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Experimental study of gas entrainment from surface swirl

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In Sodium cooled fast reactors (NaSFR), the presence of eddies at the free surface and the downward flow created by the suction of hot liquid sodium by the intermediate heat exchanger can provoke the entrainment of gas (argon). Readers can refer to [1] for more information about sodium nuclear reactors. Such entrainment could induce the transport of a large quantity of gas through the core and could lead to the accumulation of gas pockets close to the core of the reactor [2, 3]. In consequence, the absence and quantification of gas entrainment is a relevant issue for safety studies.

The present study focuses on gas entrainment from surface swirls through an experimental apparatus in water. The objectives are firstly to identify the experimental condition of gas entrainment occurrence, secondly, to define gas entrainment occurrence frequencies and thirdly, to characterize the physical mechanisms involved.

Several experimental studies addressing the topic of gas entrainment in different geometries and with different liquid medium can be found in the literature. Baum *et al.* [4], Takashi *et al.* [5] or Egushi *et al.* [6] used cylindrical cavity to investigate surface tension and scale effect. However, the gas entrainment is sustained in these studies whereas it is intermittent in NaSFR. Then, Ezure *et al.* [7] and Kimura *et al.* [8], used an open channel flow where gas entrainment appears intermittently by the combination of a shear flow (produced between a horizontal flow and a stagnant flow) and a vertical pumping below the free surface. They obtain a gas entrainment mapping according to the inlet and suction flow rates.

Experimental set up of the present study is close to that of Ezure *et al.* and Kimura *et al.* It is designed with a rectangular cavity opened at the top, two vertical plates (separating the inlet and the outlet flow from a stagnant region) and a 50mm diameter suction nozzle (with a height of 100mm) placed at the bottom of the cavity. The figure 1 illustrates the rig filled of water leading to the flow dimensions, with a free surface, 700 mm x 108 mm x 210 mm.

The shear flow is created in the central zone of the cavity between the two plates. The suction from the nozzle induces a secondary down-flow which is combined with the shear flow to generate the vortex surface. The main difference between the present study and Ezure *et al.* or Kimura *et al.* lies in the inlet conditions, in particular, obstacles can be added to vary the shape of the inlet channel to trigger different inlet conditions for the shear flow.

According to the inlet Q_{in} and suction Q_s flow rates, two gas entrainment regimes can be reached:

- a continuous surface swirl reaches the suction nozzle to provoke gas entrainment in its core (fig. 2a and 2c),
- gas entrainment is performed through bubbles separation from a non-continuous surface swirl (fig. 2b and 2d).

According to the geometry and the size of the obstacle, gas entrainment occurs or not and the frequency of occurrences vary. Both occurrences and their frequencies are characterized in the present experiments.

Current investigations focus on the characterization of the velocity fields under different flow conditions (e.g. varying the geometry and size of the obstacles) using PIV measurements. The main purposes of these PIV experiments are to complement gas entrainment observations, to identify possibly different structures (and their intensity) of these turbulent flows so as to quantify the more relevant physical parameters in order to explain the physical mechanisms responsible for gas entrainment and its intermittency.

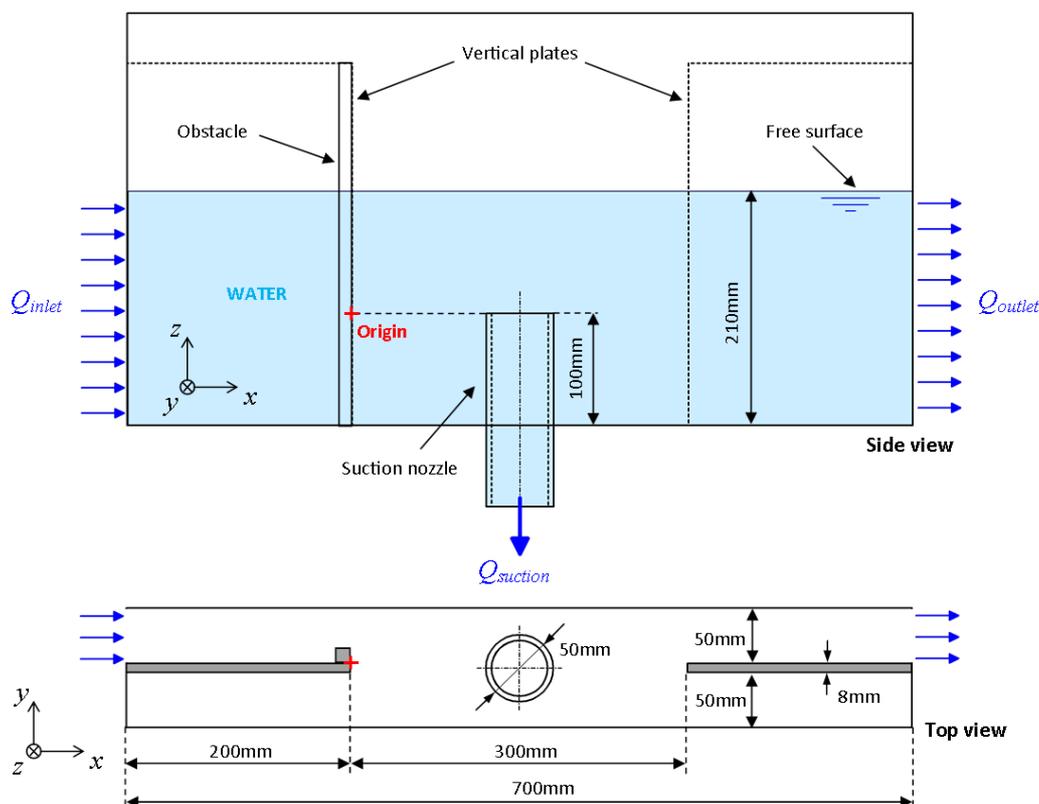


Figure 1. Experimental set up. The origin of the Cartesian frame is set on the border of the vertical plate at the height of the suction nozzle. The x-axis coincides with the horizontal main flow, y and z axis are respectively horizontal and vertical.

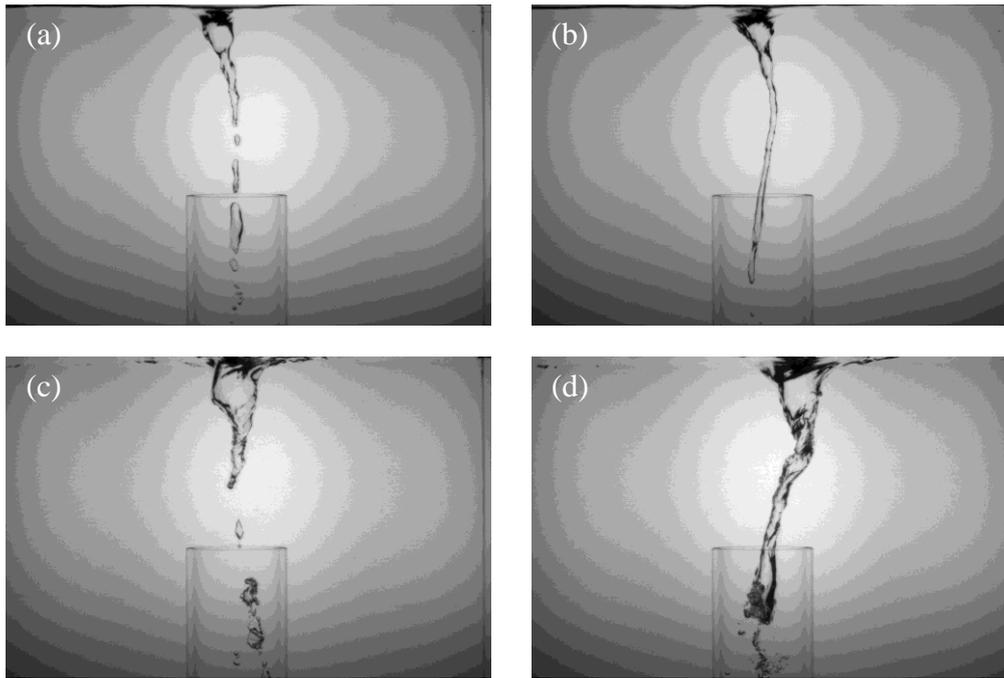


Figure 2. Snapshot of non-continuous surface swirls and gas entrainments for (a) $Q_{in} = 5.7\text{m}^3/\text{h}$, $Q_{suction} = 4.9\text{m}^3/\text{h}$ and (c) $Q_{in} = 9.5\text{m}^3/\text{h}$, $Q_{suction} = 7.1\text{m}^3/\text{h}$. Snapshot gas entrainment trough Continuous Surface swirls for (b) $Q_{in} = 5.7\text{m}^3/\text{h}$, $Q_{suction} = 4.9\text{m}^3/\text{h}$ and (d) $Q_{in} = 9.5\text{m}^3/\text{h}$, $Q_{suction} = 7.1\text{m}^3/\text{h}$.

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