows (Figure 1). With this resemblance which makes it possible to calculate in both cases a critical speed of entry into the transcritical regime (with a consequent increase in the resistance to the advancement of the ship in the fluvial case), it therefore appears natural to attempt to generalize the results at total lateral confinement (the obstacle/boat occupies the entire width of the channel) to partial lateral confinement (the obstacle/boat does not occupy the entire width of the channel) then partial sectional (a bottom obstacle inverted = an obstacle on the surface = a boat). 3 dimensionless numbers allow us to characterize the 2 situations:
- the ratio between the draft of the boat or the height of the obstacle with the height of water in the canal: T/h
- the ratio between the main beam of the boat or the width of the obstacle with the width of the channel: B/W
- the ratio of the sections of the boat or the section of the obstacle to the section of the canal: m=Ab/Ac

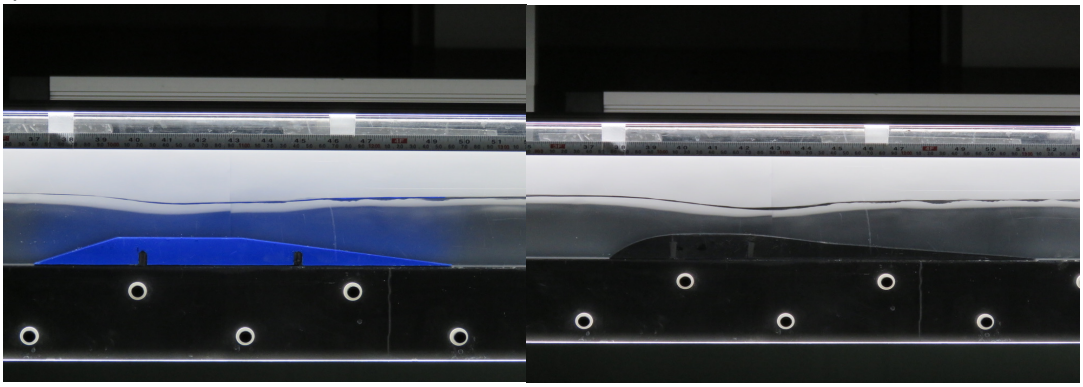

Figure 1: (left) obstacle with discontinuous geometry; (right) obstacle with continuous geometry. The undulation downstream of the obstacle occupying the entire width of the channel corresponds to the 1D wake of the boat in an equivalent confined environment.

Therefore, we propose a thesis subject combining experiments of fluid-structure interactions in the channels of the Pprime Institute and theoretical/numerical modeling. On the experimental level, the recruited doctoral student will characterize the flow regimes around and above a fixed bottom obstacle which does not occupy the entire width of the channel in a central position then eccentric (the analog boat moves closer to the banks) in relation to a free surface canal 3m long with a canal section of rectangular/trapezoidal/triangular/any geometric shape. Then the obstacle will be turned over and fixed on a vertical actuator: a classification of the flows around the obstacle which is first rigid then allowed to pitch and/or pound will be sought. Finally, a scale-up in the 30 m long hull test tank of the PHE platform of the Pprime Institute (environmental hydrodynamics platform: https://pprime.fr/la-recherche/fluides-thermique-combustion/plateforme-hydrodynamique-environnementale-fr/?cn-reloaded=1) will be carried out to complicate the situation compared to the model case of the obstacle in a flow (Figure 2). Background obstacles designed by 3D printing with different geometries (continuous and discontinuous, see Figure 2) and aspect ratios will be studied. Model boats with different block coefficients will be used.

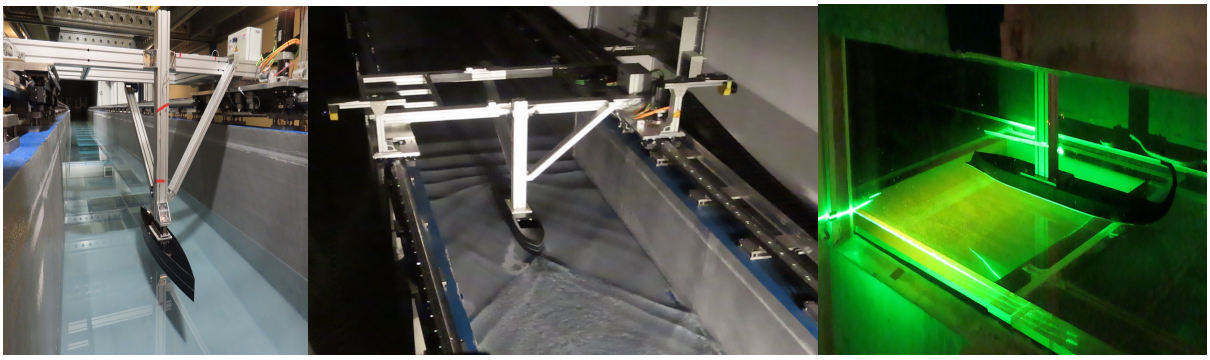

Figure 2: (left) towing tank at the Pprime Institute with its traction trolley and a model of a maritime boat; (middle) transcritical wake of a river boat with solitons emission (right) particle image velocimetry of the flow around an ancient galley.

At the metrological level, surface characterization methods in fluid-structure interaction will be implemented supplemented by measurements of currents around the object (obstacle or boat) by particle image velocimetry (Figure 2) as part of the CEMOP platform of the Pprime Institute (https://www.univ-poitiers.fr/accompagner-les-entreprises/innover/plateformes-technologiques/plateforme-de-metrologie-cemop/).

Modeling taking into account the hydraulic effects in line with the boat and including wave forces (horizontal, vertical forces and torque) will be implemented, drawing inspiration from river navigation models present in the literature. The justification of these models is the subject of research in applied mathematics [3] carried out in parallel at the LMA as part of the collaboration with VNF. The latter are based on a connection of hydraulic models (close to the boat) and dispersive models (far from the boat).

The results will be the subject of, in addition to progress reports for VNF, international scientific publications co-signed VNF/Pprime/LMA. The position is located in a sector falling under the protection of scientific and technical potential (PPST), and therefore requires, in accordance with regulations, that the arrival of the recruited person be authorized by the competent authority of the MESR.
The thesis will be co-supervised by Germain Rousseaux, HDR CNRS Research Director (Pprime Institute) and Julien Dambrine, Lecturer at the University of Poitiers (LMA).

Bibliography:
[1] P.-J. Pompée, *"About modelling inland vessels resistance and propulsion and interaction vessel – waterway Key parameters driving restricted/shallow water effects"* - Proceeding of Smart Rivers, Buenos Aires, 7-11 September (2015).
http://www.pianc.org.ar/_stage/pdf/papers_sr2015/180_paper_Pompee_FRA.pdf
[2] Thèse de Clément Caplier, Université de Poitiers, 01/11/2015 - 05/12/2015.
Sujet : Etude expérimentale des effets de hauteur d'eau finie, de confinement latéral et de courant sur les sillages et la résistance à l'avancement des navires.
http://www.theses.fr/2015POIT2315
[3] J. Dambrine, M. Pierre, Regularity of Optimal Ship Forms Based on Michell's Wave Resistance, Applied Mathematics and Optimization, **82**, pages 23–62 (2020).
https://hal.science/hal-01383229v2/file/DPregularity_preprintv3.pdf

Constraints and risks
Short-term trips, in France and abroad, are to be expected.
Experiments in hydraulic channels will be carried out.

Further information
An “experienced” level or “mastery” in French is required (C2 or C1 according to the European framework of reference). Please consult the European Framework of Reference for Languages (CEFR): https://www.service-public.fr/particuliers/vosdroits/F34739
The laboratory reserves the right to request the test result (TEF or DELF).