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Aerosol Scrubbing Performance Test for Self-Priming Scrubbing Nozzle Submerged in Water Pool

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1. Introduction

A scrubbing nozzle is one of the key components for a wet scrubber process based Containment Filtered Venting System (CFVS). As a part of a development of Korean CFVS, a self-priming scrubbing nozzle shown in Fig. 1 has been developed based on the well-known venturi scrubber concept [1]. The thermal-hydraulic performances such as the pressure drop across the nozzle, water suction behavior and droplet generation inside throat have been tested in the non-submerged condition as well as submerged condition [2].

Fig. 1. Schematic of self-priming scrubbing nozzle.

In this study, the aerosol scrubbing performance of the developed self-priming scrubbing nozzle has been tested with prototypical CFVS operational conditions that the scrubbing nozzle is submerged in the water pool. Most of previous studies for the aerosol scrubbing tests available for the public [1,3,4,5] were performed at the non-submerged conditions with air as main carrier gas. On the other hand, this study focuses on the scrubbing effects on the various nozzle inlet pressures, pool water level and different aerosol sizes with different carrier gas steam fractions.

2. Aerosol Scrubbing Test Loop

Fig. 2 shows the schematic of aerosol scrubbing test loop to conduct the aerosol scrubbing performance tests for the self-priming scrubbing nozzle. The single nozzle which has prototypical dimensions is submerged in the water pool. The main carrier gas such as steam and air is mixed in the pre-mixing tank and then supplied into the aerosol mixing tank. The aerosols from aerosol generation and feeding system is injected into the aerosol mixing tank and mixed with main carrier gas. The main carrier gas including aerosol particles supplied to the inlet of scrubbing nozzle. The aerosol sampling system is installed at the inlet and outlet of the test section to measure the aerosol concentration and estimate the scrubbing efficiency. The optical particle counter (OPC) is installed at the same location as the aerosol sampling system. The OPC can be used for the real time measurement about aerosol concentration as well as aerosol size distribution during the tests. The measurement of absolute aerosol concentration is based on the aerosol sampling in the aerosol scrubbing tests. On the other hand, the real time data from the OPC is used to confirm the steady generation and feeding of aerosol during the tests.

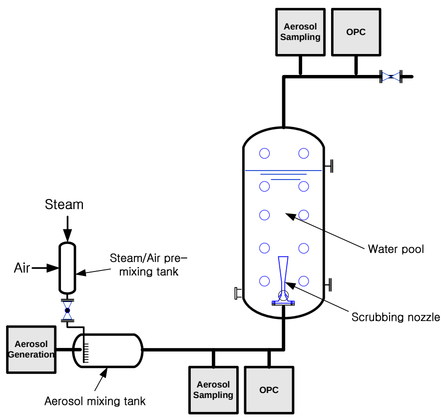

Fig. 2. Schematic of aerosol scrubbing test loop.

Fig. 3 shows the overview of aerosol scrubbing test loop. The design pressure of aerosol scrubbing test loop is 900kPa(g) and maximum operating pressure is 700kPa(a) which is based on the steam and air capacity [6].

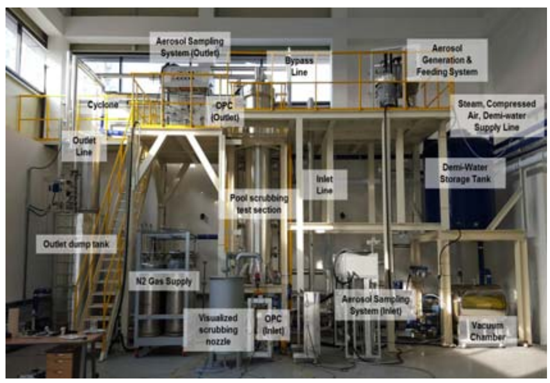

Fig. 3. Overview of aerosol scrubbing test loop

3. Aerosol Scrubbing Test Results

The aerosol scrubbing tests have been performed with various test conditions such as different aerosol size, different pool water level, different carrier gas steam mass fraction and different inlet pressure. Due to the data security, the scale of Y-axis is removed from Fig. 4 through Fig. 7.

Fig. 4 shows the aerosol scrubbing efficiency against the aerosol size. It is seen that the scrubbing efficiency is increased with the increase of aerosol size.

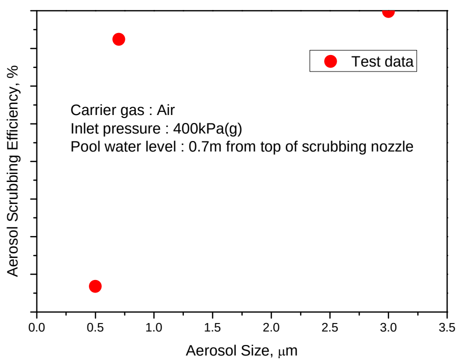

Fig. 4. Aerosol scrubbing efficiency against aerosol size (carrier gas : air, inlet pressure : 400kPa(g), pool water level : 0.7m from top of scrubbing nozzle)

Fig. 5 shows the aerosol scrubbing efficiency against the carrier gas steam mass fraction in the steam/air mixture. The 0% and 100% of steam fractions mean the carrier gas is fully air and steam, respectively. It is seen that the scrubbing efficiency is increased with the increase of steam mass fraction in the mixture.

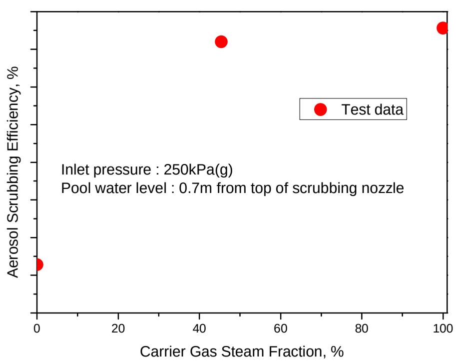

Fig. 5. Aerosol scrubbing efficiency against carrier gas steam fraction (inlet pressure : 250kPa(g), pool water level : 0.7m from top of scrubbing nozzle)

Fig. 6 shows the aerosol scrubbing efficiency against the pool water level. The water level is measured from the top of the nozzle exit. It can be seen that the aerosol scrubbing efficiency is increased with the increase of the pool water level.

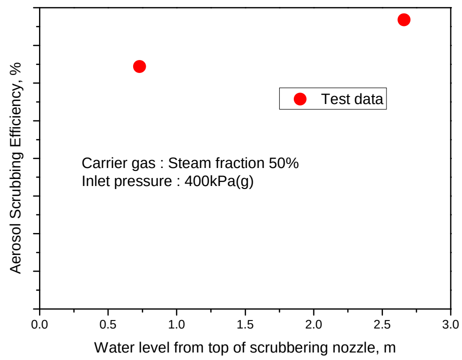

Fig. 6. Aerosol scrubbing efficiency against pool water level (carrier gas steam fraction : 50%, inlet pressure : 400kPa(g))

Fig. 7 shows the aerosol scrubbing efficiency against the nozzle inlet pressure. It can be seen that the effect on the aerosol scrubbing efficiency with different nozzle inlet pressure is not significant. The main parameter to estimate the scrubbing efficiency of the nozzle is the gas velocity inside the throat of nozzle [1,3,4,5]. Since the nozzle throat velocity based on the gas volumetric flow is mostly similar even though the gas mass flow changes depending on the nozzle inlet pressure, the aerosol scrubbing efficiency against the nozzle inlet pressure might not so different.

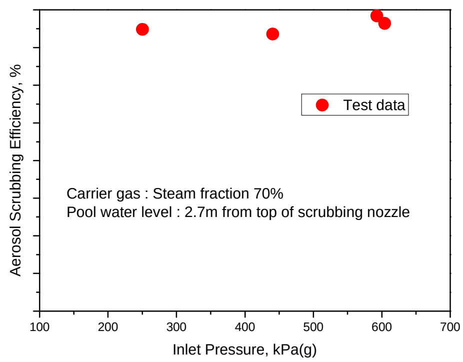

Fig. 7. Aerosol scrubbing efficiency against nozzle inlet pressure (carrier gas steam fraction : 70%, pool water level : 2.7m from top of scrubbing nozzle)

3. Conclusions

The self-priming scrubbing nozzle used for the wet scrubber based CFVS has been developed, which is submerged in the water pool. When there is gas flow at the inlet of the nozzle, the pool water is passively sucked from the water suction slit. The fine droplets generated inside the throat capture the aerosol particles and is discharged into the water pool. In the water pool, the pool scrubbing happens.

The aerosol scrubbing performance tests for the developed self-priming scrubbing nozzle has been conducted under the operational conditions such as different aerosol sizes, different carrier gas steam

fractions, different, different pool water level and nozzle inlet pressure. The major findings are as follows.
(1) Aerosol scrubbing efficiency increases with the increase of the aerosol size.
(2) Aerosol scrubbing efficiency increases with the increase of the carrier gas steam fraction.
(3) Aerosol scrubbing efficiency increases with the pool water level.
(4) Since the aerosol scrubbing efficiency of the self-priming scrubbing nozzle depends on the gas velocity inside the throat, the effect on the aerosol scrubbing efficiency is not significant with nozzle inlet pressure if the gas volumetric flow is not so changeable.

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