Study of the protective properties of special clothing fabrics under the influence of crude oil

Mukhabbat Chorieva[1*], *Fazliddin* Kurbanov[1], *Sitora* Asadova[1], *Zarina* Asadova[1], and *Feruza* Sultanova[2]

[1]Bukhara Engineering-Technological Institute, Bukhara, Uzbekistan
[2]Termez State University, Termez, Uzbekistan

Abstract. This study explores the chemical fixation method for imparting special properties to fabrics used in special clothing for oil and gas industry workers in Uzbekistan. The primary objective is to evaluate the water, oil, and fire resistance properties of these fabrics and propose methods for enhancing them. Experimental results show the adsorption and desorption of oil products, as well as the hydrophobic and flame-retardant properties of the fabrics. The treatment with a collagen-based flame-retardant composition was found to be effective in improving the flammability and flame charring performance of cotton and viscose fiber fabrics. Additionally, halogen-free flame retardants were identified as having low toxicity and low smoke generation during combustion. The study also examines the impact of oil soaking and drying regimes on the physical and mechanical properties of the samples.

1 Introduction

Materials with special (hydrophobic, oleophobic, heat and fire-resistant) properties are produced from fibers that have such properties by nature or are treated with substances that give such properties to the fabric. Often, due to the poor connection of the fibers of textile materials with special properties, their protective properties decrease during their use.

In this regard, the method of chemical fixation of substances giving special properties to the fibers of the main material is the most promising method. For example, copolymers of polystyrene with ethyl cellulose and cellulose have been synthesized to obtain hydrophobic material. Natural or chemical organic polymer fiber textile materials are combustible, easily flammable and can be sources of fire [1, 2]. Treatment of textile materials with a special fire-resistant composition reduces their fire risk. The greatest positive effect is achieved by chemical fixation of fire retardants with fabric fibers. Flame retardants in textiles can include halogen and organophosphorus materials. The former contains bromine or chlorine bonded to carbon, while organophosphorus refractories contain phosphorus bonded to carbon. Halogen-free flame retardants have proven to be an effective method due to their low toxicity and low smoke generation. In recent years, it has been shown that the generalization of

* Corresponding author: muhabbatchoriyeva1@gmail.com

several physico-chemical and technological processes in textiles is becoming an urgent task [3, 4].

2 Materials and methods

According to the hydrophilic-hydrophobic theory, the equilibrium of the balance is primarily determined by the polarity of substances. Silicon and fluorine-containing organic compounds with non-polar chemical bonds and non-polar groups, high hydrocarbons are among the substances that give fabrics hydrophobic properties. However, organosilicon compounds and hydrocarbons do not exhibit oleophobic properties, which is characteristic of fluorine-containing compounds. Therefore, perfluoroacrylates are used to impart hydrophobic-oleophobic properties.

The purpose of this paper's research is to determine and propose ways to increase the oleophobicity and flame retardant properties of fabrics used for special clothing of oil and gas workers.

Taking into account the climate, working conditions, and physical and mechanical requirements for clothing in Uzbekistan, the range of fabrics for special clothing provided to the employees of the oil and gas industry in accordance with the regulations was analyzed in laboratory conditions (Table 1).

Table 1. Physical and mechanical properties of fabrics.

№	Indicators	Experimental results						
		Exam №1	**Exam №2**	**Exam №3**	**Exam №4**	**Exam №5**	**Exam №6**	**Exam №7**
1	Fiber content, %	100% viscose	100% cotton	60% cotton, 40% nitrone,	60% viscose, 40% polyester	50% polyester, 50% viscose	67% nitrone, 20% cotton, 13% viscose	60% viscose, 40% nitrone
	Air permeability, $cm^3/cm^2 sec.$	5.19	32.13	12.09	3.37	6.28	9.4	6.28
2	Hygroscopicity, %	5.32	6.22	5.01	1.47	1.36	2.43	1.36
3	Tensile strength, N Relative elongation, %, mm	796 612 14 21	714 528 12 24	793 407 14 23	1000 769 11 18	886 694 11 18	1000 736 11 17	886 694 11 18
4	Surface density, d/m^2	248	254	233	243	204	253	204
5	Color consistency, score Dry rubbing Wet friction	 4 3	 4 3	 5 4	 4 4	 4 3-4	 4 3	 4 3-4
6	Friction, cycle	25000	21000	26500	25000	25000	25000	25000
7	Entry, % a) horizontal b) vertical	 A-2.5 T-1.5	 A-7.5 T-2.5	 A-1 T-0	 A-0 T-0	 A-1 T-0	 A-2 T-2.5	 A-1 T-0
8	electrification	253	21	512	851	94	100	94

The properties of the fabrics presented in the table were studied as such and with hydrophobic-oleophobic and fire-resistant treatment, for hydrophobic-oleophobic treatment, an emulsion based on perfluoroacrylate and diisocyanate oligomers (PDOE) was selected [5,6].

To prepare the fabric for appretization, the fabric was boiled in a solution containing 30g of baking soda (NaNCO3) and 15g of household soap in 3 l of water and washed in cold water. A 1% sodium hydroxide solution was prepared and boiled for 1 hour. Then it was thoroughly washed, finally rinsed in distilled water and dried.

Samples of 5x30 cm size were cut from fabrics for processing. After measuring the mass of the sample, PDOE or KAOK was soaked, compressed to the level of 80-100% increase in mass using laboratory rollers and dried at room temperature. PDOE soaked fabric was thermofixed at 160-165oC, KAOK soaked fabric at 125-130oC for 3-5 minutes.

3 Results and discussion

In order to determine the tolerance to oil products, treated and untreated samples were soaked in a 20% solution of oil in gasoline. Drying was carried out in 2 different conditions: at room temperature and in a drying cabinet at 600C. Then their masses were measured again.

In order to determine the degree of purification from petroleum products, fabric samples were boiled for 1 hour in a solution prepared by adding 30 g of drinking soda (NaNCO3) and 15g of household soap to 3 l of water. Then the fabrics were boiled for 1 hour by adding 150g of washing soda to 3 liters of water. Then the samples were dried, their mass was measured and the degree of purification was concluded.

The mass change as a result of the hydrophobic-oleophobic treatment of the fabrics was investigated (Table 2).

Table 2. Modes and results of imparting hydrophobic properties to fabric.

Cloth samples	Give hydrophobic properties		
	Initial mass, g	The mass after giving the hydrophobic property, g	Mass after thermofixation at 160^0C, g
1	4.0415	4.0311	3.9273
2	4.1141	4.1114	4.0129
3	3.8289	3.8395	3.7844
4	3.8526	3.8766	3.8530
5	4.0139	4.0174	3.9629
6	3.9291	3.9397	3.9080
7	3.1940	3.1969	3.1760

It is known from table 2 that the mass did not change as a result of the treatment of the fabric, which means that the moisture of the fabric was completely removed during the drying and thermal treatment processes, and there was no increase in the surface density of the fabric. Due to the non-absorption of water into the fabric, it was observed that the hydrophobic properties of all the samples increased dramatically compared to the untreated fabric.

Their oil absorption properties are important when using fabrics to make special clothing for oil miners. This property was determined by changing the mass of the sample as a result of the absorption of petroleum products.

According to the data in Table 3, the degree of absorption of petroleum products into fabric depends on its fiber content. Fabrics made of cotton and viscose fibers absorb oil to a greater extent. The inclusion of polyester and nitrone synthetic fibers in the fabric reduces oil absorption, and the level of oil absorption decreases with the increase in the percentage of

synthetic fibers. When boiled in a soap-soda solution, the capillarity of fabric fibers increases, as a result, the level of oil absorption increases. Mass gain after soaking in oil solution and drying at 60oC on samples boiled (a) and unboiled (b) in soap-soda solution In further studies, the degree of oil absorption of untreated and PDOE-treated samples and dried at room temperature was determined.

Mass change after drying at room temperature of petroleum solution soaked in PDOE treated (a) and untreated (b) samples Table 3.

Table 3. Indicators of oil desorption from fabrics.

Fabric samples	Given a hydrophobic property, dried at room temperature (a)		boiled, at 60^0C Dried (b)		Not boiled			
					dried at room temperature (a)		at 60^0C Dried (b)	
	Oil sponge mass gain, %	Oil remaining after washing, %	Oil sponge mass gain, %	Oil remaining after washing, %	Oil sponge mass gain, %	Oil remaining after washing, %	Oil sponge mass gain, %	Oil remaining after washing, %
1	19.5	5.9	25.4	2.7	19.1	3.3	18.2	3.6
2	17.3	6.0	37.5	3.5	19.2	2.6	17.8	1.7
3	9.3	7.3	12.8	9.5	18.3	1.1	11.2	5.9
4	9.2	5.8	21.1	3.2	14.9	2.3	12.5	2.4
5	16.8	8.3	16.5	9.1	17.8	9.0	14.6	4.8
6	12.5	3.8	12.4	3.2	12.0	6.3	9.9	3.5
7	12.7	4.8	12.7	7.1	13.0	7.2	10.3	4.8

The following data show that oil soaked fabric samples retain more oil when dried at room temperature than when dried at 60oC, especially for fabrics made of cotton and viscose fibers. Increasing the drying temperature will cause the saturated oil products to evaporate from the sample. Hydrophobic-oleophobic treatment significantly reduces the oil absorption of samples 1, 2 and 4. Thus, PDOE chemically binds to cellulose fibers and provides oleophobicity:

$$\cdots Sel - OH + O = C = N - RF_x - \cdots \rightarrow \cdots Sel - O - CO - NH - RF_x \cdots$$

The treatment composition does not bind sufficiently to polyester and nitrone fibers. The effects of fabric treatment, oil absorption and drying regimes on the physical and mechanical properties of the samples were determined (Table 4).

From the data in Table 3 it can be seen that the physico-mechanical properties of fabrics dried at 60oC after oil soaking are higher, while samples 3,5 and 7 meet the standard requirements. When boiled in a soap-soda solution and treated with PDOE, only 4 samples met the standard requirements [7,8].

It was found that the presence of oil products in the samples dried at room temperature has a negative effect on the physical and mechanical properties.

Table 4. Physico-mechanical properties of fabrics made of natural, chemical fibers and their mixtures after exposure to oil.

Fabric samples	State standard 12.4.290-2013 according to		Boiled, dried at 60°C		Treated with PDOE		Not boiled			
							at 60°C dried		Dried at room temperature	
	Breaking strength (N)	Relative elongation, (%)	Breaking strength (N)	Relative elongation, (%)	Breaking strength (N)	Relative elongation, (%)	Breaking strength (N)	Relative elongation, (%)	Breaking strength (N)	Relative elongation, (%)
1	800	20	396	10	360	23	790	25	297	7
2	800	20	292	9	420	10	490	16	374	9
3	700	50	437	17	452	15	840	13	437	15
4	700	50	816	24	717	22	697	18	583	20
5	700	50	256	19	445	22	700	38	359	22
6	700	50	570	41	470	31	570	37	625	40
7	700	50	240	24	525	50	1010	33	575	44

Researches were carried out in order to determine the conditions of desorption of oil soaked in fabrics when using them to make special clothes for oil and gas workers.

Boiling the fabrics in a solution prepared by adding 30g of baking soda and 15g of household soap to 3 l of water for 1 hour did not work. After adding 150g of washing soda to another 3 l of water and boiling the fabric for 1 hour, the results are shown in histograms 1-2. In this case, hydrophobic property is given, oil adsorption in fabrics dried at room temperature is less than in fabrics boiled and dried at 600C. Adsorption of oil on unboiled, room temperature dried fabrics, unboiled, compared to the fabrics dried at 600C. As a result, the unboiled, untreated fabrics have less oil adsorption and the mass after oil washing is almost close to the original mass, which means that special clothes made of these fabrics can be used for a long time by releasing the soaked oil. The antistatic sample 3, which is composed of 60% cotton and 40% nitrone, and the 6th sample, which consists of 67% nitrone, 20% cotton, 13% viscose, gave good results compared to other fabrics, both in terms of physical and mechanical properties, and in terms of oil absorption indicators. These fabrics can be offered for special clothing for oil and gas producers.

Further studies were carried out at the Scientific Research Institute of Fire Safety and Emergency Situations of the Ministry of Emergency Situations of the Republic of Uzbekistan in order to increase the fire resistance of fabrics. Experiments were carried out in order to determine the fire resistance properties of non-processed and KAOK samples of the investigated fabrics on the basis of the State standard 50810-95 in OVT equipment. The obtained results are given in Table 5.

Table 5. Flammability parameters of flame retardant treated and untreated textile fabric samples.

Fabric samples	Indicators							
	The time to ignition when the fabric surface ignites, s, up to		**When the surface ignites burn to the edge of the sample**		**The average length of the charring area when ignited from the surface, in mm**		**Combustion of cotton wool under the sample when ignited from the surface**	
	Processed	**Not processed**	**Processed**	**Not processed**	**Processed**	**Not processed**	**Processed**	**Not processed**
	According to the state standard							
	5 sec. up to	5 sec. up to	does not exist	does not exist	up to 150 mm	up to 150 mm	does not exist	does not exist
1	5	118	does not exist	is available	35	220	does not exist	is available
2	5	135	does not exist	is available	60	220	does not exist	is available
3	109	116	is available	is available	170	220	is available	is available
4	112	145	is available	is available	176	220	is available	is available
5	111	132	is available	is available	173	220	is available	is available
6	105	125	is available	is available	168	220	is available	is available
7	109	139	is available	is available	171	220	is available	is available

According to the results of the study presented in Table 4, all untreated samples did not pass the test according to the standard requirements and were evaluated as flammable. Samples of fire-resistant treated fabrics with a composition of 100% viscose and 100% cotton meet the standard requirements. This is because the substances contained in KAOK chemically bond with cellulose and were developed for cellulose fabrics. However, it was found that the treatment of synthetic and mixed fiber materials leads to a decrease in the duration of burning and the fraction of char.

4 Conclusion

The special properties of fabrics used for oil and gas industry workers' clothing are determined by their composition, presence and conditions of their processing. Oil product adsorption is low and desorption is high, physical and mechanical properties meet standard standards, antistatic fabric with 60% cotton and 40% nitrone, and 67% nitrone, 20% cotton, 13% viscose fabrics are special clothing for oil and gas workers. is recommended for

In order to preserve the physical and mechanical parameters, it is recommended to first dry oil-absorbed fabrics at 60oC, then wash them in at least 5% soda water for 1 hour. Treatment with a collagen-based flame-retardant composition dramatically reduces the flammability and charring performance of cotton and viscose fiber fabrics.

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