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Filtration of process industrial gases through basalt filter material

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Abstract. This article presents the results of the study and analysis the use of basalt fibers as a filter material to improve filtration of emitted gases from dust, modern gas cleaning facilities foundries metallurgist plants. It is established that fibers have well porosity, due to crystallizable fiber structure high heat resistance, due to the high content of basalts Uzbekistan SIO_2 (within 427-for 59.9%) 1 1 TiO2 (within 5 for 2,8 %). In the article one of the conditions of use basalt fibers as a filtering material, the possibility of their resist the high heat flow of the air flow. This indicator presented as basic technology see option normally basalt filter material mode.

Keywords. Filter, basalt fiber, hygroscopicity swelling, gas flow, gas treatment plant, technologically parameter filtering material.

Basalt fiber materials have good porosity and lack of viscosity due to the crystal structure of basalt fibers. The crystal structure of basalts is formed in the process of one-stage processing of the rock, where it takes the form of fibers [1-4]. This indicator practically eliminates the possibility of fibers sticking to each other. The random occurrence of crystal fibers on top of each other creates favorable conditions for the formation of an artificial lattice. The space that is formed between the fibers at the moment of their fit is formed by slits for the free passage of gases through the filter material–partitions.

The last statement can be argued by the presence of through pores in the filter material that can freely pass gas and at the same time delay the saws of the gas phase.

It has been experimentally revealed that another feature of the basalt fiber filter material is the practical absence of hygroscopicity and swelling. This phenomenon proves that basalt fibers do not absorb moisture and retain their original geometric parameters in any humid environment. The specificity of the basalt fiber filter material in this case is as follows [5]:

(1) Heat resistance, a value that serves to determine the coefficient of capture of organic dust from sources of emissions of harmful gases from foundries of metallurgical plants into the atmosphere;

(2) relatively high flexural stiffness of basalt fibers compared to other mineral fibers, their crystal structure contributing to mechanical strength, high coefficient of resistance to air flow, absence of a tensile coefficient favoring the formation of an artificial lattice – a type of light mesh contributing to a good gas filtration rate;

(3) random occurrence of fibers on top of each other, as a result of which a free space is formed between them for the passage of a gas flow;

(4) the absence of hygroscopicity and swelling, as well as the preservation of constant porosity of basalt fibers, counteract the formation of precipitation on the path of the flow of wet gases through the filter at any filtration rate and ensure high filtration performance;

(5) the sediments remaining on the filter surface – aerosols are easily removed from the surface of the basalt-fiber filter material by blowing them with compressor air, which creates a condition for its reuse in the filtration process.

The listed positive characteristics of the basalt-fiber filter material allow using this filter to determine the coefficient of capture of harmful organic impurities from sources of emissions of harmful gases into the atmosphere of foundries of metallurgical plants. [6-7].

Determination of the mass concentration of dust in the air [5]. The method provides measurements at the value of the relative random component of the error ()), the relative non-excluded systematic component of the error (c), and the total relative error (), with the number of parallel observations n =2 and the confidence probability P=0.95, depending on the range of the mass concentration of organic dust, given in the table.1.

One of the most important points of manufacturing a basalt fiber filter is its pressing. When pressing and manufacturing basalt fiber filter material, various minimum compaction forces of the packing can be used. They vary depending on the specific and technical conditions, needs, hardening, stabilization, etc.

Good chemical resistance of basalt fiber filter material expands the scope of application of this material in the presence of high temperature resistance.

Table 1. Indicators of measurement results error

Measuring range of the mass concentration of dust mg/m3м	σ_{Δ}°	Δc	Δ
0,4 - 25,0	12,7	2,95	25,4
25,0 - 50,0	9,0	2,93	18,0

The use of a basalt filter is as follows:

(1) Basalt filter material, together with protective rings, is removed from a plastic bag, kept in a laboratory (weighing room) for one hour to accept the room temperature and establish an equilibrium in air moisture;

(2) open the halves of the protective rings, take out the filter element and fold it four times with tweezers;

(3) the mass of the filter element is weighed. The weighted filter elements are carefully straightened with tweezers;

(4) the number of each filter element is recorded on the protruding part of the protective rings, and the resulting mass is recorded up to the fourth digit in the work log. [5-7]. Filters are delivered to the selection site in plastic bags.

Determination of the dust concentration in the air is carried out as follows: turn on the aspirator and take a sample at the level of the breathing zone at a speed of 20 dm3 / min, monitoring the speed level during the entire sampling time. The duration of sampling depends on the degree of dustiness of the air. The aspirator is turned off at the end of the selection, the filter with protective rings is removed on the body, while to preserve the trapped dust, the filter is turned vertically upwards.

Open the protective rings, bend the filter element in half with the dusty side inside, clamp it between the flaps of the protective rings and put it in a plastic bag. Note the air temperature, pressure and record the sampling time. All work is carried out in accordance with the methodology.

The processing of the measurement results consists in recording the filtration time with a stopwatch and comparing the result with the results of the filtration time through a paper filter. To assess the uncertainty of measurements, the following "Normative documents" were used [8-10].

In this experimental study, it is of practical interest to determine the coefficient of dust capture at the time of its release and release into the atmosphere, which depends on: the thermal resistance of the partitions and their rigidity, the coefficient of resistance, mechanical strength, lack of hygroscopicity and swelling, as well as the purity of impurities for reuse of filter materials.

There are a large number of nonwovens that are used in gas purification plants of pyrometallurgical production, and everywhere they perform such important functions as separation, protection, filtration and drainage. They are not susceptible to rotting, the effects of fungi and mold, rodents and insects

The fulfillment of the requirements of the above indicators is the basis for the development of new filtering facilities, in the future applicable in gas cleaning facilities of foundries of metallurgical enterprises of pyrometallurgical production, which constantly need air filtering materials, since with the increase in the scale of production of such enterprises, the needs for modern gas cleaning facilities increase. Therefore, it is of practical interest to study the operation of gas cleaning facilities of enterprises where the release and emission of harmful impurities into the atmosphere is expected to be greater than permissible.

The use of basalt fibers with high temperature resistance, for the manufacture of filters to capture dust from the exhaust gases of pyrometallurgical production, is the most appropriate. Table-2 presents the comparative characteristics of the thermal resistance of the proposed filter made of basalt fibers and the active filter material of the gas purification plant.5-7].

Table 2. Comparative indicators of basalt fiber heat resistance

№	Specific strength indicators, kg/mm^2		Heat resistance indicators of the current filter, 0°					Basalt filter heat resistance indicators, °C				
			At a temperature of °C					At a temperature of °C				
	current	basalt	300	400	500	600	700	300	400	500	600	700
I	234	242	98.7	88.7	58,9	38,4	25,0	99,7	90,4	63,4	57,8	34,7
II	240	253	99.0	89.0	61.0	39.0	27.0	100	89,3	64,8	44,7	34,1
III	254	259	100	90,0	65,0	38,8	28,6	100	90,0	67,4	43,1	35,8

From the results of the analysis, it can be seen that the heat resistance of the basalt filter is not inferior to the existing filter materials. It can be noted that in both cases, especially in basalt fibers of Uzbekistan, the resistance to heat treatment can reach temperatures above 700 0C.

The technical characteristics of the purification plant for capturing dust of harmful gases of chemicals are given in Table 3.

Table 3. Technical characteristics of the purification plant for dust **capture of harmful gases and chemicals**

№	Name of indicators	Units of change.	Values of indicators
1	Diameter of the tower of emissions of harmful substances	м	0,45
2	Height of the tower of emissions of harmful substances	м	22
3	The speed of the air flow inside the tower	м/с	8,44
4	Exhaust gas temperature	^{0}C	50
5	Diameter of the basalt filtering material - "Basalt wool"	м	0,45
6	The thickness of the basalt filtering material is "Basalt wool"	м	0,05

The study was conducted according to the methodology and performed in accordance with the instructions for the technical operation of filtration materials and under normal climatic conditions (GOST 15150-69), exhaust gas temperature from 25 to 250 ^{0}C, relative humidity (35-90) % and atmospheric pressure (630-740) mm/ Hg. The results obtained are shown in Table-4.

The presence of through pores in the filtering object allows air flows to pass, but at the same time detaining solid particles of the gas phase. It has been experimentally revealed that the filter material made of basalt fibers practically

absorbs moisture due to capillarity and has no swelling, thereby retaining its original geometric parameters. Meeting the requirements of the above indicators contributes to the development of new filtering facilities, in the future, used in gas purification plants of pyrometallurgical production, chemical and cement plants that constantly need air filtering materials.

Table 4. Results of the experimental study

№	Defined ingredient	Selection point	Gas temperature, ^{0}C	Gas velocity, m/s	Конца пыли, mg/m^3	Volume of the gas -air mix3/s	Emission power, mg/s	Gas cleaning efficiency,%
1	Organic dust	at the entrance	50	8,44	24	1,34	32,21	52,1
		at the exit	48	7,24	11,5	1,15	13,24	

To study the suitability of basalt-fiber gas-purifying filter materials in gas-purifying facilities, three filter samples with different geometric parameters were manufactured. Three cassettes were prepared, the outer diameter of which corresponded to the inner diameter of the tower, i.e., 0.45 m. Then three samples were cut from the rolled material of basalt fibers.

Basalts of Uzbekistan with the following chemical compositions were used as a raw material for the manufacture of fiber filters, which were studied in the Central Research Laboratory of the Navoi Mining and Metallurgical Combine within, (in %): SiO2 42.7÷47.3; TiO_2 0.5÷1.51; $A1_2O_3$ 14.2÷20.2; CaO 7.2÷8.4; MgO_2,5÷3,7; FeO 7,0÷8,9; Fe_2O_3 8,1÷9,37; K_2O 0,2÷0,5; Na_2O 1,1÷2,0 and others that do not affect the quality of the final product.

Considering that when filtering the liquid mass, the latter is pressed against the filter with a greater force than the flow of the gas medium, the pressing of basalt fibers was carried out with minimal pressure. This is due to the fact that the filter material can give positive indicators if basalt wool has been pressed and a dense partition has formed.

The pressing forces of the samples were randomly selected: in the first sample with a force of 0.5 kg, in the second - 2.0 5 kg and in the third - 3.0 5 kg. Then the thicknesses of the pressed samples were measured, which were equal, in m: 0.05; 0.35 and 0.18. Further, in accordance with the existing methodology, measurements were made to capture dust from gases emitted into the atmosphere through the gas cleaning facilities of the foundry of pyrometallurgical production. In the first case, dust emissions were detected in the range of 50.7-51.8%. In the second case, this indicator was 46.9% and 44.3%. In the second and especially the third case, there was noticeable smoke inside the foundry.

Technical and analytical indicators of experimental filters based on basalt fibers are included in Table-5.

Table 5. Technical and analytical indicators of experimental filtersbased on basalt fibers

№ п/п	Name of the process	Unit of measurement	Gas cleaning		
			Sample No. 1	Sample No. 2	Sample No. 3
1	Filter area	m^2	0,58	0.58	0,58
2.	Filter thickness	m	0,38	0,28	0,12.
3.	Filter weight	kg	1,60	1,60	1,60
4.	Filter density	kg/ n^3	12	18	22
5.	Pressing force	kg N/m^2	50	205	305
6.	Capture time	min	1,5	1	0,45
7.	Concentration of solid particles in the air after wet cleaning (before cleaning by the proposed method)	g/m^3	18,0	18,0	18,0
8.	Concentration of solid particles in the air after cleaning	g/m^3	9,9	8,1	5,4
9.	Degree of dust capture	%	45,0	55,0	70,0
10.	Specific value of capture	g/m^3	0,078	0,095	0,119
11.	Specific weight capacity of the dust filter	g/m^3	4,50	3,42	2,17
12.	Specific volume of air flow in the pipe	m^3	500	500	500
13.	Continuous operation time of filters with a weight of 1.6 kg at a volumetric speed of 500 m3/h	d	1,5	2,25	3,0
13.1	Continuous operation time of filters with a weight of 70 kg at a volumetric speed according to claim 12	D	3,0	4,5	6,0 м-ц
14.	The proportion of solid phases, including mm	%	100	100	100
14.1.	+ 0,1		58	53	47
14.2.	-0,1+0,74		37	35	28
14.3.	-0,74 +0,50		5	11	16

The choice of three samples can be argued by the fact that the basalt fiber filter material was used for the first time and the technical parameters of the structure were taken into account. Particular attention was paid to the velocity of air flows emitted into the atmosphere, the pressure of the gas medium inside the tower, the geometric characteristics of the cassette and filters, pressure + temperature + humidity of the foundry.

As a result of an experimental study, the acceptability of using basalt fibers to solve the problems of modern gas cleaning facilities has been established. In practice, it has been proven that as particles accumulate on the filter, the gas permeability of the filter material decreases, therefore, regeneration of the filter object or its replacement is periodically required.

Studies have shown that due to the high dust concentration in the exhaust gases, the low degree of dust capture by basalt filters and the high resistance of the exhaust gases, it is impossible to use the proposed filters instead of a wet cleaning system. Therefore, it is recommended to use combined filters of different densities (sequentially No. 1, 2, 3), which allow to increase the period of use of filters and the degree of purification of exhaust gases from dust.

The concentration of solid particles in the exhaust gases after cleaning with basalt fiber filters No. 1, 2 and 3 was revealed, which amounted to: 9.9; 8.1 and 5.4 mg/m3 respectively, at an initial concentration of 18.0 mg/m3. The degree of dust capture by filters No. 1, 2 and 3 was: 45.0; 55.0; 70.0%, respectively. It is revealed that as particles accumulate on the filter, the gas permeability of the filter material decreases, therefore, regeneration of the filter object or its replacement is periodically required, which does not affect their effectiveness in any way.

It was found that the continuous operation time of filters No. 1, 2 and 3 with a weight of 1.6 kg at a volumetric exhaust gas velocity of 500 m^3/h was: 1.5; 2.25 and 3.0 days. In turn, the continuous operation time of filters No. 1, 2, 3, with a weight of 70.0 kg, with a volumetric exhaust gas velocity of 500 m3/h is 3.0; 4.5; 6.0 months. Marked: the method of additional purification of exhaust gases from dust using basalt fiber filters, after the current wet dust collection, allows to increase the degree of purification of exhaust gases from dust to 95-97% (by an additional 5-6%) and, consequently, to reduce by 2.0 - 3.5 times the amount of dust discharged into the atmosphere, it is recommended for pilot tests in the Production Association of the Novosibirsk Machine-Building Plant.

Thus, the suitability of basalt fibers for the manufacture of filter materials for capturing dust from exhaust gases of pyrometallurgical production has been proven. The available methods of manufacturing fabric basalt fiber filter materials from basalt fibers, which can be successfully applied in the technological processes of mining and metallurgical enterprises, are recommended. It has been established that the pressing forces can affect the quality of the filter material, and it has been proved that for the manufacture of filters from basalt fiber materials, it is sufficient to bring the forces up to 0.5 kg.

It was found that the crystal structure of the studied fibers contributed to the formation of a sediment layer consisting of solid impurities on the filter surface. It has been experimentally proved that with an increase in the speed of the filtration process, the amount of dust released increased until some point, and then a decrease in the release was detected. The increase in the release rate and its continuation is the result of the assistance of those dry precipitation, which, by creating an artificial partition, at some point begin to help the filtration process. Eventually, at the beginning, the gas flow will pass through the artificially created sediment layer and then through the filtering basalt-fiber material. In general, it can be considered expedient to manufacture filter materials based on basalt fibers, which can be successfully used for the purification of industrial exhaust gases from dust.

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