Study on the control effect of two different forms of side suction hoods on pollutants

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Abstract. A suitable exhaust hood form has a great influence on the control effect of pollutants. This paper uses CFD technology to numerically simulate the airflow distribution characteristics and pollutant concentration distribution characteristics of the side hood before and after improvement. The results show that: (1) The airflow of the improved side suction hood is introduced from the front of hood to make the fresh air pass through the breathing area first and then takes away the hazardous substances, which is beneficial to the breathing health of workers. (2) When the exhaust velocity (V) is more than 3.5 m/s, with the increase of the exhaust velocity, the concentration hazardous substances at each control point of the two forms of exhaust hood tends to be stable gradually. (3) When the exhaust velocity is less than 3.5 m/s, the control effect of side suction hood with baffle is better than that without baffle, and the percentage of hazardous substances concentration at the same control point can be reduced by 12%-29%, or even higher.

1. Introduction

Different industrial products may emit different pollutants (polluted gases or particulate matter). If we don’t control them effectively, it may affect the indoor and outdoor air environment and the normal operation of the production process, and may even endanger human health [1]. Local ventilation is often regarded as one of the most effective methods to prevent the spread of pollutants due to its good ventilation effect and air volume savings. Although there are many new forms of exhaust hoods (such as cyclone air hoods [2]), the new exhaust hoods have certain restrictions on the control of pollutants (e.g. some exhaust hoods are only suitable for dust particles with particle size less than 10 um, and hazardous substances with particle size more than 10 um would not be effectively controlled) and the cost is higher than that of the traditional one; Therefore, in the general factory, the traditional exhaust hoods (side suction hood, upper suction hood, lower suction hood) are mainly used, and the side suction hood is widely used in industrial places as an effective local exhaust device [3, 4]. Choosing a suitable side hood form has a great influence on the control effect of pollutants. At present, the research on side hood mainly focuses on the influence of initial emission velocity and temperature of pollutants, the distance between the hood and the source, and the source of pollution term on the capture efficiency of side suction hood. Wang Yi [5] and others studied that under the action of the dual heat source, the influence of the location of the auxiliary heat source the dimensionless initial velocity of the auxiliary heat source, and the dimensionless initial temperature of the auxiliary heat source on the trapping efficiency of side suction hood; Peng Taiyao [6] and others used the tracer gas SF6 to study the influence of the direction of the pollutants released by the pollution source, the velocity of the hood cover, the distance between the pollution source and the hood on the trapping efficiency of the side suction hood; Gao Yanling [7] and others studied the influence of the human body...
on the three-dimensional flow field of the side suction hood; and few people studied the effect of the side hood on the control effect of different pollutants.

In order to analyze its effect, this paper uses CFD technology to analyze the airflow distribution characteristics of two different forms of side suction hoods and their concentration distribution characteristics under different exhaust velocities.

2. physical model and numerical method

2.1 physical model
As shown in figure 1, the physical models before and after improvement of the side suction hood are respectively shown, and the right side is a partial enlargement. The local exhaust hood is located in a spacious factory building, due to the limited influence of the local exhaust hood, only one calculation basin is considered, which is larger than the influence range of the local exhaust hood, and the size of the basin is 5m×5m×5m; The working table size is 5m×0.8m×0.8m; At the center of the workbench, there is a source of pollution, whose size is 0.6m x 0.6m; The front side is the exhaust hood cover, whose size is 0.8m × 2√3/5m and the inclination angle is 30° and the distance from the worktable is 0.2m; The upper part of the hood cover is the eaves of the exhaust hood, whose size is 0.8m x 0.8m; The side of baffles is 2.1 m × 0.8 m on both sides of the cover, and the other dimensions of the two side suction covers are the same.

(a) Side suction hood before improvement (without baffle)                                (b) Improved side suction hood (with baffle)

Figure 1. Physical model (1 exhaust hood cover,2 pollution source release surface, 3 baffles)

2.2. mathematical model
Since the ventilation in the workshop is usually at low velocity and constant temperature, the airflow is relatively stable, and the release of pollutants are limited, the following assumptions are made:
(1)The Air flow is ambient and incompressible
(2) The airflow is a constant flow.
(3) The polluted gas is a dilute concentration phase.

Based on the above assumptions, the airflow field can be described by the isothermal incompressible N-S equation as follows:
(1) Continuity equation:
\[ \frac{\partial u_i}{\partial x_i} = 0 \]  
(2) Momentum equation:
\[ \frac{\partial}{\partial x_j} \left( \rho u_i u_j \right) = \frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + f_i \]

In the formula: P is the static pressure on the fluid micro-body; \( \tau_{ij} \) is the viscous stress tensor acting on the surface of the micro-body due to molecular viscosities; \( f_i \) is the mass force in the i-direction,
when the mass force is only subject to gravity, and the Y-axis is vertically upward, \( f_y = f_z = 0 \), \( f_x = -g \).

(3) Since the polluted gas is a dilute concentration phase, the composition equation is described as follows:

\[
\frac{\partial}{\partial x}(u_c) + \frac{\partial}{\partial y}(u_c) + \frac{\partial}{\partial z}(u_c) = \Gamma \left( \frac{\partial^2 c}{\partial x^2} + \frac{\partial^2 c}{\partial y^2} + \frac{\partial^2 c}{\partial z^2} \right) + S(X, Y, Z)
\]

\( \Gamma \) is the diffusion coefficient of any point in the space; \( S(x, y, z) \) is the source of pollution which is the release intensity of the pollutant at any point.

(4) The turbulence control model adopts the standard \( k-\varepsilon \) model equation;

2.3. Numerical method

In this paper, a numerical method is used to simulate the steady incompressible N-S equation. The numerical method is SIMPLE algorithm and use the first-order format on discrete governor equation, the discrete equations are solved by the uncoupled implicit solver, and the calculation results are completed by the post-processing software tecplot.

Meshing: A method of combining structured and unstructured meshes are used, and local encryption is performed near the tuyere and object edges. The calculated watershed is \( 5 \times 5 \times 5 \) m, and the number of grids is about \( 5.4 \times 10^4 \).

Boundary conditions: the exhaust hood covers are set to equal exhaust velocity; The harmful gases on the source surface are uniformly distributed; The both wall of the top and the face of the hood are set to the free outflow surface; The left and right sides are set to be symmetrical faces; the other walls are set to have no slip condition.

3. Numerical simulation of airflow characteristics and harmful gas concentration in side suction hood

3.1. Numerical analysis of airflow characteristics and harmful gas concentration in side suction hood

Table 1 shows the simulation conditions and parameters:

| Side suction hood form | Pollutant species | emission of source pollutants | Mask exhaust velocity |
|-----------------------|-------------------|-------------------------------|-----------------------|
| without baffle        | Carbon dioxide    | 0.001kg/s                     | 1.5~4.5m/s           |
| with baffle           | Carbon dioxide    | 0.001kg/s                     | 1.5~4.5m/s           |

Figure 2 is a streamline diagram of two different forms of side suction hoods. It can be seen from the figure that when the side suction hood is not equipped with baffles, the airflow enters the hood cover from all sides; when the side suction hood is equipped with baffles, due to the restriction of the baffle, the airflow can only flow into the hood from the front of the baffle, so that fresh air passes through the breathing zone and then removes the harmful gases in the hood, which will be beneficial to the breathing health of workers.
concentration of the two forms of side suction hoods at the exhaust velocity increases, the CO$_2$ concentration increases first and then decreases, and reaches its maximum value at Y = 2.5m; as the exhaust velocity increases, the CO$_2$ concentration of the two forms of side suction hoods at the control point decreases gradually (the control effect on harmful gases is getting better and better), but the decreasing rate of CO$_2$ concentration is gradually decreasing. When V > 3.5m/s, the CO$_2$ concentration of each control point tends to be stable gradually.
Figure 4. CO$_2$ concentration distribution map of control points at different exhaust velocities

Figure 5. CO$_2$ concentration distribution map of control points at V=3.5m/s

Figure 5 shows the CO$_2$ concentration distribution map of the two kinds of side suction hoods at different control points when V=3.5m/s. as shown in figures 4 and 5, we can see that the CO$_2$ concentration at the same control point of side suction hood with baffle is significantly lower than that without baffle, and the percentage of CO$_2$ concentration can be reduced by 12%~29%,and when V<3.5m/s, the percentage of CO$_2$ concentration may decrease more.

4. Conclusion
1. Side suction hood (without baffle) is to introduce air flow from all around the hood into the cover, and after adding baffle, side suction hood is to introduce air flow from the front of hood, so that fresh air enters the workplace first, which is beneficial to human health.

2. With the increase of exhaust velocity, the control effect of two kinds of side suction hoods on hazardous substances is getting better and better. But when V > 3.5m/s, with the increase of exhaust velocity, the hazardous substances concentration of each control point of the two forms of exhaust hoods gradually tends to be stable.

3. When the exhaust velocity is the same, the control effect of side suction hood with baffle is better than that without baffle; when V < 3.5m/s, the percentage of harmful substance concentration at the same control point can be reduced by 12% ~ 29%, or even higher than that without baffle.

References
[1] Karaismail, E., Celik, I., Steven, E.,(2013) Guffey. Flow Dynamics and Contaminant Transport in Industrial-Type Enclosing Exhaust Hoods. Journal of Occupational and Environmental Hygiene,10(7):384-396.

[2] Liu, R.H, Li, X.B., Shi, S.g, Wang, P.F, Qiu, H.F,(2009). A new type of cyclone air curtain exhaust hood numerical simulation study . Environmental Engineering, 27 (04): 68-72.

[3] Du, Z., Song, F.J., Huang, Z., Duan, Y.J., Sun, Y.Q.(2016) Progress in the design and application of local exhaust hood in different industries. China's urban and rural enterprise health 31 (11): 64-66.

[4] Zhao, R., Zhao, Y., Gao, H.,(2005) Investigation and hygienic evaluation of commonly used local
exhaust hood. China Health Engineering, 4(5): 273-275.

[5] Wang, Y., Fifth, X.T., Huang, Y.Q., (2016) Characteristics of flow field and trapping efficiency of side suction hood under double heat sources. Journal of Xi'an University of Architectural Science and Technology (Natural Science Edition), 48 (04): 568-573+592.

[6] Peng, T.y., Shao, Q., (1988) Collection efficiency experiment of local exhaust hood. Ventilation and dust removal, (03): 20-24.

[7] Gao, Y.L, Shao, Q., (1995) Three-dimensional side suction hood flow simulation experiment. Health research, (04): 253-256.