

Opinion/Recommendation

Decline of the performance of a portable axial-flow fan due to the friction and duct bending loss of a connected flexible duct

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Abstract: Objectives: In a job site, a portable fan is often used to ventilate a confined space. When a portable fan is applied to such a space, the actual ventilation flow rate must be accurately estimated in advance because the safety level of contaminant and oxygen concentrations in the space will determine the ventilation requirements. When a portable fan is used with a flexible duct, the actual flow rate of the fan decreases due to the friction and duct bending loss of the duct. Intending to show the decline of a fan performance, the author conducted laboratory experiments and reported the quantitative effect of the friction and duct bending loss of a flexible duct to the flow rate of a portable fan. **Methods:** Four commercial portable fans of different specifications were procured for the experiments, and the decline of the performance of each portable fan due to the friction loss etc. of a connected flexible duct was investigated by measuring actual flow rate. **Results:** The flow rate showed an obvious decrease from the rated flow rate when a flexible duct was connected. Connection of a straight polyester flexible duct and a straight aluminum flexible duct reduced the flow rates to 81.2 - 52.9% and less than 50%, respectively. The flow rate decreased with an increase of the bend angle of the flexible duct. **Conclusion:** It is recommended that flow rate check of a portable fan should be diligently carried out in every job site.

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Key words: Flexible duct, Flow rate, Friction loss, Portable fan

Introduction

Inside a manufacturing site or a construction site, a portable axial-flow fan is frequently used to ventilate a confined space where the risk of exposure to harmful airborne contaminants or oxygen deficiency is concerned (e.g., inside of a structure, pit, well, tank, manhole, etc.). Connecting to a polyester flexible duct, a portable axial-flow fan is applicable to both exhaust ventilation and supplying air ventilation (Fig. 1). When the ventilation by means of a portable fan is applied to such a confined space, the actual ventilation flow rate has to be accurately estimated in advance because the safety criteria for contaminants or oxygen concentration in a confined space will determine the ventilation requirements directly. For example, a material balance equation for such a space can be transformed into the following simple form, assuming complete mixing (safety factor = 1) and a steady state¹⁾.

$$Q = G / C$$

where Q: ventilation rate (volume of ventilated air per unit time)

G: generation rate of contaminant (the volume of contaminant's vapor or gas phase generated per unit of time)

C: concentration of contaminant (air concentration of the contaminant expressed as volume fraction)

Therefore, the ventilation required to maintain a permissible contaminant level for a worker can be calculated by substituting the contaminant's TLV (Threshold Limit Value) for C (in the proper units) in the equation. Likewise, administrative ventilation standards for hypoxia prevention in Japan are prescribed as "more than 20 times of ventilation per hour" (in a pit) and "more than 10 m³/min fresh air per person" (in a well)²⁾. In order to ensure a worker's safety and health, it is essential to predict the necessary volume of ventilation in advance and to execute it correctly. At a job site, the user of a portable fan will select a suitable model in accordance to the ventilation requirement, using the rated flow rate announced by

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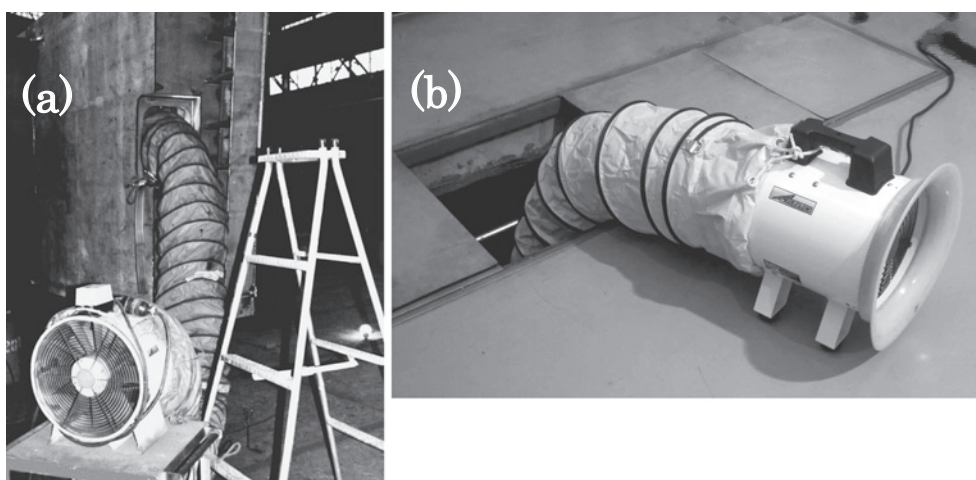


Fig. 1. Examples of the use of a portable fan and a polyester flexible duct.
(a) Exhaustion from the inside of a structure. (b) Fresh air supply into a pit.

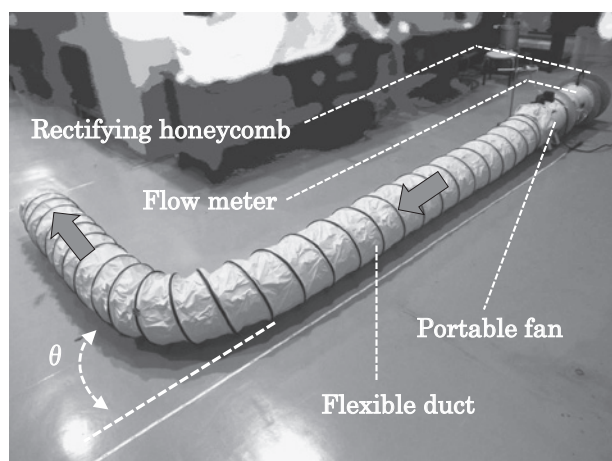


Fig. 2. General view of experimental set-up.

the manufacturer of the fan as reference. When a portable fan is used with a flexible duct, the actual flow rate of the fan inevitably decreases due to the friction loss³⁾ of the inner wall of the duct. However, the friction and duct bending loss of the duct is often overlooked, or is underestimated, by a portable fan user, which will cause insufficient ventilation at a job site. In fact, many industrial accidents of overexposure or hypoxia happen due to insufficient ventilation.

Intending to show the decline of fan performance, the author conducted laboratory experiments and reported the quantitative effect of the friction and duct bending loss of a flexible duct to the flow rate of a portable axial-flow fan. In addition, a recommended simple check method of a portable fan's flow rate by means of an anemometer was described.

Materials and Methods

The general view of the experimental set-up was shown in Fig. 2. As shown in Fig. 2, the end of a flexible duct was connected to a portable axial-flow fan so as to blow off the air from another end of the duct. In the experiments, a flexible duct was bent at angle of 0 - 180 degrees in middle for the purpose of examining the effect of the bend⁴⁾. A rectifying honeycomb and a Pitot tube air flow meter, which consists of a conventional Pitot tube and a digital velocity / flow rate convertor, were placed in-line with a portable fan. Four portable fans of different specifications were procured for the experiments. The models of the experimental apparatuses in this study are described below;

portable axial-flow fan: SJF-300RS-1, 250RS-1, 200L-1 (Suiden Co., Ltd., Japan) WB-II (Onishi Electric Industry Co., Ltd., Japan)

Pitot tube air flow meter:

AMA 150 DA, 200 DA, 250 DA, 300 DA, (Shibata Giken Co., Ltd., Japan; each has 20 insertion depths of two-10 readings in a cross configuration)

anemometer: hot-wire anemometer Model 6035 (Kanomax Japan, Inc.)

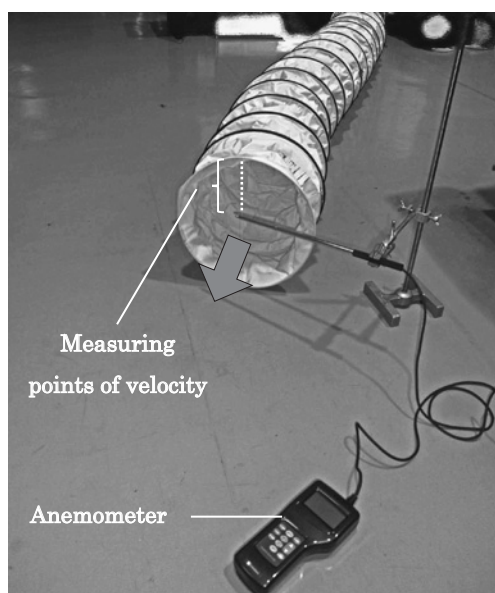
Three polyester flexible ducts with different diameters ($\phi \doteq 300$ mm, 250 mm, 200 mm) were used in the experiments since polyester is thought to be the most prevailing material for a portable fan duct. In addition, the friction and duct bending loss of an aluminum flexible duct ($\phi \doteq 150$ mm) was investigated as a substitution for a polyester duct because a commercial polyester flexible duct of 150 mm diameter was not available. The length of the polyester ducts and the aluminum duct were 5 m. With these apparatuses, the flow rate was measured by the Pitot tube air flow meter in each combination of the experimental con-

Table 1. Decline of the flow rate of a portable fan by the friction loss of a connected flexible duct with respect to the bent angle (θ)

Portable fan	Impeller dia. [mm]	Rated output [W]	Rated flow rate [m ³ /min]*	Measured flow rate by a Pitot tube flow meter [m ³ /min]**				
				$\theta=0^\circ$	$\theta=45^\circ$	$\theta=90^\circ$	$\theta=135^\circ$	$\theta=180^\circ$
SJF-300RS-1	288	550	50	40.6±1.1 (81.2%)	36.3±0.6 (72.6%)	31.8±0.7 (63.6%)	27.9±0.7 (55.8%)	25.1±0.9 (50.2%)
SJF-250RS-1	250	350	35	18.5±0.3 (52.9%)	17.8±0.2 (50.9%)	16.8±0.2 (48.0%)	15.9±0.2 (45.4%)	15.4±0.3 (44.0%)
SJF-200L-1	200	100	17	9.5±0.2 (55.9%)	9.1±0.2 (53.5%)	8.6±0.2 (50.6%)	8.3±0.2 (48.8%)	8.1±0.3 (47.6%)
WB-II	140	108	16	7.4±0.1 (46.3%)	7.2±0.1 (45.0%)	7.1±0.1 (44.4%)	7.0±0.1 (43.8%)	6.9±0.1 (43.1%)

* Rated flow rates were obtained from orifice-chamber method (static pressure = 0 Pa).

** Value are the arithmetic means of 10 measurements ± standard deviations. The ratio of the measured flow rate to the rated flow rate is shown in parenthesis.

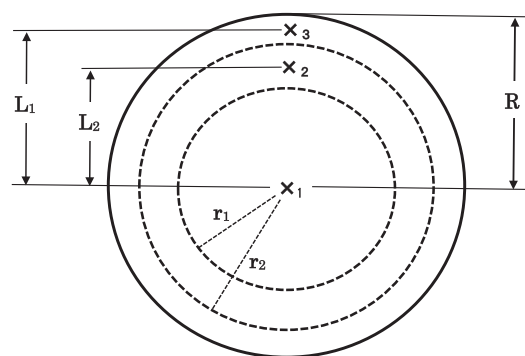
**Fig. 3.** Flow rate measurement by an anemometer.

ditions.

Along with the experiments mentioned above, the flow rate measurements by means of an anemometer were performed. The results were verified by comparing with the results of the Pitot tube flow meter measurements.

Results and Discussion / Recommendation

Decline of the flow rate of a portable fan by the friction and duct bending loss of a connected flexible duct is presented concretely in Table 1. In any condition, the flow rate undoubtedly decreased from the rated flow rate when a flexible duct was connected. Connection of a straight polyester flexible duct reduced the flow rate to 81.2 - 52.9%. Connection of a straight aluminum flexible duct



$$R^2 \pi = n r_1^2 \pi = 3 r_1^2 \pi \quad \therefore r_1 = \sqrt{1/3} R$$

$$R^2 \pi = n/2 r_2^2 \pi = 3/2 r_2^2 \pi \quad \therefore r_2 = \sqrt{2/3} R$$

$$L_1 = 1/2 (R + r_2) \quad , \quad L_2 = 1/2 (r_1 + r_2)$$

(The section of a duct is divided by three concentric circles so as to make three equal areas.)

Fig. 4. Example of the location of the velocity measuring points (x_{1-3}) on the sectional view of the duct end. The number of measuring points (n) is supposed to be three in this figure.

(Although the 10 points format is advantageous to improve measurement accuracy, a laborious method has low practicality; and therefore a model of 3 measurements was adopted.)

reduced the flow rate to less than 50%. Irrespective of the material and the diameter of the flexible duct, the flow rate decreased with the increase of the bend angle, though the effect of bend was relatively small at the aluminum duct. When such a decline of the flow rate is overlooked, a serious deficiency of ventilation will occur with a high possibility. Unfortunately, it is common at an ordinary

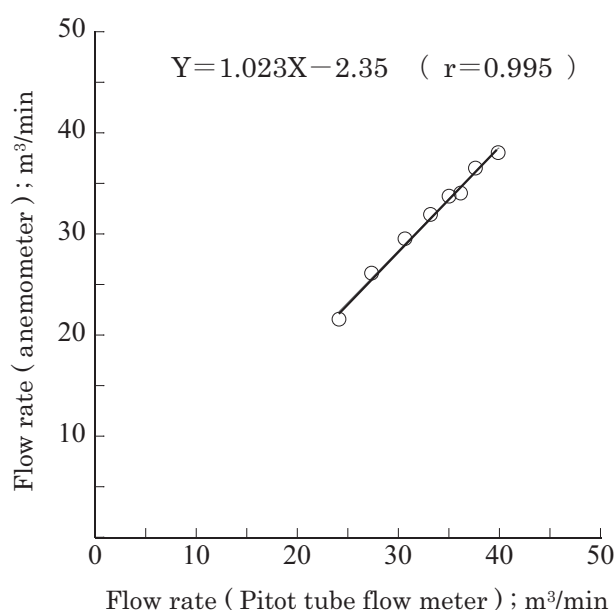


Fig. 5. Comparison of flow rate measurements. Range of velocities measured by an anemometer was 3.0–12.3 m/sec in this experiment. Measurement by an anemometer was performed in conformity with Fig. 4.

job site to misunderstand that a portable fan will work at a rated performance in any condition.

In order to avoid the ventilation deficiency of a portable fan, a prior check of the flow rate before operating inside a confined space should be strictly enforced. A simple and practical measurement of the flow rate by means of an anemometer will be suitable for this demand. Conversely, a Pitot tube flow meter, generally elaborate and bulky, is not always easy to use at an ordinary job site. Fig. 3 shows a pattern of flow rate measurement by an anemometer. In this case, the flow rate can be derived by multiplying the cross-sectional area of the duct by the average velocity at the duct opening. The average velocity ought to be the arithmetic mean of several velocities measured at different points on the duct radius (Fig. 3) because the velocity at the duct end is not uniform. In measuring these velocities, the author recommends sam-

pling the velocities according to the “round duct traverse technique” illustrated in Fig. 4. The validity of flow rate measuring by an anemometer was shown in Fig. 5, which described the comparison of two flow rates. The X-axis and the Y-axis of Fig. 5 give directly measured flow rates by a Pitot tube flow meter and indirectly measured flow rates by an anemometer, respectively. Although the measurement by the Pitot tube flow meter tends to be slightly higher than the hot-wire anemometer measurement, both measurements are similar ($y=1.023X-2.35$, $r=0.995$). (It should be noted that a significant error might occur due to the effect of an eddy current at the duct end when the suction flow rate deviates considerably from the experimental condition verified in Fig. 5.)

With references to the results and the recommendation mentioned above, it is proposed that a flow rate check of a portable fan should be carried out diligently in every job site in order to prevent a ventilation deficiency.

Conflicts of interest: The author declares that there are no conflicts of interest.

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