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## Simulation Study on Exhaust Effect of Common Exhaust Equipment in Traditional Electrical Manufacturing Enterprises

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# Simulation Study on Exhaust Effect of Common Exhaust Equipment in Traditional Electrical Manufacturing Enterprises

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**Abstract.** Based on fully understanding of the setting and operation of local exhaust facilities in traditional electrical manufacturing industry, the software FLUENT is applied to simulate the airflow field of universal arm exhaust hood in the process of removing welding dust. And the exhaust effect of typical welding dust universal arm exhaust hood and its influencing factors were analyzed. The results show that the exhaust effect of welding fume is mainly affected by the exhaust wind speed, the size of the hood, the angle between the hood and airflow, the distance from the pollutant source to the center of the hood, etc. When practical operation is feasible, the best combination of exhaust effect and economy is achieved when the vertical upward suction is adopted and the cover opening is 20-25cm away from the solder joint and the exhaust velocity is controlled at 0.4-0.6m/s.

## 1. Introduction

In the process of electrical manufacturing, various types of jobs in multiple workshops will be exposed to a variety of harmful factors, among which dust, smoke and toxic gas have great harm to human body, so it must be effectively eliminated [1]. In addition to personal protection and ventilation facilities, local exhaust equipment play an important role in effectively removing harmful substances in the production process [2].

According to the field investigation, the selection and design of local exhaust facilities in many electrical manufacturing workshops are not reasonable, resulting in unsatisfactory ventilation effect. In order to achieve the exhaust effect, some workshops increase the exhaust volume, which causes the waste of energy [3]. Therefore, designing the exhaust process of exhaust equipment according to the process characteristics and toxic properties of electrical manufacturing enterprises is of great significance for effectively eliminating toxic substances and reducing their harm to human health.

## 2. Electrical equipment manufacturing local exhaust ventilation effect factors

Traditional electrical manufacturing enterprises generally consisted of the following departments such as cutting, welding, machining, plating, insulation, and stamping department. According to the field investigation of each workshop in a traditional electrical manufacturing enterprise, local exhaust equipment is used in many links of electrical manufacturing. The local exhaust equipment mainly includes the side suction exhaust hood, the universal suction arm, the universal arm exhaust hood and the lower exhaust hood four types [4]. For different production processes using different types of exhaust



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hood, such as the elimination of welding soot using universal arm exhaust hood, cutting and grinding process often use side suction exhaust hood [5]. The main ventilation facilities in each workshop are shown in Table 1.

**Table 1.** Application of protecting measures in different departments

| Departments | Ventilation facilities                                                      | Personal protective measures        | Local exhaust facilities                                      |
|-------------|-----------------------------------------------------------------------------|-------------------------------------|---------------------------------------------------------------|
| Cutting     | Exhaust fan                                                                 | Dust mask                           | Nothing                                                       |
| Welding     | Exhaust fan, Exhaust hood                                                   | Dust mask, Gas mask                 | Universal suction arm, Side suction exhaust hood              |
| Machining   | Exhaust fan                                                                 | Dust mask                           | Nothing                                                       |
| Plating     | Exhaust fan, Lower exhaust hood, Upper exhaust hood, Universal exhaust hood | Gas mask                            | Lower exhaust hood, Upper exhaust hood, Universal suction arm |
| Insulation  | Exhaust fan, Side suction exhaust hood                                      | Dust mask, Gas mask, Dustproof suit | Side suction exhaust hood                                     |
| Stamping    | Exhaust fan, Universal exhaust hood, Side suction exhaust hood              | Dust mask, Gas mask                 | Universal suction arm, Side suction exhaust hood              |

There are many factors affecting the exhaust effect of the local exhaust hood, such as the geometry of the hood, the objects around the hood, the indoor air flow interference, the velocity of pollutant gas emission, the geometry of the pollution source, the relative position of the hood and the pollution source, etc [6]. For certain pollutant, the ventilation effect is mainly related to the capture velocity, the size of the hood and the distance to the hood. For the universal arm exhaust hood, the position and angle of the universal arm should also be considered [7].

(1) Capture velocity: Capture velocity is a technical index reflecting the ability of facilities to control harmful substances. In the application of exhaust hood, we should not only collect harmful substances as efficiently as possible, but also consider the problem of energy consumption. In order to achieve better control effect with smaller exhaust volume, the minimum capture velocity is required for the design of exhaust hood. The capture velocity limit standard is shown in Table 2 [8].

**Table 2.** Capture velocity of control points

| Pollutant dispersion                                                           | Minimum capture velocity(m/s) |
|--------------------------------------------------------------------------------|-------------------------------|
| Spread to the calm air at a slight speed.                                      | 0.25-0.5                      |
| Spread to a calm air at a relatively low speed.                                | 0.5-1.0                       |
| Spread at relatively large speeds, or spread to areas where air flows rapidly. | 1-1.25                        |
| Spread out at high speed or diverge rapidly into the air.                      | 2.5-10                        |

(2) The size of the hood: The shape of the hood is mainly square and circular. The size of the hood varies greatly in different jobs [9]. Under the same wind speed and distance, the larger the hood, the better the exhaust effect. According to the field investigation, the diameter of the hood of the universal exhaust hood in the welding workshop is 40cm.

(3) Distance to the source center: Under the premise of not affecting the operation, the local exhaust hood should be surrounded or close to the source of pollution as far as possible, so that the hazardous materials are limited to a small range, which is convenient for collection and control [10]. According to the investigation, the distance from the hood to the welding point is generally between 20-40cm.

The factors affecting the use effect of the partial exhaust hood are very complicated. The general test method is basically obtained under specific test conditions, and has certain limitations. It cannot be completely quantitatively analyzed and cannot meet the needs of practical applications, so it cannot solve design optimization problems. In this paper, FLUENT fluid dynamics calculation software is used to simulate the air flow field of universal arm exhaust hood which is widely used in the welding process of electric manufacturing industry. The optimal design scheme is determined by the effect of different influencing factors on the exhaust effect. This study is of great significance for the rational design of local exhaust equipment, effectively eliminating the poisons produced in the electrical manufacturing process and reducing its harm to human health.

### 3. Simulation of ventilation process of local exhaust equipment in electrical manufacturing enterprises

#### 3.1. Assumptions

In order to facilitate the calculation, the model was simplified and the following assumptions were made:

1) The airflow in the whole flow field can be regarded as incompressible airflow and was at room temperature; 2) Ignore the force of gravity and assume that the wall was adiabatic; 3) The airflow in the flow field was in a stable state, and the flow rate, flow rate, pressure and density at each point were constant and do not change with time [11].

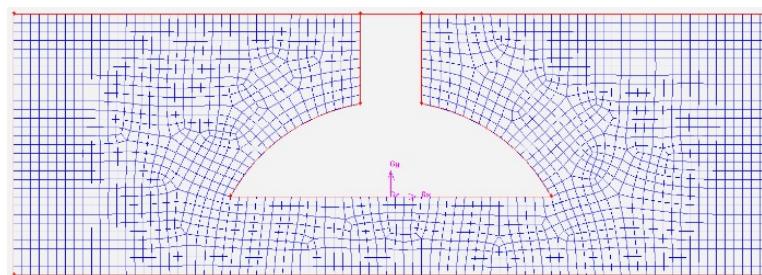
#### 3.2. Model establishment

##### (1) Physical model

The model was a universal exhaust hood that can adjust the direction. The hood had a diameter of 40cm.

##### (2) Computational model and division of grid

In this study, a grid function was given to the face of the hood to satisfy that there were enough calculating grids in the area, and the size of the grid was gradually transitional, so that the number of grids was not too large. The default grid function of GAMBIT was used in other surfaces, and then volume grids were divided. The Tgrid method was used to generate the tetrahedral unstructured grid. Finally, a grid with higher relative evaluation of smoothness, resolution and unit shape was obtained in the calculating area [12]. The calculating grid was shown in figure 1. The calculating area was with the size of 260×187×80cm.



**Figure 1.** Schematic diagram of the universal exhaust hood

##### (3) Numerical method

The steady incompressible N-S equation and the standard  $\kappa$ - $\epsilon$  turbulence model [13], the first-order upwind format and SIMPLE algorithm, and the uncoupled implicit solver were used to solve the discrete equation [14]. The software FLUENT was applied for calculating the model.

##### (4) Boundary conditions

Outlet boundary: 1) Given the velocity of the outlet, a velocity inlet was applied to the boundary, and the velocity value was negative; 2) For the other five surfaces except the ground, free outflow was selected because the velocity and pressure on the interface were unknown.

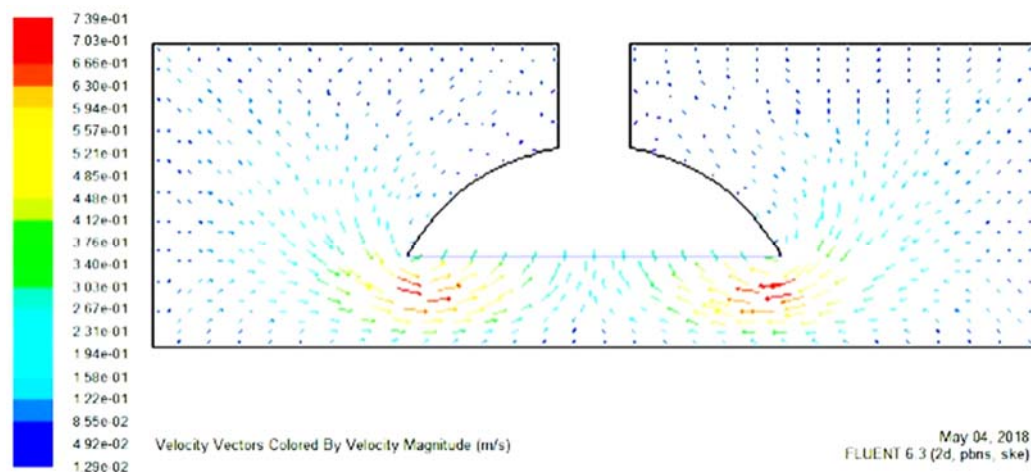
Wall boundary: All walls were subjected to the boundary condition of non-slip solid, namely  $u_i=0$ . The walls were treated as adiabatic and the pressure gradient perpendicular to the wall was 0. The standard wall function was adopted.

#### 4. Calculation results and analysis

##### 4.1. Analysis of exhaust effect of different capture velocity

In the process of welding operation, the welding personnel have great disturbance to the flow field above the welding dust. In order to achieve better control effect, the wind speed of the hood was set as 0.3m/s, 0.4m/s, 0.45m/s, 0.5m/s, 0.6m/s, 1.0m/s and 1.5m/s, respectively, to analysis the velocity vector distribution of the flow field under different capture velocity.

Figure 2 shows the velocity vector diagram of the flow field when the exhaust velocity was 0.3m/s on the plane  $Z=0$ . Compared with the flow field distribution under different inlet wind speeds, the larger the wind speed is, the larger the control range is. However, after comprehensive consideration of economic and energy saving, the optimal capture velocity is 0.4~ 0.6m /s.



**Figure 2.** Flow field profile of exhaust fan

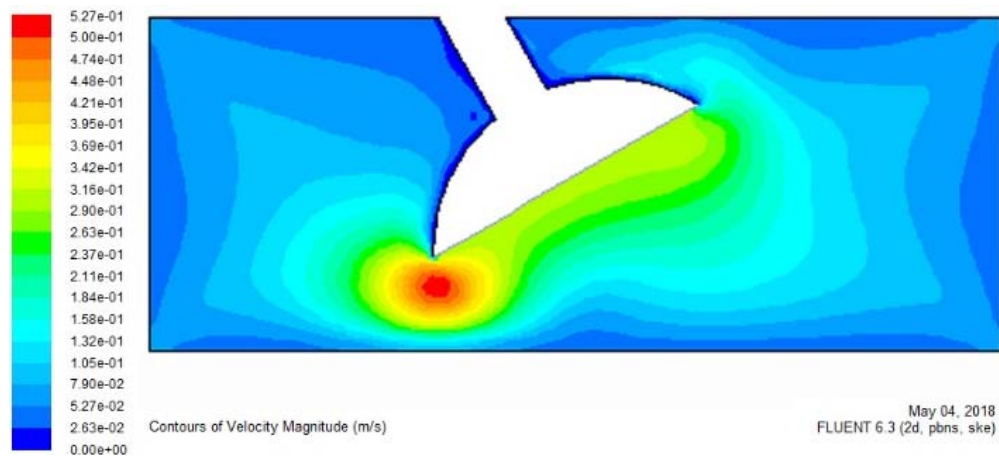
##### 4.2. Analysis of exhaust effect in different distances

In order to determine the most reasonable distance between the pollution source and the hood, this study analyzed the suction ratio of the pollution source at different positions 10~40cm away from the hood under different capture velocity. The results showed that the suction ratio varied from 80% to 99.5%, and the higher the wind speed, the closer the distance, the better the exhaust effect.

##### 4.3. Analysis of exhaust effect in different angles

The welder needs to constantly adjust the position and angle of the universal arm during work. In order to analyze the effect of the universal arm on the removal of contaminants at different rotation angles, the effect of the exhaust when the hood was rotated by 0°, 20°, and 30° was simulated.

The wind flow field when the rotation is 30° is shown in figure 3. And the wind speed at the center of the hood is 0.40 m/s. The simulation results shown that the hood has the widest control range and the most uniform wind speed distribution when the hood is rotated by 0°.



**Figure 3.** Distribution map of simulated wind velocity field

## 5. Conclusions and recommendations

In this paper, the universal arm exhaust hood of welding fume is taken as the research object. And the flow field distribution formed by the exhaust hood is simulated by FLUENT software. The following conclusions are drawn from the analysis:

(1) From the point of view of the inlet wind speed, the exhaust effect is better when the inlet wind speed increases and the suction ratio increases at the same distance.

(2) According to the simulation results, the wind speed decreases gradually with the increase of distance. From the perspective of suction ratio, the overall trend is that the suction ratio decreases with the increase of distance, but the exhaust effect within a distance of 20-25cm does not change much.

(3) According to the simulation results of exhaust effect in different angles, the vertical upward suction has the best exhaust effect due to the overall upward movement of welding soot.

(4) When the universal exhaust hood is working, a rotating air curtain is generated under the hood to prevent the spread of harmful objects from pollution sources, which can improve the control of harmful objects in the exhaust hood system. When the exhaust speed is 1.5m/s, the distance from the welding point is 20cm, and the air inlet is vertical, the welding dust can be effectively removed.

It is suggested that the exhaust velocity of the universal arm exhaust hood should be controlled between 0.4-0.6m/s, the distance of pollution source should be controlled within 20-25cm, and the effect is the best when the air inlet is vertical. All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office. When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other Publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper.

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## References

- [1] Wang Hanqing, Ventilation Engineering, Machinery Industry Press, Beijing, 2005.
- [2] Sun Yijian, Industrial Ventilation, China Construction Industry Press, Beijing, 2001.
- [3] Zhao Rong, Design requirements for common local exhaust hood, J. Labor Protection, 2005, 11: 84 - 85.
- [4] Lin Tailang, Chaitian Zhenwei, Industrial ventilation and air conditioning, Beijing University of Technology Press, Beijing, 1987.

- [5] Wu Yuebin, Zhu Mengsheng, Engineering Fluid Dynamics Pumps and Fans, Chemical Industry Press, Beijing, 2006.
- [6] Wang Hanqing, Wang Xinghua, Optimum design method of local exhaust hood, J. HVAC, 1995, 5: 11 - 15.
- [7] Lin Bao, Study of slot-side exhaust hood with jet effect, J. HVAC, 1996, 6.
- [8] State Administration of Work Safety Supervision and Administration. Technical Specification for Detection and Evaluation of Controlled Wind Speed of Local Exhaust Facilities [Z]. 2016.
- [9] Zhou Moren, Hydrodynamics, Pumps and Fans, China Construction Industry Press, Beijing, 1980.
- [10] Hyegarn, C.Z, Aerodynamic Control Exhaust, J. Conference Proceedings of International Air Organization, 1987.
- [11] Sun Yijian, Yang Yongjian, Two-dimensional turbulence numerical solution and characteristics analysis of Blow-Suction hood, J. HVAC, 1991 (1): 11 - 15.
- [12] Liu Ronghua, Li Xibing, Shi Shiliang and so on, A new type of cyclone air curtain exhaust hood numerical simulation research, 2009 (4): 8 - 27.
- [13] Liu Ronghua, Li Xibing, A new type of cyclone air curtain exhaust hood numerical simulation , J. Environmental Engineering, 2009.8 (4): 68 - 72.
- [14] Yu Lei, Lin Bao, Numerical Simulation of Inhalation Flow Under Circular Jet, J. HVAC, 2006, 36: 55 - 57.