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Effect of the Geometry on a Free Surface Fluctuation in a Vessel with an Internal Structure

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1. Introduction

In a sodium cooled fast reactor there exists a free surface in the upper plenum of the reactor vessel where the sodium coolant contacts with the cover gas. Fluctuation of this free surface causes two important phenomena. One is to secure the structural integrity of the reactor vessel due to a thermal striping. Another is the gas entrainment at the free surface. An experimental study has been performed to measure the fluctuation phenomena in a vessel with an internal structure (UIS). The effects of the vessel geometries on a free surface fluctuation are studied to develop a correlation for a free surface fluctuation.

2. Experiment

Figure 1 shows the test section used in the experiment. The water enters from the bottom of the tank and flows out at the side nozzles. The inner diameter (d_v) of the vessel was 0.78m and the height was 1.46m. Four outlet nozzles were located at a 0.46m elevation (H_o) from the bottom with a 90 degree, whose diameter was 0.046m. Four types of a UIS with a different diameter (d_U), 0.1m, 0.2m, 0.35m, and 0.6m were prepared. The height (S) of a UIS was varied at five locations, and the mean water level (H) was varied for four set steps in the experiment. The flow rate was controlled 5 times in each experiment with a fixed geometrical condition, and the overall range of the flow rate was $5x10^{-3}$~$37x10^{-3} m^3/sec$.

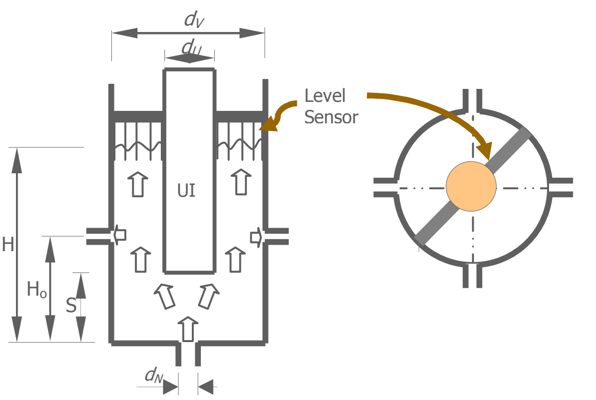

Figure 1 Test section for the free surface fluctuation experiment

The free surface fluctuation was measured by a wire level sensor at ten different locations. The calibrations of these were performed in a practical condition. Temperature of the water was controlled by a cooler to within 20±0.5℃.

3. Result and Discussion

The standard sampling deviation (σ) of a signal was measured for a free surface fluctuation. In the case of analyzing a free surface fluctuation, the Froude number (Fr) is the most adequate dimensionless number, which is developed as a new formulate related to the central velocity of a circular jet in this study as follows;

$$Fr = \sqrt{\frac{d_N}{H}}\sqrt{\frac{d_h}{\lambda}}\frac{\sqrt{V_N V_h}}{\sqrt{gH}} \qquad (1)$$

where g is the gravitational constant, V_N is the velocity at an inlet nozzle, and λ is a length scale.

The fluctuation amplitude is linearly proportional to the square of the Froude number according to a parameter study. Figure 2 shows the effect of an inlet nozzle diameter on a fluctuation by using the Froude number defined by Eq. (1). The standard deviation is inversely proportional to the root mean square of an inlet nozzle diameter in the figure, and the tendency of the distribution agrees macroscopically well with the Froude number.

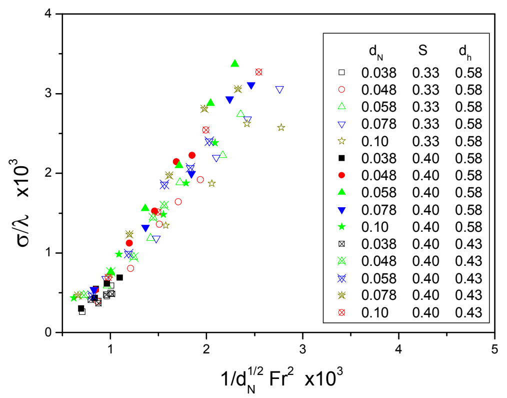

Figure 2 Effect of an inlet nozzle diameter on the fluctuation

It is considered that the effect of the height of a UIS strongly relates to the effect of the diameter of a UIS. The standard deviation is roughly proportional to the root mean square of a height of a UIS as shown in Fig. 3. The order of S is slightly less than 1/2 at d_U=0.1m, but the order is slightly greater than 1/2 at d_U =0.6m. Therefore, as the diameter of a UIS becomes larger, the order of a height of a UIS increases more, but the order increases a little when the diameter of a UIS is changed from 0.35m to 0.6m. The order of S varies roughly from 1/4 to 3/4 in the range of the experiment.

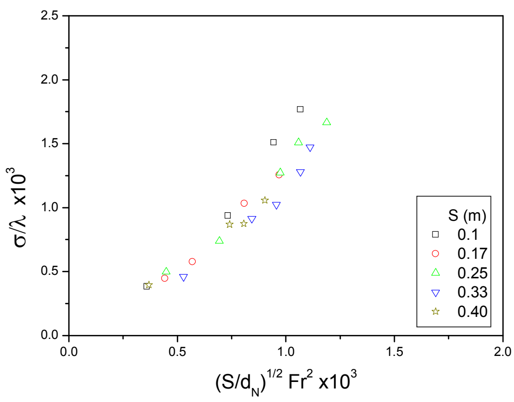

Figure 3 Effect of the height of the UIS on the standard deviation of a fluctuation at the water level of 1.0m and the diameter of the UIS of 0.1m

The effect of a water level is already considered as a form of $1/H^2$ in the square of a Froude number. The effect of a water level significantly depends on the diameter and the height of a UIS. Figure 4 shows the effect of a water level when the height of a UIS is 0.4m and the diameter is 0.1m.

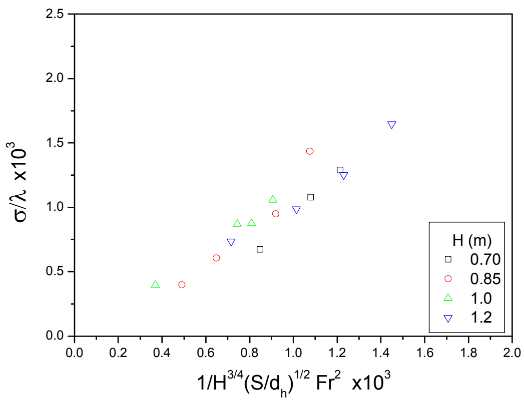

Figure 4 Effect of a water level on the standard deviation of a fluctuation at the height of the UIS of 0.4m and the diameter of the UIS of 0.1m

In this case, the standard deviation is proportional to $1/H^{2.75}$ including the H in the square of a Froude number. If the height of a UIS decreases from 0.4m to 0.1m, the order of H decreases from 2.75 to about 2.5 at a UIS with a 0.1m in diameter. When the diameter of a UIS is larger and the height of a UIS is smaller, the effect of the water level on the fluctuation amplitude decreases. The order of H reduces to about 1.5 when the diameter of the UIS is 0.6m and the height is 0.1m, where the hydraulic diameter is 0.18m. The order of H varies from 1.5 to 2.75 in the range of the experiment.

Since the effect of a hydraulic diameter is related to the diameter of a UIS, it is difficult to explain the effect of the hydraulic diameter. But the effect of the hydraulic diameter roughly agrees with the square of the Froude number defined by Eq. (1) as shown in Fig. 5.

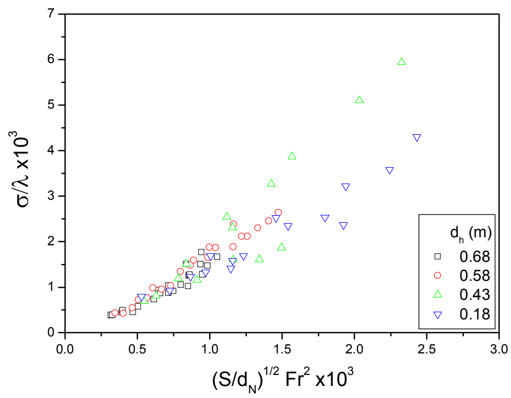

Figure 5 Effect of a hydraulic diameter on the standard deviation of a fluctuation at a water level of 1m

4. Conclusion

An experimental study has been carried out to measure the amplitude of a free surface fluctuation in a vessel with an internal structure. A free surface fluctuation is proportional to the square of the new Froude number. The effect of the internal structure was complicated due to a mixing of the geometry effects. The effect of the water level was varied from 2.75 to 1.5 for the order of H according to the geometry conditions. The fluctuation of the free surface increased with an increase of the height of the UIS, but the increasing ratio was reduced when the height was high. When the height of the UIS was small and the diameter of the UIS was large, the geometry factor was reduced rapidly, but it was reduced slowly for the other cases.

Acknowledgement

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