Exploration of $PM_{2.5}$ filtration property of filter bag for environment protection

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Abstract. In this paper, filter bag of polyphenylene sulfide (PPS) needle punched nonwoven for environment protection was investigated. The results showed that air permeability of sample was linear rise with the increase of the pressure drop. During the testing process, the residual pressure drop rose with the increase of cycles because of test dust attaching on the surface of the filter. The $PM_{2.5}$ filtration efficiency was obtained of 99.854%, which was smaller than the dust filtration efficiency of 99.971% because of the fine particles taking larger proportion of the dust through the sample. Results show that this method of evaluating the $PM_{2.5}$ filtration property is feasible.

1. Introduction

At present, with the heavy industry rapid development mainly base on the type of energy resources consumption, China has become the largest producer of iron and steel, cement, coal and chemical fiber in the world, simultaneously become the second largest producer of electric power, non-ferrous metal, chemical fertilizer[1]. The waste discharged by various industrial furnaces of above industries contains a lot of dust and harmful gas, with high temperature, was one of the main factors of haze weather occurring frequently in China[2]. $PM_{2.5}$, one of the pollutants of haze weather, has become the focus of attention. $PM_{2.5}$ refers to the particles with aerodynamic diameter less than or equal to 2.5 microns, also known as fine particulate matter in China. This kind of particles is pollutant, at the same time, also is the carrier of harmful gases and toxic substances such as heavy metals and polycyclic aromatic hydrocarbons, which cause serious damage to people's respiratory system and cardiovascular system[3].

Facing the increasingly serious environmental pollution, Chinese government put forward measures of monitoring and governance of $PM_{2.5}$ in the air in November 2011. And in 2012, the national standard GB 3095-2012 *Ambient air quality standards* published[4]. In order to comply with the standard GB 3095-2012, the index requirement of gas emission after filtration will be further strict. Industrial gas is one of the major sources of $PM_{2.5}$. Due to the regional industrial structure and geographical environment, gas and dust pollution of China is concentrated in different fields, such as coal-fired power plant, cement kiln, iron and steel plant, metallurgy factory.

Dust remover is one of the most important measures of controlling the air pollution. The dust removal technology of filter bag can effectively reduce solid particle emissions, with a good dust removal effect, which can fundamentally solve the problem of $PM_{2.5}$ emissions. At the moment, testing standards of filtration performance of filter bag for environment protection include GB/T 6719--2009 *Specifications for bag house*[5], ISO 11057: 2011 *Air quality -- Test method for filtration characterization of cleanable filter media*[6], VDI 3926-1: 2004 *Testing of cleanable filter media --*

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Standard test for the evaluation of cleanable filter media[7], but don't involve the filtration property of $PM_{2.5}$. Refer to the method above, this investigation evaluate the $PM_{2.5}$ filtration property via analyzing the size of dust and separating the $PM_{2.5}$ from the dust through the sample.

2. Experiment

2.1 Sample

The sample used in this investigation was polyphenylene sulfide(PPS) needle punched nonwoven from *Guangdong S.L.P. Environmental Protection Technology (Group) Co., Ltd.*

2.2 Airpermeability

According to GB/T 5453-1997 *Textiles--Determination of the permeability of fabrics to air*[8], the air permeability of sample was obtained by air permeability tester III (Model FX3300) manufactured by *TEXTEST AG Zurich, Switzerland*, with a circular test area of 20 cm^2 and a series of different pressure drop.

2.3 Particle size distribution

According to ISO 13320-2009 *Particle size analysis -- Laser diffraction methods*[9], the particle size was analyzed by the laser particle analyzer (Model HELOS/BR-OM/RODOS) manufactured by *Sympatec GmbH* of Germany, with a dispersive pressure of 4.00 bar.

2.4Scanning electronmicroscopic (SEM)

The morphology of sample was studied by a HITACHI S-3000N (Japan) scanning electron microscope, with a voltage of 15 kV and a work distance of 22 mm.

2.5 Filtration characterization

In accordance with ISO 11057: 2011 *Air quality -- Test method for filtration characterization of cleanable filter media*, dynamic dust filtering performance of the sample was characterized by the particle filtration efficiency testing system (Model FEMA 1-AT-SR), which is manufactured by *Fil T Eq GmbH* of Germany, with a $PM_{2.5}$ separation component for splitting $PM_{2.5}$ from the particles through the sample while testing.

3. Results and discussions

3.1 Air permeabilityanalysis

As shown in Fig. 1, air permeability of sample was linear rise with the increase of the pressure drop, which means the structure of the material was relatively stable.The structure of the fibers of the sample did not transform with the pressure drop changing.

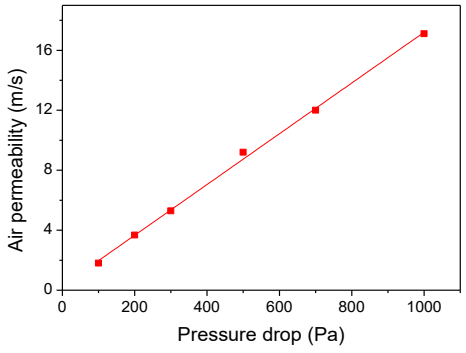


Fig. 1 The air permeability of different pressure drop

3.2Particle size analysis

According to ISO 11057:2011, test dust consists of boehmite, an aluminium-oxide-hydroxide [γ-AlO(OH)] mineral. The mass mean particle size is about 4.5 μm. From Fig. 2, test dust presents bimodal dust distribution with the peaks of about 2.0 μm and 10.0 μm. The weight proportion of $PM_{2.5}$ is about 40%.

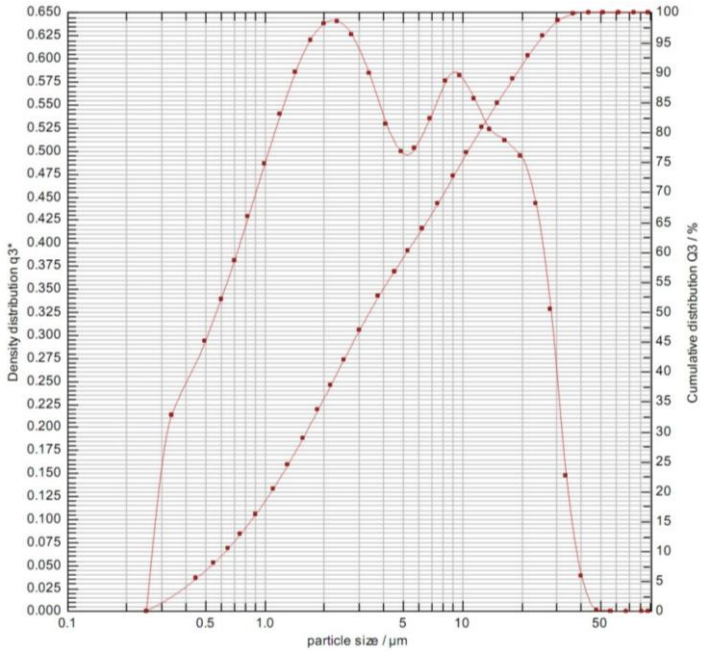
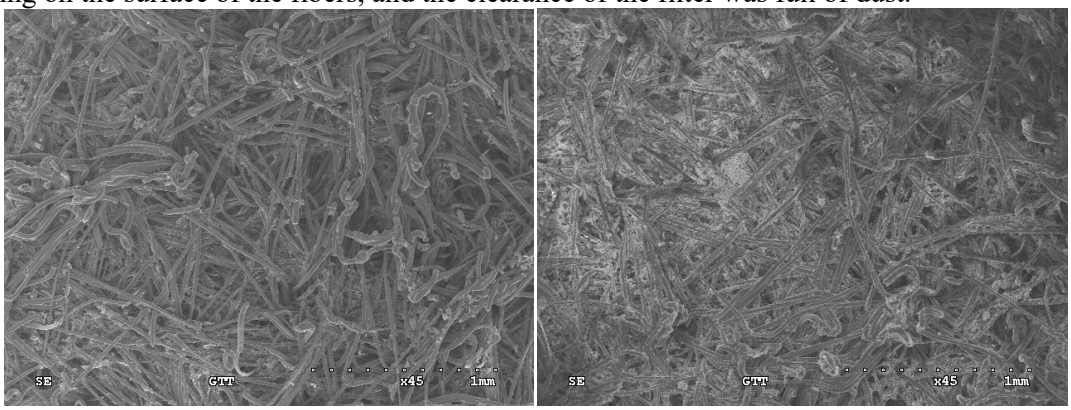


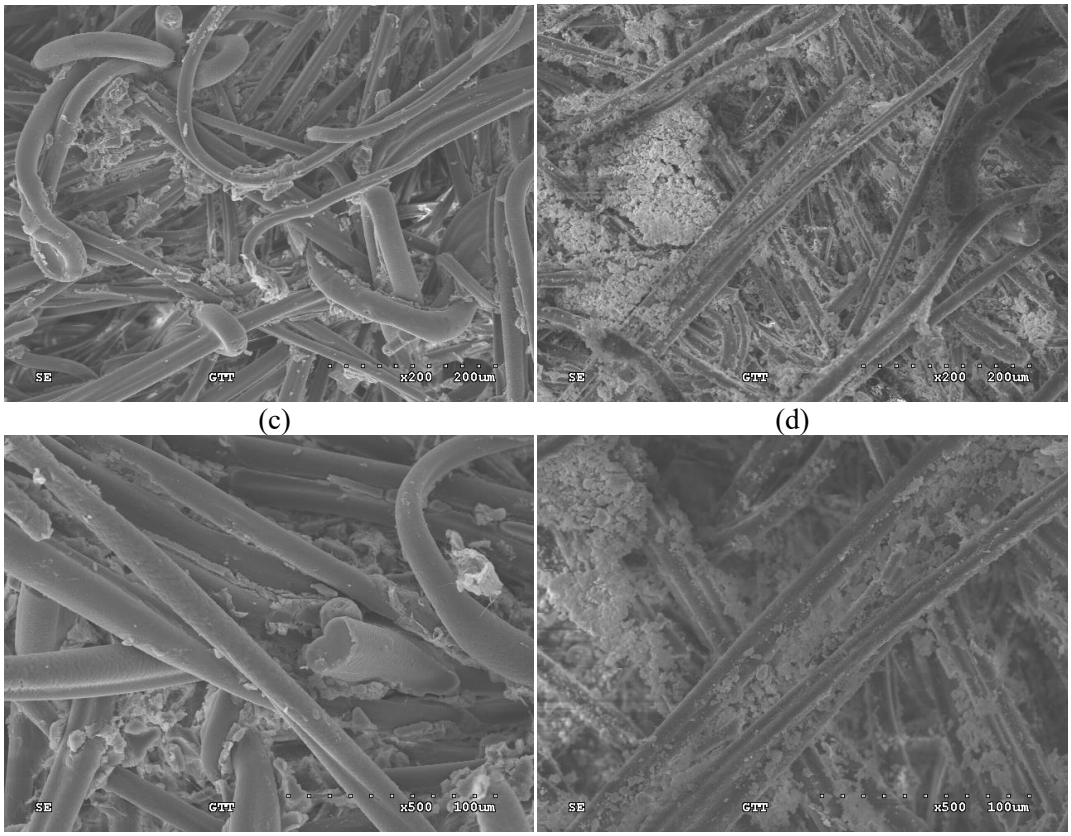
Fig. 2 The particle size distribution of test dust

3.3 Morphological structure observation

As is shown in Fig.3, pictures on the leftshowed theoriginal material and the ones on the right showed the sample tested. There were obvious traces of melting and intertangling fibers on the surface of the original filter due to the singeing during processing. After filtration testing, there was lots of dust attaching on the surface of the fibers, and the clearance of the filter was full of dust.



(a) (b)



(c) (d)

(e) (f)

Fig. 3 SEM micrographs of samples before and after filtration testing

3.4 Filtration property

In accordance with ISO 11057: 2011 *Air quality -- Test method for filtration characterization of cleanable filter media*, the whole test consist of 4 phases showed in Table 1. In the first 30 cycles of phase 1, the residual pressure drop rose slowly with the increase of cycles. But for the 30 cycles after aging of phase 4, the residual pressure drop rose quickly, as is described in Fig. 4.

Table 1 Sequence of the standard test phases

Measuring phases	**Conditions**
Phase 1: conditioning	30 loading cycles with differential pressure controlled pulse-jet cleaning and a cleaning set point of 1 000 Pa
Phase 2: ageing	2500 pulse-jet cleaning cycles at an interval of 20 s each
Phase 3: stabilizing	10 loading cycles with differential pressure controlled pulse-jet cleaning
Phase 4: measuring	30 loading cycles but at least 2 h measuring time with differential pressure controlled pulse-jet cleaning and a cleaning set point of 1000 Pa

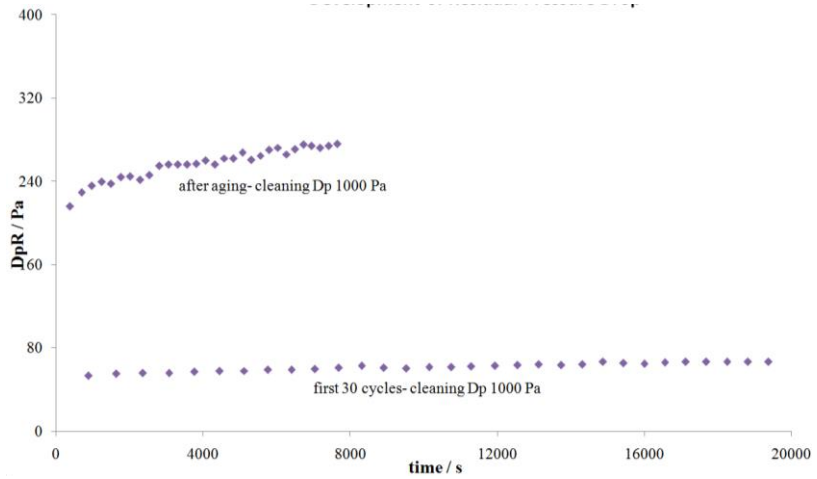


Fig. 4 Development of residual pressure drop of the sample

The first cycle duration of phase 1 was about 890 seconds, and then we can see a gradual decline of the next 29 cycles (Fig. 5). It took five hours and fourteen minutes to finish the first 30 cycles, but two hours and eight minutes to finish the 30 cycles of phase 4, due to dust residue in the sample. For the same reason, the first cycle duration of phase 4 drop rapidly to 395 seconds after aging and then the cycle duration reduced gradually.

The concentrations of dust and $PM_{2.5}$ penetrating the filter sample during the experiment could be obtained through separating the $PM_{2.5}$ from the dust. Therefore, dust filtration efficiency and $PM_{2.5}$ filtration efficiency can be calculated by the upstream and downstream concentrations of particles. The dust filtration efficiency of sample was 99.971%, with the $PM_{2.5}$ filtration efficiency of 99.854%. This was because of the fine particles taking larger proportion of the dust through the sample, which was in line with our expectations

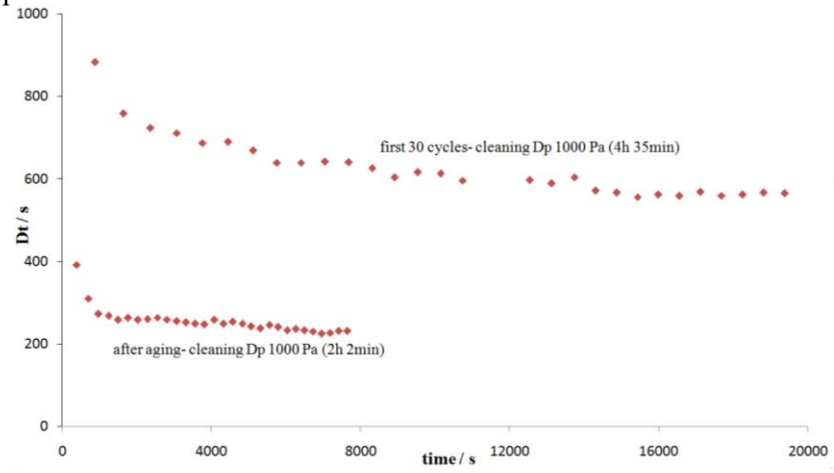


Fig. 5 Development of cycle duration

4. Conclusions

Air permeability of filter bag was linear rise with the increase of the pressure drop. The $PM_{2.5}$ filtration efficiency was obtained of 99.854% via analyzing the size of dust and separating the $PM_{2.5}$ from the dust through the sample, which was smaller than the dust filtration efficiency of 99.971% because of the fine particles taking larger proportion of the dust through the sample.

Acknowledgments

This work was financially supported by Guangzhou Bureau of Quality and Technical Supervision (Fund number: 2015kj16).

Reference:

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[9] ISO 13320-2009 *Particle size analysis -- Laser diffraction methods*