Appropriate Flow Rate for Push-Pull Ventilation System

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Abstract

When designing push-pull ventilation system as usual, it has been considered that supply airflow should be thoroughly exhausted by suction inlet. However, an escape of some of the supply airflow from an exhaust inlet could be permitted in the push-pull ventilation system, if all of the contaminants transported to the exhaust inlet do not escape and can be exhausted.

In this study, we investigate appropriate flow rate for push-pull ventilation system by using CFD techniques.

Introduction

In currently available design method used in Japan for push-pull ventilation system, e.g. push-pull local exhaust system, the exhaust flow rate has been calculated by considering that the whole of supply airflow should be thoroughly exhausted by a suction inlet. When contaminants are generating between a supply and a suction inlet, the contaminants can be carried to the suction inlet by the supply airflow. If the contaminants do not disperse to the surroundings and are exhausted by the suction inlet, an escape of some of the supply airflow could be permitted.

When the contaminants diffuse into the whole of the supply airflow, the exhaust inlet should exhaust the entirety of the contaminants and the supply airflow. However, the contaminants do not diffuse into the whole of supply airflow, it would be possible to decrease the exhaust flow rate as a result of a partial escape of the supply airflow.

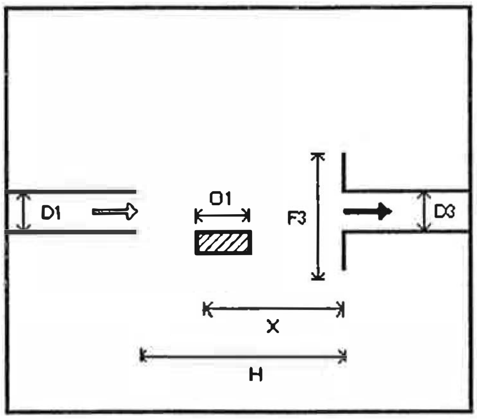
The purpose of this study is to investigate numerically how much flow rate can be decreased in the case that the contaminants do not escape and are exhausted from the exhaust inlet.

Methods

For CFD techniques, PHOENICS was used as a code of the calculations. The computational field is taken to be two-dimensional steady flow and the calculation domain is 20m long by 20m wide, the calculation cells were 30x33, and the k-epsilon model is used as the turbulence model. The kinetic turbulent energy and the rate of dissipation of turbulent kinetic energy of supply and exhaust airflow at the inlet boundaries are fixed. Surroundings of the calculation domain are taken to be a free boundary. The contaminants, assumed as the same density of air, were generated from the upper surface of the contaminant source. At surfaces of the contaminant source, wall function was used.

The computer simulations were conducted to the aspect shown in Figure 1, while the values of H, F_3, D_3 and V_1 were maintained constant and the values of D_1, X and O_1 are as variables.

Push-Pull Ventilation System



D_1: width of supply inlet D_3: width of suction inlet
H: axial distance between supply and suction inlet
F_3: length of suction flange
O_1: x directional length of contaminant source
X: axial distance between source and suction inlet
V_1: velocity at supply inlet
V_3: velocity at suction inlet
V_0: contaminants velocity at surface of source

Figure 1. Fundamental aspect of push-pull ventilation system

In this study, basically, the concept of the push-pull ventilation system depends on the flow ratio method (1, 2). The flow ratio method has been suggested at first for designing the receptor hoods and then it has been also suggested for the push-pull flows.

Applying the flow ratio method to the push-pull ventilation system, the required exhaust flow rate becomes often in excess of value practically. Because the value of exhaust flow rate, Q_3, is given as the value which all the supplied airflow should be exhausted from the suction inlet. In this system, the contaminant source should be usually located between the supply inlet and the suction inlet. The supply airflow is contaminated at the position of source and it flows to the suction inlet. Therefore, all of the airflow at the position of the suction inlet is not always contaminated. In the push-pull ventilation system, it is necessary to exhaust only the contaminated airflow. As the design method considering such the case (the diffusion of contaminant within the airflow) has not been established yet, the appropriate exhaust flow rate was investigated by CFD techniques. At first, the calculation for the two dimensional push-pull flows were conducted to confirm the accuracy of the simulation. Consequently, the simulated results show close agreement with the experimental results obtained from the flow ratio method.

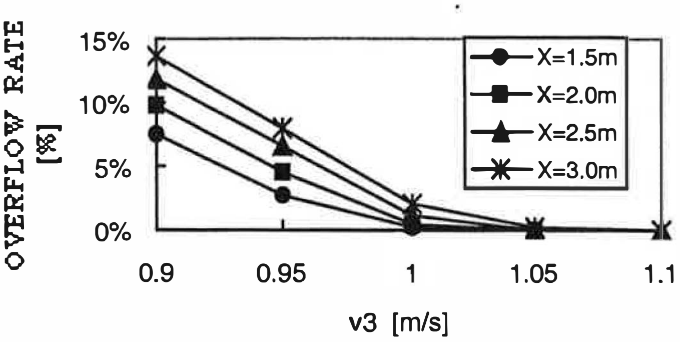


Figure 2. Relation between overflow rate and velocity at suction inlet

Decision of Overflow of Contaminants from Suction Inlet

The limit value of the exhaust flow rate can be obtained by simulating the push-pull flow when mass flow rate of contaminants does not overflow from the suction inlet. Figure 2 shows the relation between velocity at the suction inlet, V_3, and the overflow rate. The overflow rate is defined as the ratio of the escaped mass flow rate of contaminants from the suction inlet and the mass flow rate of contaminants generating from the source. Required exhaust flow rate, Q_3, can be obtained from the velocity at the suction inlet, V_3, when the overflow rate becomes to be zero.

Results and Discussion

Figure 3 shows the influences of D_1 on the limit flow rate ratio, Q_3/Q_1, when the contaminants do not overflow from the exhaust inlet in the case of $V_0 = 0$ m/s. The flow rate ratio, Q_3/Q_1, decreases with an increase of the values of D_1. However, in the region of 0.4 m< O_1 < 1 m, the values of Q_3/Q_1 are independent of O_1 values. In this figure the values of limit flow rate ratio obtained from the flow ratio method for the push-pull flow are expressed simultaneously by a dotted line. The figure also shows that the flow rate ratio obtained from the CFD techniques are considerably smaller than one calculated by the flow ratio method. The value of O_1 is taken as a parameter as shown in the figure, it can be considered that there is no influence of O_1 on the flow rate ratio, Q_3/Q_1.

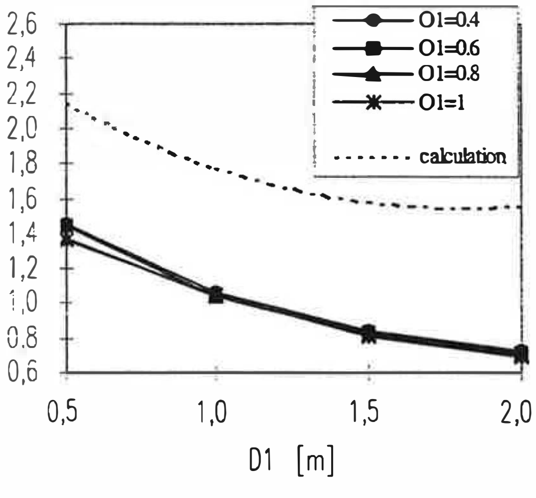


Figure 3. The influence of D_1 (V_0 = 0 m/s)

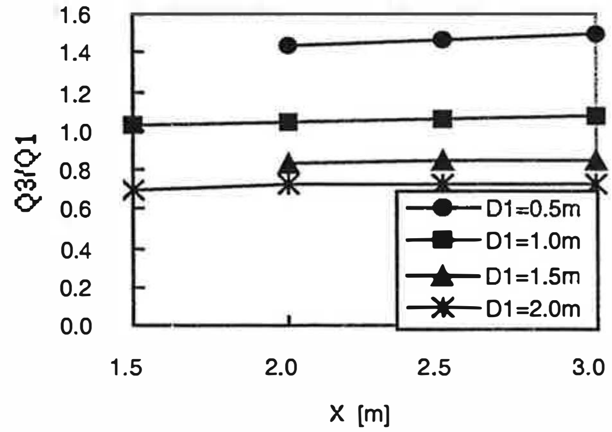


Figure 4. The influence of X (V_0 = 0 m/s)

Next, it is seen from Figure 4 that the value of X is independent of Q_3/Q_1 when generating velocity of contaminants from the source is 0 m/s. The supply air flows and is contaminated along the source surface, but the contaminated supply airflow does not diffuse into the whole of the airflow.

Figure 5 shows the case of V_0 = 0.3m/s. The values of flow rate ratio, Q_3/Q_1, increases with an increase of the values of X. The values of O_1 have some influences on Q_3/Q_1 in the case of V_0 = 0.3 m/s. When generating contaminants at a velocity of 0.3 m/s, the larger the distance between the contaminant source and the suction opening, X, the more the exhaust flow rate ratio, Q_3/Q_1.

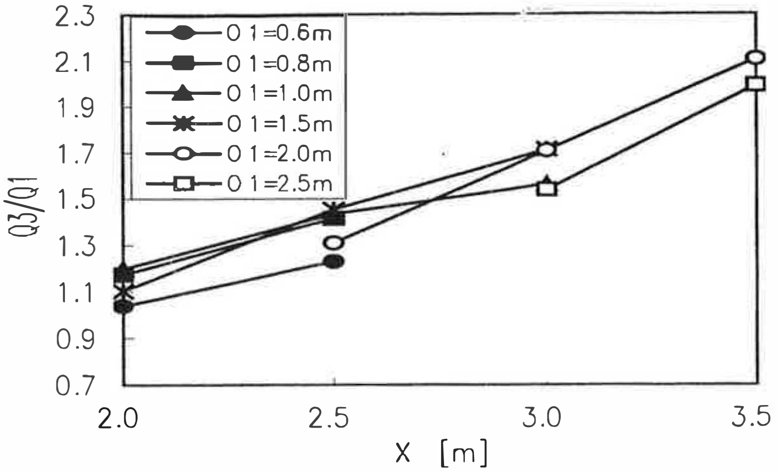


Figure 5. The influences of X (V_0=0.3 m/s, D_1=2.0 m)

The influences of O_1 on Q_3/Q_1 are shown in Figure 6 in the case of V_0 = 0.3 m/s and X=2.5 m. When the value of O_1 is around 1.5 m, the value of Q_3/Q_1 has a maximum value. In the region of 0.4 m < O_1 < 1.5 m the exhaust flow ratio, Q_3/Q_1, increases with an increase of the values of O_1. Consequently, the exhaust flow rate, Q_3, increases also.

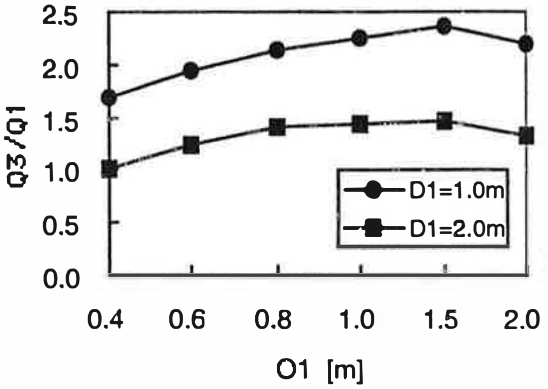


Figure 6. The influences of O_1 (V_0=0.3 m/s, X=2.5 m)

Though, when the value of O_1 is more than 1.5 m, the exhaust flow ratio, Q_3/Q_1, decreases with an increase of the values of O_1. It can be considered that the surface of contaminant source functions as like a guide vane of the supply airflow.

References

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