De-entrainment Efficiency of Vertical Rods in the Upper Plenum

Kyung-Won Lee[1], Hee Cheon NO[1], Chul-Hwa Song[2]
[1] *Korea Advanced Institute of Science and Technology, 373-1, Guseong-dong, Yuseong-gu, Daejeon, 305-701, Korea*
leekw@nsys.kaist.ac.kr, *hcno@nsys.kaist.ac.kr*
[2] *Korea Atomic Energy Research Institute, 150 Dukjin-dong, Yuseong-gu, Daejeon, 305-353, Korea*
chsong@kaeri.re.kr

1. Introduction

During a reflood phase of a large-break loss-of-coolant accident, a large amount of droplets are de-entrained by inertial impaction on the upper plenum structure such as control rod guide tubes and support columns, causing the steam binding problem. Although some useful experiments were performed on the de-entrainment efficiency [1-5], there are no available data that shows the neighboring rod effect.

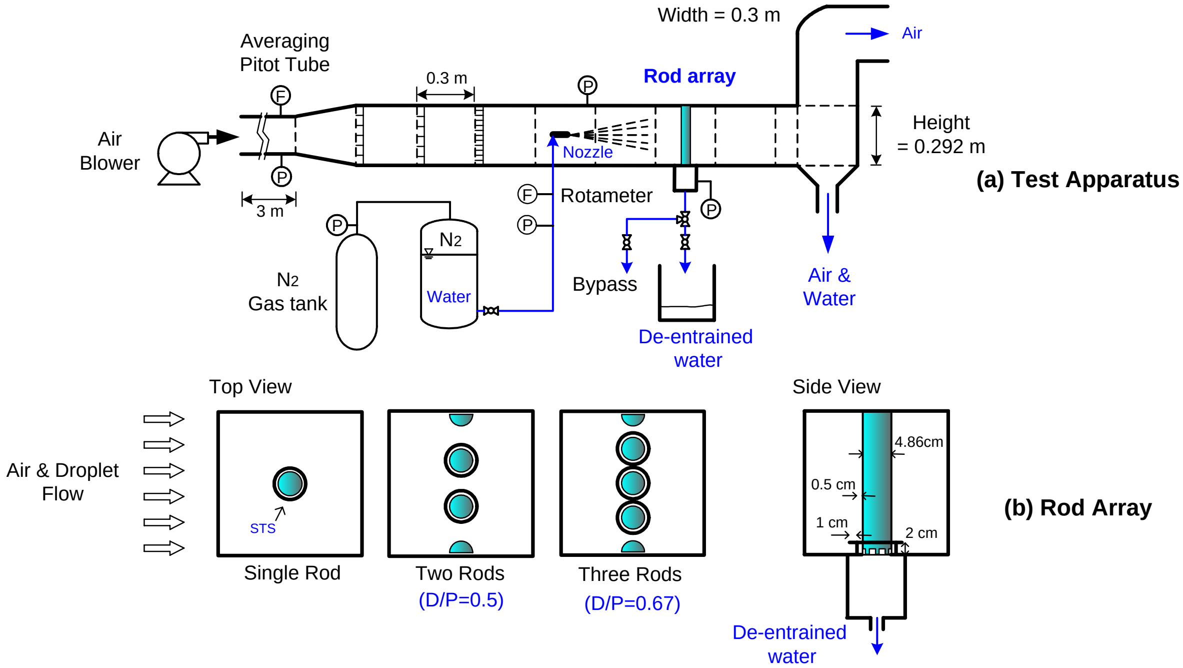
The main purpose of this study is to evaluate the effects of the droplet mass flux, the air velocity, and neighboring rods on the de-entrainment efficiency.

2. Experiments

Figure 1 shows the schematic diagram of the experimental apparatus. The height of rectangular wind tunnel is 0.292 m and the width is 0.3 m. To simulate the upper plenum structure, we installed an array of vertical rods with a diameter of 0.0486 m. The rods are made of stainless steel (STS) with smooth surface. The droplets are injected by a pressure tank through a spray nozzle and the air is injected by an air blower as shown in Fig. 1(a). The nozzle was manufactured by Spraying Systems Co., USA. The spray angles of the nozzle are from 26 degrees to 31 degrees depending upon spray pressure. The distance between the spray nozzle and the array of rods is 0.5 m.

The de-entrainment efficiency, η, is defined as the ratio of the droplet mass flow rate de-entraining along the rods to the droplet mass flow rate reaching the rods. We investigated the effects of the droplet mass flux and the air velocity on the de-entrainment. In addition, we evaluated the effect of neighboring rods on the de-entrainment by comparing the de-entrainment efficiency for a single rod with that for a single row of rods. The values of the diameter-to-pitch ratio are 0.5 for two rods and 0.67 for three rods as shown in Fig. 1(b). For the same boundary condition, half rods were fixed on both side of test section in the experiments for the single row of rods.

The ranges of average droplet mass flux were 1.2 kg/m^2s to 5.4 kg/m^2s for the single rod and 0.5 kg/m^2s to 4.2 kg/m^2s for the single row of rods. The droplet velocities at nozzle tip, V_d, were 13 m/s to 28 m/s and the droplet sizes were in the ranges of 349 μm to 695 μm. The average air velocities in the wind tunnel were 0 m/s, 3m/s, and 6m/s.



(a) Test Apparatus

(b) Rod Array

Figure 1. Schematic diagram of experimental apparatus.

3. Results and Discussion

The present experimental data for the de-entrainment efficiency are plotted as a function of the droplet mass flux in Fig. 2. The data show that the de-entrainment efficiency for the single rod, η_I , decreases slightly as the droplet mass flux increases, while it has negligible dependence on the air velocity in the present experimental ranges. As shown in Fig. 2(a), the values of de-entrainment efficiency for the single rod are less than 25 percent regardless of the air velocity. This indicates that about 75 percent or more of droplets reaching the rod splash out of the rod.

The de-entrainment efficiencies for the single row of rods, η_{SR} , are shown in Figs. 2(b) and 2(c). The results show that the general trend of the de-entrainment efficiency for the single row of rods is similar to that for the single rod. The de-entrainment efficiency, however, is slightly higher in the single row of rods than in the single rod.

The total data of each experiment are fitted linearly, and the results are plotted in Fig. 3.

The results show that the existence of neighboring rods promotes the de-entrainment efficiency and its influence decreases as the droplet mass flux increases. From the results, we can also deduce that large diameter to pitch ratio promotes the de-entrainment, that is, the de-entrainment efficiency increases as the gap distance between rods decreases due to splashing the droplets to the neighboring rods.

4. Conclusions

From our results, we make the following conclusions: (1) The de-entrainment efficiency decreases slightly as the droplet mass flux increases, while it has negligible dependence on the air velocity in the present experimental ranges; (2) The existence of neighboring rods promotes the de-entrainment efficiency due to splashing the droplets to the neighboring rods and its influence decreases as the droplet mass flux increases.

REFERENCES

[1] C. Y. Chen, "Filtration of aerosols by fibrous media," Chem. Rev., 55, pp.595-623, 1955.

[2] D. A. Barnard, J. A. Ward, P. B. Whalley, "Two-phase flow in a PWR upper plenum – an experimental study using air and water," AERE G 1047, 1978.

[3] H. J. Richter, R. Munson, M. Warren, "Deentrainment and reentrainment of droplets in air-water mixture flow through a rod array and a perforated plate," EPRI NP-1383, 1980.

[4] J. C. Dallman, W. L. Kirchner, "De-entrainment phenomena on vertical tubes in droplet cross flow," NUREG/CR-1421, LA-8316-MS, 1980.

[5] J. C. Dallman, "Droplet deentrainment in arrays of cylinders," Trans. Am. Nucl. Soc., 39, pp.1041-1042, 1981.

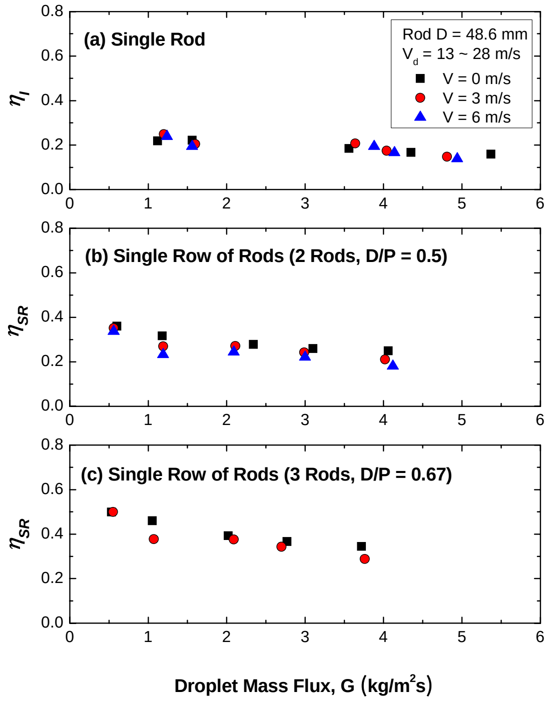


Figure 2. De-entrainment efficiencies of a single rod and single row of vertical rods.

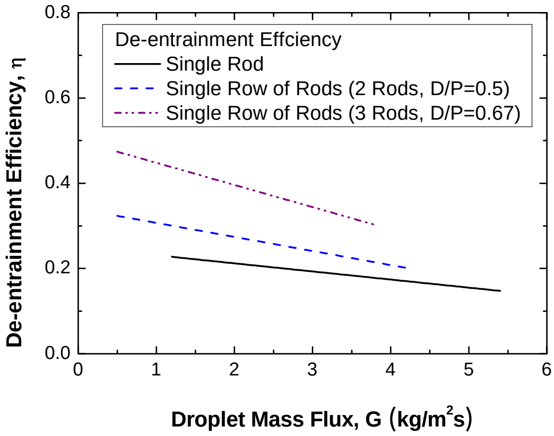


Figure 3. Effect of neighboring rods on de-entrainment efficiency.