Analysis of Influence of Nozzle Structure on Flow Field in Pulverized Coal Gasifier

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Abstract. The three-dimensional model of the pulverized coal gasifier was established, and the internal flow field of the pulverized coal gasifier was simulated by CFD software. The variation of the velocity field and vector field inside the gasifier was observed when the angle of the guide vane in the nozzle structure gradually increased. Through the comparative analysis of the simulation results of the angle between the guide vane and the axis of 20°, 30°, 40° and 50°, the following conclusions can be drawn: as the angle of the guide vane increases, the lateral diffusion capacity of the airflow at the nozzle exit increases, and the longitudinal diffusion capability decreases. Therefore, after comprehensive consideration and contact with the actual gasifier size, this paper considers that the angle between the blade and the axis is optimally 40°-45°.

1. Introduction

At present, China’s power sources are still dominated by thermal power generation. In the emissions of thermal power generation, there are not only a large amount of greenhouse gases such as carbon dioxide, but also a large amount of toxic gases such as sulfides and nitrides. Therefore, the improvement of traditional coal inefficient combustion mode has always been the core goal of China’s energy industry.

In terms of coal gasification, many scholars at home and abroad have made research: Wenchao Xing et al. studied the soft gasification technology of pulverized coal with air as a gasifying agent. It is concluded that the influence of the secondary air nozzle arrangement of the gasifier on the average residence time of the particles is greater than the change of the position of the primary air nozzle[1]. Shenqi Xu et al. used Matlab to establish a pulverized coal one-dimensional entrained flow gasification kinetic model, which was used to simulate the operation of the gasifier and optimize the operating conditions[2]. Heijing Wang et al. put forward the control measures of source reduction, process control and end treatment through combing the various process steps of the powder coal gasification process[3]. Li, Yun et al. created a two-fluid model to simulate the flow and heat transfer of vertical pipes in the quenching chamber of a coal gasifier[4]. Ni Q et al. created a new simulation method for entrained flow coal gasifiers. They built a multivariate model of the gasifier. The sensitivity of the shell coal gasifier operating control variables was also discussed[5]. Matsukata, M et al. measured the local gas concentration in a jet fluidized bed coal gasifier to discuss the gas exchange between the jet and the annulus and the local progression of the chemical reaction[6].
2. Simulation object and method

2.1 Grid model

This calculation is based on the CFD software to complete a series of simulation calculations. Figure 1(a) shows the overall mesh model. Because the size of the nozzle is very different from the size of the furnace, it is necessary to make intensive improvement on the grid at the nozzle. The processing results are shown in Figure 1(b).

![Mesh model of gasifier](image)

**Figure 1.** Mesh model of gasifier

2.2 Gas-solid two-phase flow model

Mass exchange equation:

$$ M = \frac{\Delta m_p}{m_{p,0}} $$

Energy exchange equation:

$$ Q = \left[ \frac{m_p}{m_{p,0}} c_p \Delta T_p + \frac{\Delta m_p}{m_{p,0}} \left( -h_{fg} + h_{pyro} + \int_{t_{in}}^{t_{out}} c_p \Delta T \right) \right] \cdot \Delta t $$

Momentum exchange equation:

$$ F = \sum \left[ \frac{3\beta \mu C_D R}{4 \rho_{p} d_p} (u_{p} - u) + F_{other} \right] m_{p,0} \Delta t $$

$\Delta m_p$ is the change of particle mass, $m_{p,0}$ is the initial mass of the particle, $\dot{m}_{p,i}$ is the initial mass flow rate of the tracking particle, $\Delta T_p$ is the temperature difference of the control body particles, $h_{pyro}$ is the amount of heat consumed in the volatilization analysis, $h_{fg}$ is the latent heat of volatilization analysis, $F_{other}$ is the force between other items, $m_p$ is the mass flow rate of the particles.

2.3 Working condition setting

The simulation parameters at the nozzle of the gasifier are shown in Table 1.

**Table 1.** Simulation parameters of gasifier nozzle

| Top pulverized coal nozzle | Numerical value | unit |
|----------------------------|-----------------|------|
| Pulverized coal | Coal injection (dry basis) | 400 | t/d |
| | Density | 1300 | kg/m³ |
| | Export feed rate | 7 | m/s |
| | Export feed angle | Direct injection | |
| CO₂ carrier gas volume | 3092 | Nm³/hr |
| | 1.4456 | kg/s |
| Oxygen | Top oxygen delivery | 8500.9 | Nm³/hr |
| | 12660 | kg/hr |
| | 2.5 | kg/s |
| | Export feed angle | 45 | ° |
3. Simulation result
This paper simulated the flow field inside the gasifier under the conditions of the guide vane angles of 20°, 30°, 40° and 50° respectively. The effects of the guide vanes in the gasifier were explored by analyzing the changes in the velocity and vector fields.

3.1 Velocity field
Figure 2 shows a velocity distribution cloud diagram of the nozzle when the guide vanes are at different angles. As shown in the figure, as the angle increases, its maximum speed increases from 78.1 m/s to 98.4 m/s.

![Velocity distribution contour map and nozzle velocity distribution cloud map at 20° angle](image)

![Velocity distribution contour map and nozzle velocity distribution cloud map at 30° angle](image)

![Velocity distribution contour map and nozzle velocity distribution cloud map at 40° angle](image)

![Velocity distribution contour map and nozzle velocity distribution cloud map at 50° angle](image)

Figure 2. Velocity distribution contour map and nozzle velocity distribution cloud map of the gasifier

3.2 Vector field
It is not difficult to find from the following velocity vector cloud maps that as the angle changes, the ability of the airflow to spread around is enhanced as the angle increases. Therefore, the diffusibility of the nozzle can be enhanced by changing the angle of the guide vanes.
4. Analysis and conclusion

It can be seen from the simulation results of the velocity field above that as the angle of the guide vane increases, the jet length of the airflow gradually decreases. However, the speed at the nozzle gradually increases. From the simulation structure of the vector field, it can be found that the increase of the angle of the guide vane can enhance the diffusion ability of the airflow at the nozzle outlet. It also makes the reaction in the gasifier more uniform.

Based on the above analysis, it can be found that the increase of the angle of the guide vane has both advantages and disadvantages. As the angle of the guide vanes increases, the lateral diffusion capacity of the material at the nozzle outlet is enhanced. However, the vertical diffusion capacity has been lost. Therefore, considering the actual size ratio of the gasifier, the optimum angle between the vane and the axis is considered to be 40°-45°.

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