PROPOSAL FOR A PAID INTERNSHIP/THESIS SUBJECT

Job title: Master 2/PhD Thesis: Experimental and numerical studies of the boat/obstacle-restricted waterways interaction with analog experiments and a towing tank (M/W)

Laboratory: Institut Pprime CNRS
Location of the internship/PhD thesis: Futuroscope, Poitiers (France).
Duration: 5-6 months+3 years. Starting in March-April 2025.
Internship and PhD thesis Supervisors: Germain Rousseaux, CNRS Research Director and co-Team leader of Curiosity and Julien Dambrine, Associate Professor at Poitiers University, Laboratory of Mathematics and Applications.
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Description of the subject for master's (5-6 months) and doctorate (3 years).

Context of the work:

The Curiosity team of the Pprime institute wishes to recruit a Master 2 student leading to a PhD thesis recruitment both funded within the framework of a collaboration with the Voies Navigables de France (French Waterways, VNF) and the Laboratoire de Mathématiques et Applications (LMA) of Poitiers in order to study navigation in a confined environment from a fluid-structure interaction perspective. In addition to an ongoing post-doctorate on a revisit of theoretical work on the effects of hydraulic and wave confinement for a river boat interacting with the structure (typically a trapezoidal canal), we now wish to feed the theoretical studies with 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 that the experiments could fill.

For example, one of the challenges is to determine 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 vessel, a variation in the level of the water plane, a modification of the resistance to the advancement of the vessel according to the geometry of the waterway, its roughness of the slope or the presence of a current, the characteristics of the naval architecture of the boat such as the block coefficient or the friction on the hull [1,2].

The work of the theoretical post-doctoral student in support of the future experimental master/doctoral student was first bibliographical on the basis of a state of the art provided by the French Waterways VNF of the scientific theories available in the field of the waterway. The consortium thus formed between Pprime, the LMA and VNF has since 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 engineering-type formulations with work in applied mathematics on calculations of resistance to the ship's progress to arrive at an analytical formulation of the whole which can serve as an operational basis.

An analogy [3] between the theoretical behavior of a flow over a bottom obstacle occupying the entire width of the channel and the so-called energy approach to navigation in a confined environment was also discovered independently by the Pprime team as part of another

experimental study on the hydrodynamic regimes (hydraulic + dispersive) of inhomogeneous subcritical and transcritical flows (Figure 1). Given this similarity, 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 seems natural to try to generalize the results with 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 confinement (an inverted bottom obstacle = an obstacle on the surface = a boat). 3 dimensionless numbers are used to characterize the 2 situations:

- the ratio between the draft of the boat or the height of the obstacle with the water height in the canal: T/h
- the ratio between the beam of the boat or the width of the obstacle with the width of the canal: B/W
- The ratio of the sections of the boat or the section of the obstacle with the section of the canal: m=Ab/Ac

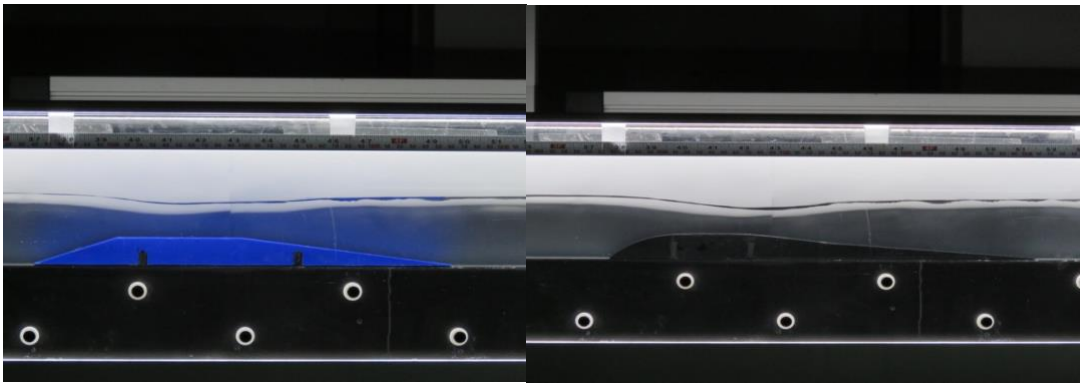

Figure 1: (left) obstacle with a discontinuous geometry; (right) obstacle with a continuous geometry. The undulation downstream of the obstacle occupying the entire width of the channel corresponds to the 1D wake of the boat in an equivalent confined environment.

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

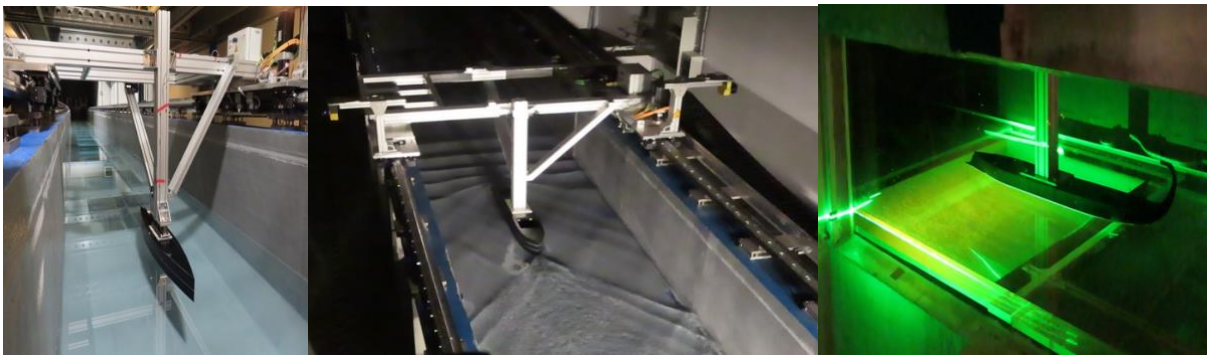

Figure 2: (left) hull test basin of the Pprime Institute with its traction trolley and a model of a maritime boat; (middle) transcritical wake of a river boat with soliton emission (right) particle image velocimetry of the flow around an ancient galley.

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) within the framework of the CEMOP platform of the Pprime Institute (https://www.univ-poitiers.fr/accompagnementr-les-entreprises/innover/plateformes-technologiques/plateforme-de-metrologie-cemop/).

A model taking into account the hydraulic effects at the level of the boat and including wave forces (horizontal, vertical forces and torque) will be set up, drawing inspiration from river navigation models present in the literature. The justification of these models is the subject of research in applied mathematics [4] 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, in addition to progress reports for VNF, of international scientific publications co-signed by VNF/Pprime/LMA. The position is located in a sector relating to the protection of scientific and technical potential (PPST), and therefore requires, in accordance with the regulations, that the arrival of the person recruited be authorized by the competent authority of the French ministry of research and higher education.

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] A. Bossard et al., On the art of designing effective space-times with free surface flows in Analogue Gravity, En cours de publication au Compte Rendu Physique (2024). Preprint : https://arxiv.org/abs/2408.15629

[4] 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 travel, in France and abroad, is to be expected.
Experiences in hydraulic canals will be conducted.

Additional Information:
Applications should include a detailed CV; a one-page cover letter.