Consideration of Outlet Flow Velocity Measurement in the Deodorizing Device Development Process

Makoto Kashino, Kunihiko Ishihara

Abstract— **This paper deals with the outlet flow velocity measuring methods of a deodorizing device under development. In a normal state, the flow velocity vector has not one direction but various directions. So we can't obtain the accurate flow rate. Then two measuring methods are examined to obtain more accurate flow rate. One is the experimental method in which a vinyl chloride cylinder is connected to the outlet of the deodorizer to guide the air passing through the filter to the cylinder (Cylinder experiment). The other method is that all the air passing through the deodorizing devise is gathered and stored in a bag (Bag experiment). Comparing the results mentioned above, the measured values of the bag experiment were lower than those of cylinder experiment. Therefore, in order to improve the measurement accuracy of the bag experiment, we conducted an experiment considering back pressure. As a result, the both results are agreement with each other.**

***Index Terms*—Flow velocity measurement method, Measurement accuracy, Cylindrical experiment, Bag experiment.**

I. INTRODUCTION

In medical institutions and long-term care welfare facilities (medical institutions), odor control becomes often a problem[1,2]. Medical institutions need to maintain comfort as a living space for patients and users of them. There are various causes of odor, such as fecal odor associated with excretion and food. Taking countermeasures against these odors not only maintains the comfort of users, but also improves the working environment of staffs. Therefore, we decided to develop a deodorizing device. The filter used for the deodorizing device (manufactured by Ito Co., Ltd .; filter) is a paper honeycomb core filled with granular bamboo activated carbon. In the previous study, we have examined the performance of the deodorizing device by using a single filter [1]. A DC fan motor (manufactured by Panasonic; fan [3]) was used to study the optimum position of the fan where air sucked into the deodorizing device most. As a result, it was shown that the closer the fan is to the filter, the faster the air flow velocity through the filter is.

In this study, when commercializing a deodorizing device, we used three filters for the purpose of enhancing the deodorizing effect, and examined an air flow velocity measuring method to understand how the air flow velocity passing through the filter changes.

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II. RELATION BETWEEN THE FILTER STRUCTURES AND THE OUTLET FLOW VELOCITY

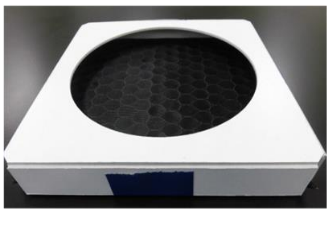
A. Experimental method

In the development of the deodorizing device, in order to increase the number of filters from 1 to 3, we prototyped a filter unit that can install three filters. Figure 1 shows the filter unit. An experimental device with the filter unit fixed to the most downstream end of the deodorizer was prototyped, and the outlet flow velocity (v) was measured. Figure 2 shows the experimental equipment. The three filters were in close contact with each other. The filter is filled with bamboo activated carbon and deodorizes by flowing air through the filter. The thickness of the filter unit is 35 mm.

In this study, it is defined that the larger the outlet flow velocity of the deodorizer is, the better the performance is. Therefore, the outlet flow velocity v, which is the evaluation index, was measured. As shown in Figure 3, the number of measurement points is 21. they are one circular center and 20 of intersections of five circulars and two orthogonal lines. Five circular lines are made as area of each circular band becomes equal, and the average value of these was taken as v[4].

As shown in Figure 2, the static pressure (P) was measured at the center of the left and right sides of the deodorizing device wall surface at 50 mm from the most downstream end of the deodorizing device. The smart probe-testo 405i (manufactured by Testo Co., Ltd .; wind speed sensor) was used for the outlet flow velocity measurement, and the digital manometer HT-1500NS (Hodaka Co., Ltd .; static pressure sensor) was used for the static pressure measurement. The position of the fan was fixed at a height of 230 mm from the floor. The measurement was performed 3 times.

a. View from directly above



b. View from diagonally above

Figure 1. Filter unit

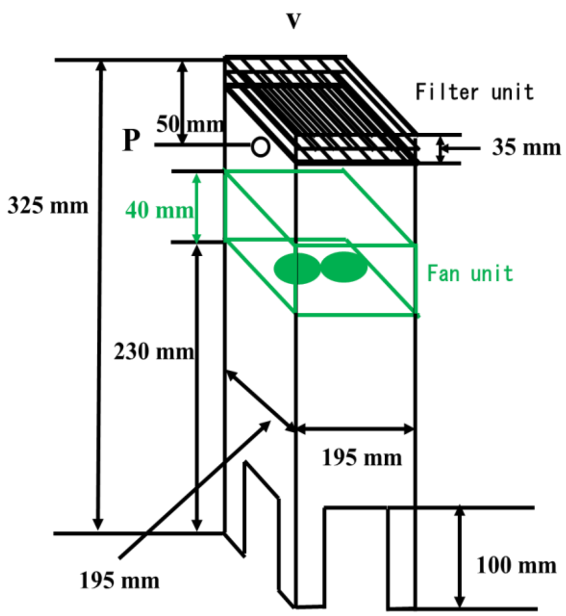


Figure 2. Schematic diagram of experimental equipment.

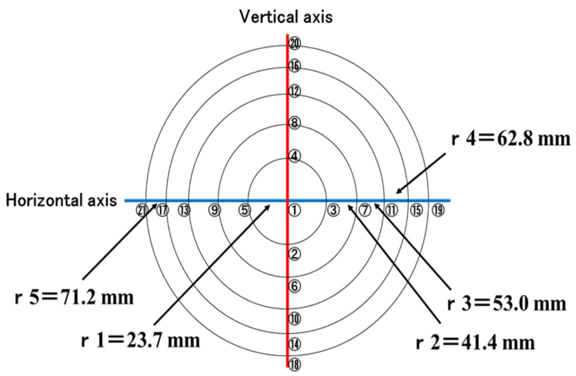


Figure 3. Exit side flow velocity measurement point

B. Experimental result

Table 1 shows the measured values of v and P. v was 0.34 ± 0.01 m / sec on average for three measurements. Figure 4 shows the flow velocity distribution on the outlet side of the deodorizer. The flow velocity tended to be faster toward the outer circumference of the circle. P was the average value of three measurements and was 19.7 ± 0.1 Pa.

Table 1. v and P measurement results

	v	P
1	0.33	19.8
2	0.34	19.7
3	0.34	19.7
mean	0.34	19.7
sd	0.01	0.1

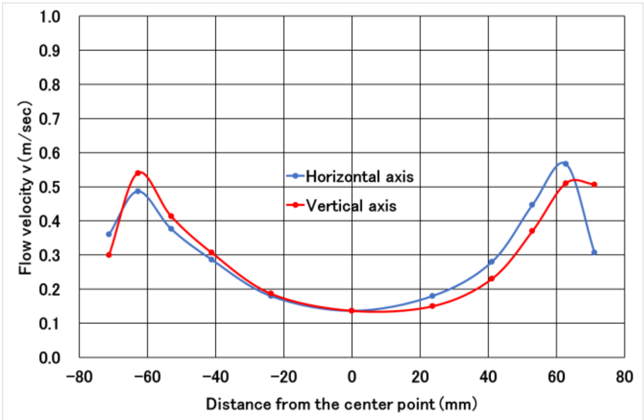


Figure 4. Flow velocity distribution on the outlet side of the deodorizing device

III. THREE TYPES OF MEASUREMENT METHODS AND RESULTS

Here, the methods and results of the three types of measurement methods are described. The first measurement method is the one described in Chapter 2. Other than that, one method is to connect the cylinder of the PVC pipe to the hole of the filter unit on the outlet side of the deodorizing device, and guide the air passing through the filter to the cylinder, and measure the flow velocity (cylindrical experiment). The other method was to measure v by a method of storing all the air passing through the filter in a bag (bag experiment), and compared the results. In the experiments using both measurement methods, the filter unit was fixed at the most downstream end of the deodorizing device, and the fan was fixed at a position 230 mm from the floor surface.

A. Experiment to measure the flow velocity by guiding all the air passed through the filter to a cylinder (cylindrical experiment)

Figure 5 shows a schematic diagram of the experiment. A PVC pipe with an inner diameter of 154 mm and a length of 1,000 mm was connected to the outlet side of the filter unit, and v was measured at the most downstream end of the cylinder. The thickness of the filter unit was 35 mm same as Ⅱ .A. The measurement points are the same as ones as shown in Figure 3. The static pressure (P) was measured at a height of 50 mm from the most downstream end of the deodorizing device and at the center of the left and right sides of the wall surface of the deodorizing device.

B. Method of storing all air passing through a filter in a bag (bag experiment)

An experiment was conducted in which all the air passing through the filter of the deodorizing device was stored in the bag through the guide tube, and the time until the static pressure in the guide tube reached 10 Pa was measured. A schematic diagram of the experimental equipment is shown in Figure 6a. A plastic bag 1 for collecting the air passing through the filter was attached to the outlet side of the deodorizing device. One end of a vinyl chloride pipe for guiding air to the plastic bag 2 for storing air was connected to the tip of the plastic bag 1, and the plastic bag 2 was connected to the other end of the guide pipe. The thickness of the filter unit was 35 mm as same 3.1. The static pressure in the guide tube was set to 10 Pa because the maximum amount of air can be regarded as almost zero tension when the bag expands. As shown in Figure 6b, when air is stored through the guide tube, the plastic bag 2 becomes roughly ellipsoidal shape, and its cross section becomes almost elliptical shape.

Therefore, the total length of the plastic bag 2 is L (m), the short axis is a (m) and the long axis is b (m) of the cross section as shown in Figure 6c, and the cross-sectional area of the plastic bag 2 is calculated by $\pi ab / 4$ [5], L was multiplied there to calculate the volume V of the plastic bag 2. For comparison with the cylinder experiment, the flow velocity v was calculated by V / S't, where S' is the cross-sectional area of the cylinder.

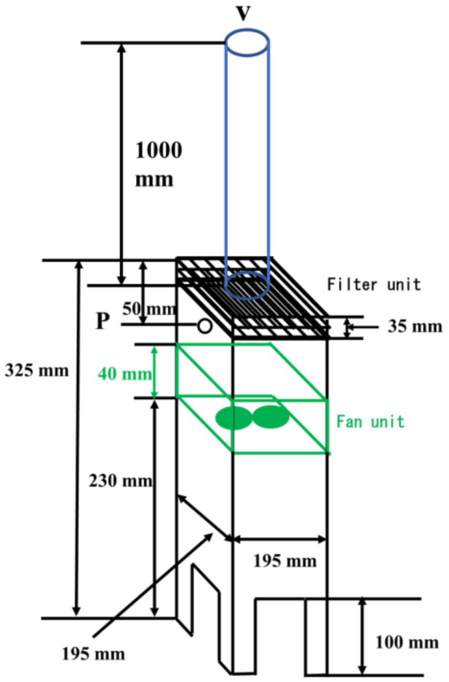


Figure 5. Cylindrical experiment schematic diagram

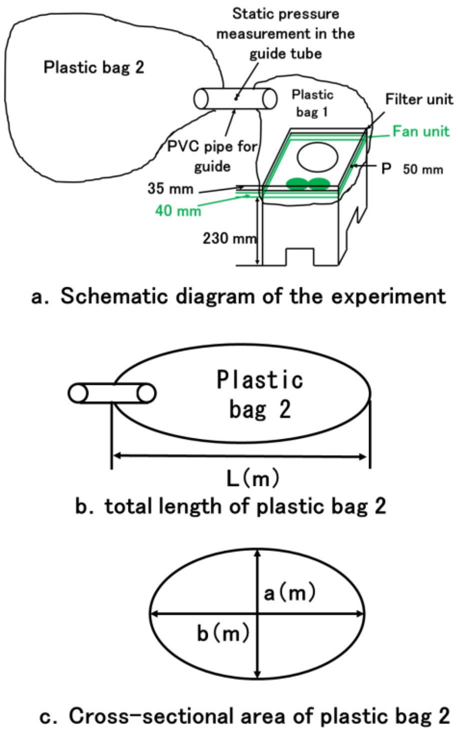


Figure 6. Schematic diagram of bag experiment

C. Measurement results

Table 2 shows the results of the cylindrical experiment. v was 0.27 ± 0.005 m / sec on average for all three times. P was 19.5 Pa on average of 3 measurements. Figure 7 shows the outlet flow velocity distribution. In both distributions of horizontal and vertical axis, the values were low at the outermost circumference, the flow was presumed to be turbulent from these velocity distribution. In fact, the Reynolds number (Re) was 2,750. This value is higher than the well-known critical Reynolds number of 2,300. Therefore, it can be seen that the flow of the deodorizing device is turbulent.

Table 2 Measurement results of v and P in the cylindrical experiment

	v	P
1	0.27	19.7
2	0.26	19.4
3	0.27	19.7
mean	0.27	19.6
sd	0.005	0.17

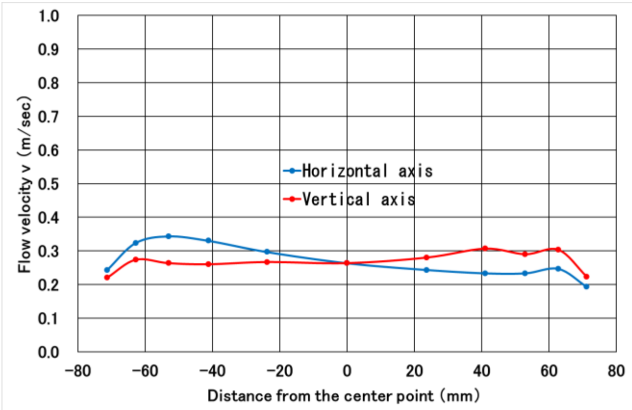


Figure 7. Cylindrical experiment deodorizing device outlet flow velocity distribution

Next, Table 3 shows the measurement results of v in the bag experiment. Five measurements were performed and v was 0.190 ± 0.014 m / sec. Compared with the cylindrical experiment, the v of the cylindrical experiment was 0.27 m / sec, so the bag experiment showed a considerably lower value. Originally, it can be expected that v should give similar results in both the cylindrical experiment and the bag experiment. However, when the actual measurement was performed, the values were different between the two. Therefore, in order to improve the accuracy of the bag experiment, we conducted an experiment considering back pressure.

Table 3. Measurement result of bag experiment

	v
1	0.211
2	0.177
3	0.194
4	0.180
5	0.187
mean	0.190
sd	0.014

IV. THREE TYPES OF MEASUREMENT METHODS AND RESULTS

A. Experimental method

The experimental equipment used here was the same as that shown in Figure 6. Until now, only the time until the static pressure in the guide tube reached 10 Pa was measured, but this time, the pressure difference ΔP(=P1-P2) was measured every 10 sec. Where P1 is the static pressure in the device and P2 is the static pressure in the guide tube. The time when the static pressure of the guide tube reached 10 Pa was measured. v was calculated in the same way as in the previous bag experiments. If the volume V at this time is related to the air flow rate Q, there is a relationship of $Q \propto \sqrt{\Delta p}$ [6]. Therefore, the area of the square root of ΔP was calculated by the trapezoidal rule, and the time-averaged volume was calculated by dividing by the time until the static pressure in the guide tube reached 10 Pa.

B. Measurement results

Figure 8 shows the measurement results. At this time, v was 0.254 m / sec, which was about the same as the cylindrical experiment (0.27 m / sec). In other words, it was found that reasonable results can be obtained even in the bag experiment.

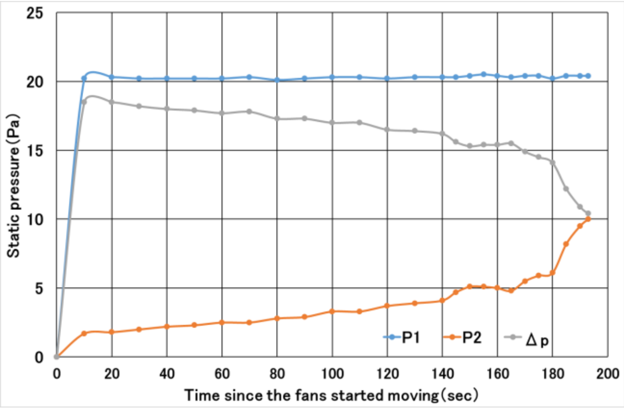


Figure 8. Change of static pressure in bag experiment

C. Consideration

When installing an object that becomes the flow resistance in the flow path, the flow resistance becomes large in proportion to the number of objects. Considering that the deodorizing device has the peculiar resistance value due to installing filter, as the number of filters increases, the flow resistance in the flow path increases and v decreases. In this study there is an almost inversely proportional relation between the number of filters and v, that is, as the number of filters increases, v becomes lower. Therefore, the number of filters was fixed at three. That is, the resistance value of the filter in the deodorizing device was kept constant. Then, v should become about the same value regardless of the measurement method.

In a normal experiment in which the flow velocity was measured on the outlet side of the deodorizing device, v showed a high value, but similar results were obtained in the cylindrical experiment and the bag experiment. In the cylinder experiment, all the air passing through the filter is guided into the cylinder, so it is considered that the high measurement accuracy will be obtained. However, in this experiment, it was suggested that the measurement results may be affected by the measurer's proficiency in measurement and the surrounding environment. In the bag experiment, as in the cylindrical experiment, all the air after passing through the filter is guided and stored in the bag. Therefore, it is considered that the high measurement accuracy is achieved as in the cylindrical experiment. Moreover, compared with the cylindrical experimental result, it was possible to measure easily regardless of the proficiency level of the measurer. The time-averaged volume value in this bag experiment was 8.96 m^3. From these, it was shown that the measurement using a bag has the highest measurement accuracy and can be easily measured in terms of measurement accuracy.

V. CONCLUSION

In developing the deodorizing device, we examined a simpler and more accurate measurement method of outlet flow velocity v. In normal measuring method, it was suggested that the accuracy of v would be low. Although the accuracy of the cylindrical experiment is high to some extent, the measurement environment and the skill of the measurer are required. The bag experiment suggested that v could be measured easily with high measurement accuracy.

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