Numerical simulation study on the influence of power plant flue gas factors on the formation of white wet plume of flue gas

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Abstract. When the wet flue gas of a gas power plant is discharged, a white wet plume of flue gas will be produced, causing environmental and visual pollution. Local governments require the treatment of white wet plume of flue gas. This paper establishes a model of the process of flue gas emission to produce white wet plume of flue gas, and the numerical method is used to solve it. The effects of factors such as flue gas emission temperature and flue gas moisture content on the generation of white wet plume of flue gas are studied respectively. The results show that the numerical simulation method has a good simulation effect for studying the generation conditions and factors of the white wet Plume of flue gas. It is possible to obtain the limit emission temperature and the emission moisture content of the flue gas emission without producing white wet Plume of flue gas. It is possible to study the generation of white wet plume of flue gas under the conditions of different flue gas emission temperature and emission moisture content, and provide reference and guidance for the engineering practice of power plant flue gas reduction or elimination of white wet plume of flue gas.

1. Introduction
When the wet flue gas of a gas-fired power plant is discharged, a white wet plume of flue gas will be produced, causing environmental and visual pollution. Local governments require the treatment of white wet plume of flue gas[1-2]. In order to better guide the elimination of white wet plume of flue gas in practical engineering, we need to know the elimination conditions of white wet plume of flue gas in advance, among which numerical simulation method is the most effective, most convenient and low-cost method. The main physical quantities that affect the formation of white wet plume of flue gas are: the emission temperature of the wet flue gas, the discharge speed of the wet flue gas, the moisture content of the wet flue gas, the temperature of the ambient atmosphere, the air circulation speed of the ambient atmosphere, and the moisture content of the ambient atmosphere. In practical engineering, the temperature and moisture content of the flue gas are often changed by thermodynamic technology to weaken or even eliminate the white wet plume of flue gas. Therefore, this paper mainly uses numerical simulation methods to study the effects of flue gas temperature and moisture content on the formation of white wet plume of flue gas.
2. Model

2.1. Physical model
According to the flue gas emission process of gas-fired power plants, the atmospheric environment is simplified into a rectangle with a length of 600m and a width of 300m. The height of the smoke stack is 120m, the bottom diameter is 12m, and the flue gas discharge aperture is 6m. This numerical simulation uses the CFD pre-processing software GAMBIT to establish a two-dimensional physical model, as shown in Figure 1. And use GAMBIT software for meshing, the meshing is shown in Figure 2.

2.2. mathematical model
In order to facilitate the elaboration of the mechanism of the process of white plume of flue gas produced by flue gas emission, this article only studies the two-dimensional model. Its control equations include fluid mass transport equations, momentum equations and turbulence equations [3-5], and the numerical calculation method is finite volume method, The discrete format uses the first-order upwind difference equation, for the coupling of the momentum equation speed and pressure, the SIMPLE algorithm is used for coupling [6].

2.3. Boundary Condition
For both ambient wind speed and flue gas emission speed, Velocity-inlet is used as its boundary condition. Considering that the outlet flow is insufficient, the Pressure-outlet is selected as the boundary condition and set to the ambient atmospheric pressure. Choose other wall surface as the wall condition, no slip, no fluid passing through.

2.4. Initial parameter setting
The initial parameters are shown in Table 1.

| Physical quantity                  | Symbols | Value | Unit   |
|-----------------------------------|---------|-------|--------|
| Atmospheric inlet velocity        | $V_{\text{air}}$ | 3     | m/s    |
| Flue gas inlet velocity           | $V_{\text{gas}}$ | 15    | m/s    |
| Atmospheric pressure              | $P_{\text{air}}$ | 101325 | Pa     |
| Atmospheric moisture content      | $d_{\text{air}}$ | 0.00417 | g/kg |
| Flue gas moisture content         | $D_{\text{gas}}$ | 0.12172 | g/kg |
| Flue gas exhaust temperature      | $T_{\text{gas}}$ | 80    | °C     |
| Ambient temperature               | $T_{\text{air}}$ | 10    | °C     |
3. Calculation results and discussion

3.1. Analysis of simulation results

Use FLUENT software to perform numerical calculations under the initial conditions set in Table 1, and perform post-processing, and obtain the following results:

The temperature distribution diagram is shown in Figure 3. Through the temperature simulation cloud diagram of wet flue gas emission, we can clearly see the temperature change of flue gas after it is discharged from the chimney and the temperature of a specific space point, which can be used as an important reference for engineering practice.

![Figure 3. Flue gas emission temperature distribution diagram](image)

The humidity distribution diagram is shown in Figure 4. The wet flue gas passes through the chimney outlet with a moisture content of 0.12172g/kg and is discharged into the ambient atmosphere, and the relative humidity cloud diagram of the flue gas can be obtained.

In order to better reflect the formation and range of the wet plume of flue gas, the maximum scale of the relative humidity cloud diagram of the flue gas is adjusted to 100%, which can clearly show the part where the relative humidity is greater than 100%, that is, the part that forms white wet plume of flue gas. Area, as shown in Figure 5.

Through the temperature simulation cloud diagram of wet flue gas emission, we can clearly see the change of relative humidity and the specific situation of wet plume of flue gas after the wet flue gas is discharged from the chimney, which can be used as an important reference for engineering practice.

![Figure 4. Relative humidity distribution diagram](image)  ![Figure 5. Wet plume area of flue gas](image)

3.2. The influence of various influencing factors on the white wet plume of flue gas

The initial conditions are set as shown in Table 1. When the flue gas moisture content \(d_{gas}=0.12172\text{g/kg}\), we increase the flue gas emission temperature; when the flue gas emission
temperature is $T_{\text{gas}}=80^\circ\text{C}$, we change the flue gas to study and observe the change of white wet plume of flue gas. Calculate the influence parameter table, as shown in Table 2.

| parameter                  | 1    | 2    | 3    | 4    |
|----------------------------|------|------|------|------|
| Flue gas temperature(°C)   | 80   | 98   | 116  | 134  |
| Flue gas moisture content(g/kg) | 0.120 | 0.105 | 0.090 | 0.075 |

3.3. The effect of exhaust gas temperature on the formation of white wet plume of flue gas
From the cloud diagram of the numerical calculation results, as shown in Figure 6, we can clearly see that as the flue gas emission temperature gradually increases, the area of the white wet plume of flue gas gradually decreases until the temperature reaches 134°C, the white wet plume is completely eliminated. It can be seen that increasing the discharge temperature of flue gas is an effective way to eliminate white wet plume of flue gas.

![Figure 6. The effect of exhaust gas temperature](image)

3.4. The effect of exhaust gas moisture content on the formation of white wet plume of flue gas
From the cloud chart of the numerical calculation results, as shown in Figure 7. We can clearly see that as the moisture content of the flue gas emissions gradually increases, the area of the white wet plume gradually decreases until the moisture content of the flue gas reaches 0.075g/kg, the white wet plume is completely eliminated. It can be seen that increasing the discharge temperature of flue gas is an effective way to eliminate white wet plume of flue gas.
4. Conclusions:
This paper describes the engineering situation of the white wet plume of flue gas produced by the flue gas emission of the power plant. The physical model and mathematical model of the white wet plume of flue gas produced by the flue gas emission are established. The numerical calculation method is used to solve the problem. The effects of power plant flue gas emission temperature and flue gas emission moisture content on the process of generating white wet plume of flue gas are studied, and the following conclusions are drawn:

(1) The numerical simulation method has a good simulation effect for studying the generation conditions and factors of the white wet plume of flue gas. The limit emission temperature and the limit emission moisture content at which the flue gas emission does not produce white wet plume of flue gas can be obtained, which can be used to guide the engineering practice of eliminating the white wet plume of flue gas.

(2) The emission temperature and moisture content of flue gas have a significant influence on the formation of white wet plume of flue gas. Increasing the emission temperature and reducing the moisture content of flue gas are important ways to reduce and eliminate white wet plume of flue gas.

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