Features of filtration of industrial gases from dust with a basalt filter

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Abstract. The scientific and technological progress of the 21st century is inextricably linked with the widespread use of new materials based on mineral and organic fibers. The most widespread in various industries received on the basis of basalt crystalline fibers. These fibers, in terms of their inherent indicators, for example, physical, mechanical and chemical properties, and price indicators, significantly exceed the classical ones, the production technology of which was implemented in industrial conditions at the end of the last century only in Russia and Ukraine and is a priority of these countries. Basalt fibers are well compatible with polymer, metal, ceramic, inorganic and carbon matrices and various fibers when creating hybrid and composite materials. These unique materials outperform their counterparts made of fiberglass and even steel in terms of performance. They are distinguished by durability, reliability, high corrosion resistance, are operational in a wide temperature range (from -275 to 800 °C), and are chemically inert.

1 Introduction

Features of basalt fibers. Basalt fiber materials are one of the directions obtaining products of spunbond production, where the melting furnace is considered to be the main tool for processing basalts. This is evidenced by the results of a study of the features of the processing of basalts “Asmansay” [1-3]. The preparation and processing of basalts in this furnace is carried out according to known technology. If we consider the method of manufacturing basalt fibrous material, then the process can be considered simple. In contrast to the technological process of obtaining products in the cast form of petrurgical production, in the production of fibrous materials, after the formation of the melt, liquid basalt passes through a spinneret, where the melt will turn into a jet stream.

To turn liquid basalt into a jet, a blower was added to the technological mode. The device works with the help of a stream of hot air, which is supplied under a pressure of 1-2 atm. The process of processing raw materials and the production of fibers is as follows. In this case, we consider the following process of obtaining basalt fiber to be an effective option for performing the work:

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- Medium crushing is performed. screening of basalts with washing and removal of sludge.
- Drying of the product and obtaining crumbs with a size within 5÷6 mm.
- Preparing the furnace for operation, heating up to 800ºC.
- Feeding the basalt product into the furnace. preparing the melt to a temperature of 1400÷1450ºC.
- Forming continuous primary fibers with a spunbond by a feeder.
- Blowing primary fibers onto a secondary fiber.
- Forming a web of fibers with a diameter of 6÷600 mkm onto a receiving drum [2-4].

2 Research results and their essence

The crystalline structure virtually eliminates the possibility of fibers sticking to each other. The space that forms between the fibers at the moment of their contact forms gaps for the free passage of gases through the filter material of the partitions. The latter can be argued by the fact that the presence of through pores in the filter material allows the passage of gas without hindrance, but at the same time retains the dust of the gas phase. The absence of hygroscopicity and swelling proves that basalt fibers do not absorb moisture even in this case. At a constant gas flow pressure, the filter material retains its original geometrical parameters in any humid environment. Gas-cleaning filtering materials called air filters have passed production tests in the gas-cleaning facilities of the foundry shop of JSC NMP NMMC [1-3, 5].

The listed positive chemical and physical-mechanical characteristics of basalt fiber made it possible to manufacture prototypes of air filters. These filters were experimentally used to determine the coefficient of trapping of harmful organic impurities from sources of emissions of harmful gases into the atmosphere of foundries of factories. For this, a “method for determining the mass concentration of dust in the air” was developed. Depending on the purpose, various types of basalt fiber filter materials can be manufactured, which can best and most effectively meet the requirements of mining, processing, metallurgical and chemical enterprises. One of the most important moments in the manufacture of a basalt fiber filter is its pressing. When pressing and manufacturing basalt fiber filter material, various minimum pressing forces of its packing can be used. They change depending on the technical conditions, needs, hardening, stabilization.

The good chemical resistance of the basalt fiber filter material expands the scope of this material. The high mechanical strength of basalt fibers (1800-:-2500 MPa) creates the condition to withstand heavy loads. Basalt fibers have increased heat resistance. Basalt fiber filter material is an effective substitute for natural and artificial filter materials existing in practice.

Materials and products based on fibers and filaments from basalt significantly surpass the used fibrous materials and products from them in terms of properties and technical parameters (low bulk density, wide temperature range of application (-270C 0 ... +800ºC), low hygroscopicity (10 times lower than that of glass and other fibers), high chemical resistance to alkalis, acids and other aggressive media. The listed positive chemical and physical-mechanical characteristics of the basalt- fiber filter material make it possible to use this filter for application in determining the coefficient of capture of VCM from sources of emissions of harmful gases into the atmosphere of foundries of metallurgical plants (Table 1).

Table 1. Technical characteristics of the cleaning baffle for trapping harmful chemicals.

No.	Name of indicators	Units	Indicator values
1	Emission tower diameter	M	0.45
2	Emission tower height	M	22
3	The speed of the air flow inside the tower	m/s	8.44
4	Exhaust gas temperature	^{0}C	50
5	The diameter of the basalt filtering material – "Basalt wool"	M	0.45
6	The thickness of the basalt filtering material – "Basalt wool"	M	0.05

The processing of the measurement results consisted in recording the filtration time with a stopwatch and comparing the result obtained in paper filter time results. To assess the uncertainty of measurements, we were guided by the following "Regulatory documents" [2, 4, 6-7]. Comparative indicators of heat resistance of basalt fibers identified and data from basalt processing countries, on the example of Ukraine, are presented in Table. 2. [8-11].

Table 2. Comparative indicators of heat resistance of basalt fibers.

No.	Specific strength indicators, kg/mm ^{2}		Indicators of heat resistance of Ukrainian basalt, ^{0}C					Indicators of heat resistance of Uzbekistan basalt, ^{0}C				
			At a temperature of ^{0}C					At a temperature of ^{0}C				
	Ukraine	Uzbekistan	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

It can be seen from the results that the basalt fibers of Uzbekistan are not inferior to the basalt fibers of Ukraine in terms of heat resistance. It can be seen that in both cases, especially for Asmansai basalt fibers, resistance to heat treatment can reach temperatures above 700 ^{o}C material and without it.

The studied crystalline filter fibers are not subject to rotting, fungi and mold, rodents and insects and meets the requirements of the instruction for the technical operation of filtration materials according to (GOST 15150-69). Flue gas temperature from 25 to 250^{0}C, relative humidity (35-90)% and atmospheric pressure (630-740) mm/Hg [5-7].

Thus, the revealed studies showed once again the presence of through pores in the proposed filter object allows air flows to pass freely, but at the same time retaining solid particles of the gas phase. It has been experimentally found that the filter material made of basalt fibers practically absorbs moisture due to capillarity and does not swell , thereby retaining its original geometric parameters.

Compliance with the requirements of the above indicators contributes to the development of new filtering facilities, in the future applicable in gas cleaning facilities of foundries of metallurgical enterprises, chemical and cement plants, which constantly need air filtering materials. Studies have established the acceptability of using basalt fibers to solve the problems of modern gas cleaning facilities for dust capture by basalt filters. The results of the study showed that due to the high concentration of dust in the exhaust gases, the low degree of exhaust gases, it is impossible to use the proposed filters instead of the wet cleaning system. Therefore, it is recommended to use combined filters of different densities (sequentially No. 1, 2, 3), which allow to increase the service life of filters and the

degree of post-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, which amounted to: 9.9; 8.1 and 5.4 mg/m^3 respectively, with an initial concentration of 18.0 mg/m^3 . The degree of dust capture by filters No. 1, 2 and 3 was: 45.0; 55.0; 70.0% respectively.

It has been established 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 efficiency in any way. It was revealed that the time of continuous operation of filters No. 1, 2 and 3 with a weight 1,6 kgat a space velocity from the outgoing gas of 500 m ^{3} / h was: 1.5; 2.25 and 3.0 days. In turn, the time of continuous operation of filters No. 1, 2, 3, with a weight of 70,0 kg, at a space velocity from the outgoing gas of 500 m^3/h is 3.0; 4.5; 6.0 months.

It was noted that the method of post-purification of exhaust gases from dust using basalt fiber filters, after the current wet dust collection, allows increasing the degree of purification of exhaust gases from dust up to 95-97% (additionally by 5-6%) and, consequently, reduce by 2.0 - 3.5 times the amount of dust emitted into the atmosphere, it is recommended for pilot testing at the production department of NMZ JSC NMMC.

Thus, the suitability of basalt fibers for the manufacture of filter materials for trapping dust from exhaust gases has been proven. Available methods are recommended for the manufacture of fabric basalt fiber filter materials from basalt fibers , which can be successfully applied in the technological processes of mining and metallurgical enterprises.

To study the suitability of basalt fiber gas cleaning filter materials in gas cleaning facilities, three filter samples with different geometric parameters were made. 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.

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. Taking into account that during filtration the liquid mass is pressed against the filter with a greater force than the flow of the gaseous medium, the pressing of basalt fibers was carried out with minimal pressure. The pressing forces of the samples were arbitrarily chosen: in the first sample with a force 0,5 kg, in the second - 2.05 kg and in the third - 3.05 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 the metallurgical plant. In the first case, dust emissions were found in the range of 50.7÷51.8%. In the second case, this figure was 46.9% and 44.3%.

In the second and, especially, in the third case, there was a noticeable smoke inside the foundry. Thus, part of the gases from the flow, receiving resistance, returned back to the shop. To compare the results obtained, the data are entered in a table. In Table. 3 includes technical and analytical indicators of experimental filters [9-12].

Table 3. Technical and analytical indicators of experimental filters based on basalt fibers.

No.	The name of indicators	Unit rev.	Gas cleaning		
			arr. #1	arr. #2	arr. No. Z
1	**2**	**3**	**4**	**5**	**6**
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	Trap time	min	1.5	1	0.45
7	The concentration of particulate matter in the air after wet cleaning (before cleaning by the proposed method)	g/m^3	18.0	18.0	18.0
8	The concentration of particulate matter in the air after cleaning	g/m^3	9.9	8.1	5.4
9	Degree of dust capture: - working filter - recommended filter	%	38 45.0	40 55.0	42 70.0
9.1	Degree of dust capture				
10	Specific capture value	g/m^3	0.078	0.095	0.119
11	Specific gravity of 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	Time of continuous operation of filters with weight 1,6 kgat a flow rate of 500 m^3/h	d	1.5	2.25	3.0
13.1	The time of continuous operation of filters with weight 70 kgat a volumetric velocity according to item 12	D	3.0	4.5	6.0 ms
14	The share of solid phases, incl. 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

3 Conclusion

Thus, it has been established that for the manufacture of filters from basalt fiber materials, pressing forces in the range of up to 0.5 kg are sufficient . It has been proven that the pressing of the filter septum can affect the size of the pores and their shape. Therefore, it is of practical interest to manufacture and press fibrous materials with minimal effort.

It was revealed that the crystal structure of the studied fibers contributed to the formation of a deposit layer consisting of solid impurities on the filter surface. But, in the beginning, with an increase in the speed of the filtering process, the amount of dust released increased to a certain point, and then a decrease in emission was detected.

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