Experimental research on combustion and explosion characteristics of medium density fiberboard on building

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Abstract. In recent years, the amount of medium density fiberboard (MDF) used in the construction industry is huge. The dust produced in the production has a great risk of dust combustion and explosion in different thermal runaway environments. Therefore, this paper takes the MDF dust as the research object to explore its combustion and explosion characteristics. The minimum ignition temperature of dust layer and 20L explosion vessel were used to study the changes of minimum ignition temperature (MIT) and combustion morphology of dust layer with different particle sizes of wood powder, and the influence of different influencing factors on the maximum explosion pressure was analyzed. The results show that with the decrease of particle size, the MIT decreases from 350℃ to 260℃, the maximum heating rate increases, the carbonization phenomenon becomes more obvious, and the maximum explosion pressure increases gradually; Under 200 mesh dust, with the increase of mass concentration and ignition delay, the maximum explosion pressure first increases and then decreases, and 50 g/m³ and 60 ms are the best mass concentration and ignition delay.

1. Introduction

With the improvement of the quality of life, people's demand for wood products has gradually increased, and the probability of dust explosions in wood product processing enterprises has also increased significantly[1]. A large amount of wood powder will be produced in the production process of sawing, drilling, grinding, etc. This dust not only threatens human health and pollutes the environment, but also the personal injuries and property losses caused by dust explosions are huge. Further research on dust explosions has become especially critical, it has great theoretical and practical significance for preventing and reducing the occurrence of dust explosion accidents.

Dust explosion is a special form of combustion, and there is the possibility and hazard of dust combustion transforming into dust explosion in dust explosion accidents. The current research on dust combustion and explosion is also the focus of Chinese and foreign scholars. Zhang et al[2] used MIE and MIT test device to conduct experimental research on polyamide fiber dust. The lowest ignition temperature of dust layer was 307℃, and the lowest ignition temperature of dust cloud is 300℃. Zhong et al[3] used a self-developed experimental device to carry out a hot surface ignition experiment with stone pine nut dust and found that the thicker the dust thickness is, the longer the initiation time and duration of dust layer ignition are. Qing et al[4] used a 20L spherical explosion device to conduct a comparative explosion test study on nanometer and micrometer aluminum powder. Tests show that the maximum explosion pressure and explosion index mainly depend on the dust...
concentration, which increases first and then decreases as the dust concentration increases. Matsuda et al [5] conducted tests on relevant parameters of dust that may explode in the industry. The experimental results show that the characteristics of dust explosion are related to the experimental method, dust category and form, external environment and other factors. Cashdollar et al [6] comprehensively and systematically studied the relationship between the volatile content of coal dust and the lower explosion limit of the mixture in the state of coal dust and gas mixture, and shows that the increase of ignition energy, the decrease of volatile content and the decrease of coal dust particle size will lead to the decrease of ignition lower limit of coal dust to some extent.

Research on coal powder, starch dust, aluminum dust and alloy dust has been relatively common. However, there has not been much research on the associated dust of the MFD that has appeared in the construction or manufacturing industry in recent years. Therefore, studying the minimum ignition temperature and maximum explosion pressure of fiberboard dust is of great significance.

2. Materials and Methods

2.1 Materials
The experimental materials are selected from wood products processing plants, and the experimental dust is obtained through cutting, mechanical polishing and other links. The mechanically polished dust was sieved and dried, and sieved out 20, 40, 60, 80, 100, 150 and 200 mesh. The dust of the target sample is dried in a high-temperature oven at 50°C for 12 hours. After drying and cooling, it is placed in a sealed bag for storage.

2.2 Experimental method of the lowest ignition temperature of the dust layer

The MIT of dust layer refers to the minimum temperature at which the accumulated dust ignites and burns under the action of external energy. In this experiment, the MIT device of dust layer is used, the diameter of metal ring is 9cm and the height is 1.3cm, as shown in Figure 1. The initial heating temperature of the experiment is 300°C. If the dust catches fire, the temperature will be increased by 20°C, otherwise, the temperature will be lowered by 10°C to determine the MIT of the wood dust layer of different particle sizes. 20, 40, 60, 80, 100, 150 and 200 mesh wood flour were selected and spread on the hot plate with metal ring thickness of 1.3cm to observe the dust combustion morphology at different temperatures.

2.3 Experimental method of maximum explosion pressure of dust cloud
The 20L explosive vessel was used in the experiment. The experimental device is shown in Figure 2. The powder injection pressure is 2.0MPa. The maximum explosion pressure of wood dust with different particle size, concentration and ignition delay was studied, and the influence of different factors on the maximum explosion pressure was analyzed.
3. Results & Discussion

3.1 The effect of particle size on the minimum ignition temperature and combustion form of the dust layer

According to the combustion criteria\cite{7}, the MIT of dust layers with different particle sizes are obtained, as shown in Table 1.

| Particle size /Mesh | 20  | 40  | 60  | 80  | 100 | 150 | 200 |
|---------------------|-----|-----|-----|-----|-----|-----|-----|
| MIT/℃              | 350 | 310 | 290 | 280 | 270 | 260 | 260 |

![Image](image1.png)

(a) 130℃  (b) 200℃  (c) 319℃  (d) 608℃  (e) 642℃  (f) 668℃

Figure 3. Combustion state of wood dust at different stages

The hot plate temperature was set at 300℃, and the combustion process of 200 mesh wood dust was illustrated. Figure 3 shows the combustion state of wood powder at 130, 200, 319, 608, 642 and 668℃ respectively. When the dust was heated to 130℃, a little white smoke appeared on the surface, accompanied by the fragrance of wood powder; At 200℃, the smoke increased, the aroma became stronger, and the surface color of wood flour became darker; At 233℃, black carbonization occurs locally on the surface; At 319℃, the area of surface carbon expanded, and the rate of smoke production and temperature rise accelerated; At 608℃, the rising rate of temperature slowed down, and the white smoke turned to green smoke with a pungent burning smell; At 642℃, the surface carbonization is basically completed, and there are some sparks on the edge; The maximum temperature of wood powder combustion was reached at 668℃, the mars began to disappear, the whitening phenomenon appeared in the outside and center of the sample, the temperature decreased, and the combustion was completed. The phenomenon of dust layer during combustion is: with the decrease of particle size, the MIT decreases, the temperature increases at the end of carbonization, the carbonization phenomenon is more obvious, and the carbonization time is gradually delayed.
Figure 4 shows the relationship between the MIT and particle size of dust layer. It can be seen from the figure that with the decrease of particle size, the MIT of dust layer decreases from 350°C to 260°C. This is because the smaller the particle size is, the larger the specific surface area is, the more complete the reaction with combustion supporting materials is[8], and the reaction heat increases, which makes it easier to reach the MIT.

3.2 The effect of particle size on maximum explosion pressure

Figure 5 shows the curve of the maximum explosion pressure with the particle size measured at the mass concentration of 50g/m³. It can be seen from the figure that with the decrease of particle size, the maximum explosion pressure increases gradually, and the growth rate begins to slow down. This is because the larger the mesh, the smaller the particle size, the larger the specific surface area of dust, the more the reaction with oxygen, the more the heat generated by the increase of combustion rate, and the explosion pressure increases correspondingly. When the specific surface area increases to a certain extent, due to the lack of oxygen, the maximum explosion pressure increases slowly.

3.3 The effect of concentration and ignition delay on the maximum explosion pressure

Figure 6 shows the curve of maximum explosion pressure with mass concentration under ignition delay of 30, 60, 90 and 120 ms. Taking 60ms ignition delay as an example, when the initial dust concentration increases, the maximum explosion pressure increases. When the mass concentration reaches 50g/m³, the maximum explosion pressure is 0.4916 Mpa, reaching the maximum value. As the mass concentration continues to increase, the maximum explosion pressure begins to decrease. This is because with the increase of dust concentration, the number of effective molecular collisions increases, the reaction rate accelerates, and the energy generated increases. When the mass concentration continues to increase, the oxygen concentration in the explosion ball is relatively insufficient, resulting in more and more dust not participating in the reaction and absorbing the heat generated around, which reduces the maximum explosion pressure.
Figure 6. Variation of maximum explosion pressure with mass concentration under different ignition delay

With the increase of ignition delay, the maximum explosion pressure of wood dust increases gradually at the same concentration, and reaches the maximum value in 60ms. When the ignition delay continues to increase, the maximum explosion pressure of wood dust begins to decrease, because with the increase of ignition delay to 60ms, the turbulent motion of gas in the container makes the wood dust disperse more evenly and reach a good explosion state; The ignition delay time will be increased continuously, and the wood powder will enter the settlement process[9]. The dust participating in the reaction will decrease, and the maximum explosion pressure will continue to decline, so the best ignition delay time is 60ms.

4. Conclusion

With the construction and manufacturing industry's huge demand for wood products, especially medium density fiberboard, leading to safety risks are also increasing. In order to reduce the damage caused by dust explosion accidents, this paper studies the characteristics of dust combustion and explosion, and obtains the following conclusions:

(1) Using the MIT of dust layer device, it is found that within a certain range, the MIT of wood dust with a thickness of 1.3cm decreases with the decrease of the dust particle size.

(2) Using 20L explosive vessel, under the condition of powder injection pressure of 2.0MPa, ignition energy of 10kJ and ignition delay of 60ms, with the decrease of particle size, the maximum explosion pressure rises and the growth rate of maximum explosion pressure slows down.

(3) Under the same ignition delay, with the increase of 200 mesh dust concentration, the maximum explosion pressure first increases and then decreases, and 50g/m3 is the best concentration; When the mass concentration is 50g/m3, with the increase of ignition delay, the maximum explosion pressure first increases and then decreases, and 60ms ignition delay is the best ignition delay time.

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