# Optimization of the Airflow Organization of the Roof Hood of Electric Furnace under the Influence of Lateral Wind

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**Abstract.** This paper investigates the effect of the "tornado" air distribution in a roof hood under the influence of lateral winds and the ability of this air distribution to resist the influence of lateral winds using numerical simulations. Numerical simulations were conducted to investigate the effect of the "tornado" air distribution on improving the pollutant trapping effect of the roof hood under the influence of lateral winds. The results of the study show that the "tornado" air distribution can effectively improve the capture efficiency of the roof hood under the influence of lateral winds. The results show that the "tornado" airflow can effectively improve the capture efficiency of the rooftop hood under the effect of lateral wind. For the study subject, the ventilation system can achieve energy saving of $74 \times 10^4$kW·h/a and carbon reduction of 720t/a. It provided a reference for the renovation and new construction of roof hoods for large electric furnaces.

**Keywords.** Tornado, Roof hood, Lateral wind, Foundry, Electric furnace, Angular velocity

## 1 Introduction

In the foundry industry large electric furnace work process produces a large number of high-temperature fumes. For the roof hood, the hood mouth and the source of pollution have a certain distance, through the increased exhaust volume is difficult to ensure the contaminant capture effect, but will increase the ventilation energy consumption. It is not in line with the current "green low-carbon" requirements. In this paper, the air distribution form of "tornado" is adopted to improve the efficiency of pollutant capture by the roof hood and reduce the ventilation volume.

Wang Jin [1] et al. established a new tornado simulator for the experimental study of tornado air distribution and its wind loads acting on the structure, which can be used for the simulation of tornado wind field; Xu Feng [2] studied the effect of inlet wind speed and inlet angle change on tornado wind field characteristics, and gave the near-surface core radius, maximum tangential wind speed and vortex ratio of each numerical calculation model; The literature [3-5] has done research on the control of tornado suction and confirmed the feasibility of the idea of artificial tornado control suction, which has done a lot of meaningful work in the solution of industrial problems such as dust control and harmful gas prevention; Wang Pengfei [6] proposed that the suction flow field under the action of rotating jet shielding has the effect of lower central pressure and improved suction capacity, and the suction flow under the action of rotating jet can not only effectively control the diffusion of harmful substances, but also realize the long-distance trapping of harmful substances and the discharge of harmful substances with smaller ventilation volume; Jing Deji [7] proposed a vortex blowing and suction dust removal technology to control the dust diffusion during coal fall based on the generation mechanism of vortex airflow and the transport characteristics of dust particles in the vortex airflow field; Zhang Hui [8] first installed a rotating shielded jet device in the front of a common range hood to couple the range hood suction flow field with the rotating jet flow field to obtain an artificial tornado flow field, and used the artificial tornado to achieve controlled extraction of grease and smoke; Cao Zhixiang [10] proposed and studied a new type of vortex exhaust hood. Vortex ventilation based on the principle of cylindrical air vortex has strong application potential for pollutant collection and control in local exhaust systems.

In this paper, a physical model design and numerical simulation are used to study the effect of "tornado" distribution under the influence of lateral wind. This paper provides a reference for the renovation and new construction of large roof hoods of large electric furnaces.

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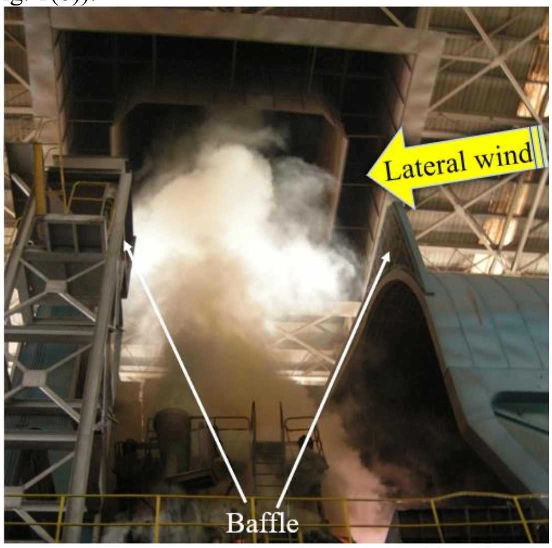
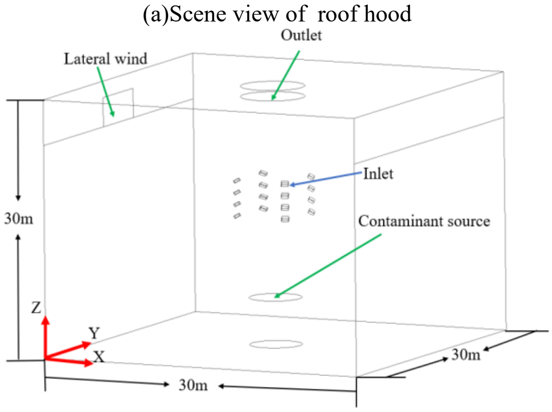
## 2 Physical model

Due to the operation of the traveling car in the casting workshop, a spacing of about 3 meters needs to be kept between the roof hood and the deflector hood. The smelting workshop is a tall plant, and the airflow caused by the through wind and high side windows of the workshop enters the airflow trapping area from this space, causing the fumes to escape (Fig. 1(a)). This paper selects a roof hood of a large electric furnace as the research object, and a numerical simulation model based on the air distribution of "tornado" is designed with reference to the installation angle and arrangement form of the air supply opening proposed by literature [10] (Fig. 1(b)).




(a)Scene view of roof hood




(b)Diagram of roof hood with a rotary jet device

**Fig. 1.** Caption of the Figure 1. Below the figure.

## 3 CFD model and parameter setting

### 3.1 Geometric modeling and mesh generation

According to the physical model shown in Figure 1(b), the 3D modeling software SpaceClaim was used to simplify the modeling of the roof hood, and the temperature of the contaminant source was set to 1500°C. In building the model, local encryption was performed when dividing the grid for air supply, exhaust and lateral air outlets. An unstructured grid was used, and the total number of grids was about 2.2 million. The validation method of reference [9] verifies the grid-independence of the numerical simulation results.

### 3.2 Mathematical model

In this paper, the numerical model is simplified accordingly:

1) The flow is steady-state turbulent, and the turbulence satisfies the Boussinesq assumption;
2) Gravity is neglected and wall adiabatic is assumed;
3) Air is assumed to be an incompressible fluid.

The calculations are based on the method of solving the Reynolds-averaged RNS equation, and the turbulence model is chosen as the Realizable $k$-ε model. The solver uses a pressure-based steady-state algorithm to solve the discrete control equations using the Simple algorithm, and the Body Force Weighted format is chosen for the pressure interpolation, and the first-order windward format is chosen for the rest.

### 3.3 Boundary conditions

The boundary conditions are shown in **Table** 1.

**Table 1.** Boundary condition setting

| Region | Boundary Type | Parameters |
|---|---|---|
| Angular momentum air supply outlet | Velocity | 13m/s |
| Exhaust air outlet | Velocity | 8m/s |
| Contaminant source | Wall | 1500℃ |
| Lateral air outlet | Velocity | 3m/s |
| Wall | Wall | 26℃ |
| Environmental area boundary | Pressure out | 26℃ |

## 4 Results and discussion

### 4.1 Study of the control distance between the contaminant source and the exhaust hood on the capture efficiency

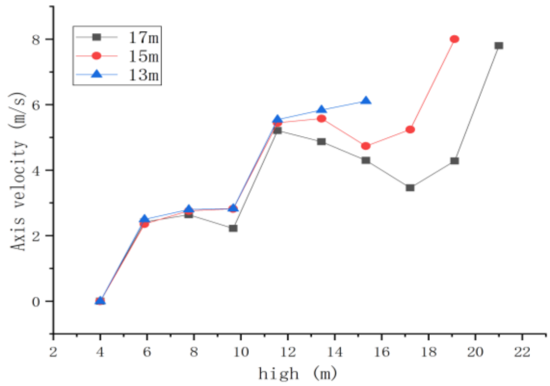



**Fig. 2.** Different control distance axis line speed comparison chart.

The control distance between the source and the exhaust hood affects the pollutant capture effect. To determine the effective control distance of the roof hood, the axial velocity distribution of the exhaust hood at the control distance of 17m, 15m, and 13m was studied (Fig. 2). The greater the axial velocity, the greater the ability to resist lateral winds and the better the capture effect.

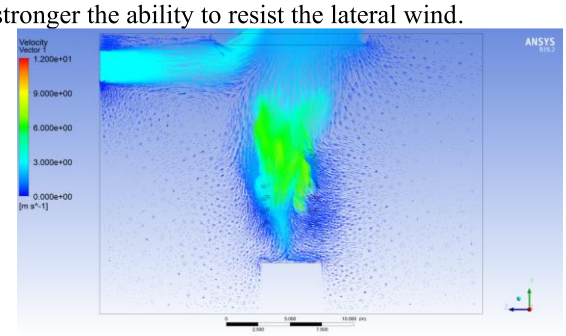
As can be seen from Fig. 2, when the height from the source is greater than 13 m, the axial velocity increases with the decrease of the distance between the source and the mouth of the exhaust hood. The smaller the control distance between the source and the exhaust hood, the stronger the ability to resist the lateral wind.

### 4.2 Study of hood wind speed on improving the trapping efficiency

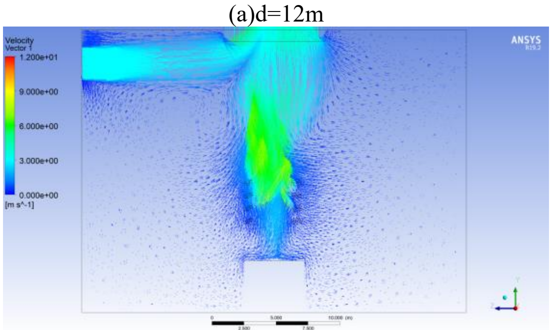
The velocity of the hood opening is one of the influencing factors of the flow field of the "tornado". In the case of constant ventilation volume, three typical vent sizes of 12m (original hood size), 8m and 4.6m in diameter were selected to study the ability of the “tornado” air distribution to resist lateral winds (Fig. 4).

From Fig. 3,Fig. 4, it can be seen that the position of “tornado” airflow is related to the wind speed at the hood opening. When the size of the hood is larger, the rotational strength of the "tornado" is smaller, and the heat pressure from the source near the hood is superimposed on the negative pressure of the exhaust, resulting in a small negative pressure at the hood. When the hood size is small, the rotational strength of the “tornado” airflow is increased, and the rotating airflow is pulled up to the hood near the hood, and based on the suction ability of the "tornado" airflow, the air around it is sucked up and contracted to the hood of the roof and discharged.

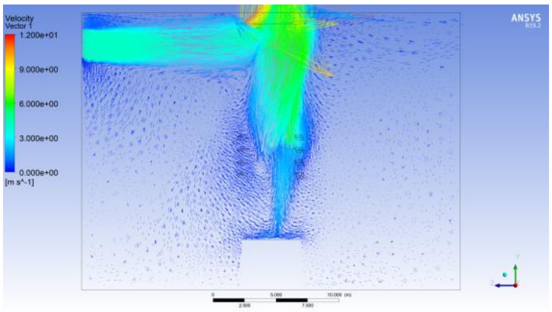
When the hood size is larger, the wind speed at the hood is smaller and the lateral wind has a greater effect on the axial pressure. When the hood size is small, the closer to the hood, the smaller the axial pressure, the stronger the ability to resist the lateral wind.



(a)d=12m



(b)d=8m



(c)d=4.6m

**Fig. 3.**Velocity diagrams for different exhaust air outlet diameters

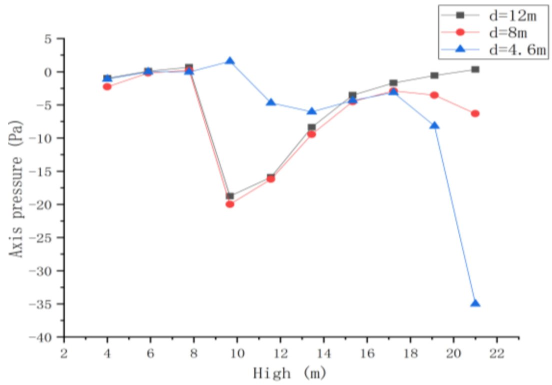



**Fig. 4.** Axial pressure diagram for different hood wind speed conditions

### 4.3 Study on the effect of roof hood ventilation on resistance to lateral winds

Under the condition of constant pollutant control effect, the smaller the ventilation volume is, the better the ventilation system is [11]. The “tornado” air distribution and the original working condition with three ventilation volumes of 80×10$^4$ m$^3$/h, 70×10$^4$ m$^3$/h (original design volume) and 60×10$^4$ m$^3$/h were selected respectively (no the “tornado” air distribution form). By comparing the axial velocity of the four working conditions (Fig. 5), the effect of the exhaust air volume on the capture of the “tornado” air distribution form is analyzed.

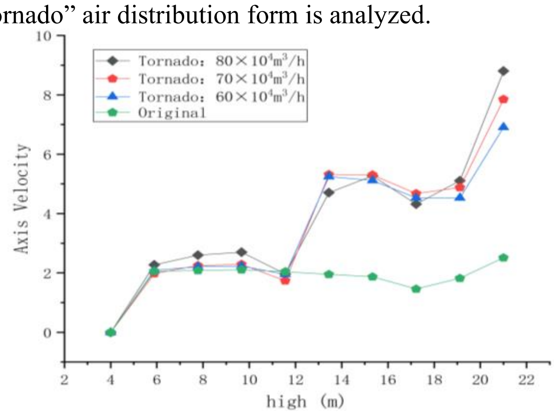



**Fig. 5.** Comparison chart of axial velocity with different air discharge volume.

From Fig. 5, it can be seen that the axial velocities with the “tornado” air distribution form and the ventilation volume of 60×10$^4$ m$^3$/h are similar in size to those of 70×10$^4$ m$^3$/h and 80×10$^4$ m$^3$/h, and are much larger than the axial velocities when the “tornado” air distribution form is not used. Judging from the effect of resisting the lateral wind, the control effect that needs to be achieved can be satisfied at 60×10⁴ m³/h.

According to the actual research of the project, when the tornado air distribution form is not adopted, the ventilation system needs 100×10⁴ m³/h ventilation volume to effectively resist the influence of side 3m/s lateral wind. After adopting the tornado air distribution form, the ventilation volume of 60×10⁴ m³/h can achieve the same effect of smoke capture. According to this calculation, the energy saving of the ventilation system is 74×10⁴kW·h/a, and the carbon reduction is 720t/a.

### 4.4 The effect of different angular momentum air velocity on the trapping effect

The angular momentum air velocity of a tornado is one of the influencing factors of the pollutant capture effect of a "tornado". In this paper, the variations of axial pressure and axial velocity were studied for three different angular momentum wind velocities of 16m/s, 13m/s and 10m/s (as shown in Fig. 6).

As can be seen from Fig. 6, among the three angular momentum air velocities, the axial pressure and axial air velocity of 16m/s air velocity are conducive to resist the influence of lateral wind and improve the pollutant capture effect, 13m/s is the second and 10m/s is the worst.

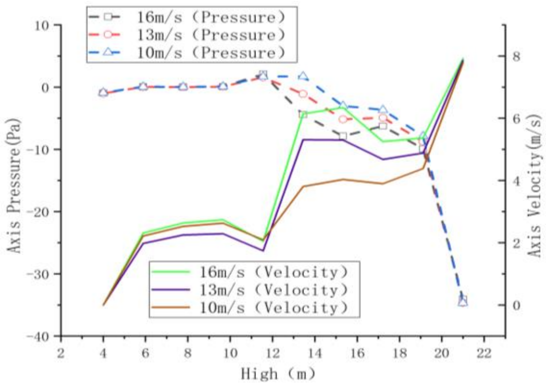



**Fig. 6.** Axial pressure distribution and axial velocity distribution at different angular momentum supply air velocity.

## 5 Conclusion

In this paper, the effect of smoke capture in large electric furnace roof hood ventilation using "tornado" resist the influence of lateral wind is studied. The effect of smoke capture under the influence of lateral winds was studied in terms of the distance between the roof hood and the contaminant source, the wind speed at the hood opening, the exhaust air volume and the angular momentum supply air speed, respectively. The main conclusions are as follows:

(1) The addition of a rotary air supply device between the exhaust and the source of pollution can meet the basic conditions for the formation of the "tornado" flow field, and a stable "tornado" suction flow field can be obtained.

(2) On the basis of meeting the process requirements, the distance between the roof hood and the furnace opening of the electric furnace is appropriately reduced, by using to improve the ability of the "tornado" to resist the lateral wind.

(3) Under the same ventilation volume, appropriately reducing the area of the roof hood and increasing the hood wind speed can effectively improve the ability of the "tornado" to resist lateral winds and improve the effect of pollutant capture.

(4) For the subject of this study, the same smoke capture effect can be achieved at a ventilation volume of 60×10⁴ m³/h under the same lateral wind influence working conditions, compared to the traditional air distribution, after adopting the "tornado" air distribution form. The energy saving of ventilation system is 74×10⁴ kW· h/a.

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