

Research Progress and Preventive Measures of Combustible Dust Explosion

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Abstract: The research on explosion characteristics of metal dust is reviewed. Summarize and condense the main research results in the field of dust explosion. Its contents include: explosion propagation law, lower explosion limit concentration, maximum explosion pressure, maximum pressure rise rate and ignition source causing dust explosion. Finally, some prevention and mitigation measures for dust explosion are put forward.

Keywords: Propagation law; Lower explosion limit concentration; Maximum explosion pressure; Ignition source.

1. Introduction

The wide application of powder has covered many fields of China's national economic development, and more than 70% of the powder belongs to combustible dust[1][2]. Therefore, there are large explosion-related safety hazards in most powder-related industries[3]. In industrial production, the explosion of dust is often caused by the sudden rise of temperature. The ignition sources such as smoldering caused by dust accumulation and small sparks generated by friction static electricity during transportation can increase the temperature of the nearby dust cloud to the ignition point in the form of heat transfer, and then produce a dust explosion with strong propagation[4]. Therefore, studying the explosion characteristics of combustible dust can provide an effective reference for dust explosion prevention and control. The essence of dust explosion is that combustible dust contacts with oxygen when it encounters fire source, generates oxides, undergoes redox reaction and releases a lot of heat. Therefore, it is concluded that only combustible dust can explode. Although some cement and sand can also form dust clouds, they will not explode because they are not combustible dust. This paper mainly discusses the explosion characteristics of metal dust in polishing and grinding workplace.

2. Propagation Law

Li Gang[5] choose to use starch dust to do experiments in a 1m³ dust explosion test system. By recording the flame propagation speed during dust explosion in S-shaped, U-shaped, vertical elbows and long straight pipes, the flame propagation law during dust explosion was obtained. The conclusion is that under the premise of controlling the consistency of dust concentration, the flame shows a continuous acceleration state in the pipe, but the flame at the corner has a significantly smaller increase than the flame without the corner, indicating that the shape of the pipe has a certain influence on the propagation of the flame. The specific performance is that the elbow hinders the propagation of the flame. Taveau[6] studied the law of flame propagation in small-sized pipes and found that with the decrease of pipe diameter, flame propagation will become extremely difficult, but even so, it can still propagate about 7m in a pipe with a diameter of 25mm. At the same time, for combustible dust, there are usually complex pipeline networks and

transportation systems that are interconnected and interlaced. If combustible dust is accidentally ignited in the process shell, a large amount of heat and high pressure will be generated, and the deflagration pressure will push the fireball through the process interconnection. As turbulence increases, the flame front will stretch and accelerate, exacerbating the severity of the initial event. Finally, when the flame reaches the next process shell, more intense secondary deflagration is likely to occur.

3. Explosive Lower-limit Concentration

The upper and lower limit concentration of dust explosion is the most important content in the study of dust explosion characteristics, and the lower limit concentration of explosion is more important for safety production. According to the requirements of the national standard (determination method of lower limit concentration of dust cloud explosion)GB/T 16425-2018, the experimental device is a spherical explosion tank with a volume of 20L, and a dust diffuser is also placed under the explosion tank. The dust diffuser is connected to a dust storage tank with a volume of six liters, so that the corresponding content of dust is diffused into the test device to determine the lower limit content of dust explosion. The pressure sensor is installed on the side wall of the explosion tank. The pressure sensor is connected with the data recorder. The purpose of the pressure sensor is to collect the data and then analyze it. Moreover, this experimental device is only suitable for the determination of the lower explosion limit concentration of combustible dust with a particle size of less than or equal to 75 microns and a moisture content of less than 5%. The explosion pressure should be less than 0.15MPa and the flame cannot be effectively diffused in the explosion tank as the criterion for judging the lower explosion limit. The ignition energy used in the experiment of the lower limit concentration of dust explosion at home and abroad is different, including: 2.5kJ, 5kJ, 10kJ ignition energy. Therefore, it is of great significance to study the influence of different ignition energy on the lower limit concentration of dust explosion. Hu Weixi[7] completed the detection test of the lower explosive limit concentration under different ignition energy in the 20-litre standard dust explosion characteristic test equipment. Thus, the change of the lower explosion limit concentration in the dust with the ignition

energy is determined. The experimental results show that the lower limit content of dust explosion decreases with the increase of ignition energy.

4. Maximum Explosion Pressure, Maximum Pressure Rise Rate

Fangwei[8] mainly selected a 5L explosive device and simulated the explosion test of aluminum powder in it. The explosion characteristics were studied by controlling three variables: particle size of aluminum powder, ignition energy and dust concentration of aluminum powder. The following situations are mainly analyzed: Firstly, under the condition that the concentration of aluminum powder dust is constant, the explosion range of aluminum powder with the same particle size is observed by controlling different ignition energy. The final conclusion is that the greater the ignition energy is, the more severe the explosion is. Secondly, under the premise of the same ignition energy, the range of aluminum powder explosion with different particle sizes is observed. The conclusion is that the smaller the particle size, the more intense the explosion. Through experiments, it is found that the influence of aluminum powder concentration on the maximum explosion pressure and pressure rise rate increases first and then decreases with the increase of aluminum powder concentration, that is to say, there will be a peak value, while the influence of aluminum powder particle size on the maximum explosion pressure and pressure rise rate decreases with the increase of aluminum powder particle size. The main research contents of this experiment have the following two points:

(1) The experimental verification of the explosion limit range of aluminum powder: by starting the explosion parameter setting system, setting the ignition delay time and ignition energy, and seeing the pressure change in the container to determine whether there is an explosion in the container. The experiment should be gradually reduced from high concentration. The smaller the concentration is, the

smaller the interval step size should be. The purpose is to ensure that the error is within an acceptable range.

(2) The maximum explosion pressure(500g/m³) of aluminum powder was measured by selecting different concentrations of aluminum powder dust: the ignition delay time and ignition energy were set by starting the explosion parameter setting system, and the pressure change in the container was observed by adjusting the concentration of aluminum powder.

5. Ignition Source of Metal Dust Explosion

5.1. Naked fire

In the polishing and grinding workplace, when the metal is processed, there are both open flames generated by mechanical welding and cutting, and metal dust generated by metal processing is left in the workplace. At this time, the open flame is enough to ignite the dust, causing dust explosion accidents.

5.2. Electric spark

There are two cases of spark generation, one is the spark or arc generated when the circuit is short-circuited, and the other is the charge generated on the ungrounded object. The above two cases can ignite the dust cloud in the air, causing dust explosion accidents.

6. Dust Explosion Prevention and Mitigation Measures

The cause of dust explosion is to meet the following three conditions: sufficient oxygen concentration in the air, dust concentration, ignition source[9][10]. Therefore, the prevention and mitigation measures of dust explosion should be discussed from the following three aspects. The explosion prevention measures of combustible dust are shown in Fig.1.

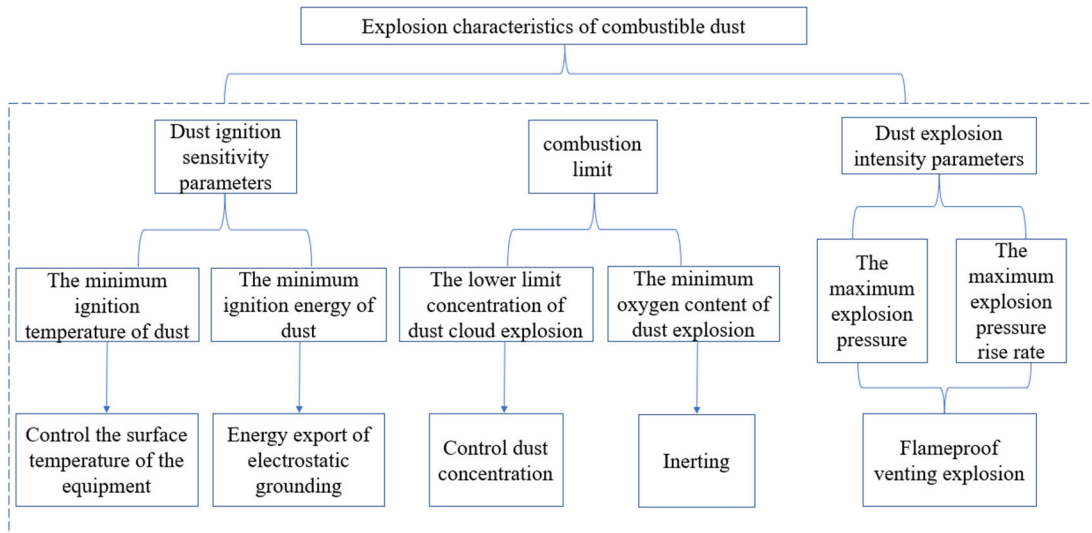


Figure 1. Explosion prevention measures of combustible dust

6.1. Reducing the concentration of oxygen in the air

The most important measure to reduce the oxygen

concentration in the air is to add inert gas. By filling enough inert gas into the system, the oxygen content in the system is maintained below the limit oxygen concentration (LOC), so that the three elements of dust explosion cannot be satisfied

at the same time, so as to achieve the possibility of suppressing dust explosion. At the present stage, the commonly used inert gases are as follows: N₂, CO₂ and rare gases.

6.2. Dust concentration is not within the explosive concentration range

Making the dust concentration in the system not in the explosive concentration range can also prevent dust explosion, but this is too idealistic. In real life, because the dust concentration in the system is difficult to predict its content, it is difficult to prevent the dust concentration from being in the explosive concentration range.

6.3. Prevent the generation of ignition source

(1) Prevent open fire. By implementing strict safety production management regulations, such as banning smoking and strict examination of hot work orders, this can avoid most potential ignition sources of open fire types.

(2) Prevent the hot surface. Working in the polishing and grinding workplace is extremely likely to produce hot surfaces.

(3) Prevent sparks caused by mechanical impact. There are two main cases of sparks generated by mechanical impact. The first is flammable materials. Some flammable materials are ignited by sparks generated by mechanically impacted objects, resulting in a fire source, which is very common in metal processing workshops. The second is the contact point of mechanical impact. For example, in a rotating mechanical device, the machine may repeatedly impact a certain point, which will cause a significant temperature change at the point, and a second fire source is generated. The fire source is a hotter surface, not a metal particle spark.

(4) Prevent electric spark. The principle is to comply with the current provisions on the installation of electrical appliances in metal dust areas.

7. Conclusion

The research of dust explosion has made great progress. This paper only reviews some of the contents, including: explosion propagation law, lower explosion limit concentration, maximum explosion pressure, maximum pressure rise rate and ignition source of dust explosion. The prevention and mitigation measures of dust explosion were put forward. Although a large number of countries in the world have carried out extensive research on the explosion characteristics of dust, there are still many shortcomings in the review of this paper, which need to be further summarized

and condensed, and there are a large number of other aspects of explosion characteristics that have not been reviewed, which still need to be improved.

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