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Measurement of Void Fraction in the Horizontal Jet Pool Scrubbing Regime by Using Optical Fiber Probe

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1. Introduction

In case of SGTR accident, coolant water might be injected in the secondary side of a steam generator in order to prevent fission products release into environment, usually aerosol type fission products. The aerosol concentration before and after passing the pool has been estimated in case of a submerged jet pool scrubbing [1, 2]. In this jet pool scrubbing regime, the efficiency of the pool scrubbing could be changed in comparison to globule and bubble regime [3].

For study on this phenomenon, KAERI constructed an experimental facility and has carried out several experiments to observe hydrodynamic properties, such as geometrical shape of jet, gas velocity inside jet, and void fraction, etc.

This paper introduces the method of measuring void fraction in the horizontal jet pool scrubbing regime by using optical fiber probe (OFP) and discusses the experimental results.

2. Methods

2.1 Experimental Setup

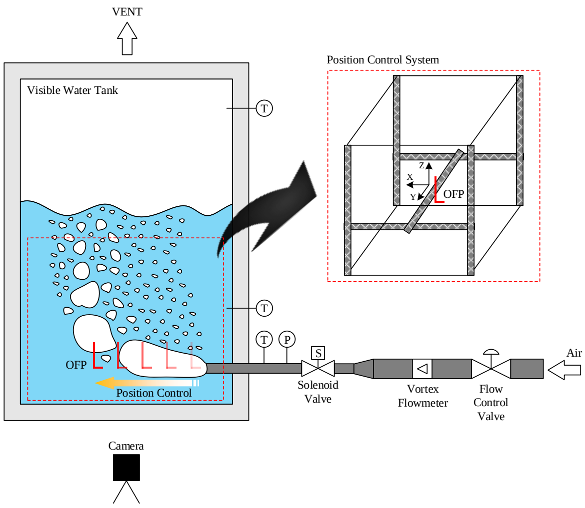


Fig. 1. Schematic diagram of the jet pool scrubbing experiment facility.

Fig. 1 shows a schematic diagram of the jet pool scrubbing experiment facility in KAERI. It consists of visible water tank, visualization system, air injection system, position control system, OFP, and data acquisition system (DAS). The cuboid water tank has the size of $1\,m \times 1\,m \times 2\,m$. In order to withstand hydraulic pressure and protect from corrosion, the frame is made with stainless-steel frame. It has three sides of polycarbonate windows to visualize the jet pool scrubbing by using cameras and LED lamps. Air is injected through submerged horizontal nozzle, which has outer diameter of 3/4". By using a vortex flow meter and a control valve, it is possible to control the flow rate of air. The position control system is constructed to shift point measuring equipment accurately, such as OFP or pitot tube, without water drainage. The system which is made up of several timing belt driven actuators has three hand wheels and three position indicators outside of water tank. These wheels and indicators take charge of X-direction, Y-direction, and Z-direction, respectively. OFP is one of the most common tools for gas-liquid two-phase flow system. It is based on measuring the light reflection from a tip of an optical fiber. Because of the difference in refractive indexes between gas and liquid, the amount of reflected light is either large or small depending on which phase surrounds the tip [4, 5]. This optical signal is converted into analog voltage output signal by a photodetector and saved in digital data form through DAS. Fig. 2 shows the conical shape tip of OFP used for the present experiment. In order to withstand the air jet flow, it is inserted into 1/8" stainless-steel tube except the tip and bonded by epoxy.

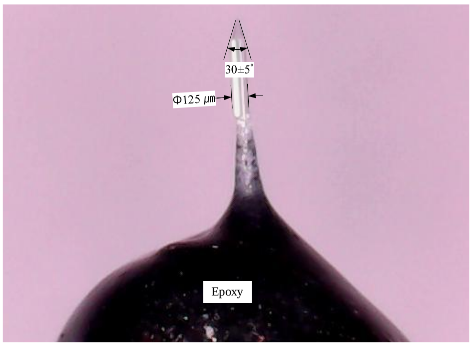


Fig. 2. The tip of OFP used for present experiment.

2.2 Experiment Conditions and Methods

Table 1: Experiment Thermal hydraulic Conditions

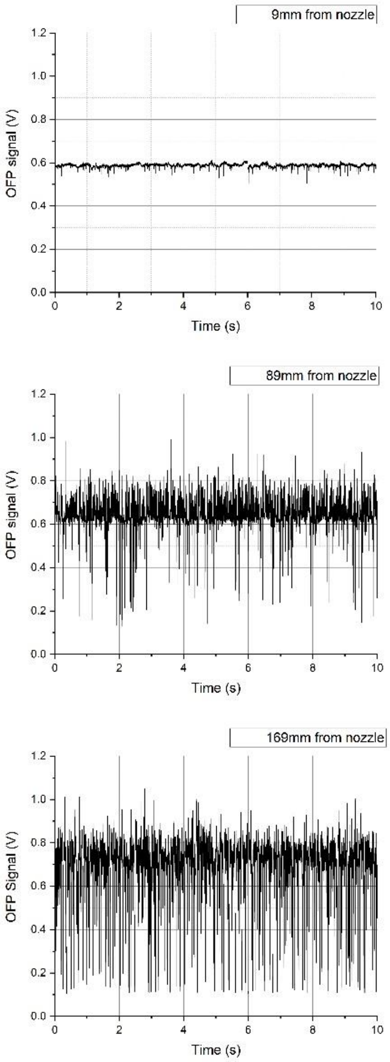
Water level (m)	Water temp. (℃)	Nozzle i.d. (mm)	Air mass flow (kg/s)	Air Inlet Press. $(bar\ a)$	Air temp. (℃)
1	24	16.56	0.089	2.4	34

Table 1. shows the present experiment thermal hydraulic conditions.

Starting at 9 mm in the X-direction from the center of the nozzle tip, OFP is located every 20 mm intervals in the X-direction. The OFP signal is saved at 5 kHz sampling rate for 10 seconds in every case.

3. Results

Fig. 3 shows the OFP signal by position. Only graphs which have a position of OFP every 80 mm intervals are presented though a lot of data were acquired in the experiment. When the OFP is located at 9 mm from nozzle in the X-direction, the signal has average 0.6 V and relatively small amplitude. It means that the surroundings of the OFP is almost air, because of the high gas jet. However, increasing the distance between nozzle and OFP, signal drops were found more frequently. It means that the fraction of water become bigger and bigger in the surroundings of OFP. Although the OFP is in the air jet bubble region as shown by Fig. 5, there would be very tiny water droplets. At 489 mm from nozzle, the signal became average 0.1 V and has small amplitude again. This is because the OFP is located totally out of the air jet's reach.



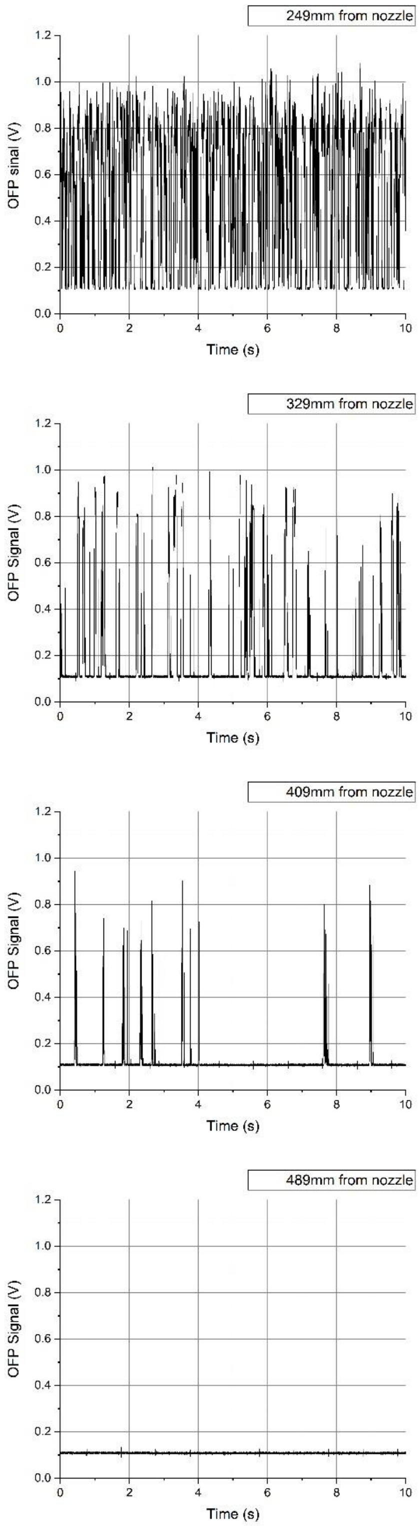


Fig. 3. The OFP signal by position.

Typically, local void fraction is calculated as the ratio of the cumulated bubble residence times on the probe tip over the total measurement time [6]. In this experiment, however, it is hard to apply the method since local minimum points and local maximum points of the OFP signal are not a constant level. It seems because, in the jet pool scrubbing regime, there would be too tiny droplets and bubbles to measure those compared with the size of the probe tip.

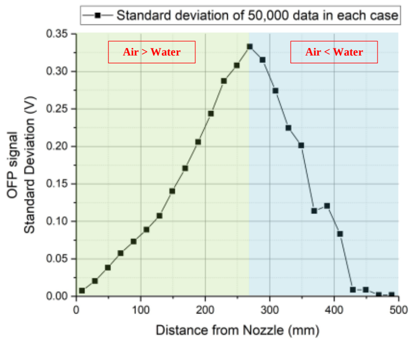


Fig. 4. Standard deviation of OFP signal by position.

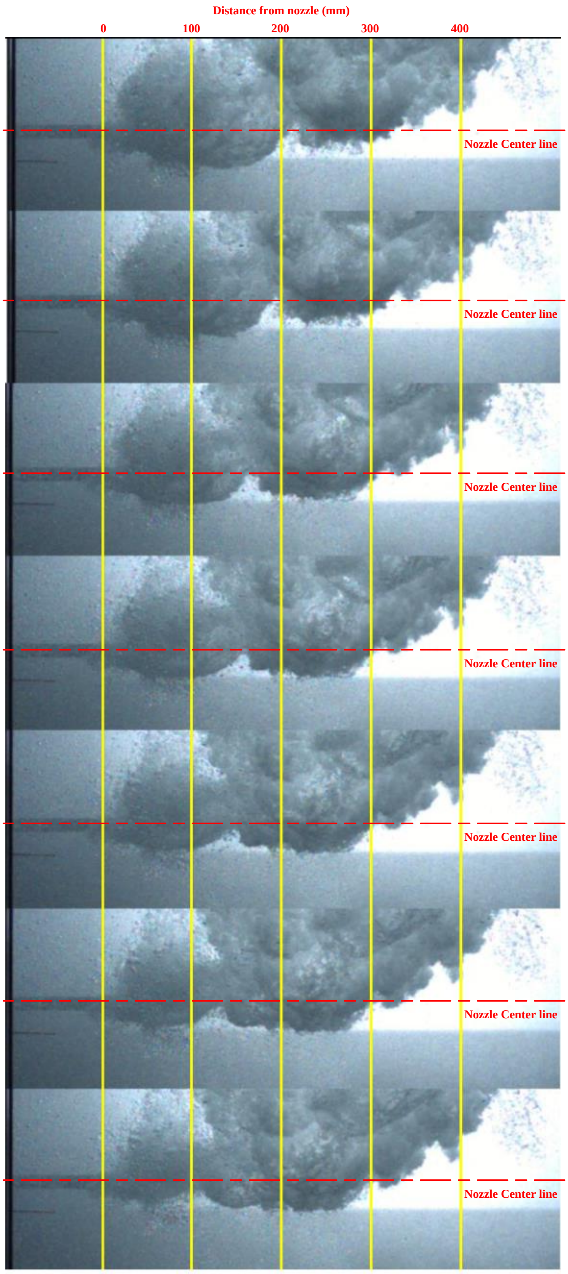


Fig. 5. The camera images of jet pool scrubbing

In this paper, standard deviation is used in order to find void fraction. Fig. 4 shows standard deviation of 50,000 OFP signal data in each case. It means the amount of dispersion of the signal. If there is only one-phase in the surroundings of the OFP, standard deviation would approach 0 V. Fig. 5 shows camera images of jet pool scrubbing with high speed camera, and it supports the OFP result. On the contrary, as void fraction becomes closer to 50 %, it would have greater value. Therefore, on the left side of the maximum point, it could be thought that the fraction of air would be higher than that of water. On the right side, it would be the opposite. However, additional studies are needed to present quantitative calculation result of local void fraction and validation of this method.

4. Conclusions

KAERI has carried out various experiments to figure out the aerosol decontamination mechanism in the jet pool scrubbing regime. As part of the study, OFP is used to measure local void fraction. In the OFP signal processing, this paper introduces the new method using standard deviation since it is difficult to apply the previous method. If the new method is validated through additional studies, it is expected that the map of void fraction in the jet pool scrubbing regime would be obtained in three dimensions. Eventually, it is expected that it contributes to development and validation of the modeling about the regime.

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