J Mater Sci (2007) 42:8040–8046
DOI 10.1007/s10853-007-1565-2

Design of filter bag media with high collection efficiency

Sang Young Yeo · Dae Young Lim · Sung Won Byun · Jong Hoon Kim · Sung Hoon Jeong

Received: 1 August 2006 / Accepted: 29 January 2007 / Published online: 28 June 2007

Abstract The various filter bag media were prepared by a nonwoven pilot plant coupled with the needle punching and thermal bonding combination processes. The prepared filter media were evaluated by the reliability assessment standard for the filter bag media of the environmental cleaning dust collector (RS K 0001). A new filter bag medium was thermal bonded with polyester felt and polyamide nano-sized web. The air permeability of the filter bag media with nano-sized web was largely reduced as compared with the control media. In the evaluation of filtration test, the filter medium with nano-sized web showed more stable filtration behavior and more higher collection efficiency than the others.

Introduction

For a long time, the filter bag has been used in the dust collector and its media has been developed with improvement of the dust collector. In the early stage of dust collector, mostly filter bag media were woven fabric which was comprised of cotton, wool, and synthetic fibers. With development of nonwoven technique, needle punched nonwovens with synthetic fibers are being predominantly used for the filter bags. Particularly, polyester nonwoven, produced by needle punching, has been mainly used in the filter bag media. As environmental pollution is accelerating, standards about air discharge pollution have changed more strictly. Conventional needle-punched polyester nonwoven had a limitation in filtration performances which could not satisfy to the recent strict environmental standard. For improvement of filtration performances of the filter bag, many workers and researchers have investigated the various methods such as addition of special fiber and membrane layer, and the finishing with coating or calendering [1–11].

A dust collector is a general equipment to remove dusts floating in the atmosphere. It has various functions such as removing ashes and particles of dust in a trash burner, a blast furnace, a boiler used in a cement factory, an iron mill, a thermoelectric power plant, etc. Many researchers and technicians have investigated to dust collector during the past several decades [12]. In recent, a filtration dust collector of pulse-jet type coupled with filter bag has been widely used because of cost effectiveness and high collection efficiency (http://www.cleanair-tech.com; http://www.donaldson.co.kr) [13, 14].

In this work, varieties of nonwoven, which were comprised of polypropylene, polyester, and polyamide, were prepared in a nonwoven manufacturing pilot coupled with needle-punch machines. Also, we designed a new filter bag medium which was mixed polyester felts and a prepared polyamide nano-sized web by an electro-spinning facility. The new filter bag medium was overlapped and thermal bonded by a thermal roll calender. All the prepared filter bag media were evaluated with the test method of reliability assessment standard for cleanable filter media (RS K 0001).

S. Y. Yeo · D. Y. Lim · S. W. Byun
Technical Textile Team, Textile Materials Division, Korea Institute of Industrial Technology, Cheonan, Korea

J. H. Kim · S. H. Jeong (✉)
Department of Fiber and Polymer Engineering, College of Engineering, Hanyang University, 17, Haengdang-dong, Seongdong-ku, Seoul 133-791, Korea
e-mail: shjeong@hanyang.ac.kr

Table 1 Characteristics of raw materials

	Polypropylene	Polyamide	Regular polyester	Low-melting polyester
Linear density (denier)	7.55	6.92	3.2	4.3
Length (mm)	71	64	50.5	50.5
Melting point (°C)	165	260	265	110
Strength (g/d)	1.84	4.15	5.8	3.5
Elongation (%)	298	67	32.0	48.0

Table 2 Classification of all samples used in this study

Media	Major component	Main-punching density	Treatment	Thickness (mm)	Weight (g/m^2)
A	PET	0	–	2.2	450
B	PET	300	–	1.3	270
C	PP	300	–	2.7	600
D	Nylon	300	–	2.7	620
E	PET	0	–	2.3	475
F	PET	0	PTFE Coating	2.3	620
G	PET	300	–	2.0	450
H	PET	300	Nano-web adding	2.0	455

Experimental

Materials

Polyester staple fiber was selected for raw material of filter media which was used mainly to filter bag under low temperature. The raw material fibers were regular polyester staple fiber (RSF-U®) and low-melting polyester staple fiber (LMF-U®) by Huvis Co., Ltd. The characteristics of materials were shown in Table 1. Polyamide nano-sized web was obtained by electro-spinning process at the condition of 20 wt.% solution concentration and 15 kV voltage.

Preparation of media

Table 2 shows the classification of samples used in this study. The obtained polyamide nano-web by an electro-spinning method was added to medium H. Except medium B, thickness of all media was ranged from 2.0 to 2.7 mm, and weight was 450 g/m^2 above.

The regular (70%) and the low-melting (30%) polyester staple fiber were opened by opener and dosed by a bale opener and a fine opener. After opening, the fiber formed in fibrous web through carding and cross-lapping process. The laid web was consolidated by two needle-punching machines which had pre-punching density of 50 punches/cm^2 and main-punching density of 300 punches/cm^2. The prepared felt was about 150 g/m^2 in weight and 800 mm in width. To make control sample, three sheets of the prepared felt were piled up and thermal-bonded by a flat-bed laminating machine at 170 °C and a roll calender at 130 °C. To make filter media with nano-sized web, the prepared nano-sized web was inserted and thermal-bonded by the same method like the control. Polypropylene spun-bond nonwoven layer, used to collect the nano-sized web in electrospinning process, was easily separated by hand after thermal bonding. After removing the nonwoven collector, the filter media was again bonded by the same method as above. It was 2 m/min in calendaring speed, 2 mm in thickness, and about 450–455 g/m^2 in weight.

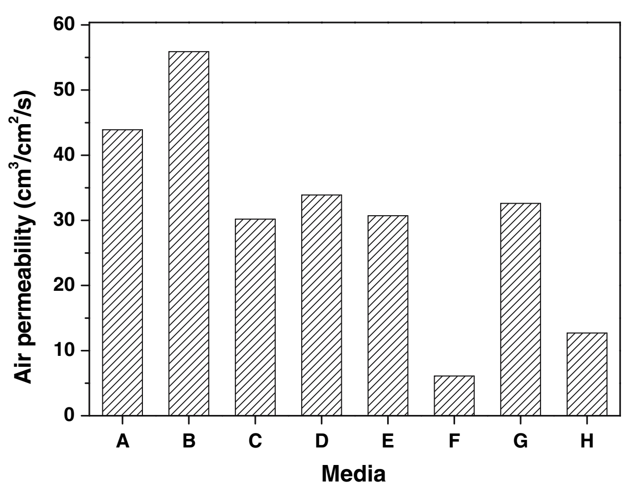

Fig. 1 Air permeability of the overall filter bag media

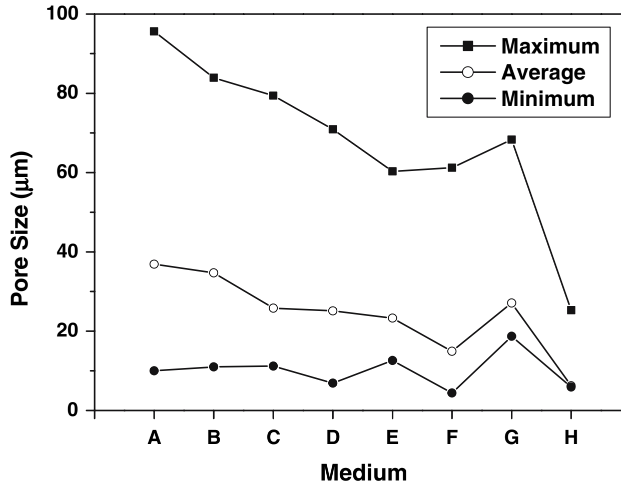

Fig. 2 Minimum, average, and maximum pore size of the overall filter bag media

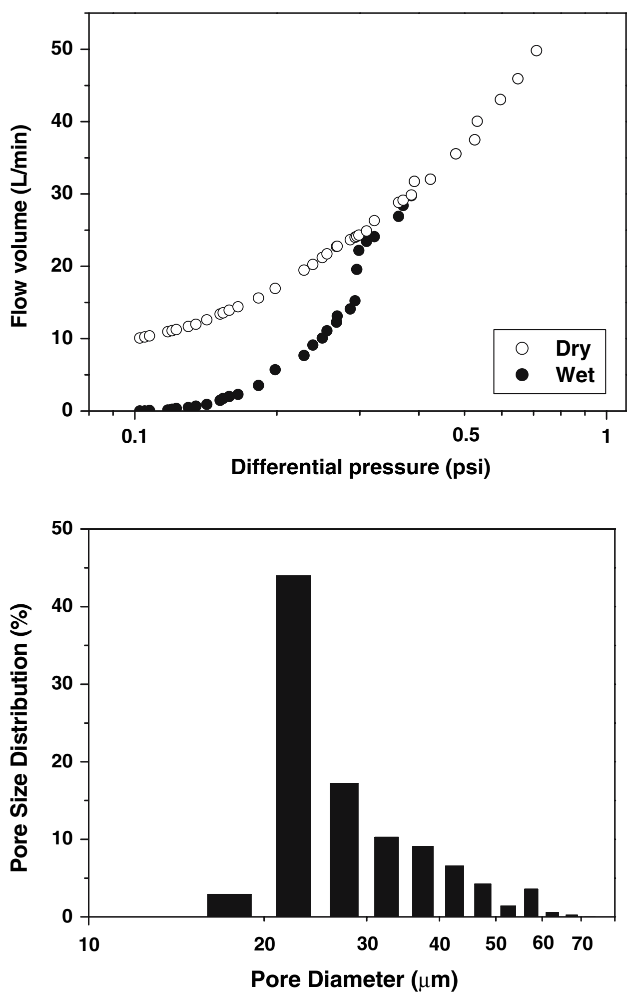

Fig. 3 Flow volume change and pore size distribution of medium G

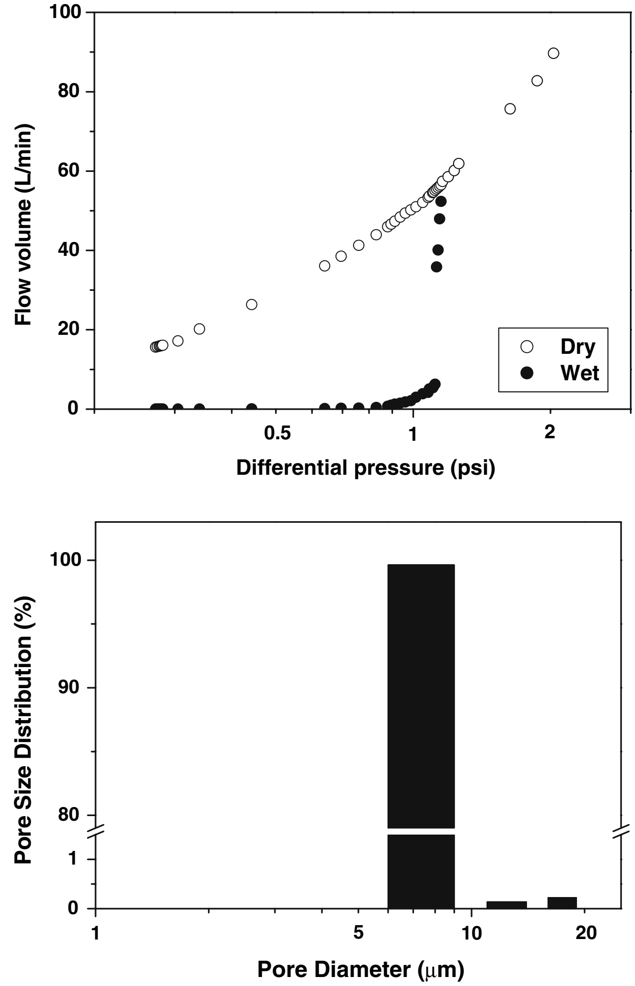

Fig. 4 Flow volume change and pore size distribution of medium H

Measurements

The air permeability of the filter media was analyzed with an air permeability tester (FX 3300, TEXTEST) according to KS K 0570. Pore size and distribution of the prepared nonwoven were measured with a capillary flow porometer (CFP-1200-AEL, Porous Materials Inc.) according to ASTM F316. The tensile strength and the elongation at break of the filter media were measured using a tensile properties tester (Hounsfield H100KS®) according to KS K 0520. For the observation of the filter media surface and inside, scanning electron microscopy (SEM, JSM-6400, JEOL) was used after gold coating for 10 min.

The filter bag media were evaluated by a tester of filtration performances for cleanable filters under operational conditions (MMTC-2000, PALAS) according to VDI 3926 type2 (Verein Deutcher Ingenieure).

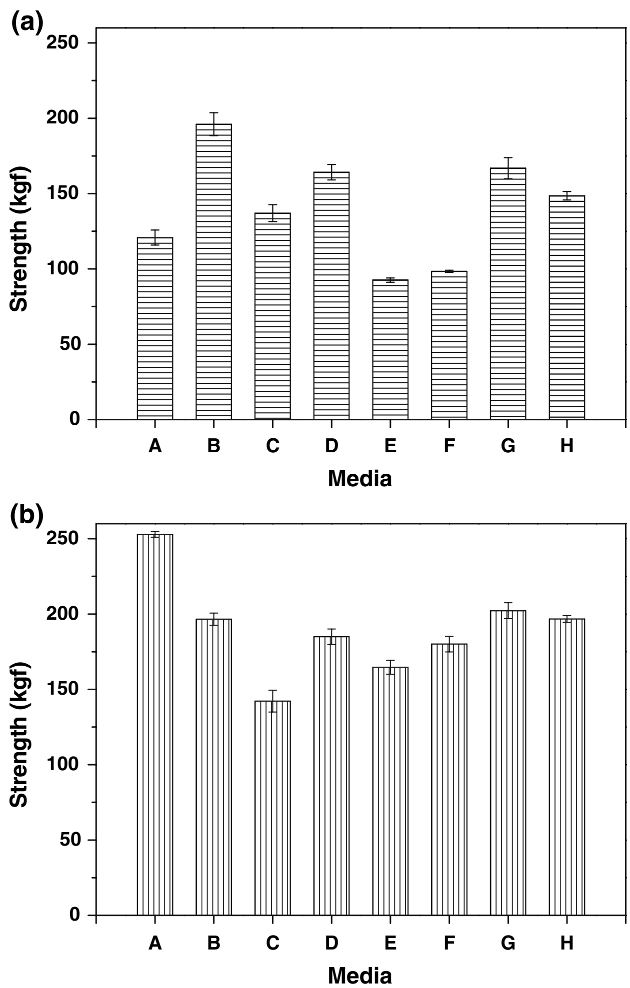

Fig. 5 Tensile strength of the overall filter bag media against (**a**) MD and (**b**) CD

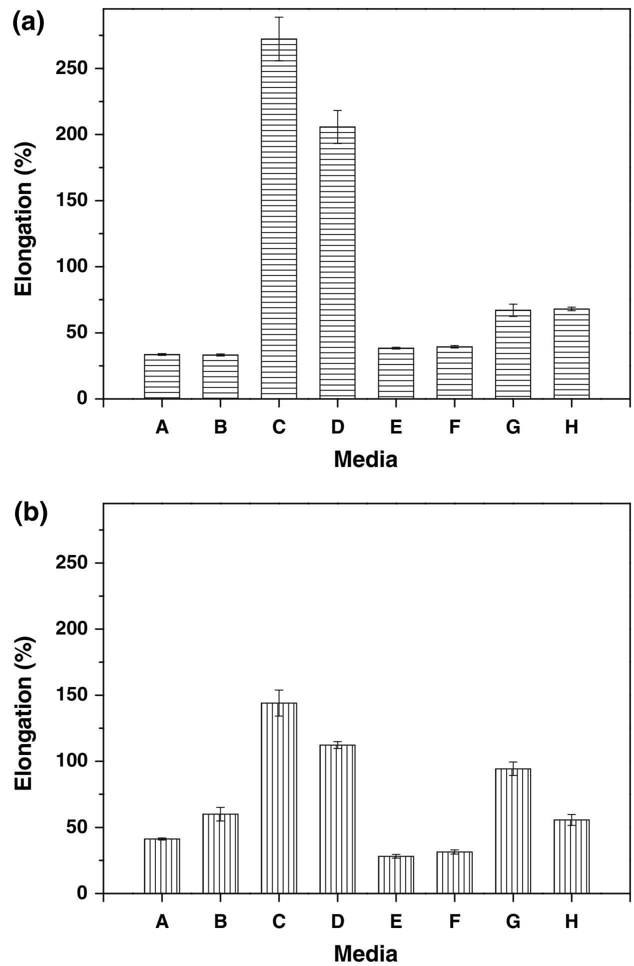

Fig. 6 Tensile elongation of the overall filter bag media against (**a**) MD and (**b**) CD

Result and discussion

Structural properties

Figure 1 shows the air permeability (Ap) of the overall filter bag media. All air permeability ranged 60 $cm^3/cm^2/s$ and less at 125 Pa. Medium F showed the lowest air permeability among the overall filter bag media because it was largely stopped up the pore of medium by PTFE solution coating. Air permeability of medium B was higher than that of the others because it had thinnest thickness and weight. Ap of medium H with nano-sized web was very low as compared with medium G.

Minimum, average, and maximum pore size of the overall filter bag media was shown in Fig. 2. Minimum pore size of medium D, F, and H was smaller than that of the other media. Average and maximum pore size of medium H was remarkably smaller than that of the others. It was revealed that medium H had the narrow pore size distribution because of nano-sized web layer.

Figures 3 and 4 shows the flow volume change and the pore size distribution of the filter medium G and H, respectively. In pore size test, the air flow volume was measured at dry state, and at wet state after dampened by wetting agent. Initial flow volume at wet state was zero because of dampened state. When maximum pore in media was broken by air pressure, this indicated bubble point. Subsequently, the air flow volume was increased with the increase of pressure loss of sample, and the flow volume at wet state met with the flow volume at dry state because all pores were broken with the air flow. When the flow volume at wet state coincided with that of dry state, the pressure loss of medium G was 0.33 psi and pore diameter was 20.35 μm and air flow volume was 25.3 L/min. The broken pore at this time was the smallest pore in medium G. In the same way, the detection condition of the smallest pore in medium H was 1.16 psi, 5.73 μm, and 57.41 L/min, respectively. Pore size distribution of medium G was

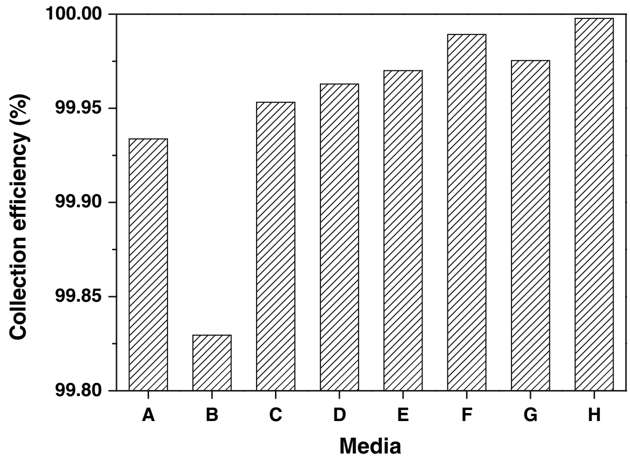

Fig. 7 Collection efficiency of the overall filter bag media

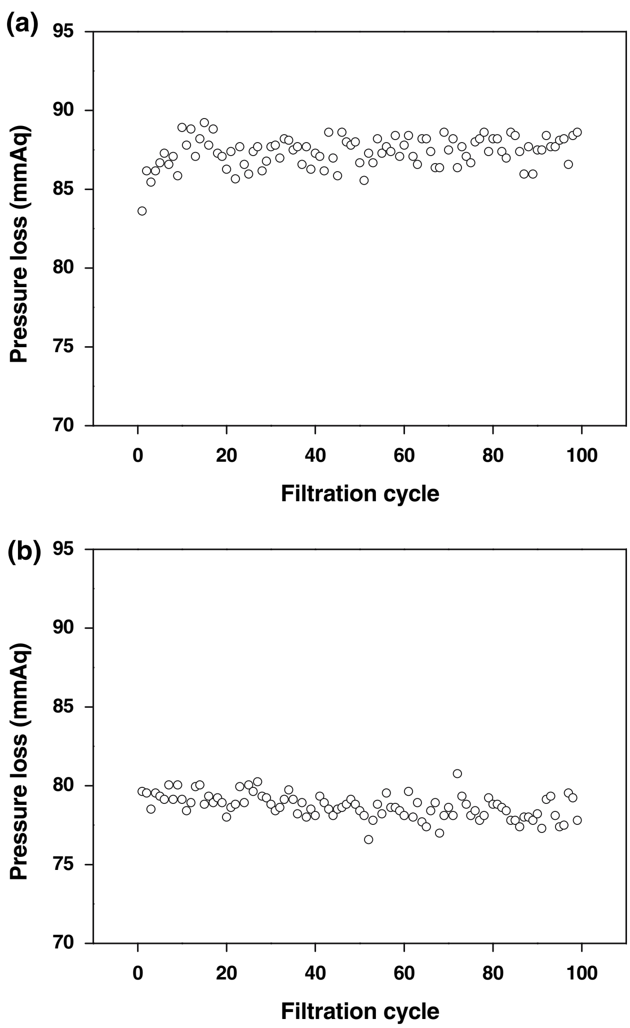

Fig. 8 Pressure loss of total filter after each filtration cycle; medium (a) G and (b) H

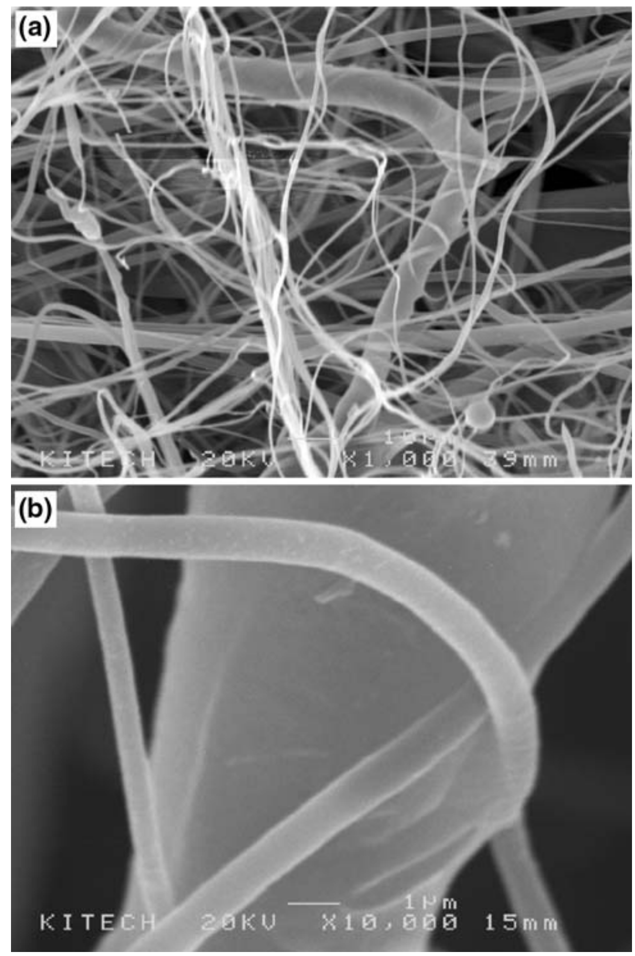

Fig. 9 SEM images of inner layer in medium H at (a) ×1,000 and (b) ×10,000

broader than that of medium H from Figs. 3 and 4. Distribution ratio of the most detection pore interval was 44% in 20~25 μm at medium G and 99.6% in 5~10 μm at medium H. It was identified that pore size distribution of medium H was swarmed around low size pore.

Physical properties

Figures 5 and 6 show the results of tensile properties of the overall filter bag media. From Fig. 5a, tensile strength against the machine direction (MD) of the samples, medium A, E, and F, which were prepared without main-needle punching, was lower than that of the other media. Tensile strengths against the cross-machine direction (CD) showed mainly similar value except A in Fig. 5b. Elongation which measured at maximum strength of the overall filter media was mostly 100% and below, except medium C and D. In particular, elongation against CD of medium C and D showed significantly high because they consisted of polypropylene and polyamide fibers which were weak polymer to heat.

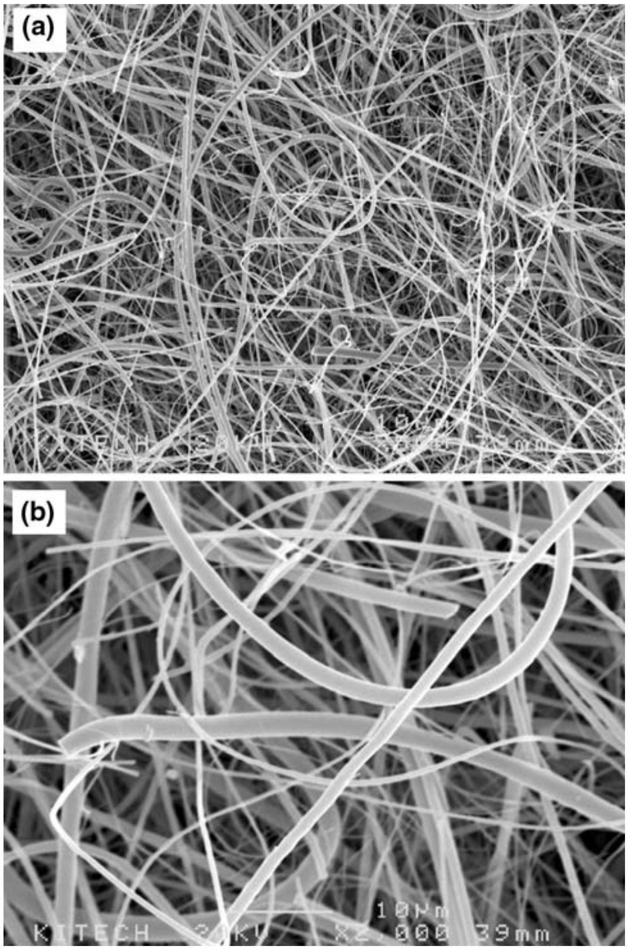

Fig. 10 SEM images of the total filter before filtration test (**a**) ×500 and (**b**) ×2,000

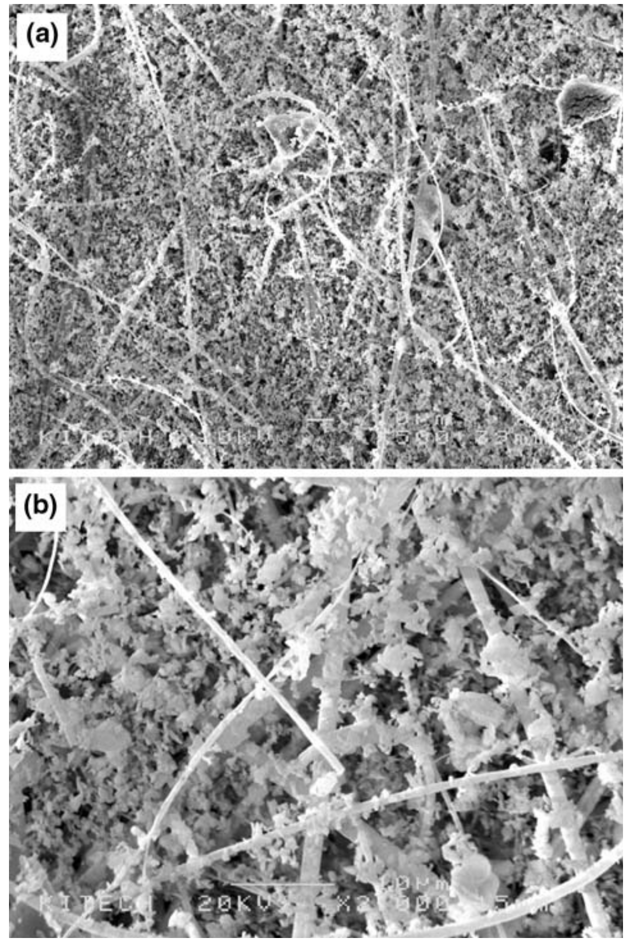

Fig. 11 SEM images of the total filter after filtration test of medium G (**a**) ×500 and (**b**) ×2,000

Filtration performances

Figure 7 shows the collection efficiency of overall filter bag media. The collection efficiency was calculated from dust concentration in clean gas. The collection efficiency of all media was above 99.9% except medium B and that of medium H was highest (99.9978%).

There was a different tendency of the pressure loss (ΔP_{total}) between medium G and H at each filtration cycle in Fig. 8. The pressure loss of the total filter of medium G was mainly 85 mmAq and above in Fig. 8a, but medium H maintained mainly 75~80 mmAq. It meant that penetrated dust through medium H was less than that through medium G. Therefore, it was deduced that the collection efficiency of medium H might be better than medium G.

Surface observation

Figure 9 shows SEM images of inner layer in medium H at 20 kV. It was identified that regular polyester staple fiber and nano-sized polyamide filament were well bonded by low melting fibers. The diameter of obtained fibers by electrospinning was observed 400~1,000 nm.

Figures 10–12 show SEM images of the total filter before filtration test, total filter after filtration test of medium G and H, respectively. A lot of dust were observed and agglomerated in total filter of medium G. On the contrary, the small amounts of fine dust were just observed in medium H. It is indicated that the collection efficiency of medium H was better than that of medium G.

Conclusions

The filter bag media were prepared utilizing a nonwoven pilot plant coupled with the needle punching and thermal bonding combination processes, and were evaluated by the reliability assessment standard (RS K 0001). Nano-sized web obtained by a conventional electro-spinning was well bonded with the regular polyester staple fiber. Compared to

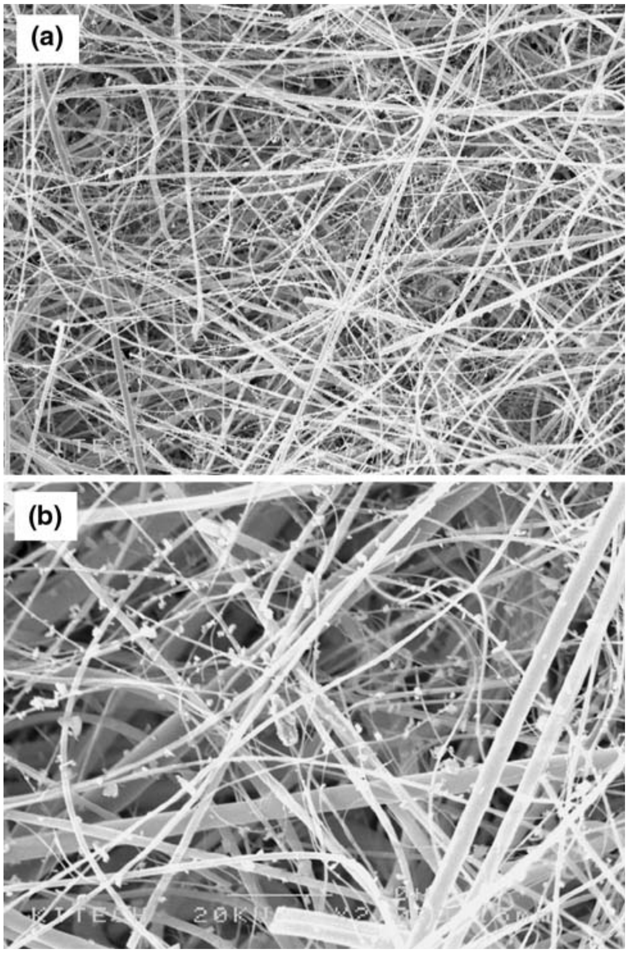

Fig. 12 SEM images of the total filter after filtration test of medium H (**a**) ×500 and (**b**) ×2,000

medium G, medium H had the similar thickness and weight, but its air permeability and pore size largely reduced because of the nano-sized web. In the evaluation of filtration test, the medium H with nano-sized web showed the stable and regular filtration behavior and the excellent collection efficiency (99.9978%).

References

1. Smithies A, Zimmerman WC (2005) High efficiency particulate air rated vacuum bag media and an associated method of production. US Patent 6,872,233
2. Fagan JP (1982) Felt-like layered composite of PTFE and glass paper. US Patent 4,324,574
3. Bosses MD (1992) Disposable two-ply filter. US Patent 5,080,702
4. Sassa R, Winkelmayer R (1993) Static dissipative nonwoven textile material. US Patent 5,213,882
5. Sassa R, Winkelmayer R (1993) Static dissipative nonwoven textile material. US Patent 5,229,200
6. Wnenchak RM, Bacino JE, Stark SK, Wildt EH, Tronto K (2000) Cleanable filter bag assembly. US Patent 6,110,243
7. Emig D, Raabe E, Klimmek A (2004) Dust filter bag including a highly porous backing material ply. US Patent 6,706,086
8. Pall DB, Connors JT Jr (1996) Filter bag. US Patent 5,586,997
9. Pryne WH (1995) Needled felt filter bags and method for forming same. US Patent 5,414,915
10. Schlör U, Veeser K (2001) Dust filter bag. US Patent 6,193,773
11. Schmidt E (1995) Filtr Sep 32:789
12. Kim JM (1996) In: Filter bag hand book. Daekwang, Seoul
13. Suh JM, Kim CH, Park CJ (2001) J Korean Solid Wastes Eng Soc 18:503
14. Derek BP (1996) In: Handbook of filter media. Elsevier Advanced Technology, Oxford