Numerical Study on Shape of Liquid Inlet for Venturi Scrubber in Self-Priming Mode

J. W. Lee [a*], H. S. Kim [a], W. S. Kim [a]
[a]R&D Center, BHI Co., LTD., 122, Janngbaek-ro, Gunbuk-myeon, Haman-gun, Gyeongsangnam-do, Korea
[*]Corresponding author: jwlee@bhi.co.kr

1. Introduction

Nuclear power plants are gradually installed the containment filtered venting system (CFVS) to ensure the integrity of containment by relieving pressure initiatively and removing radioactive products carried in the exhaust gases. Mostly CFVS installed in NPP consist of two components: wet venturi scrubber and metallic fiber filter. Fig. 1 shows venturi scrubber installed in CFVS.

The venturi scrubber rely on the high kinetic energy generated by accelerating the gas through a restriction to give good inertial collection in the gas. The venturi scrubber is composed of three sections: a converging section, a throat section, and a diverging section. The gas accelerate in convergent segment and reach maximum velocity at throat. The liquid is injected into venturi scrubber depends on static pressure difference between outside and inside of the venturi throat, then liquid is atomized into fine droplet when it contacts with high speed airflow. Aerosol removal occur in the diverging section as the inlet gas stream mixes with the fog of tiny liquid droplets.

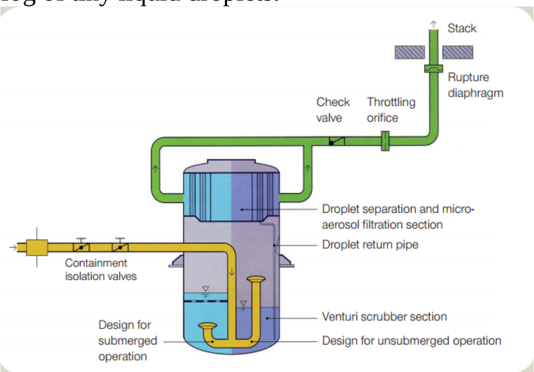

Fig. 1. Filtered venting system [1].

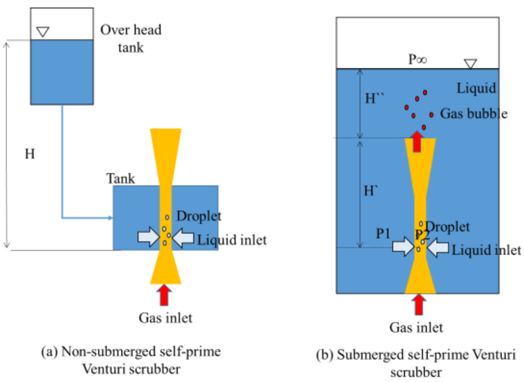

Fig. 2. Self-priming mode in venturi scrubber.

Many studies dealing with the non-submerged self-priming venturi scrbber [2,3]. The self-priming venturi scrubber is operated at two different operating condition; a non-submerged, and a submerged (Fig. 2). In a non-submerged condition, outlet nozzle of venturi scrubber is not immersed in water pool of a tank whereas in a submerged condition, the outlet of a venturi scrubber is immersed in water pool. The scrubbing liquid is supplied by water reservoir surrounding the throat and is drawn in due to a pressure difference between the outside and the inside of the venturi throat that arises out of the hydrostatic pressure of the liquid and static pressure of the flowing gas. The performance of a venturi scrubber is improved with high gas velocities and high liquid flow rate. Therefore, it is important to study the liquid fraction in venturi scrubber operated at different condition. The venturi scrubber is used to a submerged self-priming mode because the system operates in a passive mode in CFVS.

The present study focuses on the liquid flow characteristics for various shapes of liquid inlet in submerged self-priming venturi scrubber.

2. Methods and Results

2.1 Physical Model

The schematic diagram of self-priming venturi scrubber is shown in Fig. 3. The shapes of liquid inlet is cylindrical port of 4mm for a hole type, is rectangular port for a split type in the throat of venturi scrubber.

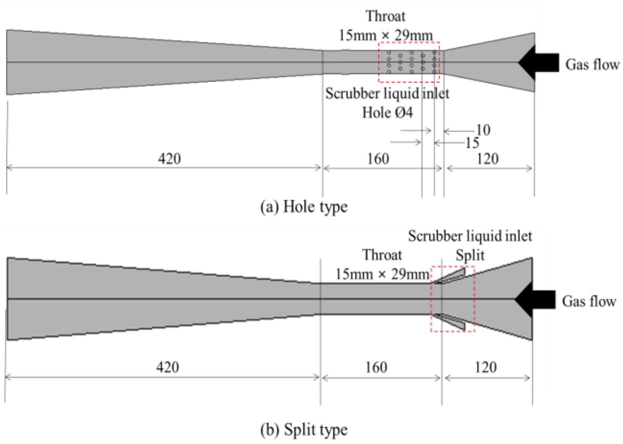

Fig. 3. Schematic diagram of venturi scrubber.

2.2 Numerical methods

The flow characteristics is analyzed by computational fluid dynamics (CFD) method according to different shapes of liquid inlet and gas flow rate for submerged self-priming mode in venturi scrubber. The computations are carried out using Fluent 16.1 [4], a commercial CFD code.

The simulation of two phase flow in venturi scrubber is conducted by mixture model approach in steady state. For the gas flow, Eulerian approach is used solving the Reynolds averaged Navier-Stokes equations (RANS) using the standard k-ε turbulence model [5]. The computational domain is meshed with the hexahedral grids of 1.2 million.

The boundary condition of venturi scrubber are defined as follows: gas volume flow rate is 107, 215 and 429 m^3/hr at inlet. The hydrostatic pressure is used for liquid inlet and outlet to calculate from the water level.

2.3 Results and discussion

Fig. 4 is plot of the static pressure in a hole type liquid inlet of venturi scrubber for submerged self-priming mode. The liquid is expected to injected into venturi scrubber due to static pressure for inside of throat at liquid inlet is lower than hydrostatic pressure for outside of throat.

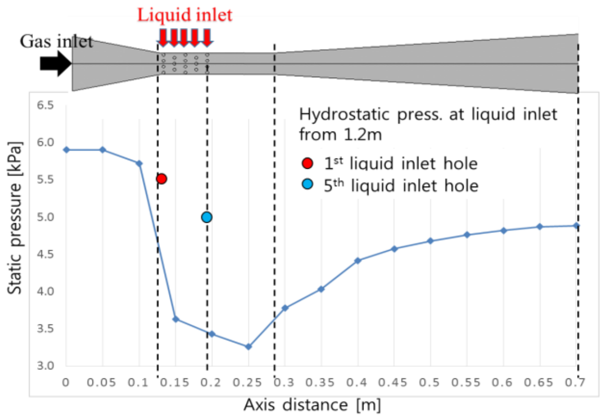

Fig. 4. Plot of the static pressure in a hole type liquid inlet of venturi scrubber (Gas inlet: 107m^3/hr).

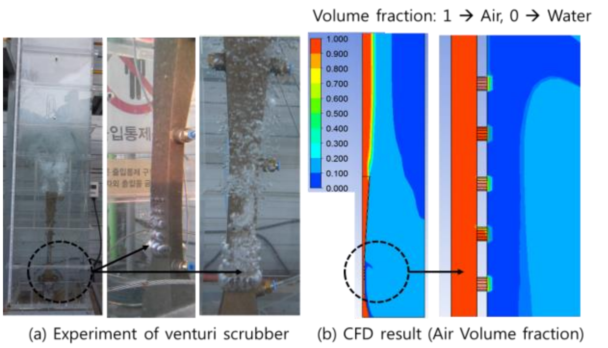

Fig. 5. Compare of experiment and CFD result for a hole type scrubber.

Fig. 5 shows gas is discharged from liquid inlet of hole type venturi scrubber with gas flow rate 107m3/hr. There is two reason. First, the gas is easy to get out in a hole type of liquid inlet. Second, the static pressure at wall is higher than center in throat, because gas velocity at wall reduce, and dynamic pressure convert to a larger static pressure.

The static pressure distribution in a split type liquid inlet of venturi scrubber are obtained under different gas volume rate for submerged self-priming mode, shown in Fig. 6. The pressure drop is increasing with higher gas flow rates, higher static pressure in the venturi throat are obtained with increasing gas velocities. The static pressure at liquid inlet is lower than hydrostatic pressure at outside of throat. The liquid is injected into venturi scrubber for all gas volume rate because static pressure at liquid inlet of inside throat (axis distance 0.13m) is lower than hydrostatic pressure at outside of throat (axis distance 0.12m).

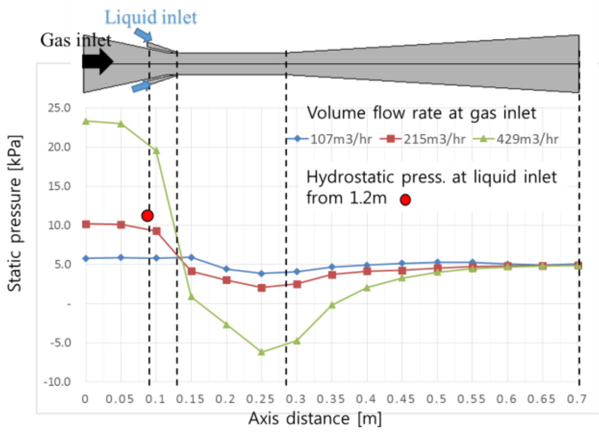

Fig. 6. Plot of the static pressure for a split type of liquid inlet in venturi scrubber.

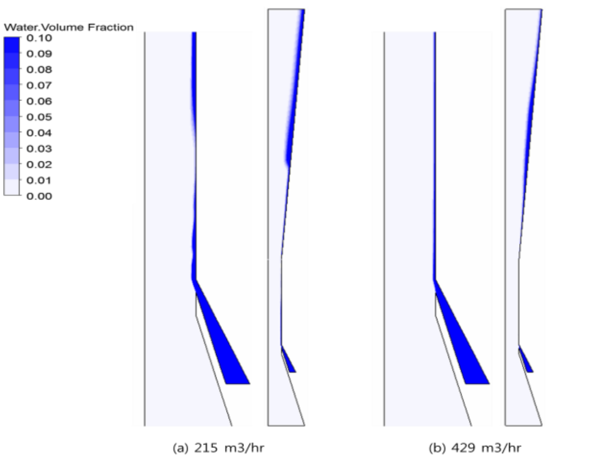

Fig. 7. Contour of water volume fraction for a split type of liquid inlet in venturi scrubber.

Fig. 7 is contours of water volume fraction in a split type liquid inlet venturi scrubber at different gas volume rate. The liquid is injected into venturi scrubber. The gas is difficult to get out through a split type of liquid inlet.

Table I: Liquid Loading in Split Type Liquid Inlet Venturi Scrubber

Inlet volume rate (m^3/hr)	Liquid loading (l/m^3)
107	9.0
215	3.8
429	1.3

Table I is results of liquid loading with different gas volume rate for split type of liquid inlet. It indicates that with the increasing of gas volume rate, liquid flow rate decrease. The increasing of gas volume rate led to a static pressure increment at inside of throat, the effective pressure difference for injection reduce.

3. Conclusions

In this study, the simulation was developed for different design of liquid inlet to improve injection in submerged self-priming mode venturi scrubber.

1. A hole type is easy to discharged gas from liquid inlet for submerged self-priming mode.
2. A spit type, the liquid is injected into venturi scrubber for all gas volume rate in submerged self-priming mode.
3. A spit type is better than a hole type on improving injection of liquid inlet for submerged self-priming mode in venturi scrubber.

4. Acknowledgements

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