Filtering technology for air purification in HVAC

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Abstract: this paper is mainly present the filtering technology for air purification in the process of ventilation and air conditioning. By the means of reviewing the related research we have made in this area, several effective programs for PM10 filtration are introduced from the view of experimental testing and practical applications. However, the selection and screening of fiber filter material has yet to be standardized, and the development of new multi-functional and energy efficient fiber filter material is pressingly required. So in the conclusion part, several views are proposed to provide new ideas for the further development of filtering technology in the process of ventilation and air conditioning.

Keywords: filtering technology; PM10; air purification; HVAC

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0 Introduction

Over the decades, the air quality and environmental problems have attracted most of people's attentions. Hence, the air purification with filtering technology played an essential role in the ventilation and air conditioning process. Basically, the traditional filtering technology mainly focuses on the particulate matter control. For China, soot and automobile exhaust are the two major sources contributing to air pollution. In particular, nearly one-fifth of cities in China have been faced to the serious air pollution problems at present, and more than one-third of the 113 major cities in China could not achieve the secondary standard of national air quality [1]. The ambient respirable particulate matter (PM 10) is considered as the most deleterious pollution for inhabitant health and circumstance, which could cause the respiratory disease by adhering to the bronchial wall or alveolar wall. Moreover, PM 10 could be the vector of the harmful compounds, bacteria and virus in most cases, causing disease by respiration procedure. Owing to its seriousness, it is indicated in national "HVAC (heating, ventilation and air conditioning) design handbook" (GB50019) that the PM10 has been regarded as the essential air pollution which should be under control and the concentration of PM10 should not extend to 0.15 mg/m^3. Meanwhile, the subject "Investigations on prevention of particular matter pollution and thoughts of control approach" has been involved in " the twelfth Five-Year National Environmental Protection Plan " by 2010 [2].

Actually, the control of PM10 should serve to two respects: one is to people's health and the other is to craft, which namely means the products produce and equipments should be protected, and the energy utilization should be improved. Although the mature technologies of air purification protecting the craft have been mainly utilized in electronics and pharmaceutical industries [3], the existing air cleaning technique cannot solve all of the issue to certain extent. At present, the air purification issues still involved in inhabitant health, craft protection and energy utilization improvement fields, such as the spread of bacteria virus (SARS), the capacity

constraints of heat exchanger by dirt, and the influence of fluid flow rate in pipe when the higher speed causing fray and lower speed inducing blockage.

In this paper, we mainly focus on the description of our research results on filtering technology application in certain fields, including the purification of indoor air circulation, the fresh air filter installation in air conditioning units, fresh air filter utilizations in industrial environment. Moreover, innovate filtering technologies and strategies are promoted to purify air during ventilation and air conditioning process. As for filtering technology, there are also some researches for individual respiratory protection, which can be seen in other papers [4][5][6][7][8].

1 Cyclic purification for internal air

Currently, most of the household air conditioners are only installed with the simple filter screens and low efficient filter, which are seldom applied with air purification procedure. Due to the lack of device arresting the PM10 effectively, it could not ensure the concentration of PM10 of the internal air could achieve the standard. Hence, it is obligatory to amend the internal purification system. The most efficient approach is to add the filtering material to the filter screen, which is similarly with wearing the mask for the air conditioner.

Accordingly, the test bench measuring the filtering capability of filtering material for PM10 has been set up based on the PM10 index of modified HVAC design handbook. Furthermore, this test bench could test the performance of filtering material under variety of filtering velocity, such as the filtering efficient with weight calculation and resistance to PM10. The experimental device is illustrated in Figure2-1 below.

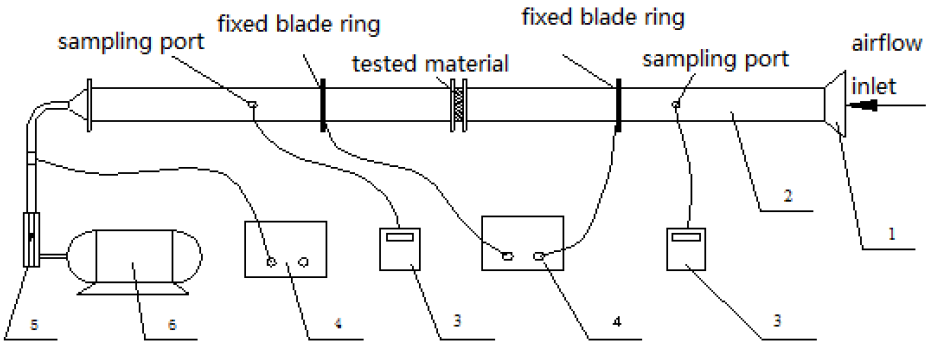

Fig. 2-1 schematic diagram of the testing bench for the filter materials performance

1-current collector，2-testing tube（φ50mm），3- TSI 8520 DustTrak^{TM} Aerosol Monitor，4- DP1000-II digital micromanometer，6- LZB rotameter，7- oil-free vacuum pump

(a) Air duct system: air duct system is made of organic glass steel, which is divided into two steps, and its diameter is 50mm;

(b) Dynamic system: the dynamic system utilize oil-free vacuum pump as resource;

(c) Measurement system: TSI 8520 DustTrak^{TM} Aerosol Monitor is used for measuring the concentration on weight calculation of particular matter of aersol, DP1000-II digital micromanometer is used for measuring the resistance, LZB rotameter is used for controlling the flow volume of filtering air;

(d) Weld fume system: using Aersol or the Talcum Powder with the diameter of 1μm.

Compared to the various non-woven filtering material samples including melt-blown, acupuncture and compound by the performance test, it could be concluded that the charged acupuncture fiber has the best filtering characteristic, which is also with the high efficient and low resistance feature. Through the electrets treatment for filtering material, the carrier would be deposited on the fiber, thus it could become the fiber electrets with charged permanently. In ordinary, the filtering material is relying on the original mechanical barrier to suspend the particular material. However, this kind of filtering material could capture the electrical material by the appeal of Coulomb force, besides it could induce the neutral particles to become polarity and then absorb the PM10. In fact, according to this approach, it could purify the phase of the sub- micro particles more efficiently, which could improve the efficiency several times [9][10]. In comparison with the conventional

filtering material, the innovated filtering material is cheaper, more flexible and less resistance, which could lessen the use of materials, could be folded in hinge deformation. With consideration of its advantages, the 150g/m3 charged acupuncture fiber was utilized in the household air conditioner. It could be concluded by practical application that the filtering effect modified significantly since this kind of material installation. For instance, the filtering efficiency to the PM10 could achieve 71% ~73.6%, meanwhile to the PM2.5 it could reach 68.4% ~ 70.2% and to PM1.0 it arrive at 66.3% ~ 69.6%. In view of the high filtration efficiency, it could reach the merit standard immediately even if in the heavily polluted conditions. Nevertheless, in terms of the initial resistance is slightly higher to the air conditioner, resulting in reducing fan velocity and low wind speed of supply and return air. Thus, it made the cooling procedure longer, but did not influence the original performance of air conditioners [11].

3 Fresh air filter installation in air conditioning units

When the concentration of outdoor respirable particulate matter does not meet the standard, the introduction of fresh air may become another source of pollution rather than improve indoor air quality. Therefore, adequate emphasis should be put forward on fresh air filter technology, which belongs to disposable filtration, during the process of ventilation and air conditioning.

We tested the performances of common used bag filters in Central Air Conditioning System, and comparative analyzed the data [12][13][14]. We have found that the efficiency of bag fibers made of ordinary fiber material increases with the increasing of the particle size, and also the amount of the dust accumulated on the filter. But for the electret filter, the variation regulation of filtration efficiency is different for its different filtering mechanism. Data shows that the filtration efficiency is higher than those ordinary ones and of clean state is

highest. With the accumulation of the dust, firstly a slight increase in the filtration efficiency, then partly declines, and then increases again. We soaked electret filtering material in the isopropyl alcohol solution, and made the charge fiber material attenuate permanently, leading to the fierce reduction of filtration efficiency while the resistance remained unchanged. Therefore, to reasonably use the charged fiber filters, the filtration efficiency reduction caused by charge neutralization should be taken into account.

Assuming that particles are uniformly distribute, indoor cleaning mode was established. If particles are uniformly distributed, the indoor particulate instantaneous concentrations can be calculated as followed:

$$N_t = \left[N_0 - \frac{Mn(1-S)(1-\eta_n)+G}{n-nS(1-\eta_r)} \right] e^{-[1-S(1-\eta_r)]nt} + \frac{Mn(1-S)(1-\eta_n)+G}{n-nS(1-\eta_r)} \quad (3\text{-}1)$$

N_t — concentration of indoor dust at a time t， mg/m3；

N — stable concentration of indoor dust， mg/m3；

N_0 — original concentration of indoor dust， mg/m3；

V — volume of the house， m3；

n — air changes， time/h；

G — dust generation volume per-unit indoor space ， mg/(m3.h)；

M — atmospheric dust concentration， mg/m3；

S —— return air ratio， %；

η_1 ——filter efficiency for fresh air， %；

η_2 ——filter efficiency for return air， %；

η_3 ——filter efficiency for terminal equipment， %；

The stable concentration of indoor dust can calculated as followed:

$$N = \frac{Mn(1-S)(1-\eta_n)+G}{n-nS(1-\eta_r)} \quad (3\text{-}2)$$

Compared the example of the applications of the electret fresh air filter with the existing fresh air filter with the equation 3-2, the result shows that the existing fresh air filter cannot meet the national requirements that PM10 should be less than 0.15 mg/m^3 while the electret fresh air filter can[15][16].

4 Fresh air filter for industrial environment

It is well known that China is an industrialized nation, thus it is necessary to filter the fresh air in the industrial environment for workers' health, which plays a key role in the production process.

Using positive pressure cleaning equipment to effectively clear particles in the atmosphere and improving the fresh air with the air-conditioning system are believed to be the main technology for "foggy yarn" in the textile industry. A kind of positive pressure cleaning equipment is provided for "foggy yarn"[17][18].The equipment with polypropylene electret filter material has the feature of compact structure, high filtration efficiency, low filtration resistance and long life. The filtration efficiency reaches 80.9％ for the particles PM2.5, with filtration resistance 95pa in clean conditions. The filtration efficiency becomes 78.3％ for the particles PM2.5, with filtration resistance 180pa after a half year when the filter needs to be replaced. The filter for fresh air is installed as showed in figure4-1.

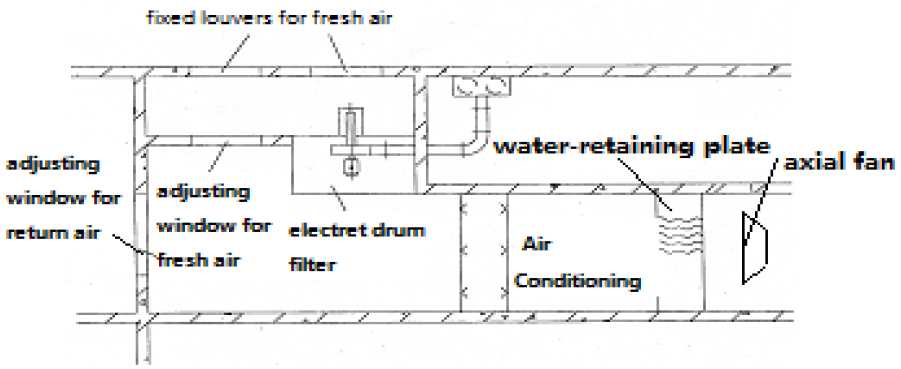

Fig. 4-1 Planar graph of electret drum filter

The working principle is that after the ambient air filtered through the drum filter, some of particulate matters would be intercepted by electret filtering material, and collected regularly by the rotative suction nozzle, then through the dusting fan sent to the dust box to be separated between dust and air. The dust which adhered to the surface of the dust bag would fall into the ash container by regular mechanical vibration, then compacted and collected by the extrusion press. The separation of air would be through the drum filter again. The air after dealing with filtering would be compound with the return air of the spun yarn workshop by axial fan. After that it need be processed in spray chamber. Then it enter the spun yarn workshop through the water-retaining plate, air main and branch duct.

The result of the practical test for the spun yarn workshop show that, compared with the other three production areas, the A area installed the air convection ventilation and purification devices, and the atmospheric environment influence of particulate matter is very less, the concentration of the fine particulate matters (PM2.5) is very low. At the same time, the generation rate of the deficient "foggy yarn" is much lower than the other three areas. The productive process of the "foggy yarn" affects by ambient air, in different ambient air conditions, the result of this device for prevention and control of the "foggy yarn" still need to be tested in practice.

5 Conclusion

As for the increasing requirement of air quality, the application of the filtration technology in the process of ventilation and air conditioning has drawn widespread attention. However, the selection and screening of fiber filter material has yet to be standardized, and the development of new multi-functional and energy efficient fiber filter material is pressingly required. Several views are proposed:

(1) As health is more important than comfort, closer attention should be paid on human health in the design of HVAC;

(2) Among China's current standards , "Indoor Air Quality Standard "(GB / T 18883-2002) is related to the concentration limits of PM10 ≤ 0.15mg/m3 in civil buildings, but it's just a recommended standard, and the technical means for ensuring the compliance of PM10 is still no clear. Therefore, the selection of fiber filter and filtering material in the actual projects needs to be pressingly standardized;

(3) The filtering technology used in industrial ventilation should be further concerned, and the development of high temperature resistant filtering material is significant;

(4) Development of energy-efficient fiber filtering material, low resistance, high efficiency and long life, is an important direction of the fiber filtering material research;

(5) Not be limited to particulate matter control, the advantage of the different characteristics of fiber material itself may be taken to achieve cooperative control of harmful gases;

(6) For the building-energy-saving requirements, fiber filtering material with appropriate comprehensive features (large surface area , small size, good performance in heat transfer, etc.), may directly service to the heat exchange parts of ventilation and air conditioning system, which can recover the exhausted heat meanwhile reduce the harmful emissions, thus provide a new solution for energy use and recycling.

Reference:

[1] (http://news.china.com.cn/rollnews/2010-09/06/content_4141268.htm) Ministry of Environmental Protection

[2] The institute for public selection undertaking unit for "The twelfth Five-Year National Environmental Protection Plan". 2010 .05

[3] Xu Zh. L., Technologies and principles of air cleaning, Shanghai, Tongji University Press, 1998, 86－116

[4] Shen H. L Yang. G Liu. H Wang. L Cai. S Liu and Y Lu, Performance of a new mask material in filtering

ambient aerosols for medical staff, *Acad J Sec Mil Med Univ*, 2003, 24(6): 629-31.(in Chinese)

[5] Yang L., Shen H. G., Wu G. 2007, " Racial Differences in Respirator Fit Testing: A Pilot Study of Whether American Fit Panels are Representative of Chinese Faces ", *Ann Occup Hyg*. 51(4): 415-421.

[6] Yang L., Shen H. G^{I}. 2005. "The Assessment on The Leakage of Simple Respiratory Protection in Ambient Air", *Proceedings of Indoor Air 2005*, Beijing, Sep. 2005, Vol.I (2): 1011-1015.

[7] Yang L., Shen H. G^{II}. 2005. "Quantitative Study on the Relationship between Leakage Volume of N95 Respirators and Inhaled Airflow against PM10, PM2.5 and PM1.0", *Proceedings of 6th International Scientific Conference of International Occupational Hygiene Association*, Johannesburg, Sep. 2005, 231-236.

[8] Yang L., Shen H. G. 2007, "Performance Evaluation of Electret Fiber, Non-woven and Cotton Fiber used for Respirators Challenged with Polydisperse Ambient Aerosols", in Proceedings of 2007 International Forum on Biomedical Textile Materials, May 2007, Shanghai, 114-117.

[9] Chen, C. Y., Filtration of Aerosols by Fibrous Filters, Chem. Rev., 1955, 55, 595

[10]A.C.Payatakes, Model of Aerosol Particle Deposition in Fibrous Media with Dendrite-Like Pattern.Application to Pure Interception during Period of Unhindered Growth, Filtration & Separation., 1976, 13, 602-608

[11]Wang H. Y. 2004, "Performance of the filter materials on PM10", Master thesis (in Chinese)

[12] JIS B 9908-1991, Air Filter Units for Ventilation，Japanese Standards Association，2001

[13] Dorman, R. G., In High Efficiency Air Filtration ,Buterworth, London, 1964

[14] Ronard G.Stafford and Harry J.Ettinger. Comparison of Filter Media Against Liquid and Solid Aerosols. American industial hygiene association Journal, V32,No.5,309~326,1971

[15] Tan L.L.2005, "The experimental investigation of the fibrous material and fibrous filter for particulate matter control in building environment", Master thesis (in Chinese)

[16]Yu X. 2005, "Investigation of Test and Application of Fibrous Filter for Particulate Matter Control in Civil Air Conditioning System" , Master thesis (in Chinese)

[17]Zhang W. 2005, "Study on Technology of Eliminating the Foggy Yarn in the Cotton Mill", Master thesis (in Chinese)

[18] Zhu H., Shen H. G., Zhang W. "Causes and Prevention of the Foggy Yarn in the Cotton Mill", Building heat energy, ventilation and air conditioning, 2004, 23(1), 80－83