THE INCREASING FILTERING ABILITY OF MATERIALS FROM NATURAL AND SYNTHETIC FIBERS

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ABSTRACT

The research gives an overview of the range of textile materials for filters in the oil industry. Modification of natural and synthetic textile materials and experiments connected with increase in the filtering ability of textile materials were implemented and their operational characteristics were investigated.

The experiments showed that metallized felt filters have an increased filtration rate in comparison with the control sample and plasma treated samples.

It was established that use of ion-plasma deposition in combination with low-pressure high-frequency capacitive plasma treatment allows to increase ~~the~~ operational characteristics of woolen non-woven materials without deteriorating their strength properties, as well as to increase the filter's life at the average in 1.5 times.

It was shown that as a result of exposure to low-pressure high-frequency plasma the structural changes occur associated with the redistribution of interfiber space in the entire volume of nonwoven material, which lead to the production of filters with specified physical-mechanical and operational characteristics.

The use of the modified filters with increased filtering capacity at the oil refining complex will increase the production efficiency and obtain a high-purity product.

Key words: filtering property, woven and non-woven material, low-temperature plasma, hydrophilicity, filtration rate, natural and synthetic fibers.

INTRODUCTION

Textile materials having great importance in the national economy are extremely varied. First of all, textile materials are used in everyday life; these are linen, clothes, sewing threads, decorative fabrics, carpets, curtains, and etc. In addition, they are widely used in technics in the form of ropes and ropes, conveyor belts, drive belts, insulation materials, cords for automobile and aircraft tires, screens, filters, fishing tackle, gaskets, etc. [1, 2].

In area of liquid filtration, especially on an industrial scale, the economical and versatile properties of filters are extremely important, because they must be suitable for different designs of filter systems.

The non-woven materials used for this purpose serve primarily for the deposition of solids during the removal of industrial pollutants such as, for example, cooling liquids or lubricating oils deposits [3, 4]

The filtration properties of non-woven materials of various chemical bases are widely used in the mining, oil refining, food industries, and also in construction and in the area of environmental protection. At oil refining enterprises dewaxing of medium-viscosity raffinate used are non-woven filters made by polypropylene thread and filters made from cotton "filter-diagonal".

However, traditional technologies do not always make it possible to obtain non-woven materials and products from them that can satisfy consumer requirements. Therefore, there is needed modification by physico-mechanical, physico-chemical or other necessary methods. A promising direction for changing the properties of synthetic and natural non-woven materials is the use of high-frequency (HF) plasma processing. Plasma treatment includes a number of processes that leads to change not only in the physical and physico-chemical properties of materials, but also in a change in the chemical composition and structure of the polymer surface layer.

MATERIALS AND METHODS

Plasma treatment has an important advantage compared by other methods of modification of polymer materials - in certain modes it does not affect to the internal structure. In addition, treatment with non-equilibrium low-temperature plasma (LTP) is environmentally friendly, highly efficient, and less expensive compared by traditional methods of chemical and physical modification of polymeric materials [5, 6].

It was known that when capillary-porous (including textile) materials are exposed to a stream of a non-equilibrium low-temperature plasma of a low-pressure high-frequency discharge, a directed change in the physico-mechanical properties of the material being processed occurs. Therefore, at the first stage of the research, took the plasma treatment regimes which the filtering ability was increased with a simultaneous dragging of strength characteristics.

RESULTS AND DISCUSSION

The technological parameters of the high-frequency capacitive of low-pressure are varied in the following ranges: voltage at the anode Ua from 1 to 7.5 kV; current strength at the anode Ja from 0.3 to 0.7 A; processing time τ from 1 to 5 minutes; the consumption of plasma-forming gas G from 0.04 g / s; the pressure in the working chamber is P 26.6 Pa; type of plasma-forming gas - argon, air.

Filter time

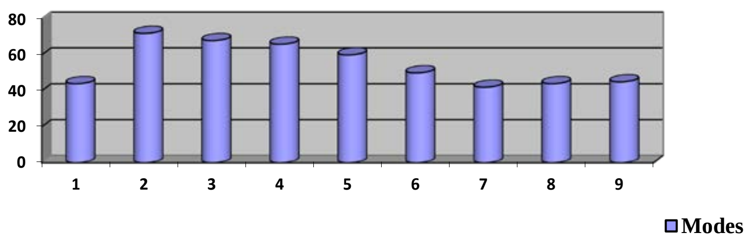

Fig. 1 - Change the filtration time during processing in argon

Fig. 1 shows the following modes:
1 - control sample;
2 - Ua = 1.0 kV, Ja = 0.3A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min;

3 - Ua = 1.0 kV, Ja = 0.4 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min;
4 - Ua = 1.0 kV, Ja = 0.6 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min,
5 - Ua = 3.5 kV, Ja = 0.7 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min,
6 - Ua = 3.5 kV, Ja = 0.3 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min
7 - Ua = 3.5 kV, Ja = 0.4 A, P = 26.6 Pa, G = 0.04 g / s, τ = 4 min
8 - Ua = 3.5 kV, Ja = 0.6 A, P = 26.6 Pa, G = 0.04 g / s, τ = 4 min
9 - Ua = 3.5 kV, Ja = 0.7 A, P = 26.6 Pa, G = 0.04 g / s, τ = 4 min

In order to reduce the cost of the process of modifying polypropylene filters, air or its mixture with argon was proposed as a plasma-forming gas, but expected the results of a decrease in the filtration rate were not achieved. Studies has shown that the filtration rate of modified samples varies slightly and, as a rule, does not exceed the time of raffinate filtration through a control (untreated) sample. An increase in voltage leads to lyophobization of the filter both on the surface and in its total working volume, and as a result, a significant increase of the filtration time.

Filter time

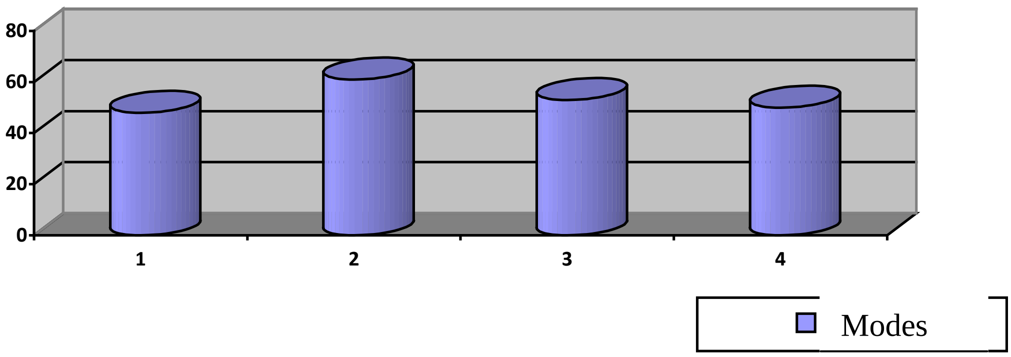

Fig. 2 - Change in filtration time during processing in an argon: air mixture (70: 30%)

Fig. 2 presents the following modes:
1 - control sample;
2 - Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 1 min;
3 - Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min;
4 - Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 7 min

Thereby, it was found that the maximal change in the degree of lyophilicity of the polypropylene filter, lead decreasing in the filtration rate of the oil product, is achieved by processing the material in a plasma-forming gas argon in the mode Ua = 3.5 kV, Ja = 0.4 A, P = 26.6 Pa , G = 0.04 g / s, τ = 4 min. This is due to structural changes associated with the redistribution of inter-fiber space in the entire volume of non-woven material.

Filter time

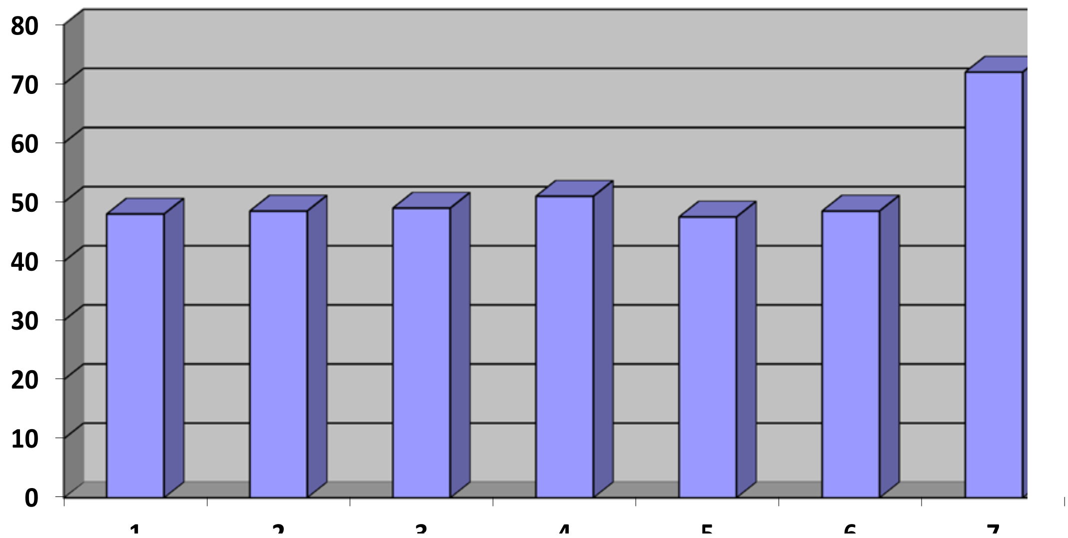

Fig. 3. Change the filtration time when processing in air

Fig. 3 presents the following modes:
1 - control sample;

2 - Ua = 3.0 kV, Ja = 0.4 A, P = 26.6 Pa, G = 0.04 g / s, τ = 1 min;
3 - Ua = 3.0 kV, Ja = 0.4 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min;
4 - Ua = 3.0 kV, Ja = 0.4 A, P = 26.6 Pa, G = 0.04 g / s, τ = 5 min;
5 - Ua = 3.5 kV, Ja = 0.4 A, P = 26.6 Pa, G = 0.04 g / s, τ = 4 min;
6 - Ua = 3.5 kV, Ja = 0.7 A, P = 26.6 Pa, G = 0.04 g / s, τ = 4 min;
7 - Ua = 7.5 kV, Ja = 0.7 A, P = 26.6 Pa, G = 0.04 g / s, τ = 7 min.

Using air or a mixture of it with argon as a plasma-forming gas, despite of its apparent cost-effectiveness is unadvisable, because of the polypropylene filters treated in an atmosphere of air or its mixture with an inert gas does not have the necessary filtering properties.

Previous research imparted lyophilic properties to textile materials of various natural made is possible to obtain plasma treatment regimes leading to a maximum increase in the degree of hydrophilicity [7–9]. Therefore, the processing of filters that made by cotton fabric of the “diagonal” type was carried out in previously known modes (Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 1-5 min).

Filter time

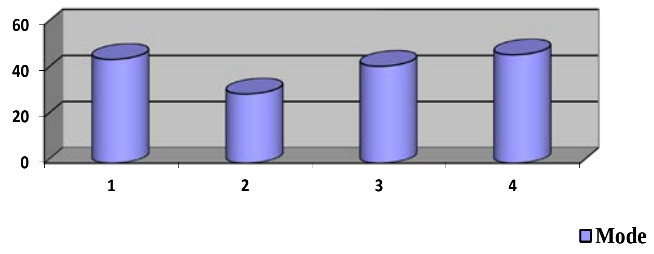

Fig. 4. Change by filtering time through a fabric cotton filter

In Fig. 4 presents the following modes:
1 - control sample;
2 - Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 1 min;
3 - Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 3 min;
4 - Ua = 3.0 kV, Ja = 0.5 A, P = 26.6 Pa, G = 0.04 g / s, τ = 5 min

As can be seen from the diagram, the filtration time through the modified fabric filter decreases in about 1.45 times. Probably, this is due to the ordering of the structure of filamentous fibers that occurs under the influence of plasma-forming gas ions, and the averaging of the interfiber distance.

The test results showed that despite the high filtration rate when using «filter-diagonal» fabric, the best results (high selection of dewaxed oil, low oil content in the slack waxes, etc.) were obtained by using a modified non-woven polypropylene filter. This is due to the fact that traditional fabric filters filter only the surface, while non-woven materials use the entire volume except the surface.

At the second stage of research, explored were carried out on the by used alternative materials - filters for paraffin fractions. One of these materials is technical felt, which is a non-woven material based on keratin-containing waste from fur production.

Wool felt is widely used in mechanical engineering for the make filters for cleaning oils and air, gaskets and oil seals. At the same time, felt products operating in conditions of increased wear should have high abrasion resistance, strength and elasticity [10].

Previous research [11] showed that the processing of wool coarse and semi-coarse felt in a RF capacitive discharge of a non-equilibrium low-temperature low-pressure plasma can significantly increase the basic strength characteristics of products. The aim of the research was to study the possibility of increasing the filtering ability of felt filters while maintaining its strength characteristics.

Samples of the wool felt were pretreated in an HF capacitive discharge with the following variable parameters: U = 2–8 kV, I = 0.3–0.9 A, t = 1–15 min, argon or propane was used by the plasma-forming gas.

The results of physical and mechanical tests of samples of non-woven materials that have undergone plasma processing are shown in the table 1.

Table 1 - The dependence of the physico-mechanical characteristics of wool felt on the processing mode

Sample	Felt, 5 mm		Felt, 3 mm	
	Maximum strength, kH	Relative elongation	Maximum strength, kH	Relative elongation
Control sample	2.0	28.5	0.97	26.5
U = 2kV; I = 0.5 A; t = 5min; argon	176	276	1.1	26.1
U = 7.5kV; I = 0.8 A; t = 10min; propane	219	296	1.26	32.4
U = 5kV; I= 0.5 A; t = 5min; argon	177	201	1.126	22.6

As demonstrated from the table, the highest value of maximum strength and relative elongation is observed when processing felt samples in a propane atmosphere. Probably, propane due to the presence of two terminal methyl groups in the molecule, acts as a potential crosslinking agent, leading to the interaction of reactive centers on the surface of neighboring fibers, which leads to an increasing in the strength of the sample.

Then, titanium particles were sprayed onto the surface of the felt samples by ion-plasma condensation and physical and mechanical tests of the samples were again carried out. The test results are presented in the table 2.

Table 2 - Results of physical and mechanical tests of nonwoven materials after titanium deposition

Sample	Felt, 5 mm		Felt, 3 mm	
	Maximumstrength, kH	Relative elongation, %	Maximumstrength, kH	Relative elongation, %
Control	2.0	28.5	0.97	26.5
U = 2kV; I =0.5 A; t = 5min; argon + Ti	1.56	27.6	1.09	27.26
U =7.5kV; I =0.8 A; t = 10min + Ti	2.19	28.5	1.19	30.1

Table 2 continuation

U = 5kV; I =0.5 A; t = 5min + Ti	1.3	17.1	1.36	27.1

Results of the test showed that the metallization of non-woven materials, contrary to expectations, does not lead to increasing in strength indicators, and in some cases even significantly reduces the strength of the samples. This can be explained by insufficient adhesion of the fibers to each other due to the titanium layer deposited on their surface.

The presented studies of the filtering ability of nonwoven materials showed that the processing of samples in an RFE discharge of a low-pressure plasma can significantly increase the filtration rate. Therefore, researched the filtering ability of felt filters processed in various modes, including with titanium spraying.

CONCLUSION

The experiments showed that metallized felt filters have an increased filtration rate in comparison with the control sample and plasma treated samples. However, the required quality indicators of dewaxed oil deposits have not been achieved. In this regard, tests of felt filters in the conditions of the central control unit were not carried out.

The research of the filtering ability of filters made from natural and synthetic fibers for petrochemistry and mechanical engineering showed that the modification of filters due to plasma treatment in inert gases with the formation of a given degree of surface lyophilicity, as well as due to the deposition of metal nanoparticles on the filter’s working surface, leads to a significant increase in the filtration rate.

It has been established that use of ion-plasma spraying in combination with low-pressure plasma treatment in high-frequency capacitive allows to increase the operational characteristics of woolen non-woven materials without deteriorating their strength properties, as well as to increase the filter life by an average of 1.5 times.

It is shown that as a result of exposure to low-pressure HF plasma, structural changes occur associated with the redistribution of interfiber space in the entire volume of non-woven material, which leads to the production of filters with specified physical, mechanical and operational characteristics.

The use of modified filters with increased filtering ability at the oil refining complex enterprises can increase production efficiency and obtain a high-purity product.

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