Scholar Publishing Group
Kinetic Mechanical Engineering
https://doi.org/10.38007/KME.2021.020103
ISSN 2790-2676 Vol. 2, Issue 1: 16-28

The Chemical Dynamics of Gas Explosion in a Confined Space

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Keywords: Confined Space, Gas Explosion, Inert Gas, Explosion Suppression, Chemical Dynamic Characteristics

Abstract: The gas explosion is the most common accident in China's coal mine oil and gas industry, which seriously affects the safety of people's lives and property. Although a lot of energy has been invested, it still cannot completely solve the problem. The fine water mist explosion suppression technology was first applied to the field of fire protection. Due to its many advantages such as environmental protection, cheapness, and high efficiency, it has gradually attracted experts and scholars to study it extensively and achieved many results. But in the field of coal mine disaster prevention and control research and application is relatively few. This paper mainly studies the chemical dynamic characteristics of inert gas to gas explosion in confined space. In this paper, the effect of inert gas on the explosion in confined space is used for experiments. In order to study the effect of inert gas on gas explosion, a medium-sized gas explosion experiment device was used for gas explosion experiments under the conditions of nitrogen volume fractions of 0%, 9%, and 14%. The effects of inert gas nitrogen on the explosion overpressure during gas explosion were compared and analyzed. The results show that nitrogen has good explosion-proof performance, which can significantly reduce gas explosion overpressure, and the maximum reduction can be reduced by more than 90%. When the nitrogen concentration is low, the impact of methane explosion is reduced, but the methane explosion limit range is gradually reduced. At the same time, under the same methane concentration, the effect of adding nitrogen on the methane explosion limit is obvious; filling the gas sample with nitrogen can reducing the concentration of reactants, inhibiting the dissociation of free radicals, reducing the concentration of reaction activation centers, and thereby reducing the intensity of gas explosions. According to the influence rule of inert gas on gas explosion, the influence rule of inert gas on gas explosion is obtained, which provides corresponding reference for improving disaster prevention and reduction capabilities.

1. Introduction

With the continuous progress and development of society, energy consumption is also increasing. When people use energy for production and living, they also cause serious environmental pollution problems [1]. Therefore, in order to meet the needs of social production and residents 'lives, and also reduce environmental pollution problems, natural gas, liquefied petroleum gas, and other clean combustible gas fuels have been widely used in industrial production and residents' lives because of their low environmental pollution after combustion [2-3]. Methane is the simplest known organic substance, and it is widely distributed in nature. Methane is natural gas, of which the main components are biogas and mine gas. It has become an important fuel and chemical raw material widely used in people's production and life[4]. Due to the flammable and explosive nature of methane, the safety issues during its development, storage, and use have always attracted much attention. In particular, coal mine gas explosions and gas leakage gas explosions often occur, causing significant loss of lives and property safety to the people, which has attracted the attention of all countries in the world. Therefore, the gas explosion has always been the focus of people's attention [5-6]. The major gas explosion that occurred at Chongqing Jinshangou Coal Industry Co., Ltd. on October 31, 2016 and the major gas explosion that occurred at Chifeng BMW Mining Co., Ltd. in Inner Mongolia Autonomous Region on December 3, 2016 is particularly serious.The State Council has been issued the latest important instructions on the two major gas explosions that caused major casualties and property damage. Although coal mine safety accidents have been declining in recent years, the total number of gas accidents is still large, and major accidents such as gas explosions have not been effectively contained. [7-8]. More than 27% of coal mines in China are high gas and 5 gas outburst mines, and with the continuous increase of mining intensity, the proportion of high gas mines is still gradually increasing, and mine gas disasters are very serious [9-10]. Gas explosion is one of the main forms of coal mine disasters in China, and it is very sudden and destructive [11].From 2001 to 2014, more than 4,000 gas disasters occurred in coal mines across the country, killing more than 17,000 people. On average, more than 4.25 people died in each accident. Among them, more than 90% of major gas accidents that kill more than 10 people each year are caused by gas explosions. Caused huge economic losses to our country, seriously threatened people's lives [12-13]. How to effectively prevent and control gas explosions in practice and how to minimize the damage caused by gas explosions are of great significance [14]. Experts and scholars at home and abroad have done a lot of research on gas explosion suppression technology. At this stage, the main technical measures for gas explosion prevention in China include: explosion-proof water bags, explosion-proof rock powder sheds, and ZGB-Y automatic explosion-proof devices.The above-mentioned explosion-proof technology has been applied in coal mines, although it can be used to a certain extent. Controlling the degree and scope of gas explosion hazards, but there are still certain shortcomings, it is necessary to open up new ways for mine gas prevention and control [15-16]. Research on inert gas explosion suppression technology has begun at an early age internationally. By adding N2, CO2, Ar, etc. to the methane-air premix, scientists have studied the effects of different inert gases on their combustion, which has led to the development of inert gas suppression explosion technology [17].

Gas explosion has always been a common problem in mines, oil and gas, and many people have done a lot of research on it. According to a study by Ki-Yeob Kang . Since gas explosions are the most common accident in the oil and gas industry, all safety-related key elements on top of offshore platforms should maintain their integrity to cope with extreme pressure requirements. Although much effort has been invested to develop explosion-proof design methods for offshore structures, there are still some issues that require further research. A flame acceleration simulator (FLACS) is commonly used to determine the duration of a triangle blasted design pressure curve with a fully positive direction from the absolute area of each measured transient pressure response. However, unlike gas explosions or TNT explosions, the negative phase pressure in general gas explosions is often critical [18]. B.-S. Nie and others analyzed the phenomenon of bright spots in the observation window during the gas explosion. The results show that soot particles with high heat radiation characteristics can produce such strong light. Characteristic gas adsorption method (LP-N2GA), scanning electron microscope (SEM), and transmission electron microscope (TEM) methods for studying soot pores and surface structure based on low-pressure nitrogen. The results show that the soot particles are composed of abundant spherical aggregates with a diameter ranging from 4 μm to 50 μm. The particle surface is well developed, and some particles have ablation characteristics. Soot aggregates are grape-like, and some primary particles are bound together. From the TEM image, most particles are 100 nm in diameter. To study the effect on gas explosions [19]. M studied the effect and mechanism of charged water mist on gas explosion overpressure, used small pipes to simulate gas explosion, and studied the gas explosion overpressure and average overpressure rise rate under different charging voltages. His results show that with the increase of the charging voltage, the propagation overpressure of the gas explosion and the rise rate of the average overpressure are significantly suppressed, while the explosion overpressure of the gas decreases significantly with the increase of the flux. Under the experimental conditions, when the fog flow rate is 4L and the charging voltage is 8kV, the gas explosion propagation overpressure decreases by 10.798 kPa, a decrease of 49.78%; the average overpressure rise rate decreases by 180.468kPa / s, a decrease of 49.90%. However, there are many reasons for the gas explosion, not just this one [20].

Many scholars at home and abroad have done a lot of research work on suppressing gas explosions, but mainly focused on the research of fine water mist. Fine water mist technology was first applied to fire fighting. With the continuous development and research of fine water mist technology, fine water mist technology can also achieve good results in suppressing gas explosions. A large number of experimental studies have proven that adding inhibitors or forming two-phase flow and two-fluid fine water mist through charged fine water mist to suppress explosion is better than using fine water mist alone. This paper draws on the existing technology research. The method of suppressing gas explosion in mines by charging inert gas has also attracted much attention. Because carbon dioxide and nitrogen have the advantages of wide sources and low production costs, scholars at home and abroad generally use it as an ideal inert gas in the research of gas explosion suppression. Therefore, an inert gas explosion suppression technology is proposed to study the effect of inert gas on gas explosion in confined spaces. In this paper, the effects of inert gas on gas explosion are used to carry out experiments to obtain the propagation of gas explosion under the influence of inert gas.

2. Proposed Method

2.1. Basic Forms of Gas Explosion

Explosion refers to the abrupt release of energy in a short period of time accompanied by sound, light, and heat. Here is a brief overview of the basic forms of flammable gas explosions:

Constant pressure combustion: The combustion process maintains a constant pressure, which usually occurs in an open system. The combustion process is a stable reaction, and the energy generated by the combustion process can be released to the outside world in a timely manner. The research on constant pressure combustion is relatively early. At this stage, the theory is basically mature and it is widely used.

Deflagration: An explosion that travels at a subsonic speed. Compared with constant pressure combustion, the biggest difference in deflagration is that the pressure on the combustion front due to external constraints or the presence of obstacles disturbs the unburned gas, which propagates before the front of the combustion front, so it is also called front pressure wave. Therefore, the deflagration is in the shape of "two waves and three zones", which is composed of the combustion flame front and the precursor pressure wave. When there are more constraints or obstacles that affect deflagration, the coincidence of the flame front and the predecessor pressure wave will form a detonation. The detonation is extremely harmful, which will be explained later.

Detonation: An explosion that travels at supersonic speeds. Detonation has a fast propagation speed and high pressure, which can cause great harm to people and environmental equipment, and has great destructive power. It is the highest form of flammable combustion explosion.

Constant volume explosion: The process of combustion and explosion caused by uniformly mixing combustible materials and combustion-supporting materials in a certain volume of container. Due to the limitation of actual conditions, the flame usually diffuses gradually from the local to the whole, and it is difficult to meet the conditions of constant volume explosion, so it belongs to the ideal model.

2.2. Gas Explosion Mechanism

Gas explosion is a rapid chemical reaction caused by combustible gases such as methane and oxygen in the air. In the reaction process, methane and oxygen molecules are first separated into a series of free radicals. These free radicals have great chemical activity, and can interact with CH4 and oxygen molecules to generate new free radicals. Explosive reactions occur when chain reactions occur. The reaction automatically accelerates the reaction by accumulating activation centers.The concentration of reactants and activation centers is the main factor of the methane chain explosion reaction, and the accumulation and loss of heat cannot determine the progress of the reaction. Of course, experiments also show that temperature has a greater effect on the rate of reaction chain formation. Increasing temperature will promote the formation of activation centers and accelerate the reaction rate, so the mechanism of methane explosion reaction is mainly chain explosion. And the chain reaction contains some thermal processes.

The explosion reaction of methane must also have certain temperature and energy conditions. At lower temperatures (<2000 °C), the mixed reaction of hydrocarbons and oxygen is very slow, the total reaction is very small, and it is not easy to form an explosion. Scientists point out that only molecules with energy exceeding a certain value can produce chemical reactions. The chain initiation of the methane explosion reaction requires a certain amount of energy to break the CH chemical bond and generate free radicals. In order to propagate the flame, the reaction rate must be very fast, that is, higher temperatures are required. Therefore, the ignition source must be used to bring the low temperature mixture into a high temperature explosion state. The minimum temperature and minimum energy required for the combustion or explosion of methane are referred to as the minimum ignition temperature and the minimum ignition energy, respectively.The minimum ignition temperature of methane is 5950C, and the minimum ignition energy is 0.28mJ.

The process of gas explosion is extremely complicated. There are two types of methane explosion mechanisms summarized from existing studies: thermal explosion theory and chain reaction theory.

According to the theory of thermal explosion, in the explosive system, the heat generated by the reaction of the system is greater than the heat lost to the outside by the system. As the energy is continuously accumulated in the system, the temperature of the system gradually increases. The ultimate thermal explosion theory of this reaction is that in an explosive system, the heat generated by the system reaction is greater than the heat lost to the outside by the system. As the energy continues to accumulate in the system, the system temperature gradually increases. In this reaction process, the energy in the exothermic system of the chemical reaction accumulates, and the temperature rises.At the same time, the reaction rate accelerates as the temperature increases. Under such repeated cycles, the reaction rate becomes faster and faster until it occurs explosion.

The chain reaction theory believes that the gas explosion process is a complex chain reaction process. As the reaction proceeds, free radicals will gradually accumulate in the system, and the reaction speed will increase with the increase of free radicals until the explosion reaction occurs. During the accumulation of free radicals, the number of free radicals in the system is the key to whether an explosive reaction can occur.Because of the dual influence of the factors of free radical growth and destruction in the chain reaction, when there are more free radical growth factors than destruction factors, when the free radical accumulation in the system gradually accumulates, the system will explode when the free radical accumulation rate reaches a certain value.

2.3. Influencing Factors of Gas Explosion

There are many factors that affect the explosion of flammable gases, including: the essential characteristics of the gas, the environmental impact, and the characteristics of the ignition source.

(1) Essential characteristics of gas

Combustible gas and air in the air are premixed to form a mixed gas cloud, and its explosion intensity and ease of ignition are affected by the nature of the combustible cloud. The main factors are the following:

1) Different types of combustible gas. The activity, reaction rate and diffusion method are different. The gas molecules with strong activity move fast, the reaction process is violent, and the possibility of deflagration and detonation increases. The type of flammable gas will largely affect the explosion intensity, type of explosion and consequences of the gas cloud.

2) Combustible gas density is analyzed from the perspective of causing hazards.When the combustible gas density is larger than the air density, the combustible gas accumulates near the ground surface. If an explosion occurs, or even a deflagration or detonation occurs, it will have a huge impact on the surrounding personnel, equipment and environment. On the contrary, if the density of combustible gas is lower than the density of air, the gas moves up, and a cloud of gas is formed at high altitude, the explosion hazard will be reduced. Therefore, it is necessary to comprehensively analyze the density and type of combustible gas when predicting the hazard of combustible explosion.

3) Combustible gas concentration. However, when the concentration of gas cloud meets the ignition source within the explosion limit range, it will violently burn and form an explosion. The difference in concentration has a significant effect on the burning rate and heat release. Research shows that the most dangerous concentration is 1.1 to 1.5 times the stoichiometric concentration. At this time, the reaction speed and reaction heat will reach the maximum, the explosion intensity will be the highest, and the harm will be the greatest.

4) Gas cloud size. During the accumulation of combustible gas to form a gas cloud, the result may produce gas clouds with significantly different sizes. For different sizes of gas clouds, the combustion methods and the types of explosions produced are quite different. Generally speaking,

the larger the size of the gas cloud is, the higher the explosion intensity is, but the intensity and size are not a linear relationship in theory.

(2) Environmental factors

The explosion effect of gas clouds is largely limited by the terrain conditions. For example, in low-lying valleys or basins, combustible gas accumulates at the bottom to reach the explosion limit. When it encounters a source of ignition, the shock wave formed is blocked by the mountain. The pressure near the explosion site will rise sharply in a short time. Its explosion intensity and harmfulness are intensified.

From the analysis of the flammable gas explosion in the confined space studied in this paper, due to the limited space, once the methane gas is generated and accumulated to reach the explosion limit, in the presence of the ignition source, due to environmental factors, its explosion is the same as that in the open ground. Explosions will do more harm. Therefore, it is necessary to analyze and consider the terrain environmental conditions.

At the same time, according to the foregoing, due to the presence of binding forces or obstacles, it has a greater impact on the combustion process, and then exploded into explosive forms such as deflagration and detonation. Therefore, the analysis of binding forces or obstacles has positive significance for the study of this paper.

Constraints refer to objects that restrict the gas cloud to a certain status and volume, usually at the boundary of the gas cloud. When an explosion occurs inside a gas cloud, an object whose flame propagation is hindered but can eventually be passed is called an obstacle. If there are constraints or obstacles around the combustible cloud, combined with this article, methane gas accumulates in a manhole and explodes when it encounters a fire source. In a confined space, its pressure rises. The more constraints, the more complicated the obstacle conditions, the pressure changes are more violent and may cause greater harm. We must pay attention and prevent them.

(3) Ignition source characteristics

Ignition sources are divided into different types due to their energy: strong ignition sources, generally with ignition energy above 1000J; weak ignition sources with ignition energy below 100mJ. Weak ignition source can only cause deflagration, the magnitude of pressure is in kPa; strong ignition source can directly achieve detonation, the magnitude of pressure is in MPa, and its scope has exceeded the study of disasters, and will not be repeated. The effect of different ignition positions on the magnitude of the pressure. Generally speaking, the ignition of the edge of gas cloud is weaker than the ignition caused by the central pressure.

2.4. Selection of Reaction Mechanism Model

GRIMech 3.0 has been recognized as the most ideal methane combustion mechanism model. This model was funded by the Gas Research Institute of the United States, and is the result of a large number of well-known combustion research groups in the world. GRIMech 3.0 was finally constructed in February 2000.

The GRIMech3.0 model is optimized by GRIMech1.2 and GRIMech2.11 (including 77 rate constants and 31 rate constants), and on this basis, more detailed chemical reaction steps such as CH3 + H, CH3 + OH and CH3 + O2, oxidation products of propane and C2, etc. Generally, GRIMech 3.0 can well predict the ignition delay time and laminar combustion rate of methane under high temperature conditions, and the error rate is low. The error is less than 7%). However, because GRIMech 3.0 has not been optimized in detail for low temperature conditions, the predicted value of GRIMech 3.0 under high temperature conditions is relatively high.

GRIMech 3.0 chemical reaction mechanism includes 53 components and 325 elementary reactions. For premixed reaction systems, GRIMech 3.0 uses a temperature range of 1000 ~ 2500K, a pressure range of 0.001333MPa ~ 1.0MPa, and an equivalent ratio range of 0.1 ~ 5.

Another mechanism model is USCMech2.0, created by the Wang Group of the University of Southern California in 2007. This model has been verified by a large number of reliable basic combustion data, and the applicable range is (T = 900-2625K, P = 0.01-10MPa), which can be used to study the ignition delay time and laminar combustion rate.

2.5. Impact on Gas Explosion in Different Environments

In order to study the explosion characteristics of methane in two different states, macro static and turbulent, the researchers used a spherical gas explosion reaction device to perform related experiments. The results show that the explosion limit of methane is not significantly affected by its external state, while avoiding and reducing turbulence plays an important role in suppressing the process of mine gas explosion. Based on previous experiments, the researchers changed the turbulence intensity by installing agitating rotors in the test vessel. By designing experiments, the researchers set up three-dimensional obstacles of different shapes in the horizontal pipeline, and concluded that the existence of the three-dimensional obstacles caused the flame's propagation speed, the maximum explosion pressure, and the rate of maximum explosion pressure to rise significantly. Based on the theoretical analysis of the explosion limit, the researchers established a system for measuring the explosion limit of methane under the coupling of temperature and pressure. The experimental results show that the upper and lower limits of methane explosion will increase under the condition that the ambient temperature and pressure increase. The impact of the upper explosion limit is greater. The researchers analyzed the danger of low-concentration gas explosions. The explosion danger gradually increased with the increase of temperature and pressure, and the rate of increase of the danger gradually slowed down.

Explosions in gas mixtures are the most common explosion phenomenon in gas explosion accidents.This gas mixture is generally a mixture of combustible gas and gas.They do not explode in any proportion. They can only explode when they are within the explosion limit. For the mixed explosion of multiple flammable gases and gas, scholars at home and abroad have conducted a lot of research in recent years, and have also obtained rich research results.

The researchers carried out corresponding experimental research on the explosion characteristics of the multi-element gas composed of several kinds of spontaneous combustion indicators, such as carbon monoxide, ethylene and methane. The analysis found that carbon monoxide has a certain damping effect on multi-element gas and a great influence on the explosion limit of the multi-element gas mixture. The researchers used a 20L spherical experimental device to study the effect of hydrogen on the gas explosion characteristics, and compared the results with the theoretical calculation method. The results show that the presence of hydrogen will greatly reduce the lower explosion limit of methane, and will also increase risk of methane explosion. Peng Fei has studied the explosion characteristics of gas such as hydrogen, butane, hexane and other combustible gases in the mine, and conducted a comparative study through experiments. Among them, in terms of the maximum explosion pressure, hydrogen has the largest impact, followed by hexane. Butane has the least impact. Researchers have studied the explosion characteristics of low-concentration methane in other combustible gases with hydrogen as the main component in the mine. The existence of multiple combustible gases increases the risk of low-concentration methane explosion.

2.6. Inert Gas Explosion Suppression Mechanism

Adding inert gas to the explosive chemical reaction system will reduce the concentration of flammable gas and oxygen, so that the flammable gas will not undergo a chemical reaction in an oxygen-depleted environment, so as to achieve the purpose of suppressing the explosion; at the same time, the addition of inert gas will absorb the heat in the reaction process, which will reduce the temperature of the explosive reaction system, which further affects the maximum explosion pressure and chemical reaction rate of methane, which reduces it and plays a role in cooling. Modern combustion studies believe that most combustion reactions are the process of collision and interaction between active molecules with certain energy, so the molecular collision form, activity intensity, collision angle and action direction will produce different reaction rates and get different reaction results. Adding inert gas to gas actually strengthens the three-body reaction in the gas explosion reaction mechanism. As a third body, inert molecules participate in ternary collisions in chain reactions. Under higher explosive pressure, these ternary collision frequencies are higher than the binary collision frequency, which causes the concentration of the active center molecules in the chemical reaction process to drop sharply, so most of the active radicals will be gradually adsorbed by inert gas molecules, resulting the chemical reaction rate decreases, and the danger of gas explosion becomes weaker, so the effect of suppressing gas explosion is achieved.

3. Experiments

3.1. Test Object

In order to investigate the effect of inert gas on gas gas explosion, a medium-sized gas explosion experimental device was used to conduct a gas explosion experimental study under conditions of N2 volume fractions of 0%, 9%, and 14%. The influence of the inert gas N2 on the change of explosion overpressure and the effect of explosion suppression during the gas explosion were compared and analyzed. The collection accuracy of the gas explosion in this experiment is 1Pa, and the response time is 1ms. The material of the exhaust membrane is polytetrafluoroethylene, the actual thickness is 0.4mm, and the burst pressure is 90kPa. The purity of the inert gases CO2 and N2 used in the experiment was 99.99%. The components of the three gas samples G1, G2 and G3 are G1 (7.10% CH4-20.53% O2-73.57% N2), G2 (9.41% CH4-19.11% O2-71.50% N2) and G3 (10.18% CH4-18.79 % O2-70.90% N2), where the number represents the volume fraction of the corresponding component.

3.2. Design and Implementation of Experiments

This series of experiments was performed at 20 °C and 101.0kPa. The system is mainly composed of an explosion cavity, a diffusion line, a vacuum pumping device, a gas distribution device, an ignition device and a data acquisition device. The parameters of the explosion cavity are 400mm × 1600mm, the volume is 100L and the safety factor is 7. The parameters of a single diffuser are 120mm × 2200mm, and the safety factor is 7. In order to achieve the needs of gas distribution and vacuum in the explosion chamber, a plastic film is used to separate the explosion chamber from the diffusion tube and seal it. The outlet of the diffusion pipeline is connected to air, and the interior is filled with air. The explosion tube is an open container. The main steps are as follows:

(1) Arrange the ignition head and seal the film in the experimental device;

(2) Debug and calibrate the test system, and calibrate and install the pressure sensor;
(3) The mixed gas-inert gas mixture is G1 (7.10% CH_4-20.53% O_2-73.57% N_2), G2 (9.41% CH_4-19.11% O_2-71.50% N_2), and G3 (10.18% CH_4-18.79% O_2-70.90% N_2);
(4) Vacuum the explosion chamber to -0.1 MPa, and then fill it with a pre-configured gas-inert gas mixture;
(5) Start data collection

With the increase of the content of inert gas N_2 in the initial mixed gas, the overpressure of gas explosion is significantly reduced, and the inhibitory effect of inert gas on higher concentration gas is significant.

4. Discussion

4.1. Gas G1 Experiment under Working Conditions 1 ~ 3

As the volume fraction of nitrogen injected into the gas sample G1 increased, the gas explosion at each measurement point decreased significantly, indicating that nitrogen has a good effect in suppressing gas explosion, as shown in Figure 1. Let d be the horizontal distance from the ignition end. It can be seen that when d <200cm, the gas explosion over pressure gradually decreases; d = 200 ~ 350cm is the gas explosion wave propagation section, and the explosion value gradually increases, but it is always lower than the measurement point 1. When d = 350 ~ 450cm, the gas explosion gradually decreased again, and finally reached the minimum value. Among them, the explosion over pressure of gas sample G1 decreased by 17.84, 55.55, 39.36, 45.15kPa, respectively, with a decrease of 11.44%, 43.91%, 26.67%, and 35.91%.

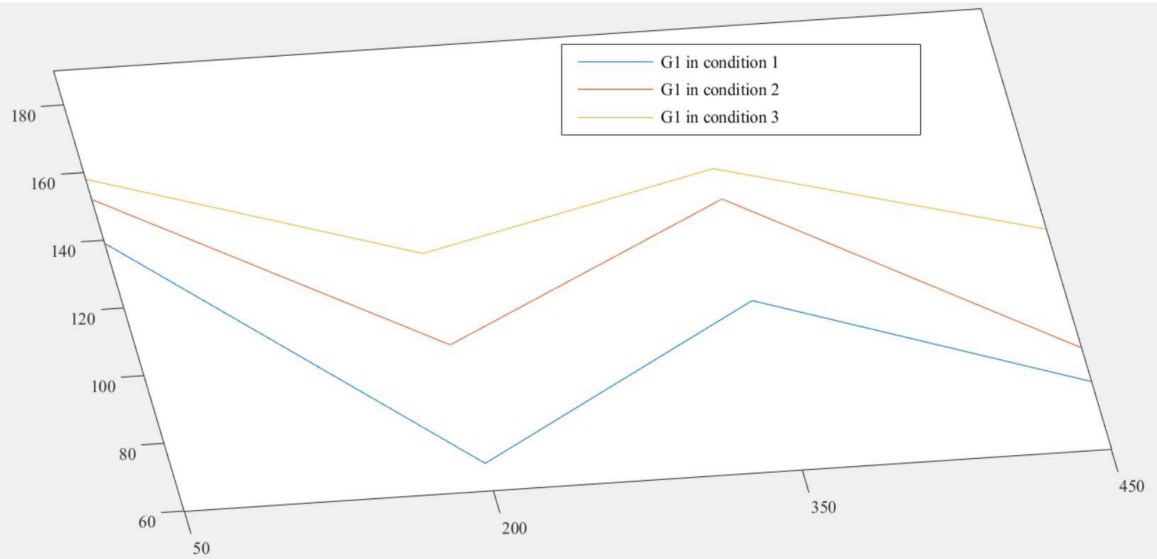

Figure 1. Effect of nitrogen gas on gas sample G1 explosion

4.2. G2 Gas Sample Experiment under Working Conditions 1 ~ 3

Compared with the gas explosion overpressure in working condition 1, the explosion overpressure of gas sample G2 decreased by 41.37, 91.27, 77.71, 89.09kPa, respectively, with a decrease of 24.97%, 54.01%, 42.88%, 52.13%.

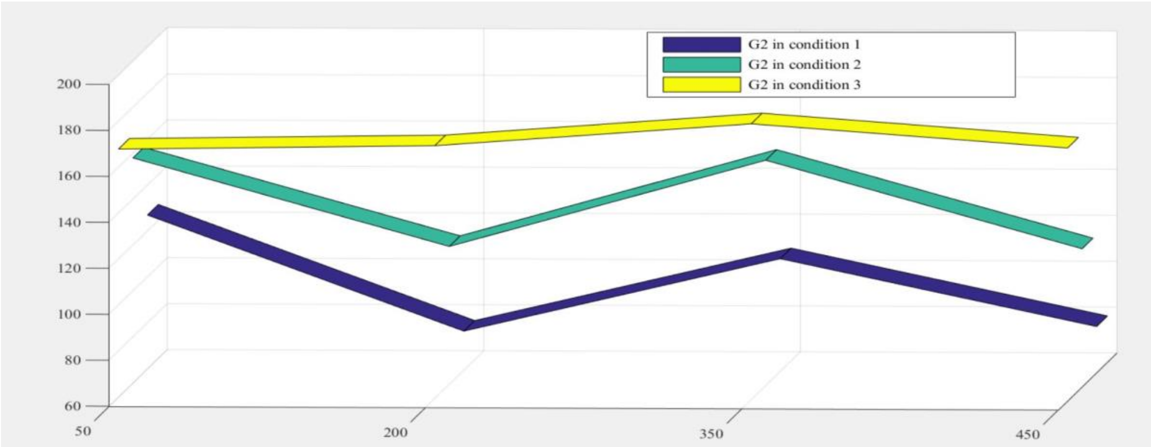

Figure 2. Effect of nitrogen on gas G2 explosion

4.3. Gas Sample G2 under Conditions 1 to 3

Compared with the gas explosion overpressure under working condition 1, the gas explosion overpressure of gas sample G3 has decreased by 29.56, 130.95, 98.91, 126.45kPa, respectively, with a decrease of 20.51%, 90.54%, 73.13%, 97.40%.

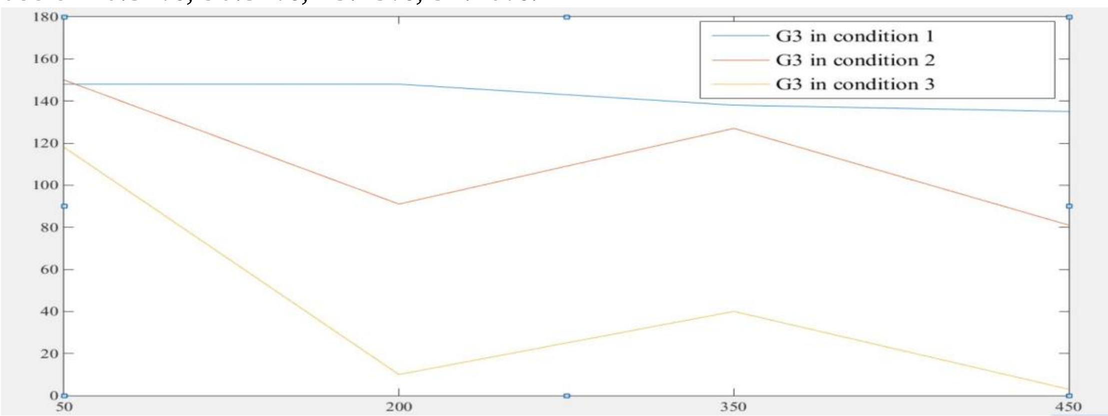

Figure 3. Effect of nitrogen on gas sample G3 explosion

4.4. Gas Explosion Overpressure Curve of Gas Samples G1 ~ G3 under Condition 2

As can be seen from Figure 4, when the concentration of CH4 in the gas sample increased from 7.10% to 9.41%, the gas explosion overpressure at each point increased significantly. Among them, the increase of the overpressure at the fourth measurement point (d = 450cm) is obviously the largest, which is 29.20kPa, an increase of 32.12%. The increase in the overpressure value at the first measurement point (d = 50cm) was the smallest, which was 2.89 kPa, an increase of 1.91%. When the concentration of CH4 in the gas sample was 10.18%, the gas explosion overpressure at each measurement point was significantly reduced (compared with the case where the concentration of CH4 was 7.10%). Among them, the second measurement (d = 200cm) reduced the explosion overpressure by 15.89kPa, which was a decrease of 14.89%; the second measurement (the distance between this point and the ignition end was 350cm) reduced the overpressure value by 16.10kPa, which decreased 11.51%.

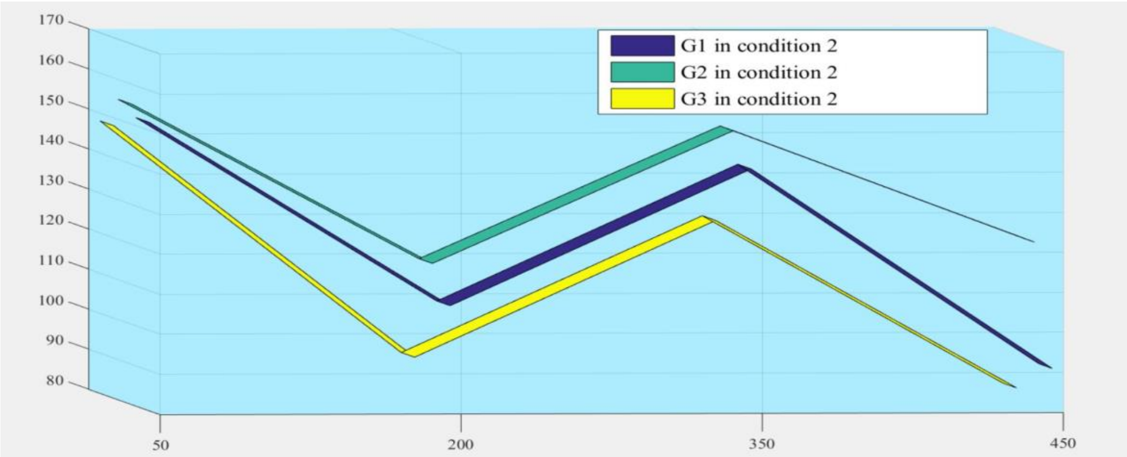

Figure 4. Gas explosion overpressure under condition 2

For gas samples G1, G2, and G3, gas explosion experiments were carried out under conditions 1 to 3, and the gas composition is shown in Table 1. Compared with case 1 (without N2), the original gas sample components in case 2 and case 3 have changed, and the concentration of CH4 and O2 has decreased, and the concentration of N2 has increased. From the analysis of the amount and magnitude of the explosion overpressure reduction, it can be seen that in this experimental system, the inhibitory effect of N2 on the gas-like G3 explosion is most obvious.

Table 1. Gas composition after filling different proportion of Nitrogen in samples G1,G2,G3

Numbering	In condition 1	In condition 2	In condition 3
G1	7.10%CH4-20.53%O2 -73.57%N2	6.32%CH4-17.81%O2 -75.63%N2	6.21%CH4-17.15%O2 -76.70%N2
G2	9.41%CH4-19.11%O2 -71.50%N2	8.60%CH4-17.44%O2 -73.82%N2	8.24%CH4-16.49%O2 -75.22%N2
G3	10.18%CH4-18.79%O2 -70.90%N2	9.34%CH4-17.33%O2 -73.30%N2	8.91%CH4-16.56%O2 -74.81%N2

5. Conclusion

This article uses experimental methods to study the mechanism of inert gas explosion suppression and experimental methods to study the law of inert gas suppression of gas explosion. The research on the inhibitor of methane explosion is a long-term exploration process. In this experiment, nitrogen has a more significant effect on suppressing the explosion of higher concentration gas. Nitrogen has better anti-explosion performance, which can significantly reduce the gas explosion overpressure, with a maximum reduction of 96.20%. When the nitrogen concentration is low, the lower explosion limit of methane is reduced, but the methane explosion limit range is gradually reduced. At the same time, under the same methane concentration, the effect of adding nitrogen on the methane explosion limit (inerting effect) is obvious, and adding the concentration of the depressant at the critical point of the methane explosion limit at nitrogen is small; filling nitrogen in the gas sample can reduce the concentration of reactants, inhibit the dissociation of free radicals, reduce the concentration of the reaction activation center, and thereby reduce the severity of the gas explosion. When the concentration of CH4 is low, as the concentration of nitrogen increases, the suppression of the explosion pressure of CH4 is obvious. When the concentration of CH4 is low, the effect of suppressing gas explosion is not great, and the greater the concentration of methane, the more obvious the inhibitory effect. Inert gas can obviously suppress gas explosion.

The experiments in this paper are mainly composed of explosion chamber, diffusion pipeline, vacuum pumping device, gas distribution device, ignition device and data acquisition device. The parameters of the explosion chamber are 300mm × 1500mm, the volume is 109L, and the safety factor is 6. The parameters of a single diffuser are 125mm × 2200mm, and the safety factor is 6. In order to achieve the needs of gas distribution and vacuum in the explosion chamber, a plastic film is used to separate the explosion chamber from the diffusion tube and seal it. The outlet of the diffusion pipeline is connected to air, and the interior is filled with air. The explosion tube is an open container. So that the closed space can meet the experimental requirements.

The research on inert gas in this paper is not comprehensive enough. Regarding inert gas, different types of inert gas can be selected for experimental research on gas suppression. The mechanism of suppressing gas explosion for different inert gases needs further research. The self-designed research platform for researching the characteristics of gas explosion suppression is used. Although the effect of inert gas on the gas explosion characteristics has been completed, there are still deficiencies and improvements that need to be made. For example, the test requires more operators. The platform is further improved to increase the degree of automation and test efficiency; change the initial conditions of the test such as temperature and ignition energy, etc., and study the effect of inert gases on the propane explosion characteristics under different conditions. Hope to achieve more perfect experiments through unremitting efforts.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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