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Stanisław Dolny, Tomasz Rogoziński

AIR FLOW RESISTANCE ACROSS NONWOVEN FILTER FABRIC COVERED WITH MICROFIBER LAYER USED IN WOOD DUST SEPARATION

Modern nonwoven filter fabrics covered with a microfiber layer make it possible to carry out surface filtration. A dust cake forms only on their upstream side and influences the air flow resistance across the filter. The mode of formation of the flow resistance caused by such a fabric during the separation of very fine wood dust particles was the subject of a comparative investigation using a homogeneous, standard nonwoven filtering fabric. The experiments carried out in a pilot-scale pulse-jet bag filter enabled a detailed description of the increase in pressure drop across the dust cake formed during filtering cycles repeated hundreds of times. Based of the results obtained the difference in this filtration parameter between polyester-based nonwoven filter fabrics with a standard and a layered structure with microfiber was also shown.

Keywords: wood dust, pulse-jet filter, microfiber, nonwoven fabric, filtration

Introduction

The development of filtering techniques used in industrial gas dedusting focuses on the geometry optimization of filtering devices, the influence of flow parameters, pulse-jet cleaning systems and the selection of an appropriate fabric. With the aim of improving the fibrous structures of filter fabrics separating dust particles from the gas stream various methods have been investigated and put into practice [Hemerka et al. 2001; Huang and Yang 2004; Mukhopadhyay 2009]. The main purpose of this improvement is always to maximize the efficiency of the separation of solid particles from the gaseous phase because the separation process is the essence of all efforts to eliminate or minimize industrial dust emissions [Lydon 2004]. The enhanced performance of a filter fabric can be achieved by the modi-

Stanisław Dolny, Wood Technology Institute, Poznan, Poland
e-mail: standol@up.poznan.pl
Tomasz Rogoziński, Poznan University of Life Sciences, Poznan, Poland
e-mail: trogoz@up.poznan.pl

fication of its surface properties using typical finishing methods such as calendering, heat setting or singeing. Other modern methods are: laminating and coating fabric surfaces with membranes, foams and inert powders, and covering with a nano- or microfiber layer [Mukhopadhyay 2009]. Therefore, the reduced dust emission is strongly connected with better dust cake release characteristics and the longer life of the filter elements. Callé et al. [2002] showed that covering the filter surface with a layer of very fine fibers promotes the detachment of the dust cake and reduces particle penetration through the filter. These studies concerned various industrial dusts, but Dobak [2002] suggested that the microfiber layer on the nonwoven fabric could also create very efficiently the conditions of surface filtration in wood dust filters.

Proper surface filtration is possible by the fact that this layer, just from the beginning of the dust-laden air inflow in a filtration cycle, makes it easier a permanent dust cake to form which has an essential separating function. Such a dust cake prevents the penetration of dust particles across the filter medium. Filtration on nonwoven fabrics covered with a microfiber layer has an additional advantage. It influences the improvement of the cleaning of the filter elements because the dust is wholly collected on their surface and can be efficiently removed from the filter surface during the cleaning pulse. Hence, filter materials with a layered structure provide an improvement in filtration efficiency at a relatively low increase in pressure drop [Kabsch 1992; Warych 1998; Mukhopadhyay 2009]. Filtration efficiency and pressure drop are the two variables which describe the performance of the filter and are monitored to evaluate it.

As a result of this existing knowledge and these suppositions, a new filter fabric was designed for use in wood dust filtration. This fabric, known as KYS – FINESS series, has been available in the filter fabric market for a few years, however there has been no comprehensive investigation concerning the filtration processes in the woodworking industry (using nonwoven filter fabrics covered on the upstream side with a microfiber layer) and the pressure drop on the filter material. Thus, the aim of this study was to determine the air flow resistance across filter bags made of a fabric modified by a microfiber in comparison with a standard fabric, and to evaluate this material in terms of its application in wood dust filters.

An additional aim was to obtain data concerning filter resistance for a comprehensive description of the characteristics of the polyester nonwoven fabric known as KYS – FINESS, based on the of existing results of the separation efficiency of this fabric.

Material and methods

The industrial conditions of the course of filtration processes were imitated using a pilot-scale testing baghouse which allowed the free setting of the filtration parameters in order to investigate the performance of pulse-jet filtration and to determine the pressure drop curves of filtration within different operating parameters. The construction and operating principle of this testing equipment was described in detail by Dolny [1998].

The experiments' similarity to the running of industrial filters was also obtained through the appropriate selection of the operating parameters of the pulse-jet cleaning system which is a component of the test filter. Operation of the cleaning device was characterized by an air pulse pressure of 0.5 MPa and pulse frequency of 1 min^{-1}.

General information on the granularity of the dust is represented by particle--size distribution. The experiments were conducted using beech wood dust with the particle-size distribution given in fig. 1. It was obtained using an Analysette 22 MicroTec Plus laser particle sizer. A calculation of the distribution was done using the MaSControl software.

The bulk density of the dust amounted to 183 kg·cm^{-3} and the tapped bulk density was – 315 kg·cm^{-3}. The polyester nonwoven fabric known as KYS – FINESS series covered with a microfiber layer was tested. A fabric of the same type with the standard homogenous internal structure known as KYS – PROGRES series was also tested for clear-cut catching the operating performance of the nonwoven fabric covered with microfiber in the case of wood dust collection. The common properties and the differences found in both kinds of filter media are shown in table 1. Bags of 1.5 m in length and 150 cm in diameter were made for the test. The dimensions were similar to those used in other investigations of filtration processes carried out using pilot-scale pulse-jet testing filters [Tsai, Lu 1998; Saleem, Krammer 2007].

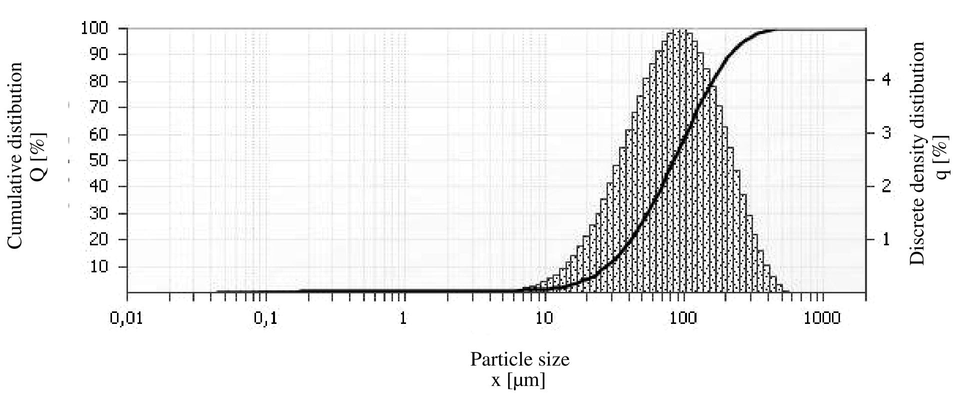

Fig. 1. Particle-size distribution of dust

Table 1. Properties of nonwoven filter fabrics used in experiments

Properties \ Filter fabric	KYS – PROGRES series	KYS – FINESS series
Fiber material: filter surface basic layer	 polyester polyester	 polyester with microfiber poliester
Thinness of fibers	basic layer 1.5 dtex	filter surface 0.8 dtex basic layer 1.5 dtex
Diameter of fibers	basic layer 13 μm	filter surface 6 μm basic layer 13 μm
Fabric finish	heat setting, singeing, calendering	
Basic weight	500 $g \cdot m^{-2}$	525 $g \cdot m^{-2}$
Thickness	2.1 mm	2.0 mm
Permeability	240 $dm^3 \cdot dm^{-2} \cdot min^{-1}$	190 $dm^3 \cdot dm^{-2} \cdot min^{-1}$
The highest tension force longitudinal Transverse	 140 daN 220 daN	
Retracility at 140°C	<1%	
Maximum temperature: continuous intermittent	 140°C 150°C	

Table 2. Flow conditions in testing filter unit

Volume air stream		Air-to-cloth ratio	Filtration velocity
$m^3 \cdot s^{-1}$	$m^3 \cdot h^{-1}$	$m^3 \cdot m^{-2} \cdot h^{-1}$	$m \cdot s^{-1}$
0.0284	102.1	145.9	0.0405
0.0339	122.1	174.4	0.0484
0.0415	149.5	213.6	0.0583
0.0536	193.0	275.8	0.0766

Each experiment, both for the first and second nonwoven fabrics, was conducted using the air flow parameters taking into consideration the range of variability of filtration velocity, which is typical for the operating of fabric filters in the woodworking industry (table 2). Measurements of the differential pressure on the down- and upstream side of the filter bag were taken for the purpose of determining the air flow resistance across the clean nonwoven fabrics and across the filtering layers created on the filtering bags made of these fabrics. For these measurements, a MPR-10 digital differential manometer was used. The filtration curves were drawn and the flow resistance correction coefficient of the layered structure was calculated on the basis of the results obtained using Microsoft Office Excel. The concentration of dust particles on the output side of the filter was not determined in this study. The existing results described in literature concerning separation efficiency were used for further analysis.

Results and discussion

The first series of experiments produced data to determine the air flow resistance across the clean nonwoven fabrics. The formation of this resistance depending on the filtration velocity is shown in fig. 2. Pressure drop increased linearly with filtration velocity. There was a noticeable difference showing a greater air flow resistance caused by the nonwoven fabric covered with the microfiber layer. The constant of proportionality of this increase amounted to 1.215. As a result, the air flow resistance across the clean filter at every filtration velocity, during the filtration process carried out using the nonwoven fabric covered with microfiber was larger approximately by 21.5% than during the filtration process using the nonwoven fabric without the layered structure. This was due to the additional microfiber layer on the filter surface which decreased the permeability of the fabric.

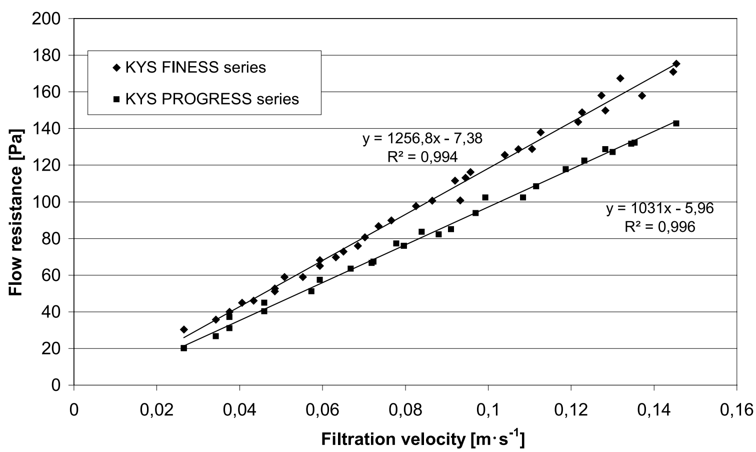

Fig. 2. Air flow resistance across the clean fabrics

The main experiments made it possible to describe the course of the increase in air flow resistance during continuous separation while 200 filtration cycles were completed (cleaning pulses were repeated every minute). Measurements of air flow resistance were taken for four earlier assumed filtration velocities. Their results for the nonwoven fabric covered with microfiber and for the nonwoven fabric without the layered structure are shown on the graphs in fig. 3 and 4, respectively. Four curves on each graph show the same type of increase in the air flow resistance across the dust layer deposited on the surface of the filtering bags. In every case, the tendency of the resistance to stabilize became clearer and clearer after a sharp increase in the pressure drop during the initial cycles. The duration time of the experiments did not enable the stabilization of a permanent pressure balance which is characteristic for the long-lasting operation of a bag filter. However, the appearance of small differences in the last stages of every experimental filtration process, especially at lower filtration velocities, portends reaching the target level of the pressure drop.

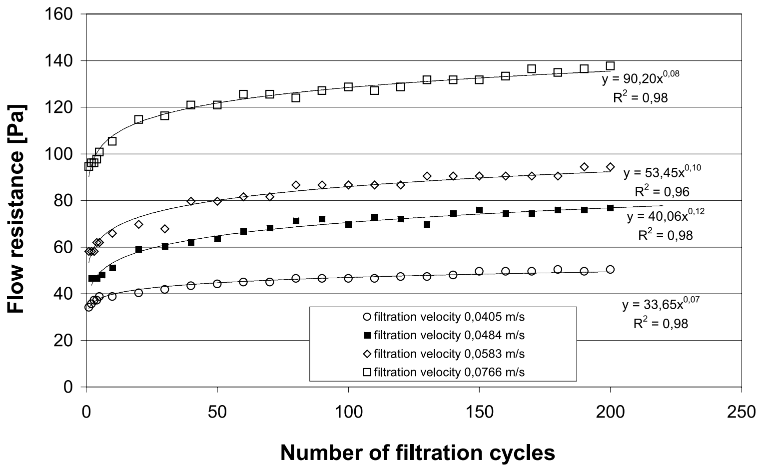

Fig. 3. Air flow resistance across the nonwoven fabric covered with microfiber layer

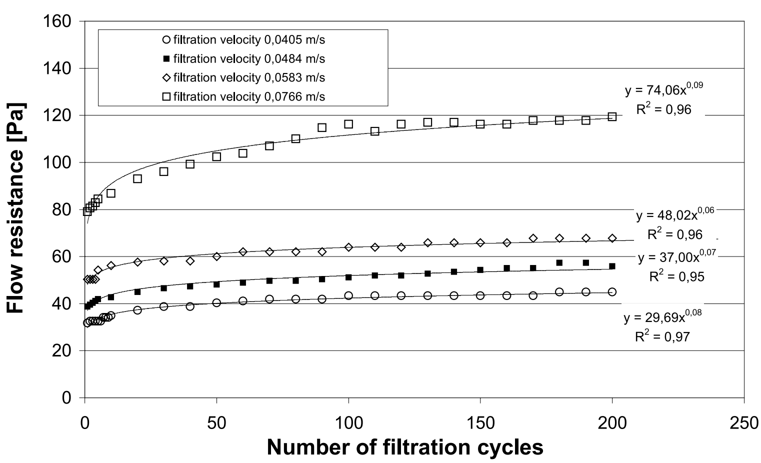

Fig. 4. Air flow resistance across the standard nonwoven fabric during filtration

An analysis of the absolute values of the air flow resistance during filtration conducted at different filtration velocities indicated that the level of pressure drop in the same flow condition was always higher for the nonwoven fabric covered with microfiber. These differences appeared at every filtration velocity used. The degree of increase in the air flow resistance along with the increase in the filtration velocity was different in both types of nonwoven fabrics. It was always higher when the nonwoven fabric covered with microfiber was investigated due to the lower permeability of this fabric. The increase in the air flow resistance within the whole range of the filtration velocity (0.0405–0.0804 $m \cdot s^{-1}$) defined in the experiments, amounted to 264% for the standard nonwoven fabric, and 275% for the nonwoven fabric covered with microfiber. The relationship in the air flow resistance described by the pressure drop values measured at the end of every experiment is shown in the graph in fig. 5. The level of the differences between the air flow resistance at every filtration velocity included was very similar for both fabrics.

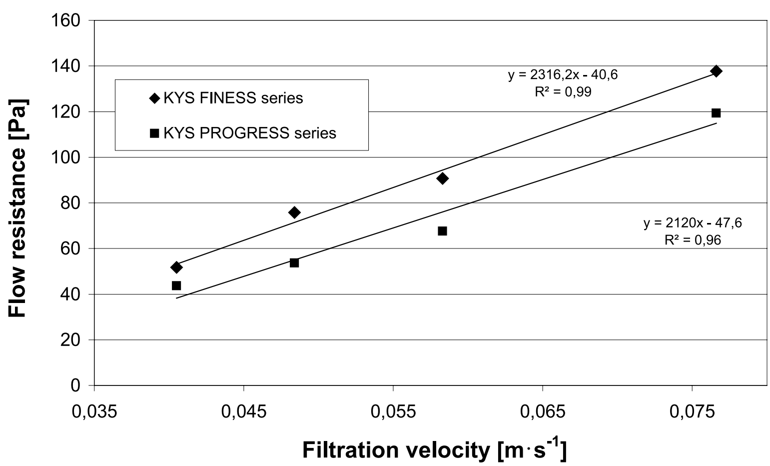

Fig. 5. Air flow resistance at end of filtration processes

The experiments carried out made it possible to develop data to calculate the air flow resistance across a filtering layer during operation of a filter equipped with filtering elements made of nonwoven fabrics with any surface properties. According to the calculation method described in literature [Dolny 1998], values for the correction coefficient of the layered structure, which is included in the basic formula for the air flow resistance across a dust layer deposited on a filtering medium, are a result of the structural properties of the filter medium.

The correction coefficient of the layered structure calculated on the basis of the results obtained depended on the filtration velocity (fig. 6). The values for this coefficient were the ratio of the pressure drop of the nonwoven filter fabric with the microfiber layer to the pressure drop of the standard nonwoven fabric at any filtration velocity. The relative increase in the air flow resistance across the nonwoven fabric covered with microfiber compared to the standard fabric was smaller at a higher filtration velocity probably due to the better dust cake detachment condition on the smoother surface of the microfiber layer. This opens up the possibility of the practical use of this fabric in difficult conditions of a very hard load (high air-to-cloth ratio) of the filter in the woodworking industry with an expected small increase in air flow resistance and significant increase in the separation efficiency. This makes it to possible to clean a large amount of air at a very high level with a relatively small increase in energy expenditure.

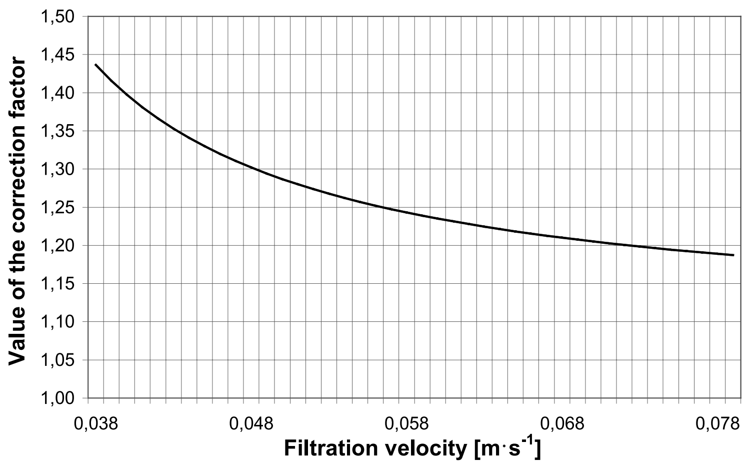

Fig. 6. Correction coefficient of layered structure

The appearance of the increased air flow resistance across the dust layer formed on the nonwoven fabric covered with the microfiber layer compared to the standard nonwoven fabric could suggest a decrease in the operating characteristic in this scope. The data concerning the air flow resistance should be related to the results of the investigation on the separation efficiency of dust particles from the carrier air. The advantage of the separation efficiency of a nonwoven filter fabric over the energetic results of its use should be taken into consideration. An advantageous view of this relationship results from earlier research conducted by Dobak and Dolny [2004] and Dolny [2005]. These authors calculated the dust concentration in the air on the clean side of the filter relying on the results of measurements of particle content taken by a MicroAir 5250A laser particle counter. They stated that the use of a nonwoven fabric covered with a microfiber layer in the separation of wood particulate matter made it possible to achieve a dust concentration at a level of approx. 0.2 $mg \cdot m^{-3}$. These were values 2.5 to 3 times lower than the values obtained in comparable conditions by using a standard nonwoven fabric. Now it can be stated that this multiple enhancement of the separation efficiency of modified filter material was associated with a relatively small increase in air flow resistance across very similar filtering layers. This increase factor amounted to only about 1.25. Adverse energy consumption consequences due to the introduction of a nonwoven fabric with microfiber layer to the filtering technique used for air cleaning in the woodworking industry are hardly noticeable in comparison with the significant advantages described by the main effects of the separation processes.

Conclusion

The experiments conducted described by the results shown above provided the basis for essential extension of the practical knowledge regarding wood dust separation related to the operating parameters of the latest kinds of advanced filter media such as nonwoven fabrics covered with a microfiber layer. The addition of these results to the existing characteristics of separating properties of the polyester nonwoven fabrics type KYS of both the PROGRES and FINESS series provides a comprehensive assessment of their usefulness as filter media in pulse-jet bag filters used in the woodworking industry at a very broad range of basic flow parameters. The more difficult the flow conditions during the filtering process, the more advantageous the use of the nonwoven fabrics covered with a microfiber layer for wood dust, due to a low increase in energy consumption and the expected significant improvement in the quality of the cleaned air. Detailed economic benefits can be calculated with regard to the specific operating conditions of the industrial filter based on of the results of this paper, showing the proportion in filter resistance and its separation efficiency. What should be particularly taken into account in this calculation is the filter's size, the dust and gas load and other conditions of the filtration process, as well as the expected level of air cleanliness.

References

Callé E., Contal P., Thomas D., Bémer D., Leclerc D. [2002]: Evolutions of efficiency and pressure drop of filter media during clogging and cleaning cycles. Powder Technology 128: 213–217

Dobak S. [2002]: Nowe możliwości w dziedzinie filtracji pyłów drzewnych (New possibilities in the field of wood dust filtration). Zastosowania Ergonomii 1–4: 41–46

Dobak S., Dolny S. [2004]: Separacja pyłów drzewnych na włókninach z warstwą mikrowłókien (Separation of wood dust in the non-woven fabrics with a layer of microfiber). Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria 3[1]: 63–72

Dolny S. [1998]: Badania oporów przepływu podczas separacji pyłów powstałych w procesach przerobu materiałów drzewnych (The study of flow resistance during the separation of dust generated in the process of processing wood materials). Wydawnictwo AR, Poznań

Dolny S. [2005]: Variability of grain-composition of dust in air cleaned on the homogeneous filtering unwoven fabric. Folia Forestalia Polonica Seria B 36: 67–76

Hemerka J., Košina O., Adámek V., Hofmann P. [2001]: Contribution to improvement of pulse jet cleaning of industrial filters. Journal of Aerosol Science 32 Supplement 1: 847–848

Huang H.L., Yang S. [2006]: Filtration characteristics of polysulfone membrane filters. Journal of Aerosol Science 37[10]: 1198–1208

Kabsch P. [1992]: Odpylanie i odpylacze. Mechanika aerozoli i odpylanie suche (Dust and dust collectors. Mechanics of aerosols and dry dedusting). Tom 1. WNT, Warszawa.

Lydon R. [2004]: Filter media surface modification technology: state of the art. Filtration and separation 41[9]: 20–21

MukhopadhyayA. [2009]: Pulse-jet filtration: An effective way to control industrial pollution Part I: Theory, selection and design of pulse-jet filter. Textile Progress 41[4]: 195–315

Saleem M., Krammer G. [2007]: Effect of filtration velocity and dust concentration on cake formation and filter operation in a pilot scale jet pulsed bag filter. Journal of Hazardous Materials 144: 677–681

Tsai C.-J., Lu H.-C. [1998]: Design and operation of a pilot-scale pulse-jet baghouse. Journal of Aerosol Science 29 Supplement 1: 1079–1080

Warych J. [1998]: Oczyszczanie gazów procesy i aparatura (Gas cleaning processes and apparatus). WNT Warszawa.

OPORY PRZEPŁYWU PRZEZ WŁÓKNINY FILTRACYJNE Z POWIERZCHNIOWĄ WARSTWĄ MIKROWŁÓKIEN STOSOWANE DO PYŁÓW DRZEWNYCH

Streszczenie

Stosowane w odpylaniu, nowoczesne materiały włókniste z powierzchnią roboczą uformowaną z mikrowłókien, dają możliwości prowadzenia tzw. filtracji powierzchniowej. Warstwa pyłowa tworzy się prawie wyłącznie na ich powierzchni a to w zdecydowanej mierze wpływa na opory przepływu powietrza przez odpylacz. Sposób kształtowania się tych oporów, w porównaniu do filtracji prowadzonej z użyciem materiałów o jednorodnej strukturze przestrzennej na całej grubości, stał się przedmiotem badań laboratoryjnych przy zastosowaniu pyłu drzewnego o bardzo wysokim stopniu rozdrobnienia. Doświadczenia przeprowadzone w tzw. skali zwiększonej dały dokładny obraz przebiegu narastania strat ciśnienia na warstwie pyłowej tworzącej się na przestrzeni następujących po sobie kilkuset cykli filtracyjnych. Uwidoczniono też różnice, jakie w obrębie tego parametru procesu filtracyjnego występują w przypadku stosowania struktur filtracyjnych wytwarzanych na bazie włókien poliestrowych o budowie jednorodnej i modyfikowanej powierzchniowo mikrowłóknami.

Słowa kluczowe: pył drzewny, regeneracja pneumatyczna, mikrowłókno, włóknina, filtracja