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Comparative Study on Separation Performance of Micro-Porous and Micro-Fibrous Filter Mediums

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Abstract

Two types of microfiltrex materials were tested for their separation performances for different air flow rates and dust loadings. Retention of dust particles within the filter and the surface cake were measured. From mass deposited inside the filter media, change in porosities together with the increase in filter and cake pressure drops were calculated as a function of loading and approach velocity. Leakage from these materials was also investigated at different approach velocities.

Key words: Micro-porous, micro-fibrous filtration.

Introduction

Microfiltrex materials are used for high temperature and pressure applications in many industrial and biomedical operations and processes for removing suspended particles in fluids. The particles may be undesirable constituents as in toxic, nuclear waste or radioactive particles, or they may be the desired product, as in the chemical preparation of pharmaceuticals. These materials are resilient at high cross flow velocities and high mass flow rates of gases.

Separation performance of a microporous medium is primarily a function of interconnected voids within the material and upon the size distribution of the solids dispersed in fluid and of the pores at the surface of these voids.

(Boundy *et al.*, 2000) investigated performance changes over time for industrial collectors that removed metal working fluid mist in laboratory and in a transmission plant. Acrosizers were used to measure the efficiency of each stage in several multistage collectors as a function of mist droplet diameter for up to one year of continuous operation. Metal-mesh, first-stage filters operated at low pressure drops and were effective at removing droplets larger than 3 to 5 μm in diameter. Some second-stage filters worked better than others. Both 65% and 95% cartridge filters failed after only a few weeks; their efficiencies decreased substantially over that time. Pocket filters and cylindrical cartridges used as second-stage filters also decreased in efficiency for submicron droplets. Whereas filters for solid particles loaded continuously to form a dust cake that increased efficiency, mist filters formed no cake and loaded only to the point where collection was equal to leakage. As a mist filter loaded, the interstitial gas velocity increased, so that efficiency decreased for small droplets that were collected by diffusion. Martin and Moyer (2000) studied three types of electrostatic respirator filters with respect to filter penetration and most penetrating particle size.

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First of these filters were loaded with a sodium chloride aerosol, and three of each filters were loaded with a dioctyl phthalate aerosol to obtain normal background penetration results for each filter. Then, two new filters of each type were dipped in isopropanol for 15 seconds to eliminate any electrostatic charge on the fibers and allowed to dry. In all six of the tested filters, filter penetration values increased considerably and the most penetrating particle size noticeably shifted toward larger particles. These results are important in better understanding how these new filter materials perform under various conditions, and they indicated the need for additional research to define environmental conditions that may affect their clogging behaviour. The present is an effort in this direction to study clogging performance of microporous and microfibrous filter materials.

Materials and Methods

Two types of filters made of sintered stainless steel particles and stainless steel fibers were studied. The diameter of the individual stainless steel particle was 50 mm (as specified by the manufacturer). The density of the stainless steel used for sintered particle filter was 7.8 g/m^3. The filters were made by compacting together the stainless steel sintered particles, and then calandering them to form a sheet of sintered particle metal. The tested fibrous filters were microfiltrex grade 5AL2. The microfiltrex media consisted of two layers made of fibres of two different diameters. The upstream layer comprised of 2/3 of the thickness of filter having diameter of 8 μm and downstream layer having diameter of 4.675μm. The surface structures of sintered particles and fibrous filter materials are shown in Fig. 1 (a and b). The thickness of tested sintered particle filter was 1.5 mm having average porosity of about 40% and that of fibrous filter was 0.25 mm with average porosity of about 70% (Berger and Chong,1992). Two sets of experiments were performed on these two different materials. The first set consisted of clean tests and pressure drop across the filter discs for different air flow rates were measured. Later dust was loaded in the air stream. The flow diagram of continuous single pass filtration test used in this experimental work, is shown in Fig. 2. The test dust particulates consisted of alumina dust having density ρ_d = 4000 kg/ m^3.

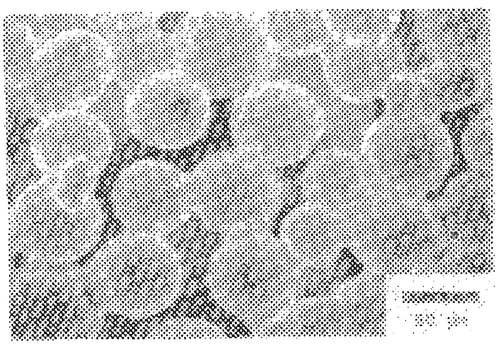

Fig. 1 (a). Surface of stainless steel particulate filter medium.

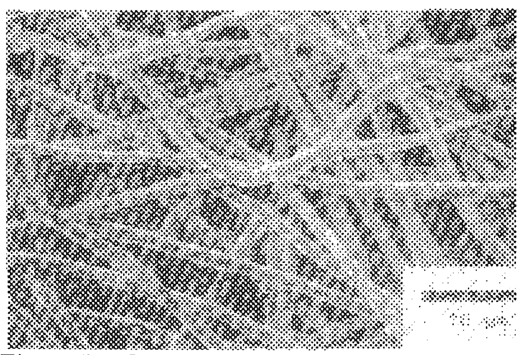

Fig. 1 (b). Surface of stainless steel fibre filter medium.

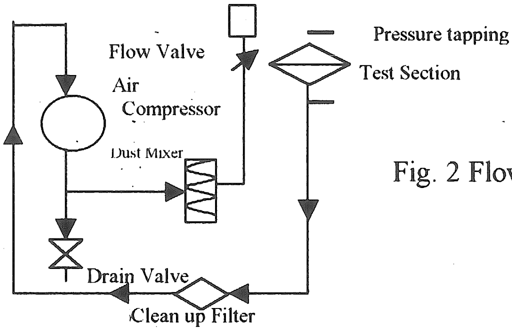

Fig. 2 Flow Diagram of Continuous Single Pass Filtration Test.

Air was used as carrier gas. Circular discs made of porous and fibrous mediums were placed in test section between two flanges. In the downstream of the test section, another filter section was placed to retain any leakage through the test section filter material.

Tests were carried out at different flow rates of air, later known quantities of dust were mixed with air in a dust mixer and then the dust laden air was passed over the test section for a specific time; keeping the same flow rates as that of the clean tests. The filters were weighed after each loading test. The masses of dust deposited as cake, inside the filter, and leaked through the test filters were noted at different flow rates.

Theoretical Calculations; Pressure drops, ΔP, were calculated using the Ergun's Equation (Ergun,1952), which was derived for filtration through spherical particles in fluidized beds (4).

$\Delta P = \alpha\ \mu v + \beta \rho_g v^2$ (1)

$\alpha = at\ (1 - \varepsilon)^2 / d_f^2 \varepsilon^3$ (2)

$\beta = at\ \ (1 - \varepsilon)\ / d_f \varepsilon^3$ (3)

In the present analysis, d_f for clean particulate filter material was assumed to be $50\text{x}10^{-6}$m and for clean fibrous material diameter was $6.9\text{x}10^{-6}$m.

Porosity, ε, varies in the range of 0.3 and 0.55. The constants at = 150 m^{-1} and bt = 1.75 have been found experimentally (by the method of least squares) for the beds of uniform spherical particles (where t is the thickness of filter medium).

Average diameter of filter material with loading was determined using the following relation:

(mass fraction of metal) d_f + (mass fraction of dust) d_p = $[m_s/(\ m_s + m_f)]d_f + [m_f/(\ m_s + m_f)]d_p$.

The theoretical values obtained for ΔP using equation (1) at different mass flow rates were found to agreed well with the experimental results if the following values of Ergun's constants were used:

for particulate filter a = $1.5\ \text{x}10^5/t\ m^{-2}$ and b = $1.75\ \text{x}\ 10^3\ /t\ m^{-1}$ for fibrous filter a = $6.4\ \text{x}10^5/t\ m^{-2}$ and b = $1.38\ \text{x}10^3/t\ m^{-1}$.

Different values of these constants in equation (1) are due to the fact that the particles are spherical whereas fibers are cylindrical. The values of α and β change with loading since ε and mean diameter, d_f changes and cake accumulates at the surface.

of clean filter can be calculated using the relation:

$\varepsilon = V_{fil}/(\ V_{fil} - V_s)$ (4)

Porosity of filter after loading

$\varepsilon = [1 - (V_s/V_{fil} + V_f/V_{fil})] = 1 - (m_s/\rho_{ss} + m_f/\rho_d)$ (5)

A computer program was developed to carry out all these calculations.

Results

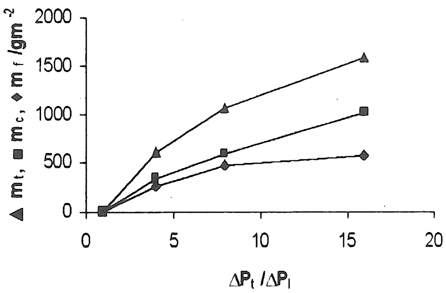

Fig. 3. Mass deposited as cake and inside the filter vs. relative pressure drop ($\Delta P_t / \Delta P_i$) for sintered particle disc filter experiment at v = 0.25m/s

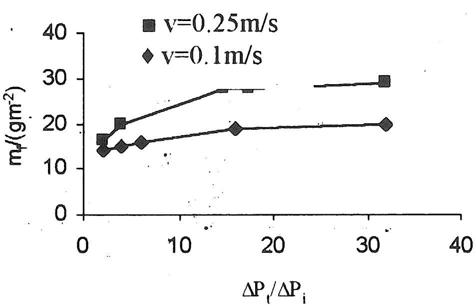

Fig. 4. Mass deposited inside the sintered fibrous disc filter vs. relative pressure drop.

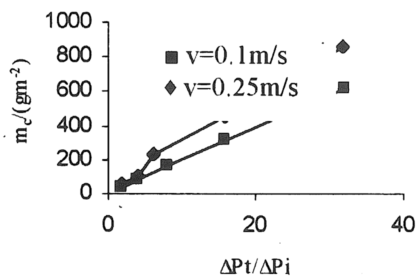

Fig. 5. Mass deposited as cake on sintered disc filter vs. relative pressure drop

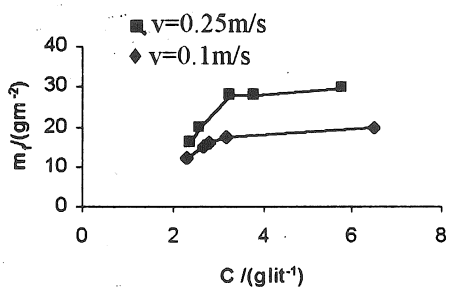

Fig. 6. Mass deposited inside the sintered fibrous disc filter vs. concentration of dust fed in air.

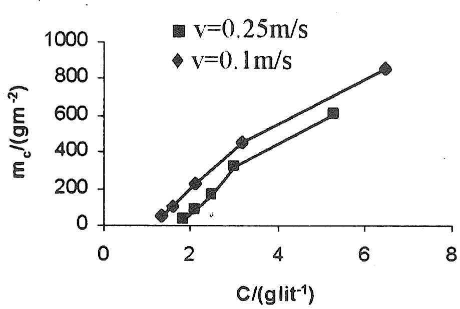

Fig. 7. Mass deposited as cake on sintered fibrous disc filter vs. concentration of dust fed in air.

Discussion

Fig.3 shows the relative pressure drop for sintered particle disc filters vs. the accumulative masses of dust retained and penetrated into the particulate filter. Loading were carried out at cross flow velocity, v = 0.25 m/s. It was observed that as the loading progressed, pores got more dust penetrated into the microporous filter disc filters compared with microfibrous filters for almost same relative pressure drops.

Experimental results also revealed that the porosities of microfibrous were considerably higher, whereas the values of a and b were of the same order as compared to particulate material. The pressure drop in the clean case was lower for microfibrous as compared to particulate, since microfibrous samples were on average six times thinner than the particulate discs. Loading tests were performed with velocities ranging from 0.1 m/sec to 0.25 m/sec, Figs. 4 - 7. The dust penetrated into the filter mainly during the first stages for loading; as loading proceeded there were only small increases in the mass of dust into the filter, m_f, and most of the dust was retained as surface cake. With increase in approach velocity, the amount of dust penetrated into the filter also increased. At low approach velocity, the total pressure loss in microfibrous was lower than in particulate filters at low loadings but became higher at high loadings. For microfibrous the total pressure loss, ΔP_t, increased more than linearly with increasing approach velocity, whereas for particulate filter it increased less than linearly. The pressure loss for unit mass of cake increased with increasing loading at first rapidly and then more and more slowly for both materials. It was found that the microfibrous samples captured the dust very effectively; no leakage was observed even at higher velocities, whereas for particulate filters at higher velocities leakage was 20 to 40% of the dust fed (Berger, 1987). Considerably less dust penetrated into microfiltrex and consequently the increase in pressure loss due to the dust retained within the filter was also less. The results obtained from above experiments were helpful in analyzing different filter materials and developing a model for predicting their separation performance when used for different application.

Conclusions

The dust penetrated into the filter mainly during the first stages of loading; as loading proceeded there were only small increases in the mass of dust into the filter, m_f, and most of the dust was retained as surface cake.

The amount of dust penetrated into the filter increased with increasing approach velocity.

At low approach velocities the total pressure loss in microfiltrex was lower than in particulate filters at low loadings but became similar or even higher at high loadings.

For microfibrous filter the total pressure loss, ΔP_t, increased more than linearly with increasing approach velocity, whereas for microporous if increased less than linearly.

Nomenclature

C = Concentration of dust fed in the air; (Kg/m^3)
d_f = Diameter clean filter material; m
d_p = Diameter of dust particle = $5x10^{-6}$m
m_c = Mass of cake per unit area; (Kg/m^2)
m_f = Mass of dust per unit area deposited within the filter depth; (Kg/m^2)
m_l = Mass of dust leaked per unit area; (Kg/m^2)
m_T = Total mass of dust loading per unit area = $m_f + m_c + m_l$
t = Thickness of the filter medium; ΔP = Pressure drop across the filter medium, N m^{-2}
ΔP_i = Pressure drop across the filter thickness in clean test; N m^{-2}

ΔP_t = Total pressure drop across the filter thickness after specific dust loading test; N m^{-2}
v = Approach velocity; m/s
V_{fil} = volume of filter; m^3
V_s = volume of metal contained in filter; m^3
V_f = volume of dust went into filter = m_f/ρ_{dust}; m^3

Symbols
α =Ergun's momentum coefficient; m^{-1}
β = Ergun's momentum coefficient
ε = Porosity
μ = viscosity; Kg/m-s
ρ_g = Gas density; Kg/m^3

References

Berger, F. P. (1987). Clogging of Filters made from Sintered Metal (Experimental apparatus and initial results), *Report QMWC, EP 4023.*

Berger, F. B., Chong, K. (1992). Loading of Particulate Filter of Nuclear Reactors. *Nuclear Engr. Design* 137: 25-34.

Boundy, M., Leith, D., Hands, D., Gressel, M., Burroughs, G. E. (2000). Performance of Industrial Mist

Collection Over time. *Applied Occupational and Environmental Hygiene* 15: (12) 928-935.

Ergun, S. (1952) Fluid Flow through Packed Columns. *Chemical Engineering Progress* 2: 40.

Ijaz, A. (1993). Flow and Dust Loading Characteristics in Tubular Filters used in AGR. *Ph.D. Thesis, Queen Mary & Westfield College, University of London.*

Martin, S. B., and Moyer, E. S. (2000). Electrostatic Filter Media: Filter Efficiency and Most Penetrating Particle Size Effects. *Applied Occupational and Environmental Hygiene* 15: (8) 609-617.

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