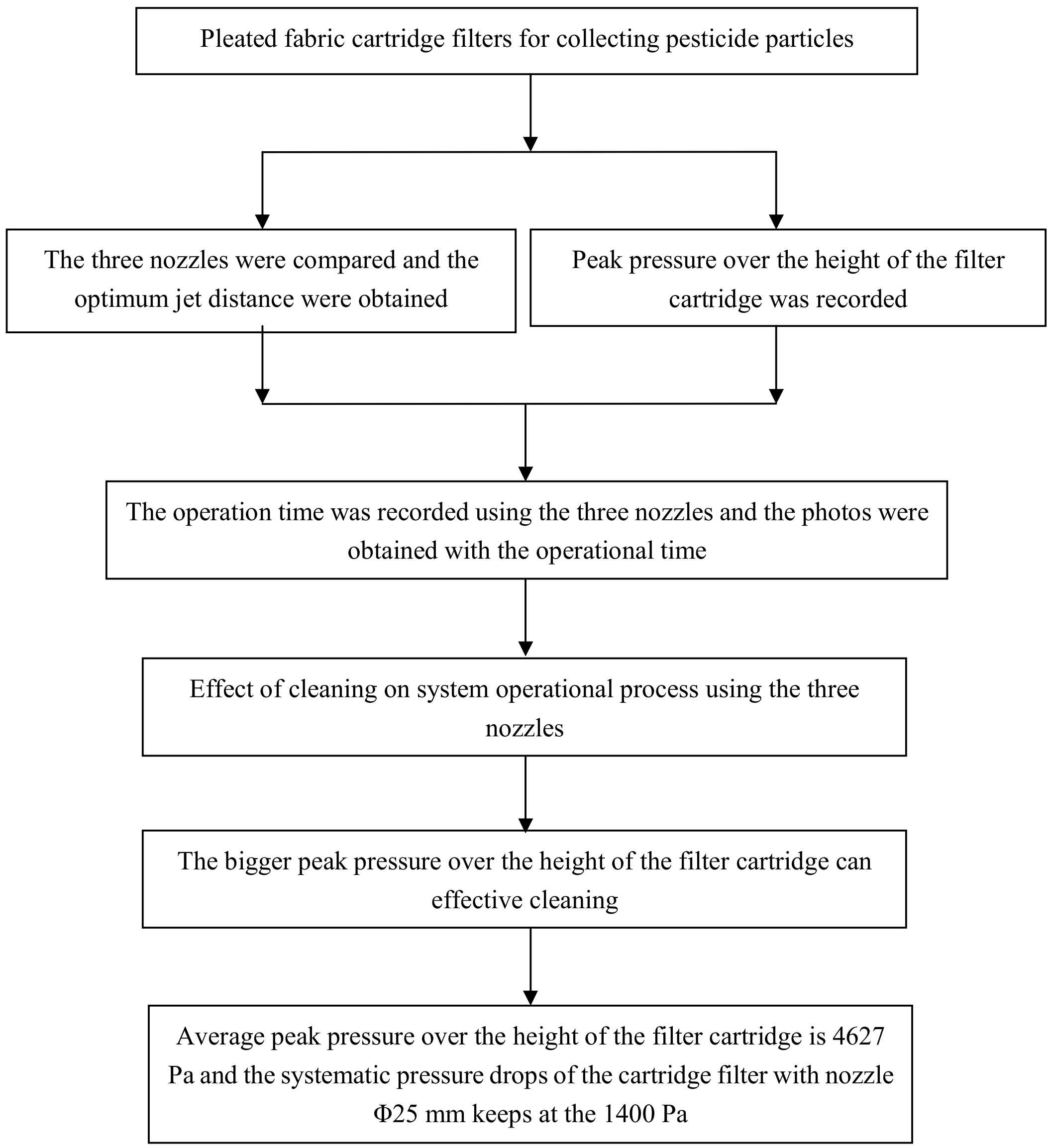
RSC Advances

Novelty: Cleaning performance of pleated fabric cartridge filters for collecting pesticide particles and the effect of cleaning on system operational process.



On-line pulse-jet cleaning of pleated fabric cartridge filters for collecting pesticides

Yan Cuiping, Zhang Mingxing, Lin Longyuan

Abstract: The objective of this work was to study the cleaning performance of pleated fabric cartridge filters for collecting pesticide particles and to determine the effect of cleaning on system operational process. A pleated fabric cartridge filter was used to collect pesticide particulate matters that went out the grinding and classification. On-line pulse-jet cleaning was used to dislodge the dust cake from the filter cartridge. It was found that the demanded detachment forces of pesticide powder dislodgement from the pleated cartridge are bigger than those of other particulate matters. The pesticide particles are not dislodgement from the filter cartridge when the average peak pressure over the height of the filter cartridge is 2473 Pa with the induced nozzle Φ16. The bottoms of the filter cartridge are remaining filled with the pesticide particles when the average peak pressure over the height of the filter cartridge is 3455 Pa with the nozzle Φ20. The whole filter cartridges are cleaned when the average peak pressure over the height of the filter cartridge is 4627 Pa and the systematic pressure drops of the cartridge filter with nozzle Φ25 mm keeps at the 1400 Pa. The bigger the peak pressures on pleated filter cartridge, the quicker the pesticide particles are dislodgement from the filter cartridge, decreasing the re-suspension pesticide particles reattached on the filter cartridge. An increase in nozzle diameter can increase the peak static pressures on the filter cartridge, solving the patchy cleaning problem of pleated fabric filter cartridge for collecting pesticide particles. The surface static pressures on the filter cartridge can give guidance to the cleaning effect on the system stable operation in industrial application.

Keywords: pleated fabric cartridge filter, pesticide particle matters, on-line pulse-jet cleaning,

cleaning performance

1. Introduction

Superfine grinding technology is a useful tool for making ultrafine powder [1-2]. This superfine powder has been applied in many fields, such as abrasive, ceramics, electronic materials, pharmaceutics, chemistry, etc. [3-7]. The superfine grinding for making ultrafine pesticide particles by air jet mill is used. Through the grinding and classification, the pesticide particles have a high mass concentration, an ultrafine particle size and a characteristic of heat sensitivity. Therefore, the effective collection technology for collecting ultrafine pesticide particles through the grinding and classification is sought by many industries. Dust collector has been applied to recover the pesticide particles and to control particle emission in many industries, meeting the strict environmental policy. Among the several collection methods, bag filters are frequently used because their separation technique only depends on the pore size of the filter medium. The particles are collected independent of their density, shape, and particulate size distribution when the particle size is larger than the pore size of filter medium. Despite the favorable separation characteristics of bag filters, they cause significant pressure drop in industrial application and the filter medium are easily destroyed during clogging and cleaning cycles. Recently, the use of pleated fabric filter cartridges in dust collectors has attracted great attention because the pleated filter cartridges offer a larger filtration surface compared to flat-sheet filter bags (if both filters are used in housing of the same size) [8-11].

Because of pleat structure, the filter cartridges can increase the filtration area and decrease the filtration face air velocity compared to flat-sheet filter bags. An increase the filtration area of cartridge filter can lead to a decrease in the overall separator size and in the cost of replacing the filter bags at regular intervals of time. However, cleaning of pleated fabric filter cartridge is more difficult compared to this of the flat-sheet filter bag [9][11]. On-line pulse-jet cleaning has been frequently used to dislodge the dust cake from the filters [12-14]. Pulse-jet cleaning of filter cartridges leads to a reduction in the systematic pressure drop; However, the on-line cleaning of filter cartridges for collecting pesticide particles is more difficult than other particulate matters. This is because the pesticide particles have the high adhesion, the low density and the fine particle size. Fig.1 shows that the pleated fabric filter cartridges for collecting pesticide particles is patchy cleaning in industrial factory.

Pleated fabric filter cartridges have the characteristics of less deformation and better filtration efficiency compared with flat-sheet filter bags. However, very little has been reportedly in the literature, in which the pleated filter cartridges were applied in pulse-jet dust collectors of industrial factory. To keep dust collectors for collecting pesticide particles from the air jet mill under a reasonable level of pressure drop, the on-line pulse-jet cleaning is adopted for dislodging the dust cake periodically. The objective of this study is to investigate the cleaning performance of pleated cartridge filter and the effect of cleaning on systematic operation in collecting the pesticide particles.

2. Materials and methods

2.1. Experimental apparatus

In order to examine the cleaning performance of a pleated fabric cartridge filter for collecting pesticide particles, a pleated fabric cartridge filter was used to examine. Four filter cartridges (Φ325 × Φ215 × 1000 mm, 125 pleat count) were installed in the dust collector. Fig. 2 showed a schematic view of the test rig (Designed by Mianyang, Liuneng, Powder Equipment Co., Ltd.). The dimensions of the dust collector compartment were Φ1260×3150 mm shown in Fig. 3. The filter cartridge dimensions were shown in Table 1. The photo and microstructure of filter cartridges were shown in Fig. 4a. A rigid wire cage supported the filter medium shown in Fig. 4b. The filter medium was coated with a layer membrane of fine polytetrafluoroethylene fibers, which has the properties of hydrophobic and oleophobic, resistance to acid and alkali. The induced pulse airflow was produced by a supersonic induced nozzle (VN25PC-50, Australia, Goyen Co., Ltd.) and an air diffuser (CC200, Australia, Goyen Co., Ltd.). The schematic diagrams of the induced nozzle and the diffuser were shown in Fig. 5. The experiment also included a pulse valve (DMF-Z-50s type with diameter 2 "), a compressed air reservoir, a pulse controller, a screw air compressor, five high precision pressure transducers (S130100), an electric charge amplifier (QSY7709), a portable data acquisition instrument (QSY-USB-8512E), and an anemoscope (SwemaAir50). A hopper was connected to the dust cartridge filter to collect the dust dislodgement from the filter cartridge.

The fabric microstructure of pleated filter cartridge was obtained using a electron microscope (Leica 440). Five high precise pressure transducers were used to monitor the static peak pressure on the surface of filter cartridge. The pulse airflow from the compressed air reservoir was controlled using a pressure regulator, a pulse valve, and a sequential timer/relay that the pulse valve opening time and interval were changed. A computer running the LabView program was connected to a charge amplifier and a data acquisition instrument to collect the data. A pulse controller was connected to control the pulse valve.

2.2. Dust test

In this experiment, a pleated cartridge filter was used to collect the pesticide particles. Through the grinding and classification, the particle size distribution of pesticide particles was 0.5~5 μm (d_{10}=0.73 μm, d_{50}=1.61 μm and d_{90}=2.68 μm). Inlet particle mass concentration of dust collector was 107 g/m^3. The pesticide particles have the characteristics of adhesion and chemical corrosion. Therefore, the stainless steel was used to make the dust collector, lowering the amount of pesticide particles that adheres to the wall of dust collector.

2.3. Filtration process and cleaning process

An induced draft fan produced the systematic negative pressure during the collection process. Through the grinding and classification, the pesticide particles collected on the filter medium using an induced draft fan. Each filter cartridge was fitted with a compressed air injection nozzle and a pulse valve. The filter cartridges were cleaned with a pulse jet injection of compressed air. The pulse airflow was in the opposing direction to the normal forward flow of filtration through the dust collector. The re-suspension of detached particles appeared after a pulse-jet cleaning. The detached particles went into hopper with the heavily force and reverse pulse airflow.

The dry air obtained from cold and dry machine was used to transport the pesticide particles and to dislodge the pesticide particles from the filter cartridge.

2.4. Experimental design

The filtration velocity was set to 0.7 m/min on the basis of production yields of air jet mill and pesticide properties. The pressure drops of the pleated fabric cartridge filter were measured using a transmitter. The cleaning mode was clean on time. The experimental designs were shown in Table 2. The pressure transducers (Φ7 mm) were fixed on the interface of the rigid wire cage on the filter surfaces. The size of the pressure transducers was smaller than this of the filter cartridge; therefore, the effect of the pressure transducers on the airflow could be ignored. Measurement one, two, three, four and five were positioned on the location of 80 mm, 150 mm, 350 mm, 650 mm, and 850 mm, respectively, from the top of filter cartridge. Pressure transducers were positioned at each measurement point. Export signals from the pressure transducer were connected to the import signal from the charge amplifier. The outlet of the charge amplifier was then linked to the inlet of the data acquisition instrument. Finally, the export signal from the data acquisition instrument was linked to the computer. The systematic connection method of pressure transducers was shown in Fig.6. In the data analysis phase, Microsoft dasView2.0 was employed to acquire and change the data into the pressure data based on sensor sensitivity and the following formula (1):

$$P = \frac{v}{K_1 K_2} \quad (1),$$

where P (MPa) is the measured pressure; v (mV) is voltage output value; K_1

(*mv*/*pC*) is a multiple of the charge amplifier; and K_2 (*pC*/*MPa*) is the sensor

3. Results and discussion

3.1. Effect of nozzle diameter on cleaning performance of pleated filter cartridge

In order to optimize the relationship of nozzle diameter and jet distance, the experiment was used to obtain the optimum jet distance. In our previously study, the static peak pressures on the filter cartridge was an important indicative of cleaning performance [11,15-17]. Therefore, the static peak pressure on the filter cartridge is chosen as an index of cleaning effect in this paper. Fig. 7, 8 and 9 show that the optimum jet distances is obtained under three different nozzle diameters. The optimum jet distances of nozzle orifice Φ20 mm and Φ25 mm are 280 mm, 200mm, respectively. This is because that the bigger the nozzle diameters, the shorter the jet distances are needed to disperse the pulse airflow shown in Fig. 10. The optimum jet distance of the induced nozzle Φ16 mm is 60 mm. This is because that the induced nozzle has a height of 168 mm. The induced nozzle changes the pulse airflow streamlines. Fig. 5 shows that the pulse airflow goes through the supersonic induced nozzle and encounters the wall of air diffuser. Then the pulse airflow beam begins to disperse. Therefore, the optimum jet distance of induced nozzle Φ16 mm is shorter than the commonly nozzle orifice Φ16 mm.

Fig. 11 shows that the static peak pressure distribution varies over the height of filter cartridge under three different nozzles. Fig. 11 shows that the nozzle orifice Φ25 mm can produce the bigger static peak pressures than those of nozzle orifice Φ20 mm. The average peak pressure over the height of the filter cartridge is 4627 Pa using the nozzle orifice Φ25 mm, the average peak pressure over the height of the filter is 3455 Pa using the nozzle orifice Φ20 mm. This is because that an increase in nozzle orifice can increase the pulse airflow velocity. This pulse airflow creates a zone and generates momentum in the surrounding fluid. The bigger the nozzle orifice, the more secondary airflow are induced into the filter cartridge. The mixed airflow of pulse airflow and secondary airflow goes into filter cartridge. The dynamic pressures are converted to static pressures when the mixed airflow is encounter with the wall of the filter cartridge. Therefore, the formed static pressures on filter cartridge with the nozzle orifice Φ25 mm are bigger than those of nozzle orifice Φ20 mm. The bigger nozzle orifice, the bigger axial velocity of mixed airflow is formed. Then more goes into the bottom of filter cartridge. The peak pressures on bottom areas of the cartridge are bigger than other areas.

However, the peak pressure distribution of filter cartridge with induced nozzle Φ16 mm is different from those of nozzle orifice Φ20 mm and nozzle orifice Φ25 mm. This is because that the airflow streamlines are changed by induced nozzle. The peak pressure over the height of the filter cartridge is 2473 Pa using the induced Φ16 mm. In our previously study, static peak pressure distribution on the filter has been changed by induced airflow [11]. This is because that the pulse airflow through the induced nozzle with the surrounding airflow goes onto the air diffuser, the mixed airflow streamlines are changed and form the bigger airflow beam with the air diffuser than this without air diffuser when they encounter the wall of air diffuser. Therefore, the optimum jet distance is shorter with induced nozzle than this without induced nozzle. The airflow goes down and continuous introduces the surrounding fluid. Then the mixed airflow goes into the filter cartridge. Therefore, the bigger beam forms the static pressures on the top to the bottom of filter cartridge. The results agree with result obtained in our previously study [11].

3.2. Systematic pressure drops during clogging and cleaning cycles

The inlet particle mass concentration of dust collector is 107 g/m^3, suitable for grinding and classification. The filtration velocity is set to 0.7 min/m using an induced draft fan. The pesticide particles are filtered on filter cartridges. A reverse pulse-jet airflow is used to dislodge the pesticide particles from the filter cartridges. As the clogging and cleaning cycles progress, the systematic pressure drops vary as the operational time shown in Fig. 12. Fig. 12 shows that an increase in nozzle orifice can decrease the systematic pressure drops of the dust collector. The pressure drop of cartridge filter with induced nozzle Φ16 mm quickly increases to 2000 Pa when the system operational time is 60 min. At this time, the four filter cartridges are taken out the dust collector; the four filter cartridges are filled with pesticide particles shown in Fig. 1. This is because that the detachment forces are not enough to dislodge pesticide particles from the filter cartridge. Fig.10 shows that the peak pressure at the measurement two is 4217 Pa and the average peak pressure is 2473 Pa using the induced nozzle Φ16 mm. Although the dust cakes at the measurement two are dislodgement from the filter cartridges. However, the dust cakes at the other measurement points are not dislodgement from the filter cartridges with the times. As the operational times, the filter cartridges are gradually filled with the dust cakes at the measurement one, three, four and five. Therefore, the filtration velocities greatly increase at the measurement two. The systematic pressure drops greatly increase with the increase of the operational times. As the cycles progress, the systematic pressure drops quickly increases to 2000 Pa. At lastly, the whole filter cartridges are filled with dust cakes, as shown in Fig. 1. This experimental result is different from the result obtained in our previously study [11]. This is because that the collected particle matters are different. In this study, the pesticide particles have the characteristics of high adhesion, the low density and the fine particle size (d_{10}=0.73 d_{50}=1.61 μm and d_{90}=2.68 μm). Therefore, the detachment forces are not enough to dislodge the pesticide particles from the filter cartridge under the same conditions in our previously study. In our previously study [11], pleated filter cartridges were used collect the protein powder from the grinding. The particle size distribution of protein powder was d_{10}=2.58 μm, d_{50}=11.24 μm, and d_{90}=28.72 μm. Inlet particle of dust collector was 19.5 g/m^3. The detachment forces are enough to dislodge the protein powder from the filter cartridge. Therefore, the bigger detachment forces are needed to dislodge the pesticide particles than other commonly particles. The biggest induced nozzle diameter is Φ16 mm in industry production. Therefore, an increase in nozzle orifice is used to increase the detachment forces in this study.

Fig. 13 shows that the bottom areas of the four filter cartridges with nozzle Φ20 mm are filled with pesticide particles when the operational time is 150 min. This because that the detachment forces are enough to dislodge pesticide particles from the filter cartridges. The dislodgement pesticide particles after a pulse-jet cleaning goes into hopper with the heavily force and reverse pulse-jet airflow. However, as the filtration progress, the re-suspension particles are reattached on filter cartridges, especially the bottom of filter cartridges. As the nozzle orifice increase, the forces of the pesticide particles dislodgement from the filter cartridge are promoted shown in Fig. 11. The systematic pressure drops of cartridge filter with nozzle Φ25 increase gradually to 1400 Pa when the system operational time is 100 min, and then the pressure drops keep at the constant value. Fig. 14 shows that pesticide particles are dislodgment from filter cartridges with nozzle orifice Φ25 mm when the operational time is 200 min. This is because that the detachment forces are enough to dislodge the pesticide particles and reinforce the pesticide particles into hopper. The re-suspension particles have no chance to attachment on filter cartridge.

However, Fig. 11 shows that the static peak pressure distribution over the full height of filter cartridge is not uniform with nozzle orifice Φ25 mm. Although the pesticide particles are dislodgement from the filter cartridge, the uniform peak pressure distribution is needed to conserve the energy and to decrease destroy of filter medium. Therefore, our next goal is to seek induced nozzle with diameter Φ25 mm, which will be used to collecting particle matters with the characteristics of high adhesion, the low density and the fine particle size.

3.3. Peak pressures of filter cartridge as the operational time

Fig. 15, 16 and 17 show that the peak pressures on the filter cartridge vary as the extension of operational time. The peak pressure is an indicative of cleaning performance. The bigger the static peak pressures, the bigger detachment forces are formed. From the Fig. 15, the static peak pressures over the height of filter cartridge decrease quickly with the induced nozzle Φ16 mm. As the clogging and cleaning progress, the detachment forces are not enough to dislodge the pesticide particles from the filter cartridge. The filter cartridges are quickly clogged by pesticide particles as operational time. Therefore, the pulse airflow is not onto clogged areas of filter Then the peak pressures decrease quickly on the clogged filter cartridge as the operational time. The systematic pressure drops increase quickly to 2000 Pa as the operational time shown in Fig. 12 and the filter cartridge are filled with pesticide particles shown in Fig. 1. Fig. 16 shows that the peak pressures on the bottom of filter cartridge decrease quickly with the nozzle orifice Φ20 mm as the operational time. is because that the bottom areas of filter cartridge are gradually clogged by the particles as the operational time. Therefore, the peak pressure on the bottom areas of filter cartridge decrease as the operational time. The systematic pressure drops gradually to 1800 Pa shown in Fig. 12 and the bottom areas of filter cartridge are with pesticide particles shown in Fig. 13. Fig. 16 shows that the peak pressures on the bottom of filter cartridge decrease a little with the nozzle orifice Φ25 mm as the operational time. The pesticide particles are dislodgement from the filter cartridges. Therefore, the systematic pressure drops can keep a constant value. The bigger the pressures on filter cartridge, the bigger detachment forces are formed to dislodge the pesticide particles.

4. Conclusions

An increase in nozzle diameter can increase the peak pressures over the full of filter cartridge. The average peak pressures increase from the 2471, 3455 to 4627 when the nozzles are changed from the induced nozzle 16mm, the nozzle Φ20 to the nozzle Φ25. Additionally, the systematic pressure drops of the cartridge filter keep at the 1400 Pa with nozzle Φ25 mm with the operational time 180min. The pulse-jet cleaning with nozzle orifice Φ25 mm can effectively dislodge the pesticide particles from the filter cartridge. However, the peak pressure distribution over the full height filter cartridge with nozzle orifice Φ25 mm is not uniform. Our next goal is to seek induced nozzle with diameter Φ25 mm, which will be used to collecting particle matters.

The peak pressures on the filter cartridge can reflect the clogged process of filter medium as the operational time. The patchy cleaning is related to a decrease in peak pressures on filter cartridge. Combined with the systematic pressure drops and photos of filter cartridge in industry application, the peak pressure is an effective indicative of cleaning performance.

The cleaning performance of pleated fabric filter cartridge for collecting pesticide particles and the effect of cleaning on systematic pressure drops is obtained. This study can give a guidance to solve the cleaning problem of pleated fabric filter cartridge for collecting the particle matters with the characteristics of higher adhesion, the lower density and the finer particle size.

Acknowledgements

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Figures:

Fig.1 Difficult cleaning of pleated filter cartridges for collecting pesticide particles (with induced nozzle Φ16mm, the filter cartridges are taken out the filters after the operational time 60 min)

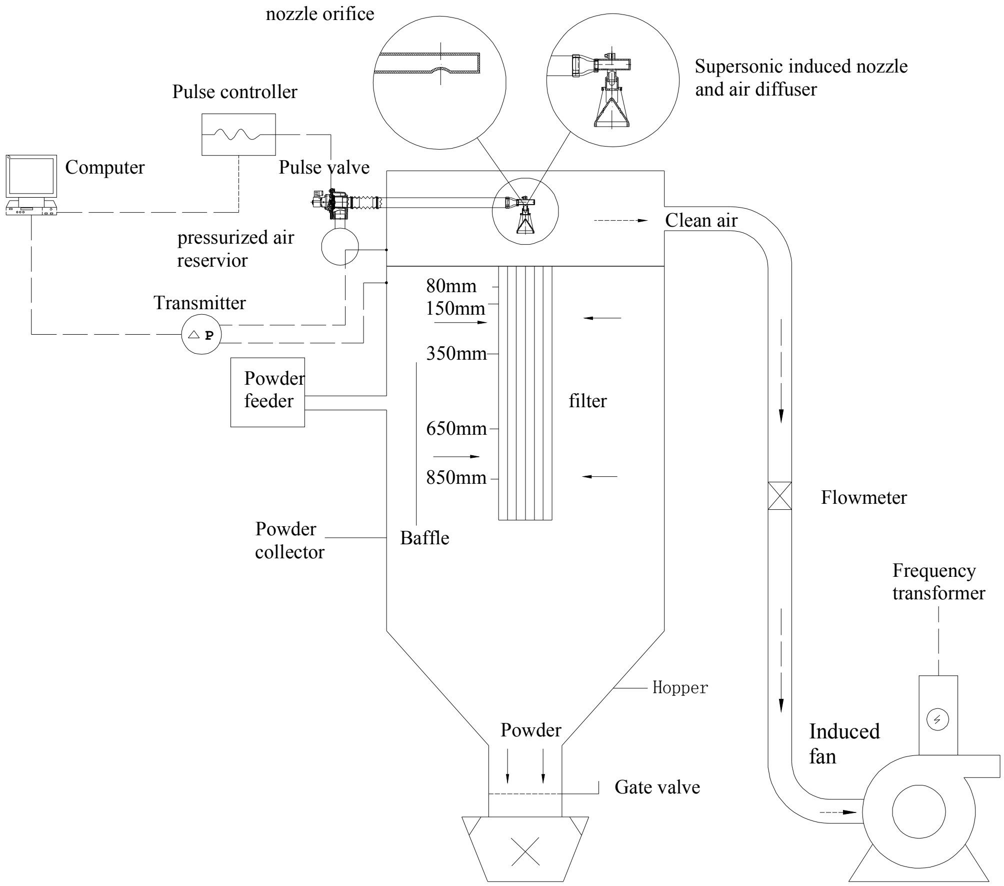
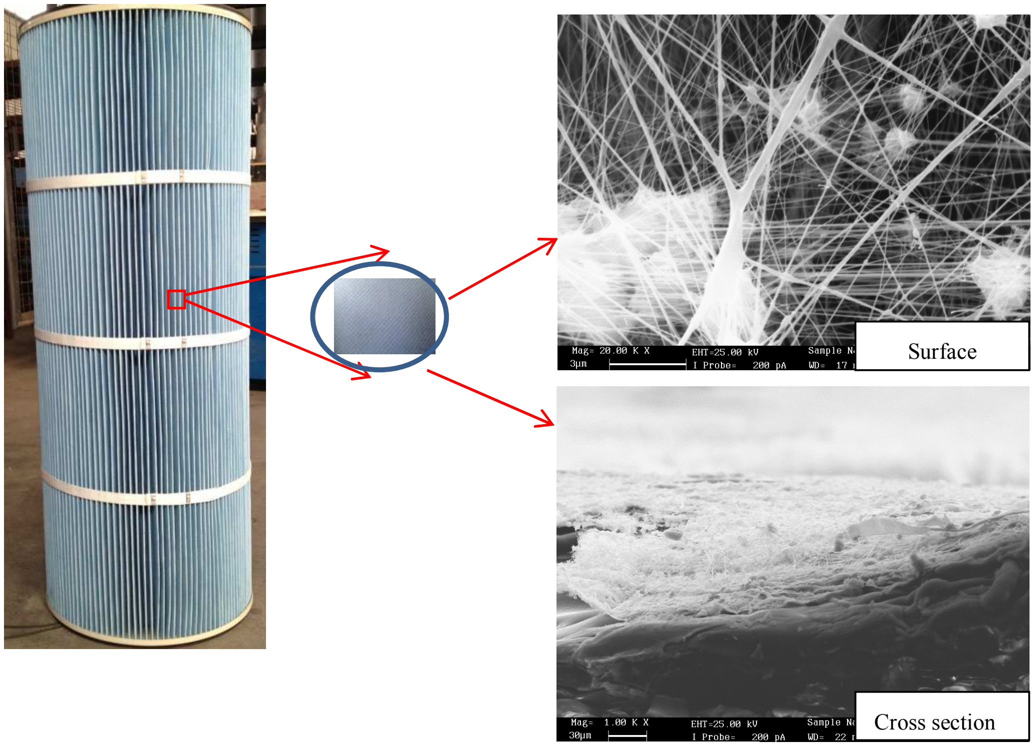


Fig.2 Schematic view of the test rig

a. dust collector and pulse jet b. hopper

Fig.3 Photos of equipment



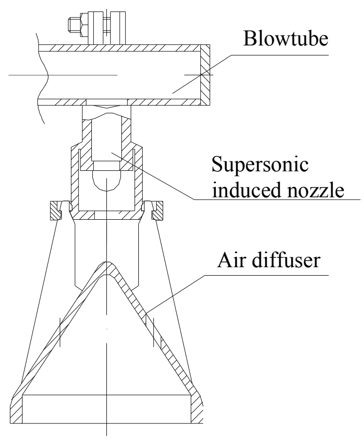
a. photo of filter cartridge and microstructure of filter medium

b. a rigid wire cage support the filter medium

Fig.4 filter cartridge

a

b



c

a. photo of supersonic induced nozzle, b. photo of air diffuser, c. schematic view of supersonic induced nozzle and air diffuser

Fig.5 Photo and schematic diagram of supersonic induced nozzle and the air diffuser

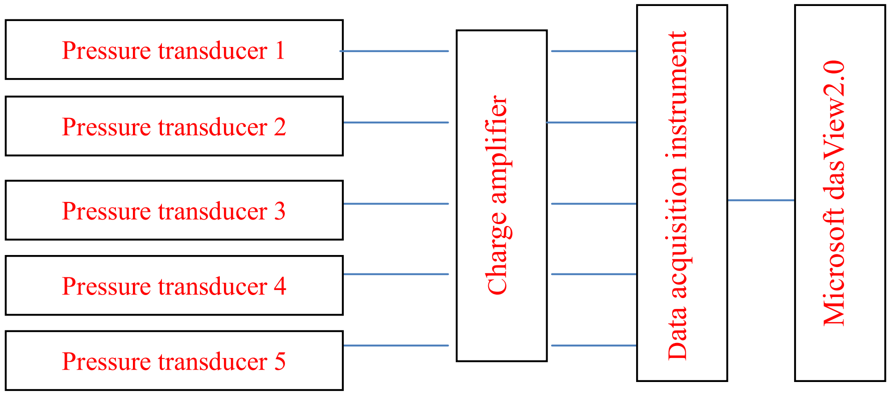


Fig.6 the systematic connection method

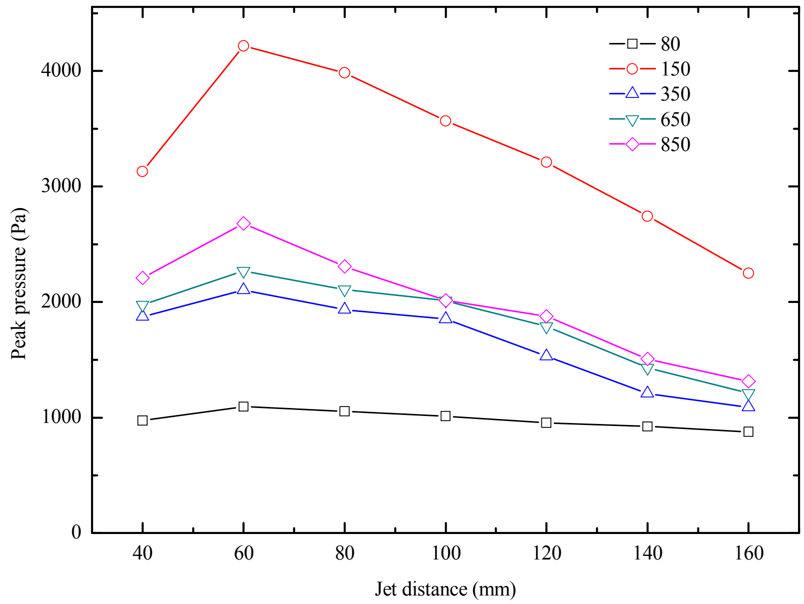


Fig.7 effect of jet distance on peak pressure with the induced nozzle Φ16 mm

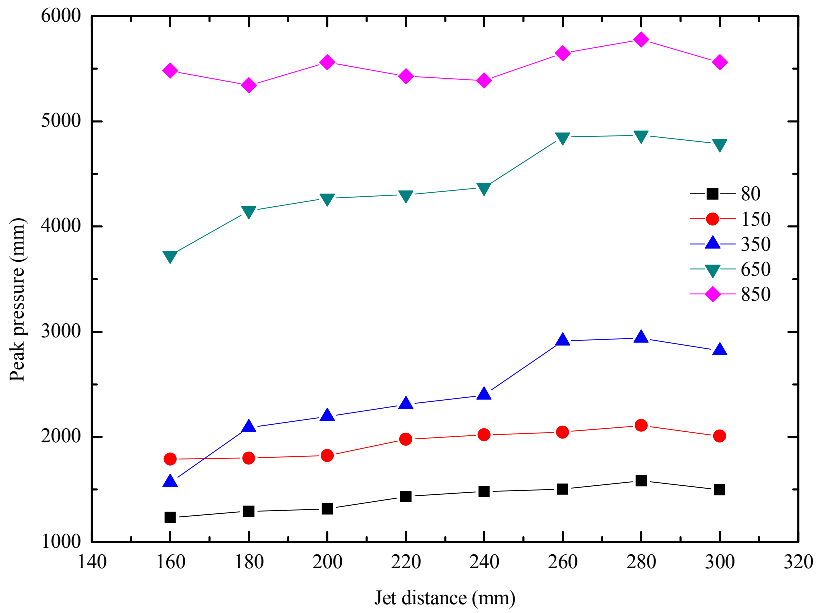


Fig.8 effect of jet distance on peak pressure with the nozzle orifice Φ20 mm

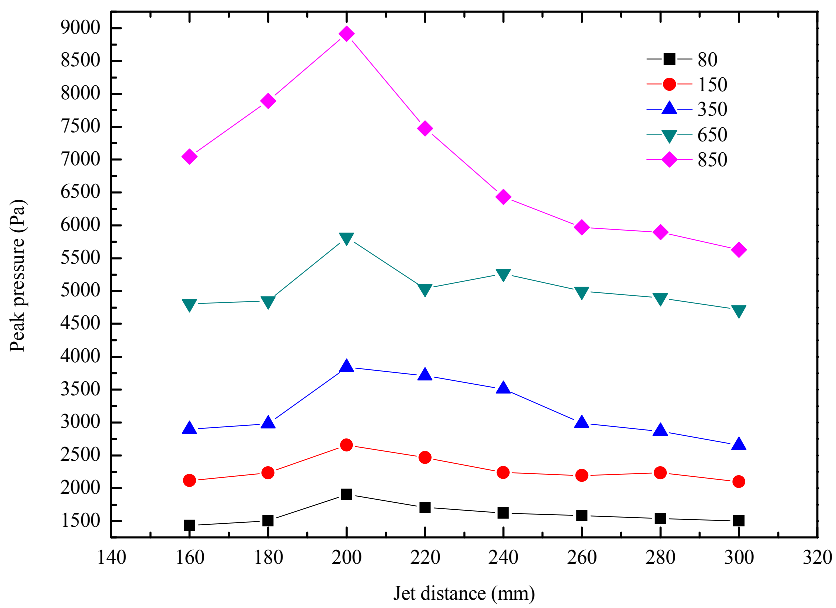


Fig.9 effect of jet distance on peak pressure with the nozzle orifice Φ25 mm

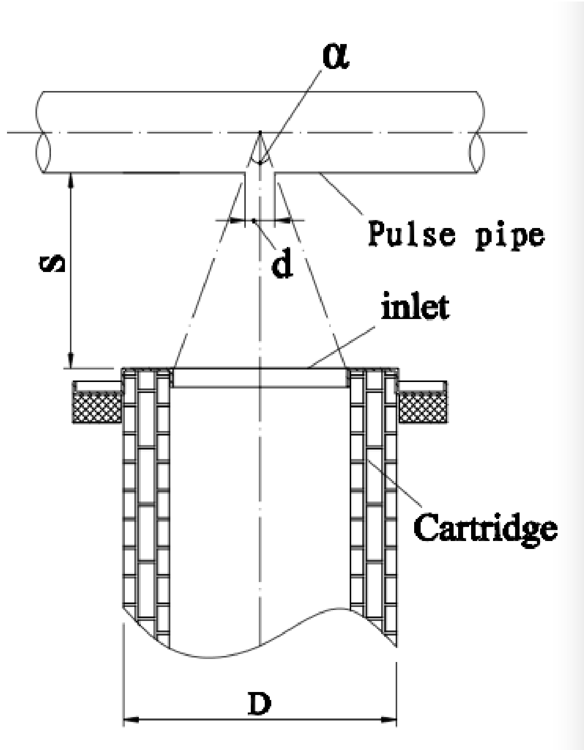


Fig.10 the relative of nozzle orifice and jet distance

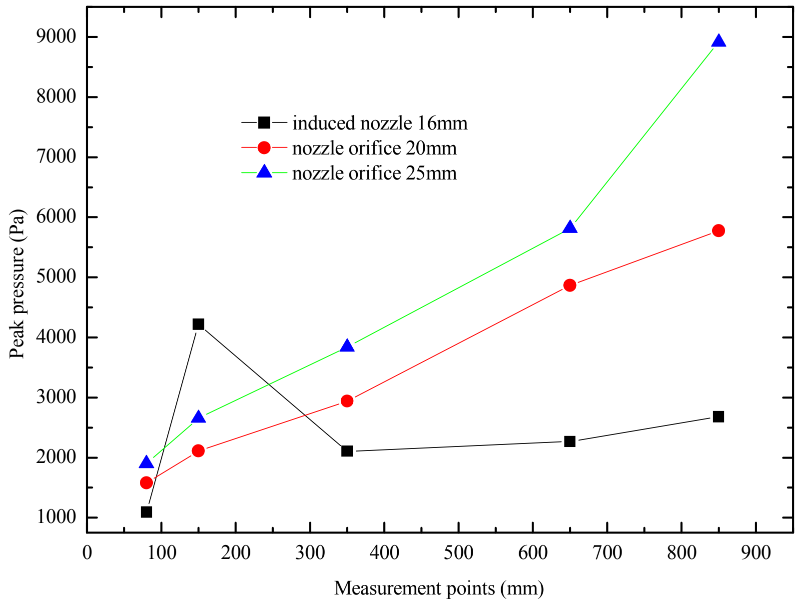


Fig.11 peak pressures over the full height of filter cartridge with three different nozzles (induced nozzle Φ16 mm with jet distance 60 mm, nozzle Φ20 mm with 280 mm, nozzle Φ25 mm with jet distance 200 mm)

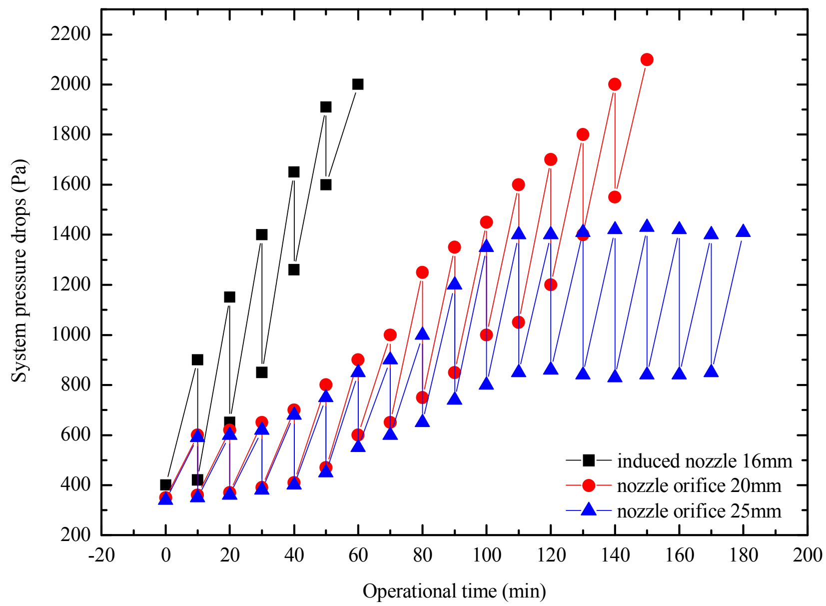


Fig.12 systematic pressure drops vs operational time during clogging/cleaning cycles

Fig.13 Bottom of filter cartridge filled with dust particles using the nozzle Φ20 mm (views from the bottom after operational time 150 min)

Fig.14 Bottom of filter cartridge filled with dust particles resolved using the nozzle Φ25 mm (views from the bottom after operational time 180 min)

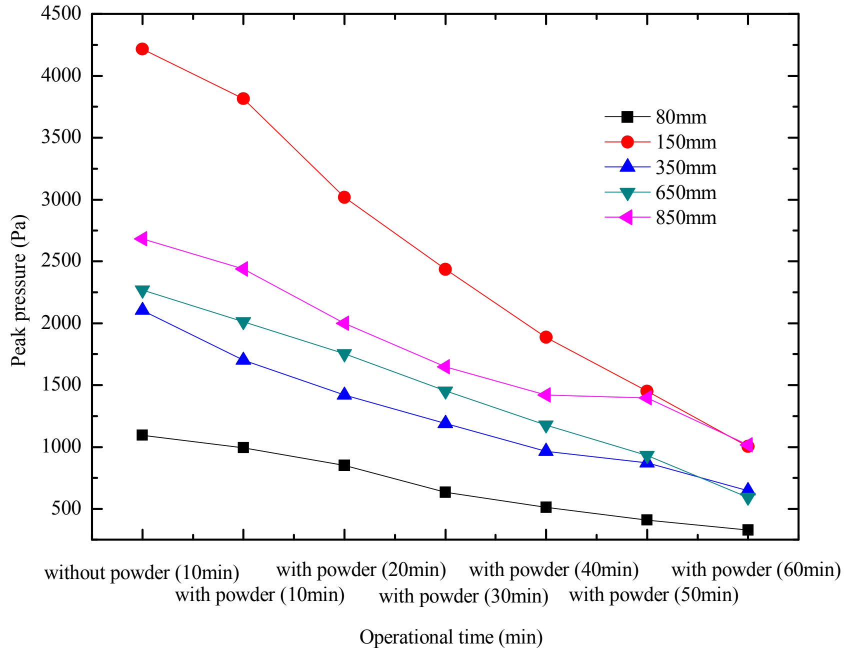


Fig.15 effect of operational time on peak pressure with the induced nozzle Φ16 mm

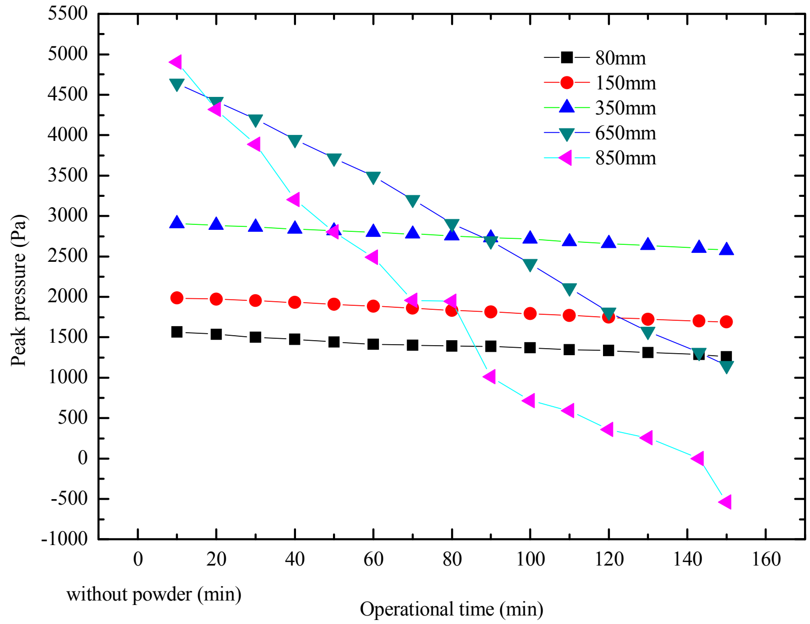


Fig.16 effect of operational time on peak pressure with the nozzle orifice Φ20 mm

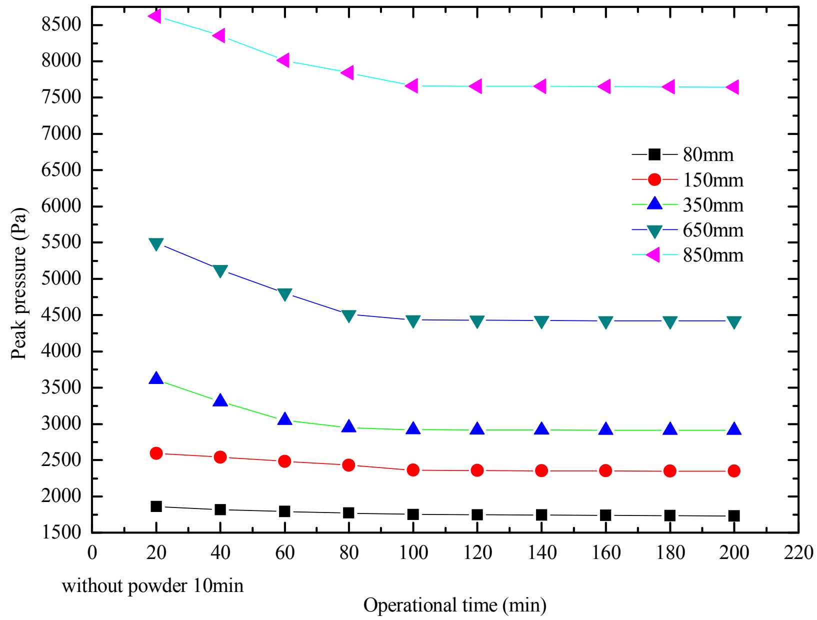


Fig.17 effect of operational time on peak pressure with the nozzle orifice Φ25 mm

Tables:

Table 1 Filter cartridge dimension

Parameters	
Pleat number (n, 个)	125
Pleat pitch (W, mm)	8.164
Pleat height (H, mm)	45
Inner diameter (D_{in}, mm)	215
Filter length (L, mm)	1000
Filtration area (A_f, m^2)	12
Surface treatment	Polytetrafluoroethene fibers
Thickness of filter medium (mm)	0.6
Air permeability ($1/m^2 \cdot s$)	80-100

Table 2 Experimental designs

Test conditions	Settings
Filter face velocity (m/min)	0.7
Inlet particle mass concentration (g/m^3)	100
Cleaning modes	Clean on time (10 s once)
Tank pressure (*MPa*)	0.6
Pulse valve opening time (*ms*)	100
Pulse flow (*L*)	80
Induced nozzle diameter (mm)	16
Nozzle diameter (mm)	20 or 25
Distance between induced nozzle and filter cartridge top (mm)	50
Diffuser height (mm)	102