Short term dynamics of a free falling jet due to solitonic collision

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Résumé :

L'impact de deux solitons cambrés se propageant dans des directions opposées conduit à la formation d'un jet résiduel en chute libre. Nous étudions théoriquement et numériquement les caractéristiques de ce jet, en y incluant le critère de formation ainsi que sa dynamique à court terme. L'approche numérique est basée sur une méthode à intégrale d'éléments de frontières, permettant d'évaluer la pression dans l'écoulement intérieur. Une description théorique basée sur la théorie potentielle sera proposée pour décrire l'évolution à court terme.

Abstract :

The impact of two steep solitonic waves propagating in counter directions leads to the formation of a free fall residual jet. We investigate numerically and theoretically the characteristics of this jet, including the criteria of formation, and the short term dynamics. The numerical approach is based on a boundary integral elements method, allowing to compute the pressure of the inner flow. A theoretical description based on potential flow theory is introduced to describe the short term evolution of the jet.

Mots clefs : **Free falling Jet, Short term dynamics, BIE Method**

1 Context and Scopes

The problem of the head-on collision of two solitary waves propagating in opposite directions, which is equivalent to the problem of a single solitary wave impacting a wall, is of major interest for ocean and coastal engineers. It has wide applications, such as predicting the runup heights of tsunamis, or evaluating the loads exerted by waves on coastal structures in shallow water. The problem has been widely studied, and is well documented. Chan & Street [1] first took interest in the problem by means of numerical computations. Later, Byatt-Smith [2, 3] studied the problem analytically, up to the second order, in a first time, and higher orders later. He emphasized the role of nonlinearity in unexplained phenomena, such as the amplitude reduction of the solitonic wave after reflection,which is due to the formation of a dispersive tail, as soon as third order is taken into account. Oikawa and Yajima [4] provided an estimation of the phase shift appearing after the collision process using a singular perturbation method developed up to the second order. Maxworthy [5] found experimentally that some of the theories are in qualitative but not quantitative agreement with his results. This experiments are still central for the problem. A lot of theoretical work came after this author, particularly about the phase shift observed [6, 7], or the runup height predicted [8, 9]. Numerical simulations were also conducted, [10, 11], and the problem is know better understood. These authors investigated deeply the interaction. Nevertheless, none of them simulated the collision of very steep solitary waves. In a recent work, we investigated numerically the dynamics of the collision of solitonic waves with normalization parameter as large as $a/h = 0.8$, a being the amplitude of the soliton, and h the water depth at rest [12]. During this investigation, we observed the formation of a thin residual jet, showing a complex behaviour. Figure 1 (left) presents the runup - rundown following the solitary waves collision. Figure 1 (right) presents a zoom in of Figure 1 (left), for time $t/\tau = 18$, around jet point. $\tau = \sqrt{g/h}$ refers to the characteristic time scale of the soliton. One can notice the formation of waves on the surface. Present work focus on explaining the dynamics of this jet, from its formation to its short time dynamics. This mechanism is still an open question. Careful numerical simulations based on a boundary integral element approach are conducted, allowing to investigate the surface dynamics and the pressure evolution in the inner flow. Analytical and theoretical description will provide information about the mechanism of formation of the jet.

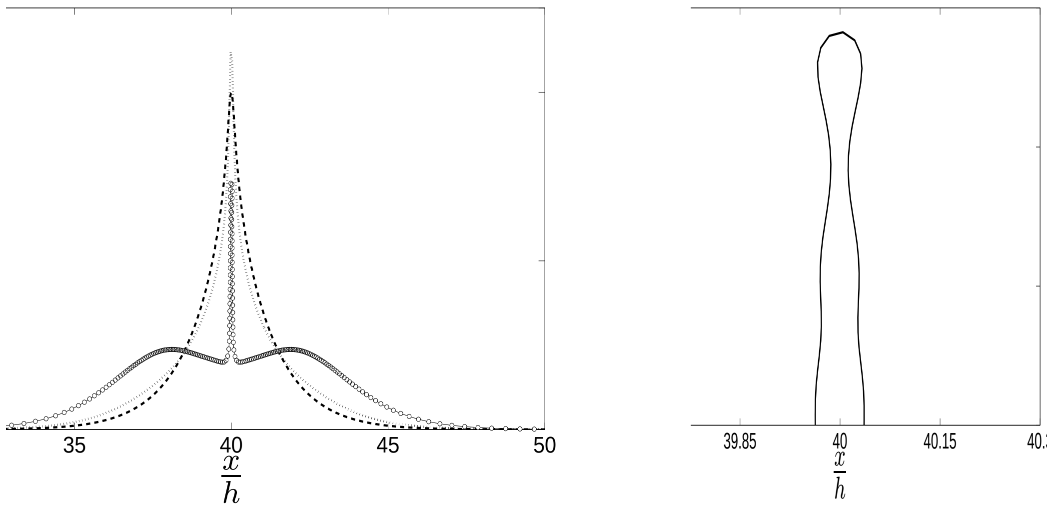

FIGURE 1 – *Left :* Rundown for soliton of initial amplitude $a/h = 0.7$. Free surface elevation at several instants of time. $(\cdots)$ $t/\tau = 16$, (- - -) $t/\tau = 17$, and $(\circ)$ $t/\tau = 18$. *Right :* Residual falling jet for initial amplitude $a/h = 0.7$ at time $t/\tau = 18$.

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