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Experimental Study on Explosion Characteristics of Micro-nano Tapioca Starch Mixture

Ruichong Zhang[1], Chengyu Xie[2], Lei Liu[1]

[1] College of Resources Environment and Materials, Guangxi University, Nanning 530004, China

[2] College of Resources and Environment, Xiangtan University, Xiangtan, 411105, China

Abstract

In order to study the basic explosion characteristics of the mixture of micro-nano tapioca starch, the minimum ignition energy, the minimum ignition temperature of dust cloud, the minimum ignition temperature of dust cloud, the minimum ignition temperature of dust cloud, the dust cloud ignition temperature measurement equipment and the 20L spherical explosion test equipment were used for the dust samples respectively. Experiment with the explosiveness of . The results show that when the fixed ignition delay is 100ms and the injection pressure is 100Kp, with the increase of mass concentration, injection pressure and ignition delay time, the minimum ignition energy first decreases and then increases. With the same mass and different injection pressures, from 0.2 grams to 0.6 grams, the ignition temperature decreases first and then increases with the increase of injection pressure. The explosion pressure increases first and then decreases under different ignition delay time, dusting pressure and dust concentration. At the same time, compared with pure micron dust, the explosion intensity of micro-nano tapioca starch mixture is higher than that of micron dust at low concentration, and it is not obvious at high concentration, but the explosion index of micro-nano mixed dust is slightly higher than that of micron dust.

Keywords

Micro-nano; Mixed Tapioca Starch; Explosive Properties.

1. Introduction

With the application of ultra-fine dust particle processing technology, especially in the application and development of various industries such as food, medicine, and cosmetics[1], the size of combustible dust particles generated in the production process has been ultra-fine, such as in organic rice flour, Chinese yam, etc. Processing (for young children and the elderly); the deep-processed products of medicinal materials such as Panax notoginseng[2], Cordyceps sinensis[3], Ganoderma lucidum, and starch as medical aids are in the state of mixture of nanometers, submicrometers, and micrometers. Micron-level tapioca starch has a great risk of fire and explosion. According to the current processing technology of grain dust and the physical characteristics of grain dust, it is difficult to separate nano-scale dust after processing. Ultra-fine tapioca starch generally exists in the form of micro-nano mixture. The fire explosion of starch micro-nano mixtures remains to be studied[4].

At present, scholars at home and abroad have carried out related research on the detonation characteristics, agglomeration and flame propagation of nano-dust, mainly focusing on hard nano-dust, such as metal and plexiglass. The explosion intensity parameters were studied, Li Chang [5] carried out experimental and theoretical research on the explosion characteristic parameters of nano-titanium powder; Zhang Xinyan [6] studied the explosion flame propagation characteristics of nano-

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PMMA dust. H.C. Wu et al. [7] measured the minimum ignition energy (MIE) of micron and nano-scale titanium and iron powders with a modified 1.2L Hartmann device. The experimental data show that the MIE of all nano-titanium and iron powders is less than 1 mJ . Studies by Dufaud o, Vignes A et al. [8-11] showed that as the particle size decreases, the minimum ignition temperature and minimum ignition energy decrease (even below 1 mJ), indicating that metal nanopowders have a higher potential fire and explosion risk. However, there is basically no soft organic nano-dust, mainly because it is difficult to process and separate pure nano-scale soft organic dust.

It can be seen that the experimental study on the explosion hazard of the combustible micro-nano tapioca starch mixture, the intermediate product of cassava starch processing, has practical reference significance for obtaining the basic parameters of the cassava starch micro-nano mixture dust fire explosion hazard and effective protection.

2. Experiment and Method

2.1 Device and Method

2.1.1 Hartmann Tube

(1) The experiment uses the HY16428A dust minimum ignition energy test device to conduct the minimum ignition energy experiment on the micro-nano mixture cassava dust.

Fig. 1 Hartmann tube diagram

(2) Experimental steps and regulations

Before starting the experiment, do the following:

1) Turn on the power of the device;

2) Connect the air pipe of the air compressor and the instrument, start the air compressor and reserve the air pressure;

3) Remove the electrode, polish it with fine sandpaper until it is bright, and then install and restore it to ensure that the electrode gap is in the center of the quartz tube. Clean up residual sample powder on the quartz tube and diffuser base;

4) Set the relevant parameters to check whether the discharge, blowing and other functions of the system are normal. If it is not normal, repair it in time. If it is normal, enter the experimental operation link.

The experimental steps are as follows:

1) Weigh the tapioca starch to be tested, spread it evenly on the conical diffuser, and seal and fasten the glass tube.

2) Enter the main menu interface of the device, and set the relevant parameters according to the instrument prompts.

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3) Carry out the experiment.

4) After ignition, if the dust is ignited and the flame spreads at least 60mm away from the spark position, the dust is considered to be on fire, otherwise, it is considered that the dust is not on fire, and the minimum ignition energy Emin of the dust is between 10 consecutive tests and no fire occurs. Between the maximum energy value El and the minimum energy value E2 at which ignition occurs at least once in 10 consecutive tests [12].

2.1.2 HY16429 Dust Cloud Ignition Temperature Test Device

The experiment used HY16429 dust cloud ignition temperature test device, namely G-G furnace, to test the minimum ignition temperature of cassava starch dust. The instrument was produced by Hongyuan Scientific Instrument Co., Ltd. as shown in picture 2.

Fig. 2 HY16429 Dust cloud ignition temperature test device

2.1.3 Experimental Procedure

(1) Turn on the power of the equipment, let it stand for 3 minutes, and weigh the tapioca starch sample of good quality.

(2) Pour the weighed tapioca starch sample into the powder storage tank through the paper funnel, fix the positioning groove and tighten the cover.

(3) Enter the setting interface window, and set the test temperature, injection pressure, constant temperature time, etc. according to the experimental sequence.

(4) After the setting is completed, start the experiment, and finally blow the tapioca starch from the powder storage bin into the constant temperature furnace.

(5) The fire is judged according to whether there is flame ejection from the lower end of the hot furnace within 3 seconds after powder spraying. If there is no fire, in the next experiment, when other conditions remain unchanged, increase the temperature in steps of 50°C on the basis of the temperature set this time, and the capping temperature is 1000°C; if fire occurs, perform the next experiment. , when other conditions remain unchanged, the temperature is reduced in steps of 20 °C, and the experiment is repeated until there is no flame ejection phenomenon at the lower end of the heating furnace for ten consecutive experiments (when the experimental temperature is 300 °C, there is still flame ejection phenomenon, then The temperature was decreased in steps of 10 °C, and the experiment was repeated until there was no flame ejection at the lower end of the heating furnace for ten consecutive experiments) [13]. In order to more accurately determine the minimum ignition temperature under certain conditions, for example, when the temperature is reduced in steps of 10 °C, and there is no flame ejection phenomenon at the lower end of the heating furnace for ten consecutive experiments, increase 5 °C in the next experiment. If there is fire within 10 times, it will be lowered by 2.5°C; if there is no fire within 10 times, it will be raised by 2.5°C until the minimum ignition temperature that is about 1°C apart from fire and no fire is found.

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(6) Adjust the pressure, mass, particle size and other parameters according to the requirements of the experiment, and redo the above steps (2) to (5) until the experiment is completed.

2.1.4 20L Spherical Dust Explosion Parameter Test Device

HY16426C 20L spherical gas/dust/liquid mist explosion parameter test device produced by Jilin Hongyuan Scientific Instrument Co., Ltd. under special conditions.

Fig. 3 20L ball type dust explosion parameter testing device

2.1.5 Operation Method

Preparations before the experiment starts:

(1) Check all connection lines to make sure they are connected correctly.

(2) Open the compressed air cylinder, check the air tightness of all ventilation pipes, and adjust the output pressure to 2.0MPa.

(3) Check the pumping performance of the vacuum pump and the air tightness of the connected hose and the connecting end, and balance the pressure in the ball through the pressure relief valve.

(4) Put the chemical igniter on the ignition electrode holder.

(5) Weigh the sample with a balance, place the tapioca starch at the bottom of the dust bin, and tighten and seal the dust bin.

The experimental steps are as follows:

(1) Open the shortcut of the software on the computer desktop, and select "dust experiment" and "chemical ignition" in the alternative project interface.

(2) According to the link of the experiment, distribute input and set various parameters in the "Set Control Parameters" interface.

(3) After the setting is completed, click the "OK" button to start the experiment.

(4) After the data transfer is completed, the process of the computer interface is as follows: 1) First detect the air pressure in the chamber; 2) Then perform the vacuuming operation, 3) After the vacuuming is completed, perform air trimming; 4) Press the set air pressure to the sample 5) Automatic ignition experiment, 6) After the ignition is over, the pressure data is received.

(5) After the experiment, depressurize the dust (to avoid the rubber ring shifting when the dust bin cover is unscrewed, and it cannot be sealed when tightening again, resulting in air leakage) and click the cleaning item to clean the inside of the dust explosion tank.

(6) According to the set concentration, pressure and delay time, each group of the same experimental conditions is performed three times, and the maximum explosion pressure and the maximum explosion index are taken and recorded.

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(7) According to the set parameters, change the corresponding variables to complete all experiments, and record and save the relevant data.

Whether the cassava dust is successfully detonated is determined by the experiment whether the maximum explosion pressure is greater than 0.15MPa[14], the maximum explosion pressure and the maximum explosion pressure rise rate are recorded, and the maximum explosion index is calculated according to the maximum explosion pressure rise rate and formula (1).

where the sphere volume:

$$V=0.02m3.Kmax=(dp/dt)max\times V1/3 \quad (1)$$

2.2 Experimental Samples

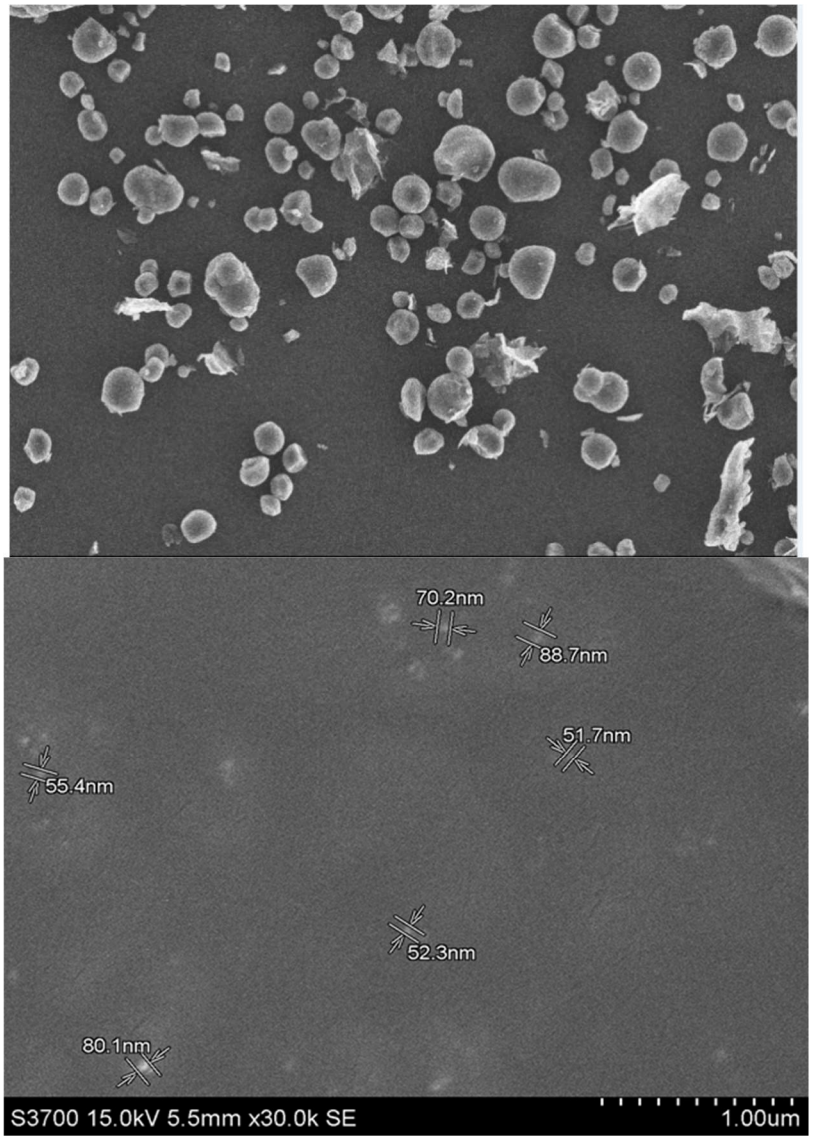

Fig. 4 Electron micrograph of micro-nano tapioca starch mixture

Table 1. Particle size range

Dust name	Particle size range
Micro-nano tapioca starch mixture	50nm-12um

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3. Results and Analysis

3.1 Determination of Explosive Properties

3.1.1 Minimum Ignition Energy of Micro-nano Tapioca Starch Mixture

During the experiment, the experiment was carried out under the condition that the ambient humidity was 30%~60% and the temperature was 20~30℃, and the tapioca starch was dried in an oven at 60℃ for 24h before the experiment. The cassava micro-nano mixed dust was selected as the research object, the ignition delay was fixed at 100ms, and the injection pressure was 100Kp. The mass concentrations in the table below were tested, and the results were shown in the table below.

Table 2. Concentration effects

quality /g	Ignition delay time /ms	injection pressure /Kpa	ignition energy /mj	test results
0.2	100	100	130 90 80 75 60	1111111111 1101001011 1000100100 1000001000 0000000000
0.3	100	100	120 90 85 65 60	1111111111 0000101000 0101000100 0000100000 0000000000
0.4	100	100	100 80 70 60	1111111111 0001010100 0000000100 0000000000
0.5	100	100	120 90 78 70	1111111111 0001000111 0000101000 0000000000
0.6	100	100	150 90 80 70	1111111111 0010000100 0000100000 0000000000
0.7	100	100	160 100 90 80	1111111111 0000100001 0000100000 0000000000

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Table 3. Effect of injection pressure

quality /g	Ignition delay time /ms	injection pressure /Kpa	ignition energy /mj	test results
0.3	100	40	120 90 80 76 60	1111111111 1101001011 1000100100 1000001000 0000000000
0.3	100	60	100 90 80 70 60	1111111111 0000101000 0101000100 0000100000 0000000000
0.3	100	80	110 90 70 54 50	1111111111 0001010100 0001000100 0001000000 0000000000
0.3	100	100	130 90 80 70	1111111111 0001000111 0000101000 0000000000
0.3	100	120	130 90 82 70	1111111111 0010100000 0000100000 0000000000
0.3	100	150	150 100 95 80	1111111111 0000100001 0000100000 0000000000

When the fixed ignition delay is 100ms and the injection pressure is 100Kp, it can be seen from Table 3 that with the increase of mass concentration, the minimum ignition energy shows a trend of first decreasing and then increasing; it can be seen from Table 4 that with the increase of injection pressure, the minimum ignition energy decreases.The ignition energy shows a trend of decreasing first and then increasing; Table 5 shows that with the increase of ignition delay time, the minimum ignition energy shows a trend of decreasing first and then increasing.

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Table 4. Effect of ignition delay

quality /g	Ignition delay time /ms	injection pressure /Kpa	ignition energy /mj	test results
0.3	15	80	120 90 80 58 50	1111111111 1101001011 1000100100 1000001000 0000000000
0.3	30	80	100 90 80 52 50	1111111111 0010101000 0001000100 0000100000 0000000000
0.3	60	80	110 90 70 65 50	1111111111 0001010100 0001000100 0001000000 0000000000
0.3	90	80	120 90 70 60	1111111111 0001000111 0000101000 0000000000
0.3	120	80	120 90 75 70	1111111111 0010100000 0000100000 0000000000
0.3	150	80	130 100 76 70	1111111111 0000100001 0000100000 0000000000

3.2 Minimum Ignition Temperature of Micro-nano Tapioca Starch Mixture

Table 5. Minimum ignition temperature of different masses under different injection pressures

quality\pressure	20kp	30kp	40kp	50kp	60kp
0.2g	472℃	461℃	452.3℃	457℃	470℃
0.3g	480℃	469℃	449℃	464℃	467℃
0.4g	482℃	475℃	445.2℃	454℃	458℃
0.5g	485℃	467℃	463.2℃	456℃	462.7℃
0.6g	487℃	472℃	464.5℃	461℃	458℃

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It can be seen from the above table 5 that for the same mass and different injection pressures, there is an optimal injection pressure to minimize the ignition temperature; from 0.2 grams to 0.6 grams, with the increase of injection pressure, the ignition temperature shows a trend of first decreasing and then increasing. . The best injection pressure is the best dust dispersion force, so that the dust can be dispersed most uniformly under the action of the injection force, and at this time, there is a minimum ignition temperature.

3.3 Vigor of Micro-nano Tapioca Starch Mixture

3.3.1 The Explosion Pressure of Cassava Dust under Different Ignition Delay Time Conditions

The injection pressure was fixed at 1.3 MPa, the cassava dust was 5 g, and the ignition delay conditions were changed. The average value of the three experiments is shown in Table 6 below.

Table 6. Explosion pressure of cassava mixed dust under different ignition delay time

Ignition delay time/ ms	explosion pressure/MPa			
	1st	2nd	3rd	Average
15	0.396	0.417	0.423	0.412
30	0.436	0.487	0.403	0.442
60	0.453	0.482	0.469	0.468
90	0.527	0.453	0.508	0.496
120	0.442	0.520	0.448	0.470
150	0.459	0.468	0.426	0.451
180	0.411	0.451	0.425	0.429
210	0.321	0.314	0.292	0.309

Substitute the maximum value of dp/dt=86.8MPa/s obtained in the experiment into the following formula,

$$Kst=(dp/dt)_m\times V^{1/3}=86.8\times\left(20\times10^{-3}\right)^{1/3}\approx23.7\text{MPa}\cdot\text{m/s} \quad (2)$$

3.3.2 The Explosion Pressure of Cassava Dust under Different Dust Concentrations

The injection pressure was fixed at 1.3 MPa, the ignition delay time was 90 ms, the mass concentration of tapioca starch was changed, and the average value of the three experiments was shown in Table 7 below.

Table 7. Explosion pressure of cassava mixed dust under different dust concentrations

Dust concentration /g/m^3	explosion pressure/MPa			
	1st	2nd	3rd	Average
200	0.365	0.421	0.354	0.380
250	0.482	0.520	0.534	0.512
400	0.632	0.627	0.643	0.634
500	0.634	0.666	0.647	0.649
750	0.666	0.689	0.679	0.675
1000	0.666	0.668	0.661	0.665
1250	0.602	0.680	0.672	0.662

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Substitute the maximum value of dp/dt=70.5MPa/s obtained in the experiment into the following formula,

$$Kst'=(dp/dt)_m\times V^{1/3}=70.5\times\left(20\times10^{-3}\right)^{1/3}\approx 19.1MPa\cdot m/sv \quad (3)$$

3.3.3 Explosion Pressure of Cassava Dust under Different Dusting Pressures

The fixed ignition delay time is 90ms, the mass concentration of cassava dust is 250g/m3, and the injection pressure is changed to obtain the following table 8.

Table 8. Explosion pressure of cassava mixed dust under different dusting pressures

Dusting pressure /MPa	**explosion pressure/MPa**			
	1st	2nd	3rd	Average
0.9	0.432	0.390	0.417	0.413
1.1	0.437	0.477	0.412	0.442
1.3	0.432	0.514	0.458	0.468
1.5	0.472	0.516	0.488	0.492
1.7	0.564	0.479	0.391	0.478
1.9	0.334	0.312	0.364	0.340

Substitute the experimentally obtained dp/dt=65.7MPa/s into the following formula,

$$Kst''=(dp/dt)_m\times V^{1/3}=65.7\times\left(20\times10^{-3}\right)^{1/3}\approx 17.8MPa\cdot m/s \quad (4)$$

The explosion pressure showed a trend of increasing first and then decreasing under different ignition delay time, dusting pressure and dust concentration.

3.3.4 Analysis and Comparison

It can be seen from the test that the explosion duration of the micro-nano mixed dust is shorter than that of the pure micron dust, and the pressure increase rate is shorter. Theoretically, the smaller the dust particles, the higher the explosion intensity of the dust. Tapioca starch micro-nano mixed dust does reflect such characteristics, which is more obvious at low concentrations. For example, at 250 or 200 g/m3, the explosion intensity is higher than that of micron dust, while at high concentrations, this is mainly due to micro-nano mixed dust. The dust also showed obvious agglomeration. In terms of value, both micro-nano mixed dust and micron cassava dust belonged to the explosion hazard level St2, but the explosion index of micro-nano mixed dust was slightly higher than that of micron dust.

4. Conclusion

1) When the fixed ignition delay is 100ms and the injection pressure is 100Kp, with the increase of mass concentration, injection pressure and ignition delay time, the minimum ignition energy shows a law of first decreasing and then increasing.

2) For the same mass and different injection pressures, there is an optimal injection pressure to minimize the ignition temperature; from 0.2g to 0.6g, the ignition temperature decreases first and then increases as the injection pressure increases.The best injection pressure is the best dust dispersion

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force, so that the dust can be dispersed most uniformly under the action of the injection force. At this time, there is a minimum ignition temperature.

3) Under different ignition delay time, dusting pressure and dust concentration, the explosion pressure first increases and then decreases.

4) The explosion duration of the micro-nano mixed dust is shorter than that of the pure micron dust, and the boosting rate is higher.At low concentration, the explosion intensity of micro-nano tapioca starch mixture is higher than that of micron dust, and it is not obvious at high concentration, but the explosion index of micro-nano mixed dust is slightly higher than that of micron dust.

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