Effect of the Experimental Parameters on a Free Surface Fluctuation

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1. Introduction

In a liquid metal 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 the 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. A measurement of the fluctuating frequency and amplitude of the free surface in a cylindrical annular vessel where the inner vessel is the UIS of a liquid metal reactor will be carried out. The experimental parameters are the diameter of the inner vessel, the height of the UIS from the inlet nozzle, the inlet flow rate, and the average height of the free surface. The experimental range of the Reynolds number based on the nozzle conditions is $6.4x10^4$~$4.7x10^5$ and the range of the Froude number based on the height of free surface and the velocity in the vessel is $3.7x10^{-3}$~$5.7x10^{-2}$. In the present paper the effects of the experimental parameters on the amplitude of a free surface fluctuation are studied to develop a correlation.

2. Experiment

Figure 1 shows the test section used in the experiment. The water is injected at the bottom of the tank and flows out at the side nozzles whose level is much lower than the level of the free surface. The test section is made of transparent acryl for a visual observation of a surface fluctuation. The inner diameter is 780mm and the height is 1460mm. The diameter of the inlet nozzle is 100mm. Four outlet nozzles are located at a 460mm height from the bottom with 90 degree, whose diameter is 46mm.

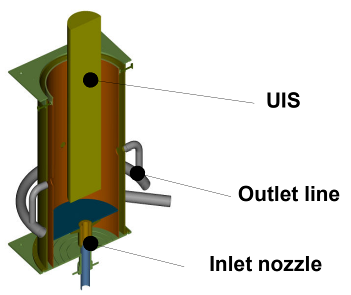

Figure 1 Test section for the free surface fluctuation experiment

Five types of UIS with different diameters, 50mm, 100mm, 200mm, 350mm, and 600mm are prepared. The gap (height of the UIS) is changed at five locations, 100mm, 170mm, 250mm, 330mm, and 400mm from the inlet nozzle. Mean water level is varied in four steps, 700mm, 850mm, 1000mm, and 1200mm from the inlet nozzle.

The flow rate is measured by a turbine flow meter, and the range of the flow rate is $5x10^{-3}$~$37x10^{-3}$ m^3/sec in the present experiment. The free surface fluctuation is measured by a wire level sensor at ten different locations. The calibrations of that are performed before and after an experiment in the practical condition. The experimental data is collected by using the HP1413C data acquisition system and 25 data points are obtained per one second during 180 seconds. Temperature of water is controlled by cooler at 21±0.5℃.

3. Result and Discussion

Figure 2 shows the typical signal of a free surface fluctuation at ten locations in the present experiment. Since the fluctuation with a low frequency is not a proper fluctuation caused by a water injection, a 0.02Hz high pass filter is applied to cut off the DC bias and a system frequency noise.

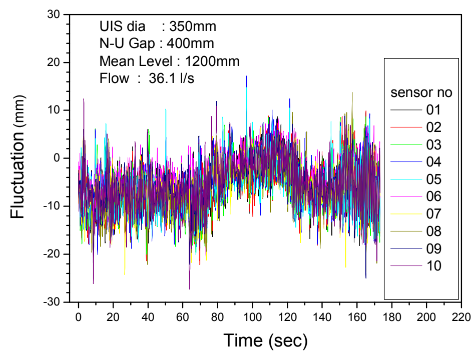

Figure 2 Typical signal of a free surface fluctuation at the ten locations in the present experiment

The standard deviation (σ) of a signal is defined as follows.

$$\sigma = \sqrt{\sum_i^N (H_{w,i} - \overline{H})^2 / N} \quad (1)$$

In the case of analyzing the free surface phenomenon, the Froude number is the most adequate dimensionless number, which is generally described by the average height of the free surface and flow velocity as follows.

$$Fr = \frac{V_v}{\sqrt{gH_w}} \quad (2)$$

where V_v is the velocity at the vessel, g is the gravitational acceleration, and H_w is the level of the free surface.

Figure 3 shows the averaged standard deviation of that at the ten locations versus the Froude number. In the case of UIS with a small diameter which is less than the nozzle diameter, the data correlates well with the Froude number. But the other data is scattered.

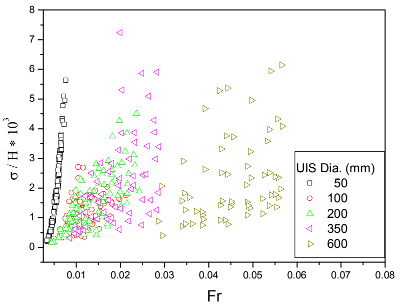

Figure 3 Standard deviation versus Froude number

According to the parametric study, the standard deviation of the surface fluctuation is proportional to the hydraulic diameter (d_h) and inversely proportional to the water level (H_w) except for the UIS with a 50mm diameter. This is similar to the previous result of a small scale experiment without UIS [1]. Therefore, a modified Froude number (Fr^*) is defined as follows.

$$Fr^* = Fr(d_h / H_w) \quad (3)$$

Figure 4 shows the trend of the standard deviation according to the gap with a 200mm UIS. The standard deviation increases with an increase in the gap at a fixed modified Froude number.

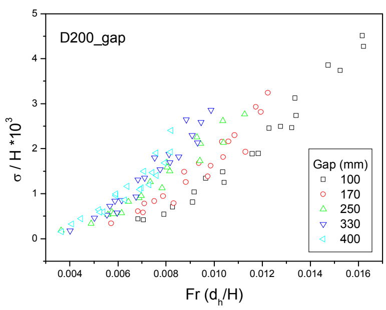

Figure 4 Effect of the UIS height on the surface fluctuation with 200mm in UIS diameter.

The surface fluctuation is also affected by the ratio (D_U/d_N) of the inlet nozzle (d_N) to the UIS diameter (D_U) and the immersed length of the UIS. When the ratio is less than 1, the effect of the gap is insignificant. But when the ratio is larger than or equal to 1, the effect of the gap increases with an increase of the ratio. And the effect of the gap increases with a decrease of the immersed length of the UIS. The phenomenon is considered to be by an increase in the effect of the jet. Since the effect of the UIS is not clear, a detailed relation needs to be studied.

Although the effect of the UIS is not clear, following equation fits the present experimental data properly as shown in figure 5. In the case of the UIS with 50mm in diameter, the value of H_w is used with a fix value, 0.35 instead of a variable parameter. It is necessary to carefully investigate a geometrical parameter matching with other data through a data analysis.

$$f_{gap} = [1 + 0.09(H_g / d_n - 1)(D_V / H_g + 1)] \quad (4)r$$

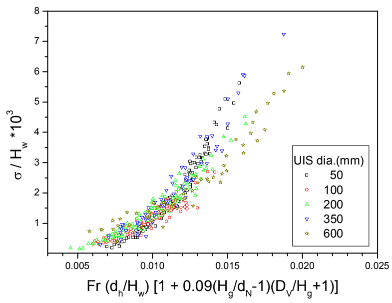

Figure 5 Relation between the fluctuation of free surface and the dimensionless number

4. Conclusion

From the analysis of the free surface fluctuation data we found that the amplitude of the fluctuation is proportional to the hydraulic diameter and inversely proportional to the water level. Also, when the ratio (D_U/d_N) is less than 1, the effect of the gap is insignificant. But when the ratio is larger than or equal to 1, the effect of the gap increases with an increase of the ratio. And the effect of the gap increases with a decrease of the immersed length of the UIS.

Acknowledgement

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Reference

[1] H. Y. Nam et al., "Experimental Study on Amplitude and Frequency of Free Surface," ASME PVP, Atlanata, USA, July 22-26, 2001.