§19. Stabilization of the Vertical Jet for the Liquid Metal Divertor

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As a divertor in a nuclear fusion reactor, a component consisting of the liquid metal shower jets has been proposed[1-3]. This concept has following advantages: high safety, high maintainability, a small amount of radioactive wastes, high pumping efficiency, and high permissible heat load. A simple vertical jet narrows in accordance with the acceleration by the gravity and finally transforms to droplets due to the surface tension instability. To stabilize the vertical jet, an idea to suppress the acceleration by the gravity by inserting a chain/wire/tape to the jet has been proposed and a preliminary experiment was conducted using water as a simulant.

Figure 1 shows the schematic view of the experimental setup used in this study. Water is pumped from the pool (1), stored in the nozzle (2), and falls from the nozzle to the pool along the chain (3). Several combinations of nozzle and chain were used in the experiment. Photos of the jet at 2 m down from the nozzle were taken by a high-speed camera with 1 ms of the shutter speed. The flow rate was estimated from the total mass of the water fallen to a bucket in a given time.

The initial velocity of the jet, v_0, is given by

$$v_0 = Q / (2 \pi d_0^2),$$

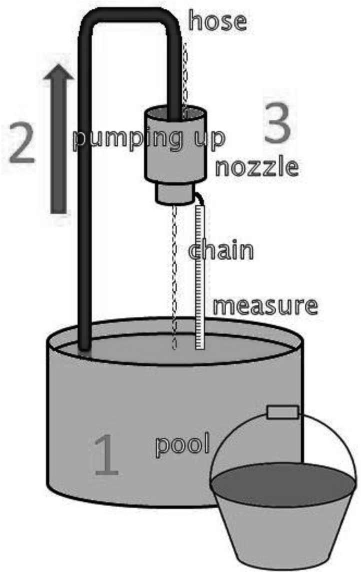

Fig. 1. Schematic view of the experimental setup. Water is pumped from the pool (1), stored in the nozzle (2), and falls from the nozzle along the chain and stored in the pool (3). Three nozzles (inner diameter, d_0, of 7, 10, and 13 mm) and two chains (width, w_{chain}, of 2.3 and 3.4 mm) were used in the experiment.

Where Q and d_0 are the flowrate and the nozzle width, respectively.

At 1–2 m down from the nozzle, the width of the jet along the chain becomes roughly constant. This observation suggests that the jet reaches the terminal velocity at > 1 m down from the nozzle. Here, we define the jet width at ~2 m down from the nozzle as d_{flow}. Then, the terminal velocity, v, can be estimated by

$$v = Q / (2 \pi d_{\mathrm{flow}}^2).$$

In Fig. 2, compared are the measured terminal velocity and the theoretical curve of the flow velocity for a free-falling jet. The measured terminal velocities are much slower than the theoretical prediction. Apparently, the chain inside the jet decelerates the jet against the gravity. On the other hand, the measured terminal velocities are ~1 m/s regardless of the initial velocity or the size of nozzle and chain, at least in the range tested in this study. Clarification of the mechanism that determines the terminal velocity is remained for the future work.

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2) Shimada, M. and Miyazawa J., J. Plasma Fusion Res. **92** (2016) 119.
3) Miyazawa, J., Goto, T., Tamura, H., Yagi, J. and Yanagi, N., Ann. Rep. NIFS (2014-2015) 245.

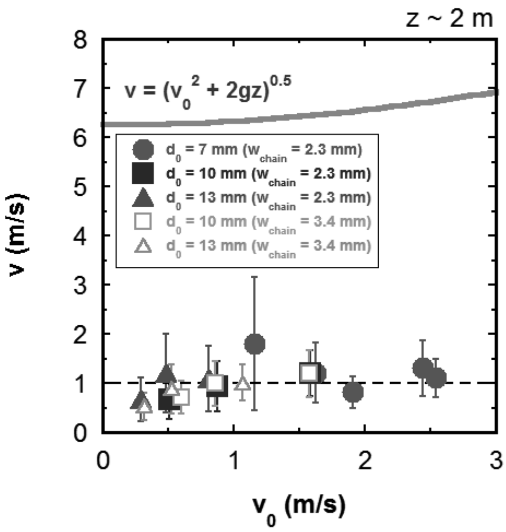

Fig. 2. Comparison of the measured flow velocity, v (symbols), and the theoretical curve of the flow velocity for a free-falling jet (solid curve). The abscissa is the initial velocity of the jet, v_0.