Theraml-Hydraulic Performance of Scrubbing Nozzle Used for CFVS

Hyun-Chul Lee [a], Doo-Yong Lee [a*], Woo-Young Jung [a], Jong-Chan Lee[a], Gyu-Tae Kim[a]
[a] *FNC Technology Co. Ltd, Heungdeok IT Valley, Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, 446-908, Korea*
[*] *Corresponding author: dylee@fnctech.com*

1. Introduction

A Containment Filtered Venting System (CFVS) is the most interested device to mitigate a threat against containment integrity under the severe accident of nuclear power plant by venting with the filtration of the fission products.

There are several filtration stages in the wet scrubber based CFVS which includes the scrubbing nozzle submerged in the scrubbing water pool. A venturi effect-based scrubbing nozzle is one of the typical methods to remove various polluted materials such as aerosols and toxic gases due to its high scrubbing efficiency as well as relatively low pressure drop.

FNC technology and partners have been developed the self-priming scrubbing nozzle used for the CFVS which is based on the venturi effect. The thermal-hydraulic performances such as passive scrubbing water suction as well as pressure drop across the nozzle have been tested under various thermal-hydraulic conditions.

2. Self-Priming Scrubbing Nozzle

The self-priming scrubbing nozzle shown in Fig.1 consists of four parts which are reducer, throat with water suction slit, diffuser and reflection header. In the CFVS, numbers of scrubbing nozzles are mounted on the distribution arm submerged in the scrubbing water pool.

When the inlet gas flow passes through the nozzle, the static pressure is decreased due to the reducer part and the scrubbing water is passively sucked through the water suction slit due to the pressure difference between static pressure inside throat and that of water head outside throat. The scrubbing water sucked through the slit would be formed as a fine droplet due to the breakup by the inside gas flow.

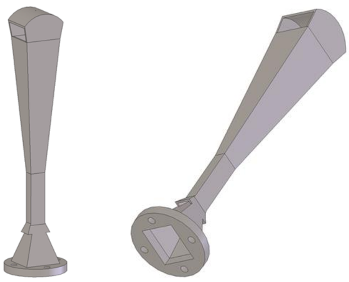

Fig. 1. Aerosol sampling system installed at aerosol scrubbing test loop.

3. Test Sections

The two types of test section have been built for testing the thermal-hydraulic performance of the self-priming scrubbing nozzle. One is the visualization loop shown in Fig.2. The single scrubbing nozzle with a rectangular cage surrounding a water suction side at the throat section made by the poly-carbonate is installed. The rectangular cage is connected to the overhead tank to supply the scrubbing water of the different water level. Using the visualization loop of the scrubbing nozzle, the hydraulic performance such as water suction behavior with different inlet gas flowrate as well as scrubbing water level can be measured under non-submerged condition. The flow behavior inside the scrubbing nozzle can be observed with a high speed camera.

Fig. 2. Visualization loop for single scrubbing nozzle

The other is a high pressure test loop shown in Fig. 3. The single scrubbing nozzle is installed in the scrubbing tank and connected to the inlet gas supply line. The single scrubbing nozzle is submerged in the different level of scrubbing water pool.

Fig. 3. High pressure test loop for single scrubbing nozzle.

3. Experimental Results

3.1 Visualized Scrubbing Nozzle

Through the visualization loop, the liquid suction performance through the slit, pressure drop across the nozzle are measured. Fig. 4 shows the results with the different overhead water levels and different inlet gas flows. The actual measured values are omitted due to the data security.

The liquid suction is increased with the increase of the overhead water level due to the water head at just outside of water suction slit. On the other hand, the liquid suction at the same overhead water level is not so much changed with the different inlet gas flows. The changes of the liquid suction at the same overhead water level can be affected by the pressure difference between outside water head and inside static pressure at the water suction slit. The pressure drop across the scrubbing nozzle is increase with the increase of inlet gas flow. Since the two-phase mixture is formed by the water suction, the pressure drop at the dry condition is relatively smaller than that at the wet condition.

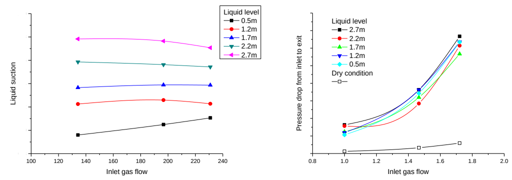

Fig. 4. Performance of liquid suction and pressure drop across the nozzle.

Fig. 5 shows the flow visualization in the throat section with the different gas flows. The scrubbing water sucked through the water suction slit meets gas and then sucked water is changed as the fine droplet and entrained by gas. These fine droplets can capture the fission products. The size of droplet has a tendency to be decreased with the increase of the inlet gas flow.

Fig. 5. Capture images of visualized scrubbing nozzle at various flow rates

3.2 Submerged Scrubbing Nozzle

The thermal-hydraulic performance especially for the pressure drop across the submerged scrubbing nozzle is tested as well. Fig. 6 shows the measured pressure drop across the scrubbing nozzle with various inlet air flows. The data shows almost linear against ($1/2\rho\ V^2$) and can be easily fitted.

The measured pressure drop with inlet steam flow is compared with the fitting of the pressure drop to confirm its applicability. It is seen in Fig. 7 that the pressure drop with steam is reasonably predicted by the fitting of the pressure drop.

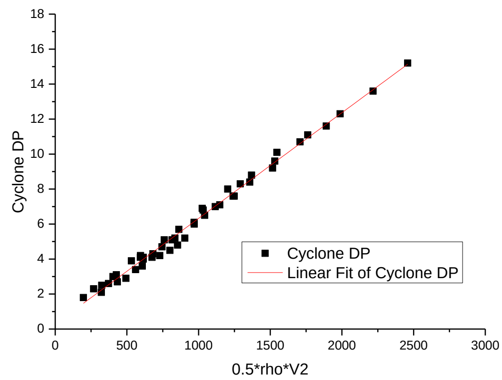

Fig. 6. Pressure drop across submerged scrubbing nozzle with various inlet air conditions.

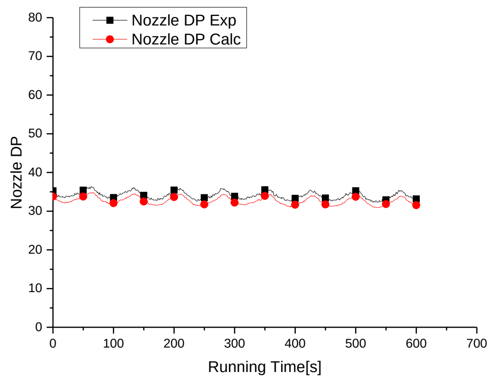

Fig. 7. Comparison between pressure drop calculation and pressure drop measurement with inlet stream flow (inlet steam pressure 565kPa-g)

4. Conclusions

The self-priming scrubbing nozzle is one of the key components used for the CFVS. The thermal-hydraulic performance has been tested to confirm the design features. The passive water suction flow through the suction slit at the throat is important parameter to define the scrubbing performance of the self-priming scrubbing nozzle. The water suction flow is increased with the increase of the overhead water level at the same inlet gas flow. It is not so much changed with the change of inlet gas flow at the overhead water level. The pressure drop across the non-submerged scrubbing nozzle is increased with the increase of inlet gas flow and that of wet condition (water suction condition) is relatively larger than that of dry condition. The pressure drop across the submerged scrubbing nozzle with various inlet air flows can be linearly fitted. The pressure drop fitting shows the reasonable prediction capability against the pressure drop at the steam conditions.

The design of CFVS will be optimized with the thermal-hydraulic performance of the self-priming scrubbing nozzle. The scrubbing performance test for the aerosol as a particle is ongoing with various thermal-hydraulic conditions as well.

REFERENCES

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ACKNOWLEGEMENT

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