Experimental Research on the Suppression Effect of Different Types of Inert Dust on Micron-Sized Lignite Dust Explosion Pressure in a Confined Space

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ABSTRACT: Coal is an important strategic resource in the world; coal production safety has always been widely concerned. In coal mine production, inert dust can effectively reduce coal dust explosion accidents in mine tunnels. To reveal the suppression effect of inert dust on lignite dust explosion, CaCO$_3$, SiO$_2$, and NH$_4$H$_2$PO$_4$ are selected for suppression experiments. It is found that the lignite dust explosion pressure decreases continuously as the mass percentages of inert dust mixed into lignite dust increase. By calculating the molar mass, the suppression effects of CaCO$_3$ and SiO$_2$ on lignite dust explosion are compared. The lignite dust no longer explodes when the mass percentage of NH$_4$H$_2$PO$_4$ dust mixed into lignite dust is 70%, indicating that NH$_4$H$_2$PO$_4$ is more effective than that of CaCO$_3$ and SiO$_2$. The smaller the particle size of NH$_4$H$_2$PO$_4$, the better the suppression effect on explosion. The lignite dust does not explode when the mass percentage of NH$_4$H$_2$PO$_4$ is 60% and the particle size of NH$_4$H$_2$PO$_4$ is 25−38 μm, which proves that decreasing the particle size of NH$_4$H$_2$PO$_4$ is important to suppress explosion. The research results are of great significance for grasping the explosion suppression effect of inert dust on lignite dust.

1. INTRODUCTION

Coal dust explosion is one of the major accidents affecting the safety production of coal mines, which usually causes huge casualties and property losses. In the process of coal dust explosion, high-temperature flame and high-speed propagating pressure shock wave will be generated. The propagation speed of the pressure shock wave is much greater than the propagation speed of the flame; theoretical research shows that the flame propagation speed of the coal dust explosion can reach more than 1120 m/s and the propagation speed of the pressure shock wave can reach more than 2340 m/s, both of which are extremely destructive. At the same time, the average theoretical pressure of the coal dust explosion in coal mine tunnels is 736 kPa, and the explosion pressure increases rapidly with the increase of the distance from the explosion source. Nowadays, with the development of dust explosion test methods, it is of great significance for coal mine safety production to master the variation law of coal dust explosion pressure characteristics and the suppression effect of different types of inert dust on coal dust explosion. Fundamentally, coal dust explosion is a combustion chemical reaction with an extremely fast reaction rate, in which rapidly propagating pressure shock waves are generated. Previous studies have found that the mechanism of combustible gas explosion is different from that of coal dust explosion. In the process of coal dust explosion, volatile matter and moisture of coal dust are first released from coal dust particles under the action of an ignition source, which can make the explosion intensity far greater than the explosion intensity of the combustible gas. Based on the experimental testing and analysis methods of dust explosion, different types of dust are used as samples; Eckhoff researched on the effects of particle dispersion and dust cloud concentration on explosion characteristics and the effects of dust cloud turbulence and particle aggregation on explosion intensity. Oran studied the flame propagation speed and flame structure of dust explosion caused by gas explosion in the

Received: June 24, 2022
Accepted: September 12, 2022
Published: September 20, 2022
duct space. Kosinski and Hoffmann\textsuperscript{21} revealed the propagation process of primary dust explosion by using the connected vessels and carried out the simulation research on explosion characteristics by establishing numerical models.

In the field of coal dust explosion, the method of suppressing coal dust explosion by inert dust is mainly used in coal mine tunnels,\textsuperscript{22,25} because in the coal mine tunnels, due to the coal mine production and transportation, a large amount of suspended coal dust and deposited coal dust will be generated in the tunnel. If there is an ignition source, the coal dust will explode, and the consequences will be very serious. Therefore, the use of inert dust can effectively suppress the intensity of the explosion, prevent the spread of the explosion, and even completely suppress the occurrence of the explosion.\textsuperscript{26,27} Even if a large amount of explosion-suppressing dust is required, it is also a safe and effective method to control explosion accidents, which is very important to ensure the safe production of coal mines. In addition, when suppressing coal dust explosion, if a smaller amount of inert dust can be used to effectively suppress the explosion, such inert dust should be selected. However, at present, new types of inert dust are still under continuous research and development, and developing an inert dust that can more effectively suppress coal dust explosion is an important research direction for coal dust explosion in the future.

In previous research, the author of this paper revealed the ignition characteristics and flame propagation process of different types of coal dust cloud under different conditions\textsuperscript{28–31} and also discovered the explosion characteristics of deposited coal dust driven by airflow carrying coal dust and the suppression effect of inert dust CaCO\textsubscript{3} on explosion.\textsuperscript{32} Using inert dust is a very economical and effective method to control coal dust explosion. The particle size and type of inert dust used in related research at home and abroad are relatively simple; in most previous research, a single particle size of CaCO\textsubscript{3} was selected as the inert dust; the comparative research results on the explosion suppression effects of different types of inert dust are insufficient. Therefore, this paper selects different types and particle sizes of inert dust to suppress coal dust explosion, which is innovative in the research content. To further study the suppression effect of different types of inert dust on the coal dust explosion pressure, in this paper, the 20 L spherical dust explosion experimental device was used to test the explosion pressure, and the micron-sized explosive lignite dust was used as the sample. CaCO\textsubscript{3}, SiO\textsubscript{2}, and NH\textsubscript{4}H\textsubscript{2}PO\textsubscript{4} were selected as three different types of inert dust to conduct an experiment on the suppression effect of lignite dust explosion pressure, by which the suppression mechanism of inert dust on coal dust explosion can be better understood. Meanwhile, the research results are of great significance for guiding the use of inert dust for coal dust explosion suppression.

2. EXPERIMENTAL SECTION

2.1. Experimental Apparatus. There are mainly two parameters that can be used to describe the coal dust explosion pressure characteristics; they are the maximum explosion pressure \( P_{\text{max}} \) and the maximum pressure rise rate \( (dP/dt)_{\text{max}} \). The 20 L spherical explosive experimental apparatus is shown in Figure 1, which is used to test the coal dust explosion pressure characteristics in this study. The test process of the experiment refers to the Chinese national standard “GB/T 16426-1996 Determination for maximum explosion pressure and maximum rate of pressure rise of dust cloud”. The experimental apparatus is used internationally, which is mainly composed of an automatic dust spraying system, an ignition data acquisition system, a data transmission system, and an automatic water circulation system. It can be got that the volume of this spherical experimental apparatus is 20 L and the volume of the dust storage tank is 0.6 L. The experimental test range of the explosion pressure is from \(-0.1 \) to \(2 \) MPa, and the test accuracy is \(0.001 \) MPa. The interval time of the pressure sensors to collect the explosion pressure data is \(0.2 \) ms, and the maximum acquisition time of the experimental data can be up to \(12 \) s, which can meet the requirements of collecting pressure data in the whole explosion process.

The structure of the 20 L spherical explosive experimental apparatus is shown in Figure 2. Before the experiment, put the dust sample in the dust storage tank. During the experiment, the dust particles are driven into the spherical space by high-pressure airflow under the action of the dispersion valve and then explode under the action of ignition; in addition, the pressure sensors would collect the pressure data in real time. After the experiment, the temperature inside the experimental apparatus can be quickly lowered by using the automatic water circulation system in a few minutes.

The parameters of the explosion experiment are set as follows. When testing the explosion pressure of the coal dust, the coal dust injection pressure is set to \(2 \) MPa, and the
ignition delay time is set to 100 ms; the setting of the ignition delay time is determined under the premise of continuous testing so that the explosion pressure can reach the maximum, which can make the coal dust particles fully diffuse in the spherical space and achieve a uniform suspension state before being ignited. Experiments were carried out according to the Chinese national standard "GB/T 16426-1996 Determination for maximum explosion pressure and maximum rate of pressure rise of dust cloud"; when the coal dust particles enter the interior of the 20 L sphere under the action of a dust injection pressure of 2 MPa, after a period of an ignition delay time of 0.6 s, two chemical ignition heads with an ignition energy of 10 kJ are ignited at the same time; the suspended coal dust cloud will be instantly ignited and exploded, which can also be observed through the circular quartz glass window with a diameter of 20 mm. Ten experiments are carried out in each pressure experiment, and the mean value is calculated. If the relative error between the measured $P_{\text{max}}$ result and the mean value is less than 4%, then the experimental result is reliable. Otherwise, the experiment needs to be repeated.

2.2. Experimental Materials. 2.2.1. Coal Dust Sample. In this experiment, the selected experimental sample is lignite with a low degree of metamorphism. The data of the proximate and ultimate analyses of lignite dust are shown in Table 1. It can be seen that the lignite dust sample is a type of highly volatile coal dust and the main components of the sample are carbon and oxygen elements. Generally, the volatile matter is the combustible gas, which is first released from the coal dust particles after the coal dust cloud is heated. So the greater the volatile content of the coal dust, the greater the corresponding explosion risk. The air-dried volatile content of the sample is 43.31%, which is greater than 40%; this indicates that the experimental dust samples have a great explosion hazard. Meanwhile, the particle size analyzer is used to observe the distribution of coal dust particles; the results are shown in Figures 3 and 4. It is found that the particle size of the lignite dust sample is greater than 58 μm and less than 75 μm; under such conditions, the risk of dust sample explosion is great. In addition, within the observation range, the particle size of all coal dust particles conforms to a normal distribution, indicating that the distribution of coal dust particles is relatively uniform.

2.2.2. Inert Dust Samples. In coal mine tunnels, inert dust can effectively suppress coal dust ignition and explosion. In this paper, the suppression effect of different types of inert dust on the coal dust explosion pressure is studied by mixing inert dust into coal dust. Three types of inert dust selected are CaCO$_3$, SiO$_2$, and NH$_4$H$_2$PO$_4$, which are shown in Figure 5. It is found that three types of inert dust are all white inorganic particles under normal temperature, among which the melting points of CaCO$_3$ and SiO$_2$ dust are greater than 1500 K, indicating that CaCO$_3$ and SiO$_2$ dust are difficult to be involved in the chemical reaction of coal dust explosion and can effectively reduce the explosion intensity. However, the melting point of NH$_4$H$_2$PO$_4$ is only 453.15 K. After mixing NH$_4$H$_2$PO$_4$ into the coal sample, it will undergo a decomposition reaction under the action of high temperature generated by explosion.

3. RESULTS AND DISCUSSION

3.1. Explosion Pressure of Micron-Sized Lignite Dust in a Confined Space. The micron-sized lignite dust is used to test the explosion pressure in the spherical explosive apparatus. During the experiment, 6 g of coal dust is placed in the dust storage tank, so that the coal dust cloud mass concentration inside the 20 L spherical space could reach 300 g/m$^3$, which can ensure that the coal dust cloud can be ignited. By using the data transmission system, the explosion pressure curve is obtained, and the result is shown in Figure 6. It can be found that as the time after ignition increases, the explosion pressure increases continuously in a short period of time. At a time of 0.8 s after ignition, the coal dust explosion pressure increases to the maximum value, indicating that the $P_{\text{max}}$ in this explosion experiment is 0.71 MPa, which is seven times the standard atmospheric pressure and can cause huge harm to the human skin and vital organs. Meanwhile, within a time of 0–0.8 s after ignition, $(\text{d}P/\text{d}t)_{\text{max}}$ in this coal dust explosion reaches 65.69 MPa/s, indicating that a violent explosion occurred in the interior of the spherical space.

However, although the lignite dust cloud with a mass concentration of 300 g/m$^3$ has exploded, it does not mean that the coal dust explosion intensity has been already at its most violent state. Therefore, to study the influence of the coal dust cloud mass concentration on the coal dust explosion pressure characteristics and to obtain the coal dust cloud mass concentration under the condition of maximum explosion intensity, in the course of subsequent research, the explosion pressure characteristics experiments under the condition of different coal dust cloud mass concentrations are carried out.
3.2. Explosion Pressure under the Condition of Different Lignite Dust Cloud Mass Concentrations. According to the Chinese national standard “GB/T 16426-1996 Determination for maximum explosion pressure and maximum rate of pressure rise of dust cloud”, experiments can be carried out with different dust concentrations to obtain the relationship between explosion pressure and dust concentration. Therefore, under the condition that the particle size of the lignite dust sample is still greater than 58 μm and less than 75 μm, in subsequent experiments, the mass of lignite dust put into the dust storage tank each time has been increased from 6 to 6.5, 7, 7.5, 8, 8.5, 9, 9.5, and 10 g, which means that the mass concentration of the lignite dust cloud in the 20 L spherical space has been increased from 300 to 325, 350, 375, 400, 425, 450, 475, and 500 g/m$^3$, respectively. To study the effect of increasing the mass concentration of the lignite dust cloud on the explosion pressure, the mass concentration of the lignite dust cloud is set to increase continuously with 25 g/m$^3$ as the step size.

The lignite dust explosion pressure characteristics obtained from the experimental tests are shown in Table 2, and the variation trend of explosion pressure characteristics with the lignite dust cloud mass concentration is shown in Figure 7. The experimental data in this paper are the average value of the data obtained after multiple tests. The average value is calculated by multiple tests, which can effectively reduce the experimental error. It can be seen that as the lignite dust cloud mass concentration increases in the range of 300 to 500 g/m$^3$, both $P_{\text{max}}$ and $(dP/dt)_{\text{max}}$ increase first and then decrease. When the lignite dust cloud mass concentration is 400 g/m$^3$, $P_{\text{max}}$ and $(dP/dt)_{\text{max}}$ increase to the local maximum values of 0.82 MPa and 76.19 MPa/s, respectively, which indicates that there are local maximum points in the curve of lignite dust explosion pressure characteristics with the lignite dust cloud mass concentration. Based on the current experimental results, the lignite dust cloud mass concentration corresponding to this local maximum point is 400 g/m$^3$, which means that when the lignite dust cloud mass concentration is 400 g/m$^3$, the lignite dust cloud explosion pressure characteristics in the 20 L spherical space are at the most violent state.

According to the lignite dust explosion mechanism, when the lignite dust cloud mass concentration is greater than 300 g/m$^3$ and less than 400 g/m$^3$, the lignite dust particles will fully undergo a redox reaction with oxygen after being ignited. Under such conditions, there is sufficient and surplus oxygen in the explosion space, so that there is still a tendency for the explosion to be more violent. When the lignite dust cloud mass concentration is greater than 400 g/m$^3$ and less than 500 g/m$^3$, after the lignite dust cloud is ignited, the volatile release rate of the lignite dust particles becomes larger; it means that the volume of the volatile gas released from lignite dust particles increases due to the increase in the number of lignite dust particles.

Table 2. Explosion Pressure under the Condition of Different Lignite Dust Cloud Mass Concentrations

| $c$ (g·m$^{-3}$) | $m$ (g) | $P_{\text{max}}$ (MPa) | $(dP/dt)_{\text{max}}$ (MPa·s$^{-1}$) |
|----------------|--------|------------------------|-----------------------------------|
| 325            | 6.5    | 0.75                   | 68.21                             |
| 350            | 7      | 0.79                   | 71.55                             |
| 375            | 7.5    | 0.80                   | 73.80                             |
| 400            | 8      | 0.82                   | 76.19                             |
| 425            | 8.5    | 0.77                   | 73.94                             |
| 450            | 9      | 0.73                   | 71.68                             |
| 475            | 9.5    | 0.71                   | 69.61                             |
| 500            | 10     | 0.70                   | 68.08                             |

$^a$ $c$, lignite dust cloud mass concentration; $m$, the mass of lignite dust put into the dust storage tank.

Figure 5. Inert dust samples: (a) CaCO$_3$, (b) SiO$_2$, and (c) NH$_4$H$_2$PO$_4$.

Figure 6. Coal dust explosion pressure curve.

Figure 7. Explosion pressure under the condition of different lignite dust cloud mass concentrations.
Table 3. Suppression Effect of Three Types of Inert Dust on the Lignite Dust Explosion Pressure Characteristics

|  | CaCO₃ |  | SiO₂ |  | NH₄H₂PO₄ |
|---|---|---|---|---|---|
| \( p \) (%) | \( P_{\text{max}} \) (MPa) | \( (dP/dt)_{\text{max}} \) (MPa·s⁻¹) | \( P_{\text{max}} \) (MPa) | \( (dP/dt)_{\text{max}} \) (MPa·s⁻¹) | \( P_{\text{max}} \) (MPa) | \( (dP/dt)_{\text{max}} \) (MPa·s⁻¹) |
| 0 | 0.82 | 76.19 | 0.82 | 76.19 | 0.82 | 76.19 |
| 10 | 0.76 | 70.63 | 0.75 | 69.15 | 0.71 | 62.78 |
| 20 | 0.68 | 65.73 | 0.63 | 64.48 | 0.62 | 55.26 |
| 30 | 0.61 | 60.19 | 0.57 | 56.03 | 0.55 | 48.09 |
| 40 | 0.56 | 50.31 | 0.53 | 46.62 | 0.47 | 39.72 |
| 50 | 0.50 | 44.15 | 0.45 | 37.17 | 0.35 | 30.64 |
| 60 | 0.44 | 35.49 | 0.40 | 32.27 | 0.16 | 16.78 |
| 70 | 0.39 | 29.16 | 0.35 | 26.42 | 0 | 0 |

\( ^{\text{a}}p \), mass percentage of inert dust mixed into lignite dust.

Figure 8. Suppression effect of inert dust on \( P_{\text{max}} \).

Figure 9. Suppression effect of inert dust on \( (dP/dt)_{\text{max}} \).

\( \text{NH}_4\text{H}_2\text{PO}_4 \) have a significant suppression effect on the lignite dust explosion.

Some previous studies also have related results on the suppression effect of inert dust on coal dust explosion\(^{25\text{-}26} \) to compare with the previous research results, in Table 4, it shows the comparison between the results of this paper and the previous research results of explosion suppression on \( P_{\text{max}} \).

Table 4. Comparison between This Paper and the Previous Research Results of Coal Dust Explosion Suppression on \( P_{\text{max}} \)

|  | CaCO₃ |  | SiO₂ |  | NH₄H₂PO₄ |
|---|---|---|---|---|---|
| \( p \) (%) | \( \varepsilon_1 \)% | \( \varepsilon_2 \)% | \( \varepsilon_1 \)% | \( \varepsilon_2 \)% | \( \varepsilon_1 \)% | \( \varepsilon_2 \)% |
| 50 | 39.0 | 42.9 | 45.1 | 46.5 | 57.3 | 55.2 |

\( ^{\text{a}}p \), mass percentage of inert dust mixed into coal dust; \( \varepsilon_1 \), percentage reduction of \( P_{\text{max}} \) under explosion-suppressed conditions obtained in this study; \( \varepsilon_2 \), percentage reduction of \( P_{\text{max}} \) under explosion-suppressed conditions obtained in previous research.
As shown in Figures 8 and 9, although three types of inert dust have a suppression effect on coal dust explosion, different types of inert dust have different suppression effects on the coal dust explosion pressure characteristics. When the mass percentages of different types of inert dust mixed into coal dust are the same, the inert dust of NH$_4$H$_2$PO$_4$ is relatively more effective in suppressing the coal dust explosion. When the mass percentage of NH$_4$H$_2$PO$_4$ dust mixed into coal dust is 70%, the coal dust explosion no longer occurs, indicating that the lignite dust has completely lost its explosiveness under the explosion suppression effect of NH$_4$H$_2$PO$_4$ dust. In terms of the explosion suppression effect, compared with the inert dust of CaCO$_3$ and SiO$_2$, the NH$_4$H$_2$PO$_4$ dust has a relatively poor suppression effect on coal dust explosion. Considering that the particle size of inert dust has a significant impact on the explosion suppression effect, therefore, it is necessary to further study the suppression effect of NH$_4$H$_2$PO$_4$ dust with different particle sizes on coal dust explosion.

3.4. Suppression Effect of the Inert Dust NH$_4$H$_2$PO$_4$ with Different Particle Sizes on Lignite Dust Explosion.

To discuss the suppression effect of the particle size of NH$_4$H$_2$PO$_4$ on lignite dust explosion, on the basis that the particle size of NH$_4$H$_2$PO$_4$ is greater than 58 μm and less than 75 μm, NH$_4$H$_2$PO$_4$ with particle sizes of 0–25, 25–38, 38–48, and 48–58 μm are selected for further explosion suppression experiments. The parameters of lignite dust are as follows: the mass concentration of the lignite dust cloud is 400 g/m$^3$, and the particle size of lignite dust is greater than 58 μm and less than 75 μm. The experimental results of lignite dust explosion suppression by NH$_4$H$_2$PO$_4$ with different particle sizes are shown in Table 5, and the experimental data are plotted in Figures 10 and 11. It can be found that in the particle size range of 0–75 μm, the smaller the particle size of the NH$_4$H$_2$PO$_4$, the better the suppression effect on the explosion pressure of micron-sized lignite dust.

In Figure 10, it is found that when $p$ is less than 10%, the suppression effect of NH$_4$H$_2$PO$_4$ dust on $P_{\text{max}}$ is very obvious, and the downward trend of the explosion suppression curve is very large. However, when $p$ is greater than 10% and less than 40%, the downward trend of the explosion suppression curve is smaller than that when $p$ is less than 10%, which indicates that the suppression effect of NH$_4$H$_2$PO$_4$ on $P_{\text{max}}$ is not linear. When $p$ is greater than 10% and less than 40%, the suppression effect of the inert dust particles on $P_{\text{max}}$ becomes smaller. When $p$ is greater than 40%, since the concentration of the NH$_4$H$_2$PO$_4$ dust particles increases, so that the heat transfer between lignite dust particles and the surrounding space can be better controlled. Therefore, the suppression effect of the inert dust particles on $P_{\text{max}}$ increases again; the downward trend of the explosion suppression curve also becomes larger again.

By comparing the explosion suppression effects of NH$_4$H$_2$PO$_4$ dust with different particle sizes on the explosion pressure characteristics of lignite dust, it can be seen that under the condition that the particle size of the inert dust NH$_4$H$_2$PO$_4$ is 25–38 μm, when the mass percentage of NH$_4$H$_2$PO$_4$ dust mixed into lignite dust is 60%, the lignite dust no longer explodes, which further verifies that the NH$_4$H$_2$PO$_4$ dust has a good suppression effect on the lignite dust explosion. When the particle size of the NH$_4$H$_2$PO$_4$ dust mixed into the lignite dust is 0–25 μm, the explosion intensity is relatively minimal. Under the condition that the mass percentage of NH$_4$H$_2$PO$_4$ dust mixed into lignite dust is 50%, when the particle size of the NH$_4$H$_2$PO$_4$ dust is reduced from 58–75 to 0–25 μm, the $P_{\text{max}}$ under the explosion suppression condition is reduced from 0.35 to 0.17 MPa; at the same time, the (dP/dt)$_{\text{max}}$ under the explosion suppression condition is reduced from 30.64 to 12.84 MPa/s, indicating that decreasing the particle size of the

### Table 5. Suppression Effect of the Particle Size of the Inert Dust NH$_4$H$_2$PO$_4$ on the Lignite Dust Explosion Pressure$^a$

| $p$ (%) | $P_{\text{max}}$ (MPa) | (dP/dt)$_{\text{max}}$ (MPa·s$^{-1}$) | $P_{\text{max}}$ (MPa) | (dP/dt)$_{\text{max}}$ (MPa·s$^{-1}$) | $P_{\text{max}}$ (MPa) | (dP/dt)$_{\text{max}}$ (MPa·s$^{-1}$) | $P_{\text{max}}$ (MPa) | (dP/dt)$_{\text{max}}$ (MPa·s$^{-1}$) |
|--------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 0      | 0.82            | 76.19            | 0.82            | 76.19            | 0.82            | 76.19            | 0.82            | 76.19            |
| 10     | 0.58            | 50.39            | 0.63            | 52.61            | 0.66            | 56.42            | 0.68            | 59.20            |
| 20     | 0.47            | 41.28            | 0.54            | 44.05            | 0.57            | 47.98            | 0.59            | 51.72            |
| 30     | 0.39            | 36.55            | 0.45            | 39.57            | 0.49            | 43.14            | 0.52            | 45.36            |
| 40     | 0.30            | 25.86            | 0.33            | 29.04            | 0.41            | 32.50            | 0.44            | 35.88            |
| 50     | 0.17            | 12.84            | 0.22            | 16.72            | 0.28            | 22.87            | 0.31            | 26.79            |
| 60     | 0               | 0                | 0               | 0                | 0               | 0                | 0               | 0                |
| 70     | 0               | 0                | 0               | 0                | 0               | 0                | 0               | 0                |

$^a$ $p$, mass percentage of NH$_4$H$_2$PO$_4$ mixed into lignite dust.
NH₄H₂PO₄ dust plays an important role in reducing the explosion intensity of lignite dust.

### 3.5 Analysis on the Suppression Effect Mechanism of Different Types of Inert Dust on Lignite Dust Explosion

In the experimental part of this paper, the reason for selecting NH₄H₂PO₄ dust for explosion suppression research is that the inorganic compound NH₄H₂PO₄ is the main component of fire extinguishing agents in many industrial fire extinguishers. Based on the experimental results, the explosion suppression effects of CaCO₃ and SiO₂ can be compared. It is known that the relative molecular masses of CaCO₃ and SiO₂ are 100 and 60, respectively, so the molar masses of CaCO₃ and SiO₂ are 100 and 60 g/mol, respectively, and the ratio of their molar masses is 5:3. To compare the explosion suppression effects of CaCO₃ and SiO₂ under the same molar conditions, the explosion suppression analysis should be carried out under the condition that the ratio of \( p \) of CaCO₃ and SiO₂ is also 5:3. In Table 3, according to the explosion suppression data of CaCO₃ under the condition of \( p = 50\% \) and the explosion suppression data of SiO₂ under the condition of \( p = 30\% \), it can be obtained that the \( P_{max} \) values under the inhibition of two types of inert dust are 0.5 and 0.57 MPa, respectively, and the \( \frac{(dP/dt)_{max}}{\max} \) values are 44.15 and 56.03 MPa/s, respectively. This shows that under the same mole of inert dust, CaCO₃ has a more significant suppression effect on the lignite dust explosion than SiO₂. However, the explosion suppression effect of both is not as effective as that of NH₄H₂PO₄ dust.

Compared with the suppression effect of CaCO₃ dust and SiO₂ dust on lignite dust explosion, NH₄H₂PO₄ dust has a more effective explosion suppression effect; it is mainly because the explosion suppression process of NH₄H₂PO₄ dust includes chemical explosion suppression. The physical suppression effect of CaCO₃ dust and SiO₂ dust in the process of lignite dust explosion is mainly reflected in that when they are mixed into lignite dust particles, the heat transfer among lignite dust particles is reduced. However, NH₄H₂PO₄ dust not only plays the role of diluting oxygen concentration and reducing temperature but also can be decomposed to generate NH₃, H₂O, and P₂O₅ under heating conditions, as shown in Figure 12. As a solid product, P₂O₅ can be mixed with lignite dust particles, which will physically suppress the explosion by isolating oxygen. As two gas products, NH₃ and H₂O can dilute the concentration of oxygen. In addition, the thermal decomposition reaction of NH₄H₂PO₄ is endothermic, which can reduce the ambient temperature, making the lignite dust particles unfavorable for ignition, so that the combustion chain reaction is interrupted.

### 4. CONCLUSIONS

The aim of this study is to get better understanding of the suppression effect of different types of inert dust on the lignite dust explosion pressure characteristics. The following results are obtained.

The lignite dust cloud mass concentration has an obvious effect on the lignite dust explosion pressure characteristics. As the lignite dust cloud mass concentration increases in the range of 300 to 500 g/m³, both \( P_{max} \) and \( \frac{(dP/dt)_{max}}{\max} \) increase first and then decrease. When the lignite dust cloud mass concentration is 400 g/m³, the lignite dust explosion in the spherical space is at the most violent state.

By carrying out the explosion suppression experiment of inert dust on lignite dust, it is found that the \( P_{max} \) and \( \frac{(dP/dt)_{max}}{\max} \) of lignite dust explosion decrease continuously as the mass percentages of inert dust mixed into lignite dust increase from 0 to 70%, indicating that the inert dust of CaCO₃, SiO₂, and NH₄H₂PO₄ have a significant suppression effect on the lignite dust explosion. When the mass percentage of NH₄H₂PO₄ dust mixed into lignite dust is 70%, the lignite dust explosion no longer occurs, indicating that the explosion suppression effect of NH₄H₂PO₄ dust is more effective than that of CaCO₃ and SiO₂.

The smaller the particle size of the inert dust NH₄H₂PO₄ in the particle size range of 0–75 μm, the more obvious the suppression effect on the lignite dust explosion pressure characteristics. Under the condition that the particle size of the inert dust NH₄H₂PO₄ is 25–38 μm, the lignite dust no longer explodes when the mass percentage of NH₄H₂PO₄ dust mixed into lignite dust is 60%, which verifies that decreasing the particle size of the NH₄H₂PO₄ dust is important to reduce the lignite dust explosion intensity.

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*Figure 12. Suppression effect of NH₄H₂PO₄ dust on coal dust explosion.*
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Notes
The authors declare no competing financial interest.

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