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Filtration process of industrial gases from dust using basaltic filter

Filtracija prahu iz industrijskih plinov z uporabo bazaltnega filtra

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Abstract

This article presents the results of research and analysis of the use of basalt fibers as a filter material for improving the filtration by modern gas purifying facilities of metallurgical plant foundries of emitted gases from the dust. It is found that the basalt fiber has good porosity due to crystal structure of the fiber and lack of viscosity, as well as high heat resistance due to the high content of SiO_2 in the Uzbekistan basalts (within 42.7 % and 59.9 %) and TiO_2 (in the range 0.5–2.8 %). The given basalt fiber features allow them form in a simple process of rock processing, in which they take the form of basalt fibers. In the article as one of the conditions of using basalt fibers as a filter material, the possibility of their resistance to high and thermal air flow is indicated. This factor is presented as main technological parameter ensuring the normal operation of the basalt filter material. As a result, it presents data demonstrating the possibility of using basalt filter materials by modern gas purifying facilities of metallurgical plant foundries of emitted into the atmosphere gases from the dust.

Key words: filter, basalt rock, research, gas flow, gas purifying facilities, process variable, filter material

Izvleček

V prispevku so prikazani rezultati raziskave uporabnosti bazaltnih vlaken kot filtrske snovi v sodobnih čistilnih napravah za boljše ločevanje prahu iz plinov, ki izhajajo iz livarn. Ugotovili so, da imajo bazaltna vlakna primerno poroznost spričo njihove kristalne zgradbe ter ustrezno viskoznost in visoko toplotno odpornost zaradi znatne vsebnosti SiO_2 (v razponu od 42,7 % do 59,9 %) in TiO_2 (od 0,5 % do 2,8 %) v uzbekistanskih bazaltih. Navedene lastnosti vlaken omogočajo njihovo pridobivanje v enostavnem procesu iz bazalta. V članku poudarjajo kot eno izmed prednosti uporabe bazaltnih vlaken za filtrsko snov njihovo odpornost proti visokotemperaturnemu zračnemu toku. Ta dejavnik predstavljajo kot poglavitni tehnološki parameter, ki zagotavlja normalno delovanje bazaltne filtrske snovi. Prikazani podatki potrjujejo uporabnost bazaltne filtrske snovi v sodobnih čistilnih napravah metalurških livarskih obratov za odstranjevanje prahu iz plinov, ki izhajajo v ozračje.

Ključne besede: filter, bazaltna kamnina, raziskava, plinski tok, čistilne naprave, procesna spremenljivka, filtrska snov

Introduction

Basalt materials have good porosity and lack of viscosity due to the crystal structure of basalt fibers. The crystal structure of basalts is formed during the one-stage processing of rocks in which it takes the fiber form [1–4]. This virtually eliminates the possibility of fibers sticking together. The random occurrence of crystal fibers on each other creates favorable conditions for the formation of artificial lattice. The space formed between the fibers while occurrence creates a gap for the free passage of gases through the filter material-walling. The last statement can be grounded by the presence in the filter material of through pores capable of freely let gas pass and thus capture the gas phase dusts.

Experimentally determined that another feature of basalt filter material is that it substantially lacks hygroscopicity and swelling ability. This phenomenon shows that basalt fibers do not absorb moisture and retain their original geometric parameters at any wet environment. Specificity of basalt-fibrous filter material in this case is as follows [5]:

— heat-resistance, the value used to determine the coefficient of organic dust capture from harmful gases emission sources of metallurgical plant foundries into the atmosphere;
— relatively high bending stiffness of basalt fibers compared with other mineral fibers, their crystal structure that promote the creation of mechanical strength, high resistance to air flow rate, the lack of stretch factor favoring the formation of an artificial lattice like light mesh that promotes good filtration speed of gases;
— inordinate occurrence of fibers on each other resulting in the formation of a space between them for the gas flow;
— lack of hygroscopicity and swelling ability, as well as maintaining a constant porosity of basalt fibers counteract the formation of deposits on the wet gas flow path through the filter at any filtration speed, and provide high filtering efficiency;
— deposits remaining on the filter surface – aerosols can be easily removed from the surface of the basalt-fibrous filter material, blowing them out by compressor air that creates the conditions for its repeated use in the filtering process.

These positive characteristics of basalt-fibrous filter material allow the use of this filter to determine the wash-out rate of harmful organic impurities from the sources of metallurgical plant foundries into the atmosphere. [3–4]

Materials and methods

Determination of the mass concentration of dust in the air [5]. The technique provides the measuring at the value of the random component of relative error ($\sigma(\Delta^{\circ})$), relative Residual error component (Δc), and total relative error (Δ); in case of the number of parallel observations $n = 2$ and confidential probability $P = 0.95$, depending on the range of values of the mass concentration of organic dusts listed in Table 1.

One of the most important moments of basalt-fibrous filter manufacturing is its pressing-in. In the process of pressing-ing and manufacturing basalt-fibrous filter material various minimum pressing force of the packing may be used. They vary depending on the specific and technical conditions, needs, reinforcement, stabilization, etc.

Good chemical resistance of basalt-fibrous filter material extends the scope of application of this material in the presence of high thermal stability.

Basalt filter use happens as follows:

— Basalt filter material together with the protection rings is removed from the plastic bag,

Table 1: *Indicators of measurement results' error*

The measurement range of dust mass concentration, mg/m³	σ_{Δ}°	Δc	Δ
0.4–25.0	12.7	2.95	25.4
25.0–50.0	9.0	2.93	18.0

for one hour kept in a laboratory (weighing room) so that it took a room temperature and establishment of balance of air moisture;
- half of the protective rings is opened, the filter element is removed and is piled up using tweezers in four parts;
- The mass of the filter element is weighed. Weighed filter elements using tweezers carefully straightened, put in protection rings and placed in a plastic bag;
- Number of each filter element is recorded on the projecting part of the protective rings, and the resulting mass is accurately recorded in the workbook up to the fourth digit [5]. Filters are delivered to the place of collection in plastic bags.

Determination of the dust concentration in the air is happens follows: an aspirator is switched on and a sample is taken at the breathing zone at a rate 20 dm^3/min while controlling the speed rate at all times during the selection. The duration of sampling depends on the degree of dust in the air. Aspirator is switched off after selection and filter is removed from the protection rings on the body; in order to store the collected dust allonge is rotated into a vertical position filter up.

Protection rings are opened, and the filter element is folded in half dusty side inside, and it is clamped in between the protection rings flanges and put in a plastic bag. The air temperature and pressure are noted, sampling time fixed. All the work is performed in accordance with the procedure.

Processing the measurement results was to record the filtration time by stopwatch and comparing with the results of filtering time through a paper filter. To estimate the uncertainty of measurement, we were guided by the following »regulatory documents« [3].

In this experimental study, determination of the dust entrainment coefficient at the time of its emission and release into the atmosphere is of practical interest which depends on: the thermal resistance of walls and their stiffness, resistance coefficient, mechanical strength, lack of hygroscopicity and swelling ability, as well as cleanability from impurities for repeated use of the filter materials.

There are a large number of non-woven materials that are used in the gas purifying facilities of pyrometallurgical production, and everywhere they perform important functions such as separation, protection, filtration and drainage. They are not subject decay, impact of mold and mildew, rodents and insects.

Compliance with the above parameters is the basis for the development of new filter objects in the future applicable in gas purification plants foundries of metallurgical enterprises - pyrometallurgical production, which is constantly in need of air filtration materials, since an increase in the production scale of enterprises means and increase of the need for advanced gas purification facilities. Therefore, it is of practical interest to study the work of gas purifying facilities of enterprises, where gas emission and release of harmful contaminants more than permissible are expected.

Application of basalt fibers with high heat resistance is the most appropriate for manufacturing filters for dust entrainment from the exhaust gases of pyrometallurgical production. Table 2 presents the comparative characteristics of the thermal resistance of the proposed basalt-fibrous filter and the current gas purifying facility filter materials [2, 4–5].

Table 2: *Comparative thermal indices of basalt fibers*

№	Index of unit strength, kg/mm^2		Thermal stability index of current filter, °C					Thermal stability index of basalt filter, °C				
			At a temperature °C					At a temperature °C				
	Existing	Basaltic	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 analysis it is clear that the thermal stability of the basalt filter is not inferior to current filter materials. It can be seen that in both cases, especially Uzbekistan basalt fibers' resistance to heat treatment could reach temperatures above 700 °C.

Technical characteristics of purifying facilities for dust entrainment from chemical harmful gases are shown in Table 3.

The study was conducted according to the procedures and carried out in accordance with the instructions for the technical operation of the filtration materials and under normal climatic conditions (State Standards 15150-69) – off-gas temperature from 25 °C to 250 °C, relative humidity (35–90 %) and atmospheric pressure 838–986 mbar (630–740) mm Hg. The results are shown in Table 4.

The presence of through pores in the filter element allows the free passage to air flow yet retaining at the same time the solid particles of the gas phase. It is experimentally found that the filter material of basalt fibers substantially absorbs moisture due to capillarity and has no swelling ability, thus retains its initial geometrical parameters. Compliance with the above mentioned factors facilitates the development of new filtering objects in the future, applicable in gas purification plants of pyrometallurgical production, chemical and cement plants, which constantly are in need of air filter materials.

To investigate the suitability of basalt-fibrous gas purifying filter materials in gas purification plants, three sample filter with different geometrical parameters were prepared.

Three tapes were also prepared, the outer diameter of which corresponds to the inner diameter of the tower, that is, 0.45 m. Then, from the coiled material three samples of basalt fibers were cut.

As a raw material for the production of basalt-fibrous filters, Uzbekistan basalt was used with the following chemical composition, which were investigated in the central research laboratory of the Navoi Mining and Metallurgical Combinat (NMMC) in the range (in %): SiO_2 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 the fact that during the filtration of liquid mass, the latter is pressed against the filter strongly than the flow of the gaseous

Table 3: *Technical characteristics of purifying facilities for dust entrainment from chemical harmful gases*

#	Name of index	Unit of measurement	Parameter values
1	The tower diameter for harmful substances emission	m	0.45
2	The tower height for harmful substances emission	m	22
3	The rate of air flow inside the tower	m/s	8.44
4	Exhaust gas temperature	°C	50
5	Diameter basalt filter material – »Stone wool«	m	0.45
6	Thickness of basalt filter material – »Stone wool«	m	0.05

Table 4: *Results of a pilot study*

№	Selected ingredient	Selection point	Gas temperature, °C	Gas velocity, m/s	Dust concentration, mg/m³	Amount of gas mixture, m³/s	Emission power, mg/s	Gas purification efficiency, %
1	Organic dust	Inlet	50	8.44	24	1.34	32.21	52.1
		Outlet	48	7.24	11.5	1.15	13.24	

medium, the compression of basalt fibers was accomplished with a minimum pressure. This is because the filter material can yield positive performance in the event that basalt wool was pressed and dense partition was formed.

Samples of compaction effort were selected randomly: in the first sample with a force of 0.5 kg, the second – 2.05 kg and in the third – 3.0 of 5 kg. Then the thickness of molded samples was measured which were equal in m: 0.05, 0.35 and 0.18. Further, in accordance with the existing procedure, measurements were made to detain dust from the gases emitted into the atmosphere through the purifying facilities of pyrometallurgical production foundry. In the first case, the dust emission was found within 50.7–51.8 %. In the second case, the figure was 46.9 % and 44.3 %. In the second and especially in the third case there was a noticeable haze inside the foundry.

Choice of three samples can be argued that the basalt-fibrous filter material was used for the first time and technical parameters of the facility are taken into account. Particular attention was paid to the air flow rate released into the atmosphere, the pressure of the gas medium inside the tower, the geometric characteristics of the tape and filters, pressure + temperature + foundry humidity.

As a result of experimental studies, the acceptability of the use of basalt fibers to meet the challenges of modern gas purifying facilities was established. In practice, it is proved that the accumulation of the particles on a filter, the permeability of the filter material is reduced, so periodically it requires regeneration of filtering object or its replacement.

Research has shown that because of high concentration of dust in the exhaust gases, the low degree of dust entrainment in basalt-fibrous

Table 5: *Technical and analytical indicators of experimental filters based on basalt fibers*

#	Process name	UOM	Gas purification		
			# 1	# 2	# 3
1.	Filter area	m^2	0.58	0.58	0,58
2.	Filter thickness	m	0.38	0.28	0.12
3.	Filter mass	kg	1.60	1.60	1.60
4.	Filter density	kg/m^3	12	18	22
5.	Pressing strength	$(kg\ N)/m^2$	50	205	305
6.	Entrainment time	min	1.5	1	0.45
7.	Concentration of hard particles in the air after scrubbing (till purifying using offered method)	g/m^3	18.0	18.0	18.0
8.	Concentration of hard particles in the air after purification	g/m^3	9.9	8.1	5.4
9.	Degree of dust entrainment	%	45.0	55.0	70.0
10.	Specific value of entrainment	g/m^3	0.078	0.095	0.119
11.	Specific mass capacity of a filter on dust	g/m^3	4.50	3.42	2.17
12.	Specific volume of the air flow in the pipe	m^3	500	500	500
13.	Continuous operation of filters with a mass of 1.6 kg at a flow rate of 500 m^3/h	d	1.5	2.25	3.0
13.1	Continuous operation of filters with a mass of 70 kg at a flow rate of 12 points, month	d	3.0	4.5	6.0
14.	Fraction of solid phase, 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

filters and high resistance of exhaust gases, it is impossible to use offered filters as replacement for the scrubbing system. Therefore it is recommended to use combination filters of different density (number series 1, 2, 3), which allows to extend the use of filters and the degree of tail gas cleanup from dust.

The Table 5 includes technical and analytical indicators of experimental filters on the basis of basalt fibers.

Concentration of hard particles in the flue gas were noticed after their purification by basalt-fibrous filters 1, 2 and 3, which were as follows: (9.9; 8.1 and 5.4) mg/m^3, respectively, at an initial concentration of 18.0 mg/m^3. Degree of dust entrainment by filters number 1, 2 and 3 were as follows: (45.0; 55.0; 70.0) % respectively. It was also revealed that as the particles accumulated in the filter, the gas permeability of the filtering material is reduced and thus periodically it is necessary to regenerate the filtering object or replace it, which is not that effective.

It is found that continuous work time of filters 1, 2 and 3 with a mass 1.6 kg at a flow rate of the exhaust gas 500 m^3/h was (1.5; 2.25 and 3.0) d. In turn, continuous work time of filters 1, 2, 3, with a mass 70.0 kg, at a flow rate of the exhaust gas 500 m^3/h is (3.0; 4.5; 6.0) months. It is noted that the method of purification of waste gases from the dust using basalt-fibrous filters after existing wet dust entrainment can increase the degree of purification of flue gases from the dust up to 95–97 % (additional 5–6 %), and hence reduce dust emission into the atmosphere in 2.0–3 5 times; it is recommended for pilot testing in experimental and industrial test in Navoi Mining and Metallurgical Combinat (NMMC).

Conclusion

Thus we have proved the suitability of basalt fibers for the manufacture of filter materials for dust removal from flue gases of pyrometallurgical production. It is recommended to use available method of preparing from basalt fibers basalt-fibrous filtering materials that will successfully be applied in the technological processes of mining and metallurgical enterprises.

It was revealed that the quality of producing filter materials can be affected by compression force and for manufacturing filters from basalt-fibrous materials, pressure force up to 0.5 kg is sufficient.

It was found that the crystal structure of the investigated fibers contributed to the formation of sediment layer consisting of solid particles on the filter surface. It is experimentally proved that with increasing speed of the filter process, the amount of dust emitted is increased to a certain point, and then the decrease of the emission is observed. The increase of the emission index and its continuation is the result of the dry sediments influence that created an artificial barrier, at some point began to help the filtration process. Concluding, at the beginning the gas flows through artificially created a layer of sediment, and then through the filtering basalt-fibrous material. In general, it can be considered appropriate manufacturing filtering basalt-fibrous materials that can successfully be used for the emitted industrial gases purification from dust.

References

[1] Dzhigaris, D. D., Mahova, M. F. (2006): *Base of basalt production fibres and products*, 410 p.

[2] Kurbanov, A. A. (2009): *Specific of basalts featureof Kyzyl Kum.* The onography; publishing. »Fan« RUz., 160 p.

[3] Kurbanov, A. A., Abdurahmonov, S. A., Turaev, A. S. (2010): *Base of processing of basalts of KyzylKum.* The monography publishing »Fan« AN RUz, 167 p.

[4] Luchinskiy, V. I. (1949): Petrography. M.: Gosgeolizdat, pp. 213–225.

[5] Pashchenko, A. A. (1978): New cements. Under the editorship of Member correspondent Academy of Science of Ukraine. Publishing house «Budivelnik», Kiev, 220 p.