Ph.D. Doctoral position in Fluid Mechanics and Hydraulics

Subject : Experimental study and modelling of large objects in a free-surface flow: application to the search for drowning victims in rivers

Project summary:
The aim of this project is to improve the search for drowning victims in urban waterways. In order to optimize the search area, we are seeking to define the probability map of the victim's presence at each moment during search operations (aiming a resuscitation, lasting for one to two hours) and, in the event of failure, in the longer term (search for the body). This involves modeling the trajectory of an object in a turbulent free-surface flow. The specificity of the project is that it focuses on "large" objects, i.e. of a size comparable to the characteristic scales of the flow (depth, secondary currents or coherent structures). The aim of this Ph.D. is to develop a model adapted to the interactions between this type of object and the flow. The work will initially be experimental, focusing on flows in the laboratory, using simple objects and scale models of victims, but also *in situ*, monitoring the drift of dummies in the Rhône and Saône rivers in Lyon. The aim is to understand the parameters influencing the trajectory of victims, and then to integrate their influence into Eulerian-Lagrangian models.

Funding : Agence Nationale de la Recherche (Project « ARCO » 2024-2027)

University : INSA Lyon, France ; Ecole doctorale « MEGA », Lyon

Laboratories : LMFA, Lyon, France; HECE, Liège, Belgium ; INRAE-RiverLy, Lyon ; France

Collaboration : SDMIS (Divers from the fire brigade), Lyon

Location : INSA Lyon, 69100 Villeurbanne, France

Start **:** Fall 2024

Information / Application :

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Background and operational objectives

In large urban areas, rivers represent a major asset in terms of cultural identity, sustainability and tourist and economic appeal. However, urban rivers are also associated with a darker side: the tragedy of drowning. In Lyon, France's second largest urban area, crossed by two major rivers, the Rhône and the Saône, around a hundred river rescue operations are recorded every year. Despite the professionalism of rescuers, too few of the victims who are not rescued before sinking are saved by underwater searches. The ARCO project, funded by the French National Research Agency (ANR), brings together several laboratories and the divers from the fire brigade (SDMIS, Lyon), with the aim of improving the search for drowning victims. It includes technical work (detection, search assistance) and research in the human and social sciences (prevention, collection of reliable testimonies), as well as in fluid mechanics and hydraulics (prediction of the victim's position underwater). The latter is the focus of this thesis, involving the LMFA (Lyon), HECE (Liège) and INRAE-Riverly (Lyon) laboratories.

Scientific objectives

The operational objective of the Ph.D. is to define a probability map of the victim's presence at each instant during search operations for resuscitation (i.e. several tens of minutes) and in the longer term, in the event of failure (search for the body). To achieve this, it is necessary to understand the parameters that affect a victim's trajectory, and then to include them in a model that can predict trajectories, in order to better circumscribe search zones. Understanding and modeling the dynamics of solid objects in a flow is a central issue in many industrial and environmental applications[1]. The most suitable viewpoint for describing or modeling the motion of an inclusion (a solid object within the flow) is a Lagrangian one, whereas an Eulerian viewpoint is required for free-surface flow. This type of mixed Eulerian-Lagrangian model is not new, but most existing models are restricted to small inclusions[2,3], with the possible exception of studies carried out for the very specific case of floating objects such as wood - including those recently conducted at LMFA[4].

When searching for drowning victims in rivers, the size of the solid inclusions is comparable to the typical dimensions of the flow. These inclusions will therefore be subject to flow heterogeneities (velocity gradients, turbulence) and interact with the bed and any obstacles (piles, bridges, objects on the bottom). These complex effects are not considered in existing models, and the role of turbulence - with its different scales - on the dispersion of large inclusions remains to be determined, as does the way to model it.

Work planned

The first part of the work will be to examine and quantify the influence of various parameters on the trajectories of the victims. These parameters may be characteristic of the flow (depth, speed, presence of bridge piers or macro-rugosities on the bed) and of the object (size, apparent weight and, for scale models, morphology, clothing, etc.). Their role will be characterized in a laboratory channel, using 3D video trajectories initially of simple objects (spheres) and then of scaled dummies, in the absence or presence of obstacles. This technique is well suited to the large number of experiments required to characterize the parameters with a stochastic influence. The expected results are (i) a prioritization of the key parameters influencing body drift, (ii) a modeling of their influences. Indeed, these influences can be deterministic (e.g. drag or lift coefficients) or stochastic (e.g. a distribution of the values of these parameters due to other degrees of freedom such as the rotation or position of the victim, but also the probability of a macro-roughness or a bridge pier "trapping" the victim). The second part of the work will focus on taking these parameters and their influence into account, and integrating them into a Euler-Lagrange model. Firstly, this concerns the choice of equation, such as the Basset-Boussinesq-Oseen equation used for small particles. Secondly, it concerns the coefficients used in these equations, for deterministic phenomena (e.g. drag or added mass) or stochastic ones (diffusion coefficient associated with turbulence or secondary currents). For the latter, the work will also implement real-life field experiments, involving 3D tracking of the drift of dummies released into the Rhône or Saône rivers.

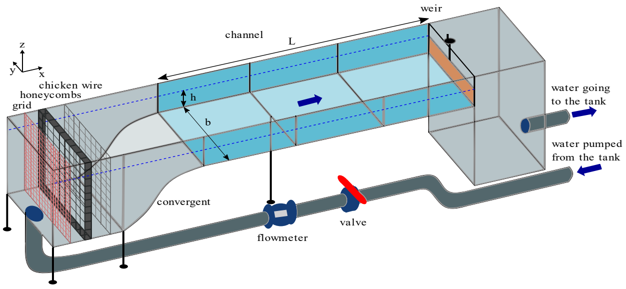
Resources available

The project draws on the skills and resources of two laboratories renowned for their expertise in free-surface flows. The experiments will take place at LMFA, which has a facility ideally suited to the project[4,5]: a 6 m long free-surface channel, equipped to measure velocities and associated turbulence, and large optical accesses with multiple cameras for tracking the 3D trajectory of large inclusions. HECE also boasts additional resources for force measurement[6] (hull tank, wind tunnel) or for simulations[7] (WOLF software). Field experiments will benefit from the resources and expertise of INRAE-RiverLy laboratory (*in situ* field depth and velocity mapping using ADCP coupled with a differential GPS)[8], dummy location by underwater GPS and those of firefighters (boats, divers, test dummy).

Applications

- Applicants: M.Sc 2 or Equivalent in Fluid Mechanics, Hydraulics, Civil Engineering, Mechanics or Physics.
- Educational skills: fluid mechanics, general mechanics
- Skills required: taste for experimentation (setting up and running experiments), ability to work on a boat in the open air, use of numerical tools (Python, R or Matlab®) for data processing, as well as writing and communicating in English.

In-situ drift tests with a dummy –
credits: C. Maghakian



Open-channel at LMFA (L=6m)

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