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# Analysis of Atomization Characteristics of Gas-Liquid Two-Phase Flow Nozzle Based on CFD

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**Abstract.** As a key component of the mine spray dust reduction system, the atomization effect of the nozzle directly affects the dust reduction efficiency of the nozzle, and the effective atomization range of the nozzle determines the atomization effect of the nozzle. In this paper, the VOF two-phase flow model and turbulence model are established by Fluent simulation software for the nozzle of gas-liquid two-phase flow structure. The distribution of gas-liquid two-phase in the nozzle and the influence of gas pressure, liquid velocity and gas-liquid channel diameter ratio on the atomization effect of the nozzle are studied. The simulation results show that when the gas pressure increases from 0.3Mpa to 0.8Mpa, the effective atomization range of the nozzle increases from 0.65m to 1.65m. When the liquid velocity increases from 0.2m/s to 0.8m/s, the effective atomization range of the nozzle decreases from 1.45m to 0.4m. When the gas-liquid channel diameter ratio increases from 0.5 to 1, the effective atomization range of the nozzle increases from 1.1m to 1.8m.

**Keywords.** nozzle, gas-liquid two-phase flow, numerical simulation, falling dust

## 1. Introduction

As the generating device of the atomization process of the spray dust reduction system, the performance of the nozzle directly affects the atomization effect and dust reduction efficiency of the spray dust reduction system[1-2]. At present, high-pressure spray is widely used in mines to reduce dust, which can effectively inhibit the diffusion of total dust, but the dust reduction efficiency of respirable dust is not high, which seriously threatens the occupational health of mine workers[3-4]. Due to the good atomization effect and moderate atomization uniformity[5], the gas-liquid two-phase flow nozzle has higher dust reduction efficiency for respirable dust than the ordinary nozzle [6-7]. At present, many scholars at home and abroad have carried out experimental research and numerical simulation analysis on gas-liquid two-phase flow nozzles. Wang *et al*.[8]explored the influence of the internal structure of gas-liquid nozzles on the atomization effect. Yuan *et al*.[9]designed and processed a new type of gas-liquid two-phase flow atomizing nozzle, and optimized the structural parameters such as nozzle inlet hole diameter and inlet hole diameter. Liu *et al*.[10]designed a circulating gas-liquid atomization dust suppression

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device suitable for tunneling face. In this paper, the gas-liquid two-phase distribution inside the gas-liquid two-phase flow nozzle is simulated and analyzed by Fluent simulation software. The effects of gas phase pressure, liquid phase velocity and gas-liquid two-phase diameter ratio on nozzle atomization are studied.

## 2. Model construction

### *2.1. Geometric model*

Based on the basic principle of gas-liquid two-phase flow, a new type of nozzle is designed. The nozzle consists of four parts: gas channel, liquid channel, mixing chamber and outlet channel. The gas channel is an L-shaped channel bent at a certain angle, which exists in pairs and is located on both sides of the liquid channel. When the nozzle is working, air and water enter the mixing chamber from the gas phase channel and the liquid phase channel respectively. In the mixing chamber, the high-pressure air impacts and breaks the water, so that the water is atomized to form fine droplets. In order to better observe the atomization effect of the nozzle, the outflow field is simplified into a cylindrical area with a diameter of 0.8m and a length of 2m. The geometric models of the internal fluid domain and the outflow field of the nozzle are shown in Fig.1 and Fig.2, respectively.

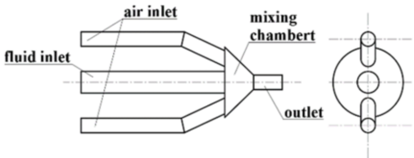



**Figure1.** Internal flow field calculation model of nozzle


**Figure2.** Calculation model of outflow field

### *2.2. Mathematical model and nozzle internal flow field simulation settings*

The gas-liquid flow simulation in the nozzle adopts the VOF mixed multiphase flow model, and the control equations of the flow field are the continuity equation and the momentum equation. The turbulence model uses standard $k-\varepsilon$ model. Other boundary conditions are shown in Table 1. In the simulation of the internal flow field of the nozzle, the diameter ratio of gas-liquid channel is 0.67, the liquid inlet velocity is 0.5m/s, and the gas inlet pressure is 0.5Mpa.

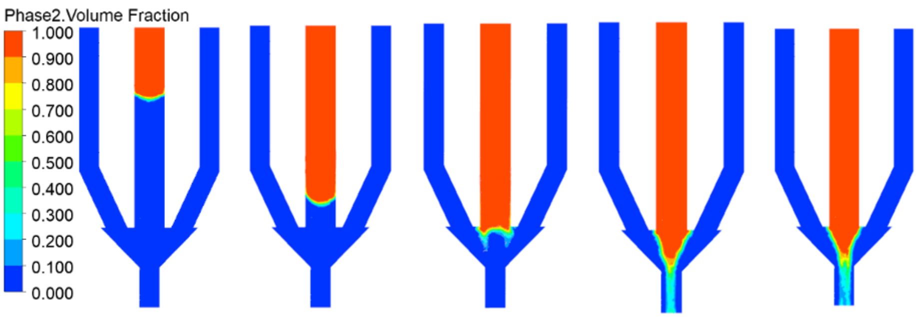
**Table 1.** Boundary condition setting

| Name | Parameter |
|---|---|
| Air inlet type | Pressure inlet |
| Fulid inlet type | Velocity inlet |
| Outlet type | Pressure outlet |
| Wall | No-slip |
| Surface Tension Cofficient | 0.072N/m |
| Outlet pressure | Normal atmosphere |
| Energy | OFF |

## 3. Results analysis

### *3.1. Analysis of internal flow field characteristics of nozzle*

After the end of the fluid dynamics simulation process, we imported the results into CFD-Post post-processing, and obtained the change of the gas-liquid two-phase volume distribution inside the nozzle over time, as shown in Fig.3. Among them, blue represents that the fluid here is air and the volume fraction is 1, and red represents that the fluid here is water and the volume fraction is 1. In the initial stage, the volume fraction of the second phase is set to 0, that is, the inside of the nozzle is all air. Therefore, in the initial stage, the mixing chamber of the nozzle is completely blue. 0.005s-0.0175s is the gas-liquid inflow stage, and air and water enter from the gas phase channel and the liquid phase channel respectively. 0.0175s-0.275s is the atomization stage. Air and water enter the mixing chamber, and the high-pressure gas impacts and atomizes the water. 0.0275s-0.03s is the droplet ejection stage, and the fully atomized gas-liquid mixture is ejected from the nozzle outlet. When calculated to 0.03s, the gas-liquid integral number, velocity, pressure and other physical quantities no longer change greatly with time, and the gas-liquid two-phase distribution is basically consistent with the state at 0.0275s, indicating that the flow inside the nozzle has reached a steady state.




0.005s 0.015s 0.0175s 0.0275s 0.03s

**Figure 3**. Gas-liquid two-phase distribution in axial section

### *3.2. Effect of gas pressure on nozzle atomization*

In order to study the influence of gas phase pressure on the effective atomization range of the nozzle, other parameters are kept unchanged, and the gas phase pressure is 0.3 MPa, 0.5MPa and 0.85MPa respectively for simulation. Because the velocity of the outflow field only has the ability to carry droplets when it is greater than 2m/s, in order to better observe the spray effect, the upper limit of the velocity of the spray velocity cloud map is set to 2m/s, that is, the red cloud map indicates that the fluid velocity is greater than 2m/s. The effective range of the spray is set to 5m/s, that is, the upper limit of the velocity of the spray velocity change map is set to 5m / s, that is, when the velocity is greater than 5m/s, it is shown as 5m/s. The spray velocity countour of the outflow field under different gas pressure conditions and the change diagram of the spray velocity of the outflow field along the nozzle axis are obtained, as shown in Fig.4 and Fig.5.

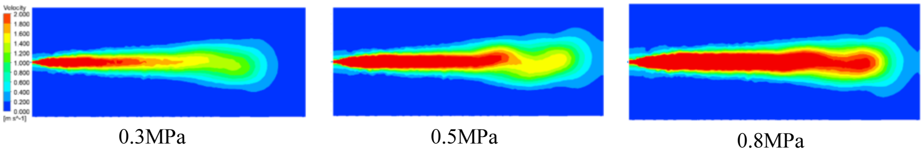



**Figure 4**. Spray velocity contour of outflow field under different gas pressure

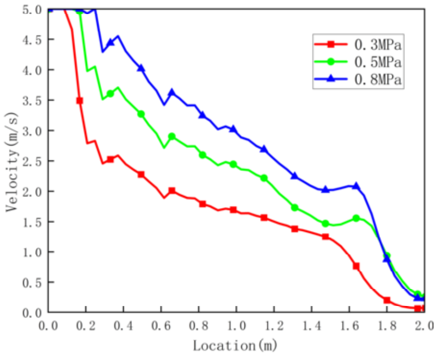



**Figure 5.** Variation of spray velocity along the axis of the outflow field under different gas pressure

It can be seen from Fig.4 and Fig.5 that as the gas phase pressure increases, the effective atomization range of the nozzle gradually increases. When the gas pressure is 0.3MPa, 0.5MPa, and 0.8MPa, the effective spray range is 0.65m, 1.21m, and 1.65m, respectively. This is because as the gas pressure increases, the kinetic energy of the gas also gradually increases, the impact on the droplets is stronger, the atomization effect is better, and the dust removal efficiency is higher.

### *3.3. Effect of liquid velocity on nozzle atomization*

In order to study the influence of liquid inlet velocity on the effective atomization range of the nozzle, other parameters are kept unchanged, and the liquid inlet velocity is 0.2m/s, 0.5m/s and 0.8m/s respectively for simulation. The spray velocity contour of the outflow field and the change diagram of the spray velocity along the axis under different liquid inlet velocity conditions are obtained, as shown in Fig.6 and Fig.7.

From Figure 6 and Figure 7, it can be seen that with the increase of liquid velocity, the effective atomization range of the nozzle gradually decreases. When the liquid velocity is 0.2m/s, 0.5m/s and 0.8m/s, the effective atomization range of the nozzle is 1.45m, 1.2m and 0.4m respectively. This is because as the liquid velocity increases, the water flow into the mixing chamber is also greater, the gas needs to atomize more water under the same work, while the gas phase pressure remains unchanged, thus the atomization effect is reduced, and the dust removal efficiency is reduced.

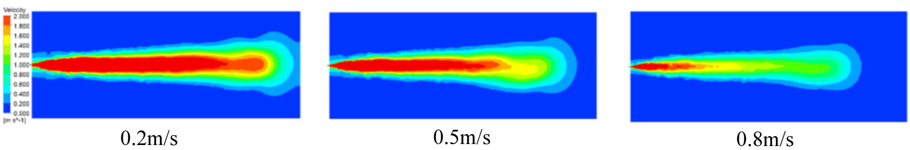



**Figure 6.** Spray velocity contour of outflow field under different liquid inlet velocity conditions

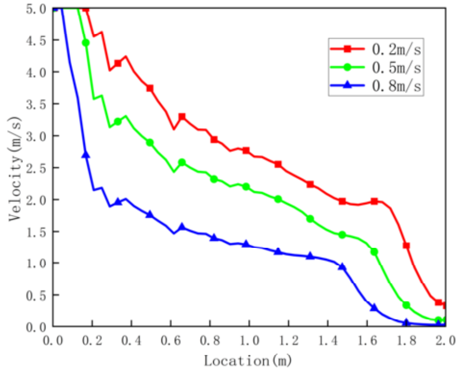



**Figure 7**. Variation of spray velocity along the axis of the outflow field at different liquid inlet velocities

## 3.4. Effect of gas-liquid channel diameter ratio on nozzle atomization

In order to study the influence of the diameter ratio of gas-liquid channel on the effective atomization range of the nozzle, other parameters are kept unchanged, and the diameter ratio of gas-liquid channel is 1, 0.67 and 0.5 respectively for simulation. The spray velocity contour of the outflow field and the spray velocity of the outflow field along the axis under different gas-liquid channel diameter ratios are obtained, as shown in Fig.8 and Fig.9.

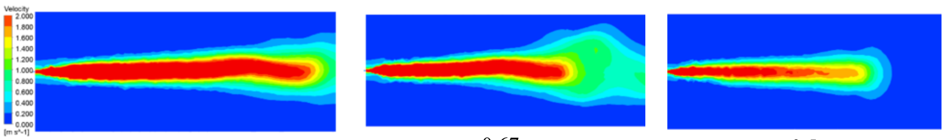



**Figure 8.** Spray velocity contour of outflow field under different gas-liquid channel diameter ratio

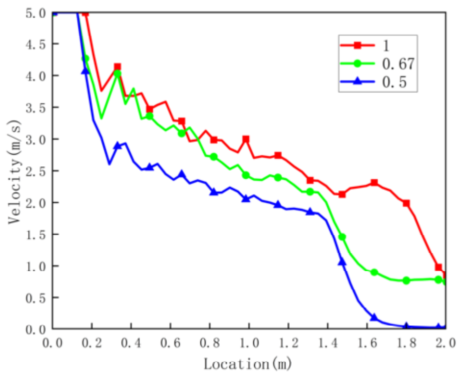



**Figure 9.** Variation of spray velocity in the outflow field along the axis under different gas-liquid channel diameter ratios

From Figure 8 and Figure 9, it can be seen that with the decrease of the diameter ratio of the gas-liquid channel, the effective atomization range of the nozzle gradually decreases. When the diameter ratio of the gas-liquid channel is 1, 0.67 and 0.5, the effective atomization range of the nozzle is 1.8m, 1.4m and 1.1m respectively. This is because with the decrease of the diameter ratio of the gas-liquid channel, the greater the difference between the air inflow and the water inflow in the mixing chamber per unit time, the less the kinetic energy exchange between air and water, so that the atomization effect is reduced and the dust reduction efficiency is reduced.

## 4. Conclusion

1) The gas-liquid two-phase flow in the nozzle is divided into three stages, namely, the gas-liquid inflow stage, the mixing chamber atomization stage, and the spray ejection stage. The gas in the mixing chamber impacts and breaks the droplets, and the liquid phase is fully atomized to form a fine water mist, and a stable and fine gas-liquid mist beam is formed after the nozzle is ejected.

2) The gas phase pressure, liquid phase velocity and gas-liquid channel diameter ratio have a great influence on the atomization performance of the nozzle. High gas phase pressure, low liquid phase velocity and low gas-liquid channel diameter ratio will obtain a longer spray range, but low gas-liquid channel diameter ratio will reduce the water content in the spray and affect the dust reduction effect. The influence of three aspects on the atomization performance of the nozzle should be considered comprehensively.

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