APRI0006-1

Behavior of a human body in water

Research Proposal

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1 Context

In the last few years, the number of deaths by drowning increased considerably, even with the lockdown due to Covid-19 in 2020. In particular, during the summer, people are tempted to swim, especially in hazardous areas, which leads to more accidents. Some people can be saved, but unfortunately, other people die. That leads to a new problem: the search of the bodies. Currently, firefighters search for bodies by traversing the banks and dredging streams, but this method takes a lot of time and resources.

There are very few studies about the behavior of a dead human body in water (e.g. Mateus (2013)[1] and Xia (2014)[2]). The complexity of our organism is maybe one of the reason of this lack of information. It is not yet possible to establish a real theoretical model of the movement of a dead human body. And yet, this determination could considerably help firefighters in their research of drawn people.

2 Goal of the project

Beyond this project, the final goal would be to implement a model that could predict the movement of a human body in water. To do so, experimental tests in laboratory with dummies in channels will be done in order to determine if the behaviour of the human body can be reproduced at laboratory scale. To study the movement of this body, some parameters are essential: drag, lift and yaw coefficients. The work of this project will be to define the variation of those essential variables (section 3.1) and the movement that will take the body (section 3.2), by plunging the dummies in the channel with different initial parameters: flow conditions, density and shape of the body, depth and bottom of the stream.

3 Methodology

In this project, we will focus on the hypothesis of a rigid body. The dummies are rigid, so this assumption can be reproduced at laboratory scale. Moreover, according to several studies, the body in the water will usually be in the position as in Fig.1. The dummies will be put in the same position for all the experiments, with flow conditions that will represent at a reduced scale the conditions found in a river such as river Meuse or river Ourthe.

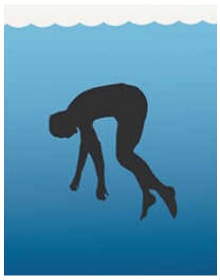

Figure 1: Position of a body in the water. The body trunk is higher in the water due to residual oxygen, while arms and legs are lower because the blood descends and stagnates in the outer limbs of the body.

Reference for Fig. 1: https://www.planetesante.ch/Magazine/Sport-loisirs-et-voyages/Noyade/La-vraie-noyade-ne-ressemble-pas-a-celle-qu-on-voit-au-cinema, 08/02/2021 15:15.

[1]Mateus, M., de Pablo, H., & Vaz, N. (2013). An investigation on body displacement after two drowning accidents, in *Forensic Science International*, Vol. 229, N°1, pp. 6-12.

[2]Xia, J., Falconer, R. A., Wang, Y. & Xiao , X. (2014). New criterion for the stability of a human body in floodwaters, in *Journal of Hydraulic Research*, Vl. 52, N°1, pp. 93-104.

3.1 Important coefficients

The parameters that will be essential for the determination of a numerical model will be the drag, lift and yaw coefficients. This latest will be addressed in the next section with the 2D movement. The first part of the project will then concentrate over lift and drag coefficients. Their variability, in function of, notably, the orientation of the body in the stream, will lead to an important number of experiments. Indeed, each orientation has to be taken into account, because the projected area of the body changes, and so, drag and lift coefficients. Moreover, those have to be studied for a body partially and totally submerged, and for different stream conditions. To analyse those coefficients, it is planed to make a numerical simulation of an approximate body on the Siemens-NX program, to have preliminary data. Then, experiments in laboratory will be done, with, e.g. a force sensor uni-axial, to feed a first simple numerical model. The analysis of this first phase will make it possible to highlight its possible limitations and thus show avenues for improvement, also well in terms of measurements than of model.

3.2 2D movement

The second objective of this project is the generalization of some model of wood transport in rivers[3], as seen in Fig.2, to the similar transport for a rigid human body. Starting from stream parameters, known thanks to the modalization of the reference rivers streams, we should determine an approximate movement of the body. This approximate movement includes the horizontal movement (along x and y), as well as the rotation of the body (yaw coefficient) in this same plane. This yaw coefficient is important to determine the lift and drag coefficients at each time in the stream, and then, the horizontal (and vertical) movement. Moreover, the horizontal movement should be studied for different depths (which can be controlled by adding weights to the dummies), because of the influence of the bottom of the stream (and the friction it builds up) but also the influence of the total or partial submergence. After that, verification about the validity of this model will be done experimentally in laboratory.

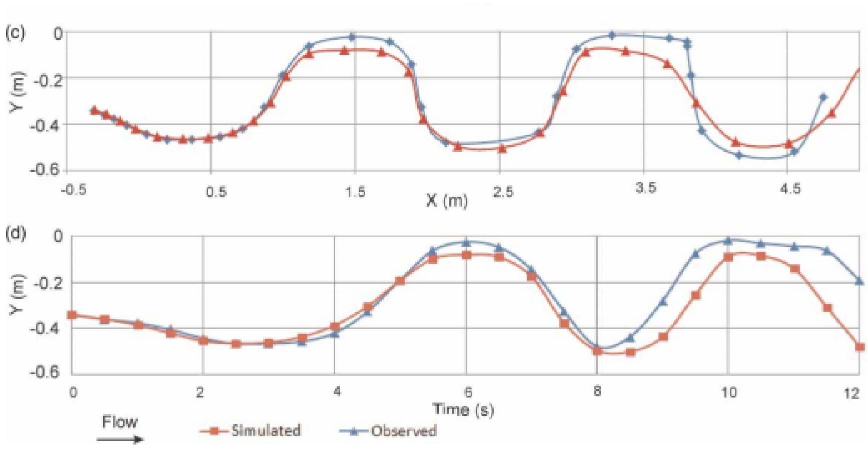

Figure 2: Observed (blue) and simulated (red) wood log center trajectory for a channel with obstacles. Reference: Ruiz-Villanueva, V., Bladé, E., Sánchez-Juny, M. & co. (2014). Two-dimensional numerical modeling of wood transport. *Journal of Hydroinformatics*, Vol. 16, N°5, p. 1089.

[3] See e.g. Ruiz-Villanueva, V., Bladé, E., Sánchez-Juny, M. & co. (2014). Two-dimensional numerical modeling of wood transport. *Journal of Hydroinformatics*, Vol. 16, N°5, pp. 1077–1096.

3.3 Beyond this project

To analyse the problem in 3D, one has to take a biological component into account. Indeed, when the person is drowning, it begins with the lungs filling with water. The body then sinks in the stream. There is a bloating phase for which the body will be at the bottom, and friction will be important. Finally, because of the decomposition of the body, gases will be produced and it will make the body resurfacing. Those three steps can be seen in Fig. 3 and will influence the time at each depth, and the the whole movement of the body.

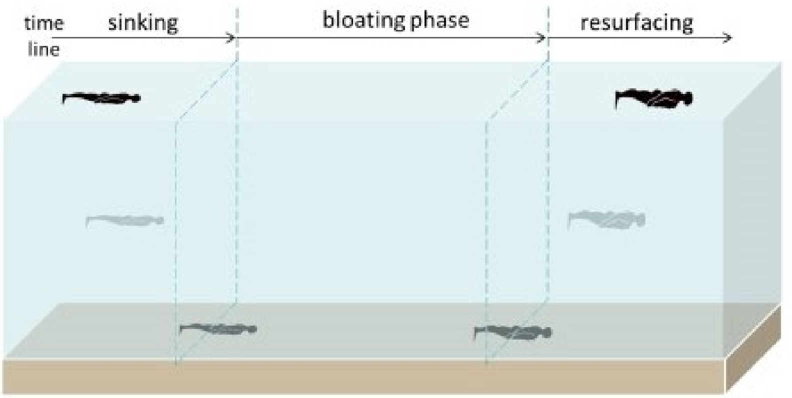

Figure 3: Human body in water. Due to sinking and decomposition, the body will move vertically in 3 phases: sinking, bloating and resurfacing. Reference: Mateus, M., de Pablo, H., & Vaz, N. (2013). An investigation on body displacement after two drowning accidents, in *Forensic Science International*, Vol. 229, N°1, pp. 6-12.

It will be essential for this part to contact doctors or biologists to establish the comportment of a dead body in water (time of sinking, advancement in the decomposition, etc.) for the model to be complete. An obvious parameter of this evolution will be the temperature of the water, but there is certainly others that have to be taken into account. It will be very important especially for the friction forces with the bottom of the stream, which will largely influence the horizontal movement. To go even further, firemen of the province of Liège proposed their help to verify the final model at real scale.

4 Management

The project is essentially based on laboratory experiments to determine parameters or to verify the validity of the model. The experiments will be done in the flume available in the laboratory (subject to timetable availability). Three dummies will be available to represent different morphologies, with a probably adjustment of the weight in order to have a correct density scale.

Those experiments should take approximately 100 hours of work, including 10 full days in laboratory (about half for the first part and half for the second) and the implementation of the numerical analysis. The project is done in association with an engineering student whom does the 2D modelling. The task will then consist in the whole section 3.1, and the laboratory experiments for the section 3.2.