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Thesis Outline

Study on Improvement of Decontamination Factor of Filtered Containment Venting System

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This dissertation presents a study on the effects of an advanced venturi scrubber (AVS) nozzle on the two-phase flow pattern and the decontamination factor of a filtered containment venting system (FCVS). To understand the effects of the AVS nozzle on the performance of FCVS, the visualization measurement method and the Ultrasonic Velocity Profiler measurement method were applied to measure the flow field of the two-phase flow in the wet scrubber. The dissertation includes five chapters outlined below:

Chapter 1. "Introduction"
In March 2011, one of the strongest earthquakes in records triggered a tsunami that hit Tohoku Island, Japan. Following, the tsunami disabled the power supply and the cooling system of the Fukushima Daiichi Nuclear Power Plant and caused a nuclear severe accident with core damage, containment failure, and release of a large amount of fission product into the environment. One of the most important lessons learned from the accident of Fukushima Daiichi Nuclear Power Plant is that a system should be required for accident management. A Filtered Containment Venting System (FCVS) is one of such systems that can enhance the capacity to suppress the occurrence of a severe accident due to reduction of steam water, flammable gas, and then pressure in the reactor vessel. This chapter gives an overview of the development of FCVS, the necessity, and the status of implementation of FCVS. Currently, the wet-type scrubber-based FCVS is the most commonly use technology in the world. And one of the most important parts of this type of FCVS is the scrubber nozzle. In this study, an advanced venturi scrubber (AVS) nozzle was used. The nozzle was developed by Prof. Narabayashi in previous studies, and it showed its effectiveness to remove the aerosol particles from the venting flow. However, the mechanisms that the AVS nozzle affects the decontamination factor of FCVS has not been investigated deeply. The objective of this dissertation is to study the effects of this venturi scrubber nozzle on the decontamination factor of FCVS and the two-phase flow mechanism.

Chapter 2. "Effects of Double Stage Venturi Scrubber Nozzle on Liquid Injected Flow"
In this chapter, the experimental apparatus of FCVS and AVS nozzle will be described in detail. As using AVS nozzle, a high velocity of the gas stream was presented in the throat, the water is atomized and formed small droplets in the throat through a small hole due to the difference of the hydrostatic pressure at the outside and static pressure at the inside of the throat. An amount of aerosol carried in the air stream can be removed due to interaction with the water droplets in the nozzle throat and diffuser. Therefore, the efficiency of the venturi scrubber also depends on the atomization liquid flow rate into the nozzle. The atomization water flow rate through narrow gaps on the nozzle throat was measured using a combination method of Ultrasonic Velocity Profiler and Particle Tracking Velocimetry. A comparison for the atomization water flow rate between the using single-stage and double-stage venturi scrubber was performed. It showed that the atomization water flow rate was higher by using the double stage venturi scrubber nozzle. And it is an explanation for the improvement of the FCVS decontamination factor by using a double-stage venturi scrubber which has been measured in the previous research.

Chapter 3. "Effects of Baffle Plate of Advanced Venturi Scrubber on Decontamination Factor of Filtered Containment Venting System"

In Chapter 3, a comparison of the FCVS aerosol decontamination factor between using two configurations of nozzle: with and without the baffle plate to understand the impact of the baffle plate on the removal efficiency of FCVS. The visualized observation was applied using a high-speed camera and backlight illumination to understand how the baffle plate impacts the flow pattern in the wet scrubber. As the result, the baffle plate contributed to change the moving direction of the gas phase at the exit of the nozzle. In this way, it increased the residence time of air bubbles in the water column and increasing fluctuation of the gas phase in the pool. The results of measurement of the bubble column height showed that with the baffle plate, the aerated height of the bubble column was smaller. It contributed to decreasing the entrainment effects. It also allows a higher accumulation of water in the scrubber, and therefore, it increases the decontamination factor and capacity of decay heat removal of FCVS.

Chapter 4. "Interactions in Mixing Flow"

In general, the aerosol removal efficiency of the nozzle depends on the relative velocity between the gas and the liquid droplets. In this chapter, the water droplet velocity field inside the nozzle was measured using the Particle Image Velocimetry method using backlight illumination to understand how the baffle plate affects the liquid droplet velocity field. The results showed that the baffle plate decreased the droplet velocity in the nozzle. Thus, it contributed to increasing the decontamination factor. The observation of a high-speed camera also showed that there was a film layer of liquid on the surface of the baffle plate. Therefore, the change in direction of the airflow at the exit of the nozzle under the effect of the baffle plate may increase the centrifugal force which impacts the aerosol particles. Thus, the particles tend to slip out to contact and be absorbed into the liquid layer on the baffle plate surface.

Chapter 5. "Conclusion"

In this chapter, the summary of findings from Chapter 2 to Chapter 4 was described.