PERMANENTLY CORONA CHARGED FILTER MATERIALS OF STAPLE FIBERS

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Permanent electrical charging of fibrous filter materials by corona is one of the ways to increase filtration efficiency without increase in the pressure drop. The authors present teoretical and experimental knowledge of charging process. Charging of various fibrous materials and their surface finish are the topics described in a part „Experimental". Various fibrous materials are corona charged by TANRET METHOD. The results of the experiments and new arising questions from the experiments are discussed in conslusion.

INTRODUCTION

It is the goal of the researchers active in the filter materials development to reach maximum filtration efficiency and simultaneously minimum pressure drop of filters. Permanent electrical charging of fibrous filter materials is one of the ways to increase filtration efficiency without increase in the pressure drop. An electrostatic field is generated in vicinity of charged fibers. Due to this field, the particles of dust are attracted towards fiber surfaces by Coulomb forces. Thus, an additive factor increasing filtration efficiency occurs besides other known mechanisms (interception, diffusion, inertia). Both electrically charged and non-charged particles are transported in the electric field, the latter because of generating dipole. The efficiency of this mechanism, and that of the coulomb interaction, depends on the quotient of the drift velocity of the particle under the influence of the electric force tending to attract it to the fibre and the convective velocity of the flow field tending to take it past [1].

THEORY

Permanently charged fibrous filter materials are produced using following three methods [4]: triboelectric charging, electrostatic spinning and corona charging [2].

This article deals with the corona charging process. Corona is evolved in the vicinity of thin wires in the electrization device. The filter material passes through the device between the wires and metal cylinders. These are binted with the sources of high voltage. Charged particles are entraped in the polymer of fibrous filter material. After electrization, the life time of charge is studied by measurement of electrical field. Filtration efficiency and pressure drops are tested by NaCl aerosol according to British Standard BS 4400. The testing apparatus measures and compares concentration of NaCl particles before and after filtration process using flame photometry [1].

Many patents cover various methods of corona charging filter materials [3, 5, 6, 7]. The charging process and the life of charge on the filter material are influenced by various factors such as temperature, humidity and convection of surrounding air and electrical properties of polymer material. Electric conductivity of fibers leads to decrease of the entraped charge in time. Conductivity of fibers depends on kind of the fiber polymer and on the state of fiber surface, especially on kind and amount of fiber finishing agents.

EXPERIMENTAL

The influence of above mentioned factors on life time of charge and on filtration properties of charged filter materials has been studied. Various fiber materials were processed and influence of fiber finish evaluated.

1. Charging of various fiber materials

The polymer materials showing low electric conductivity such as polypropylene and polycarbonates, processed into fiber layers by melt-blown method or by electrostatic spinning, found practical use as bases for permanent charging so far. Fibers produced by these methods do not contain any fiber finishes on their surface. Fiber finishes present on surfaces of staple fibers increase their total electric conductivity and therefore decrease the life time of charge. In the experiment, textile filter materials were produced of various fibers. The filters were corona charged at 25 kV and the charging effect measured.

A considerable difference in the filtration efficiency between charged and non-charged materials was found whereas no difference in pressure drop occured. Polypropylene materials show the highest filtration efficiency especially when charged (Fig. 1).

Table 1 Comparison of following materials, both charged and non-charged

Nr. Sample	Electrostatic charge [kV/inch]	E1 [%]	Δp1 [Pa]	E2 [%]	Δp2 [Pa]
1	0.3	34.5	0.0*	19.6	0.0*
2	0.0	11.9	0.0*	4.5	0.0*
3	0.2	19.6	0.0*	9.8	0.0*
4	3.3	86.7	14.0	42.5	14.0
5	1.0	25.5	0.0*	12.3	0.0*
6	0.2	36.7	3.0	21.7	3.0
7	0.3	16.7	4.0	8.8	4.0

1. Cross-laid, needle-punched, 200 g/m^2, polypropylene 6.7 dtex, 60 mm, 2. dtto, polyethyleneterephtalate 6.7 dtex, 60 mm, 3. dtto, polyethylene 3.5 dtex, 40 mm, 4. Melt-blown polypropylene, 20 g/m^2, 5. Spun-bond, polyethylene, 50 g/m^2, 6. Cross-laid, needle-punched 200 g/m^2, bi-component polypropylene/polyethylene 2.5 dtex, 40 mm (Danaklon, Danmark), 7. dtto, bi-component polypropylene/polyethylene 3.0 dtex, 40 mm (Hercules, USA).

* Δp very low, not measurable
E1, E2 – filtration efficiency of charged and non-charged materials
Δp1, Δp2 – pressure drop of charged and non-charged materials

2. Effect of fiber finishes

Electric conductivity of fiber materials evokes decay of electrostatic charge within a few hours or days, regardless of whether based on conductivity of polymer itself or on that of fiber finish. There is no way to reduce the conductivity of polymer and polyamide or polyethylenterephtalate fibers cannot be successfully used to produce permanently charged filters. On the other hand, it is possible to remove fiber finishes of the fiber surface using either hot air or solvents such as water solution of surfactant or an organic solvent. Unfortunately, processing of fibers without fiber finish is almost impossible on the contrary. Partial evaporation of fiber finish during the through-air thermobonding process appears to be a feasible method. Hot air (150–200 °C) is passing through the fiber layer in thermobonding chamber. Needle-punched textile filter materials 200 g/m^2 made of staple fibers were processed by flowing hot air (air velocity 1 m/s, air temperature close under the polymer melting point, time 1 min.). Another series of the same samples was extracted by chloroform in Soxhlet extractor. Then the materials were corona charged and filtration properties tested (Table 2).

In Fig. 2 is shown decay of the filtration efficiency on the materials with and without fiber finish. The results in Table 2 and Fig. 2 show significant role of fiber finishes on life time of charge as well as on filtration properties.

CONCLUSION

The results have shown significant role of fiber polymers as well as fiber finishes in production of electrically charged fibrous filter materials. There are various methods to suppres negative influence of fiber finishes. Extraction of finishes from textile materials by organic solvents or by water solutions of surfactants is a hardly acceptable method in production process. Through-air bonding seems to be a useful method to partially remove electro-conductive parts of the finishes. Development of the finishes allowing processing the fibers without increasing their conductivity appears to be another chance.

The experiments also proved a significant difference in filtration properties of charged and non-charged

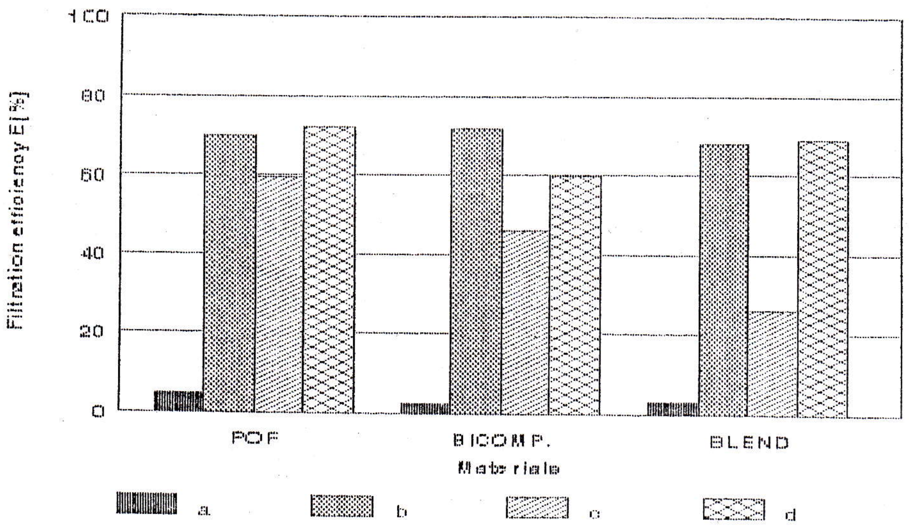
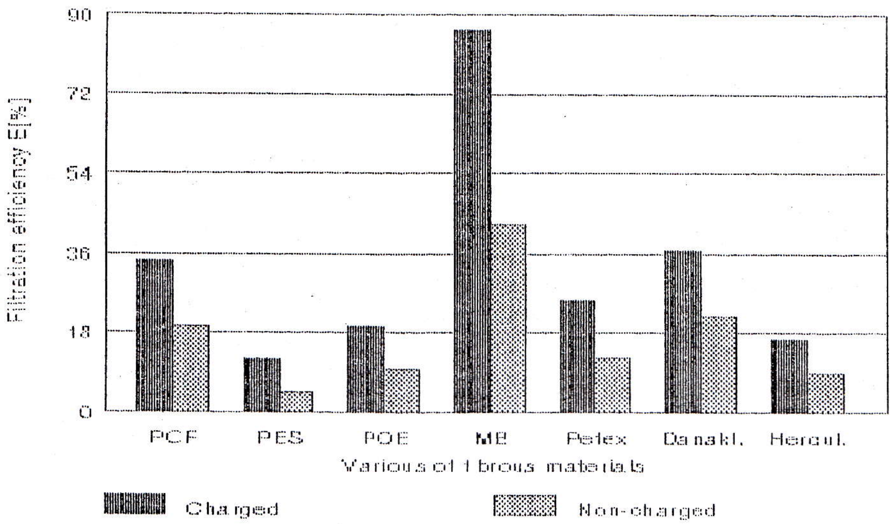


Table 2

Material	Process	Non-charged filters		Charged filters	
		E [%]	Dp [Pa]	E [%]	Dp [Pa]
Polypropylene 6.7 dtex	non-process	6.1	6.0	4.7	5.0
	extraction	9.3	6.0	70.1	7.0
	air-heated	5.0	6.0	59.6	6.0
	extraction+air heated	3.6	6.0	72.4	6.0
bicomponent Hercules	non-process	10.7	9.0	2.5	9.0
	extraction	9.3	6.0	71.9	9.0
	air-heated	14.5	10.0	45.9	9.0
	extraction+air heated	10.2	10.0	59.7	9.0
blend 75 POP/25 bicomponent	non-process	5.5	6.0	3.1	6.0
	extraction	10.3	6.0	68.2	6.0
	air-heated	5.2	7.0	26.1	6.0
	extraction+air heated	4.7	6.0	69.1	6.0



filter materials. Corona charging brings better filtration efficiency without increase in the pressure drop.

The relation between measurable charge and filtration properties is not yet clear. These discrepancies indicate variety in nature of charged particles, their binds in the polymer as well as contribution to filtration efficiency.

REFERENCES

1. Brown, R. C.: Air filtration, Sheffield UK, 1993.
2. Bláha, A.: Technika plazmy a el. výbojov, SVTL Bratislava, 1966.
3. Letters patents U. S. 4308223, 4375718, 4588637.
4. Gubkin, N. V.: Elektrety, Moskva, 1975.
5. Hilczer, B., Malecki, J.: Elektrety, piezopolimery, PWN, Warszawa, 1992.
6. Wadsworth, L. C., Tsai, P. P.: In Forth Annual Conference TANDEC, Knoxville, 1994.
7. Brown, R. C., Wake, D., Thorpe, A., Hemingway, M. A. and Roff, M. W.: Theory and measurement of the capture of charged dust particles by electrets, J. Aerosol Sci. Vol 25, No 1, pp. 149–163, Elsevier Science Ltd., 1994.