UDC 549.657:553.611 https://doi.org/10.34185/tpm.2.2020.05

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Вивчення впливу різних типів бентонітових глин на показники якості окатишів

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Study of the influence of different types of bentonite clays on the quality indicators of pellets

Мета: проаналізувати та визначити вплив бентонітових глин різних родовищ та обмінних іонних комплексів на металургійні властивості залізорудних окатишів. Методика: виконання реологічних досліджень зразків бентонітових глин та їх хімічний аналіз, електронно-мікроскопічні дослідження зразків. Для оцінки металургійних характеристик отриманих окатишів визначені вологість окатишів, міцність при стисненні сирих і сухих окатишів, кількість скидань без руйнування сирих окатишів і температура «шоку».
Результати: проведено лабораторні випробування по визначенню придатності різних по мінералогічному складу і обмінному іонному комплексу бентонітових глин для виробництва окатишів. Проведені випробування показали, що міцність на удар і опір стисненню сирих окатишів при дещо підвищеній питомій витраті бентоніту Черкаського лужноземельного бентоніту не поступається цим же властивостям окатишів з використанням в якості сполучного лужного Саригюхського бентоніту. Показано, що сприятливим, для забезпечення гарної якості сирих окатишів, різновидом глин Черкаського родовища є глини IV шару, що представляють собою природну суміш лужноземельного бентоніту II шару і палигорскіту (III шару). Проведено випробування композиційних сумішей глин IV зі II і II з III шарами, які показали, що якість сирих окатишів з Черкаським бентонітом дещо гірше, ніж з Саригюхскім, проте абсолютні значення їх показників задовольняють пред'явленим промисловістю вимогам. Проведено порівняльні випробування огрудкування шихти з різною вологістю, з добавкою 0,5 % лужного бентоніту і суміші глин IV і II шарів Черкаського родовища. Показано, що зі збільшенням вологості у окатишів з обома видами сполучних добавок підвищується динамічна міцність, пористість і температура «шоку» окатишів, при мінімальній різниці абсолютних значень показників з різними сполучними. Для об'єктивного підтвердження можливості використання щелочноземельного бентоніту Черкаського родовища (II-III-IV шарів) у виробництві окатишів, необхідно провести порівняльні промислові випробування на окомковательних фабриці (наприклад, Північний ГЗК), що використовує концентрат з підвищеною жорсткістю технічної води. Наукова новизна: Вивчено вплив заміни лужного бентоніту в шихті для виробництва окатишів лужноземельними, палигорськітовими глинами і сумішами їх форм. Вивчено порівняльний вплив вологості сирих окатишів на їх пористість і міцність характеристиками з лужним і лужноземельними бентонітами в шихті.
Практична значущість: на прикладі властивостей сирих, сухих і обпалених окатишів показана можливість використання менш дефіцитних і менш вартісних місцевих бентонітових глин замість дорогих експортуємих лужних глин без погіршення технології виробництва і характеристик окатишів.
Ключові слова: бентонітові глини, окатиші, виплавка чавуну, монтморилоніт, палигорськіт, дисперсія, обмінний комплекс, набухання, міцність окатишів.
Objective: to analyze and determine the influence of bentonite clays of different deposits and exchange ionic complexes on the metallurgical properties of iron ore pellets. Methods: performing rheological studies of bentonite clay samples and their chemical analysis, electron microscopic studies of samples. To assess the metallurgical characteristics of the pellets obtained, the moisture of the pellets, the compressive strength of the wet and dry pellets, the number of dumpings without destroying the wet pellets, and the temperature of the «shock» have been determined. Results: laboratory tests were conducted to determine the suitability of bentonite clays of different mineralogical composition and exchange ion complex for the production of pellets. Tests have shown that the impact resistance and compression resistance of raw pellets at a slightly increased specific consumption of bentonite Cherkasy alkaline-earth bentonite does not concede to the same properties of pellets with the use as a binder alkaline Saryugyhsky bentonite. It is demonstrated that to ensure good quality of raw pellets, an auspicious variety of clays of the Cherkasy deposit are clays of the IV layer, which are a natural mixture of alkaline-earth bentonite of the II layer and palygorskite (III layer). Tests of composite mixtures of clays IV with II and II with III layers showed that the quality of raw pellets with Cherkassky bentonite is slightly worse than with Sarygyuhsky, however, the absolute values of their indicators satisfy the industry requirements. Comparative tests of pelletizing of charges with different humidity and with the addition of 0.5% alkaline bentonite and a mixture of clays of the IV and II layers of the Cherkassky deposit have been carried out. It is shown that with increasing humidity in granules with both types of binders, the dynamic strength, porosity and temperature of the "impact" of granules increase with a minimum difference in the absolute values of indicators with different binders. To objectively confirm the possibility of using alkaline-earth bentonite of the Cherkassky deposit (II-III-IV layers) in the production of pellets, it is necessary to conduct comparative industrial tests at a pelletizing plant (for example, SevGOK), using a concentrate with the increased hardness of industrial water. Scientific novelty: the influence of alkaline bentonite replacement in charge for pellet production with alkaline earth, paligorskite clays and mixtures of their forms has been studied. The comparative influence of moisture content of raw pellets on their porosity and strength characteristics with alkaline and alkaline earth bentonites in the charge was studied. Practical significance: using the properties of raw, dry and calcined pellets as an example, the possibility of using less scarce and expensive local bentonite clays instead of expensive exported alkaline clays without impairing the production technology and characteristics of the pellets is shown.
Keywords: bentonite clays, pellets, iron smelting, montmorillonite, palygorskite, dispersion, exchange complex, swelling, pellet strength.

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Table 1. Properties of unfluxed pellets from concentrates of cgok, lebgok, sevgok With the addition of alkaline bentonite and clays of the cherkassky deposit

Name of additive	Concentrate	Raw pellets properties				Burning pellets properties			
		Number of drops, from 300 mm/times	Compressive strength, kg/pell		The temperature of the «shock», °C	Compressive strength, kg/pell	Drum test		The degree of recovery, %
			raw	dry			+5 mm	-0,5 mm	
Sarygukh alkaline	CGOK	8,7	1,00	5,2	575	427,4	96,0	3,8	68,60
IV layer of Cherkassky dep.		8,8	1,30	6,1	580	382,0	95,6	4,4	67,25
II layer of Cherkassky dep.		12,4	1,35	6,1	540	446,6	96,1	3,9	60,90
III layer of Cherkassky dep.		10,7	1,38	4,3	540	not carried out			
50 % IV layer + 50 % III layer		16,5	1,67	5,5	510	419,6	96,0	4,0	62,10
50 % IV layer + 50 % kaolinite		8,1	1,48	5,5	530	–	–	–	–
40 % IV layer + 40 % II layer + 20 % kaolinite		14,9	1,54	6,6	540	487,6	96,2	3,7	46,80
80 % II layer +20 % III layer		16,5	1,20	6,4	540	–	–	–	–
50 % II layer + 50 % III layer		14,3	1,20	5,6	530	–	–	–	–
Sarygukh alkaline	SevGOK	12,9	1,52	6,3	470	–	–	–	–
IV layer of Cherkassky dep.		18,8	1,51	5,9	490	–	–	–	–
II layer of Cherkassky dep.		14,5	1,54	4,6	495	–	–	–	–
Sarygukh alkaline	LebGOK	12,0	1,45	5,7	560	455,7	97,7	2,3	60,30
IV layer of Cherkassky dep.		11,8	1,36	5,9	580	415,0	97,5	2,5	56,30
II layer of Cherkassky dep.		11,6	1,50	5,6	520	451,5	96,9	3,1	47,20
50 % IV layer + 50 % III layer		11,5	1,70	4,9	595	428,3	97,4	2,6	70,40
40 % IV layer + 40 % II layer + 20 % kaolinite		10,6	1,40	5,2	570	528,7	97,7	2,3	47,30

Introduction. Pellets are one of the main types of iron ore raw materials for modern smelting, and their quality indicators depend on many factors, including the type of binder [1, 2]. The material composition and characteristics of bentonite clays for use as a binder in the production of iron ore pellets are described in the work [3].

The purpose and objectives of research. Analyze and determine the influence of bentonite clays of different deposits and exchange ionic complexes on the metallurgical properties of iron ore pellets.

Materials and methods of research. Continuing the research, we conducted laboratory tests to determine the suitability of bentonite clays of different mineralogical composition and ion exchange complex for the production of pellets. Pellets with a diameter of 12-13 mm were obtained on a laboratory granulator with continuous operation. The preparation of charge materials was as follows: the averaged sample of bentonite clay was dried at a temperature of 105-110 °C, and then crushed to a grain size of 95% of class 0,05 mm. The crushed bentonite clay was dosed on a wet concentrate. Mixing a 100-kilogram sample was carried out in a drum mixer with mixing bodies and with a mixing efficiency of more than 95 %.

Research results. In the process of research, the following was determined: moisture content of pellets, the compressive strength of raw and dry pellets, the number of raw pellets dropped from a height of 0,3 meters on the rubber plate and the temperature of the «shock» at a rate of filtration of the coolant through a layer of raw pellets of 1,2 nm/sec.

The consumption of bentonite pelletizing powder is usually 0,5-0,7 % in dry weight relative to the wet concentrate. In the first series of experiments, a slightly larger (1 %) consumption of binder was adopted so that the influence of the studied clays on the quality indicators of the pellets was revealed more noticeably. In addition to purposively selected samples (by layers), mixtures of samples in various ratios were tested (Table 1), taking into account that when mining in a quarry, the ratio of clays of different varieties can vary widely, and selective excavation and storage can be practically impossible.

Kaolinite was added to some mixtures. The experimental results (Table 1) indicate that, with increased specific consumption of bentonite, the impact resistance (drop) and compressive strength of raw pellets with the addition of Cherkassky Cabentonite are not inferior to the same properties of pellets using alkaline Sarygyuh bentonite as a binder. The strength of raw pellets in all experiments was higher than the prevailing pelletizing requirements in practice (impact strength of 5,6 drops without breaking, the compressive strength of 0,75-0,80 kg/pell). The compressive strength of the dried pellets was approximate up to two times the minimum requirements of 2.3-2.5 kg/pell.

Thus, with the appropriate amount of bentonite powder in the mixture from clays of the Cherkasy deposit, you can get raw pellets of the required quality. When using clays of the IV layer, raw pellets from all types of concentrates were characterized on average by the highest values of compressive strength after drying and the temperature of the «shock». In the case of adding to the clay of the IV layer 50 % palygorskite clay of the III layer, the strength of dry pellets from LebGOK and CGOK concentrates decreased, respectively, from 5,9 to 4,9 kg/pell and 6,1 to 5,5 kg/pell with stable values of dynamic and static strength of raw pellets.

The addition of only kaolinite (50 %) to the clay of the IV layer also did not improve the quality of the raw pellets. A favourable combination of the properties of the raw pellets of CGOK (dynamic strength of 14,9 drops, static strength of 1,54 kg/pell, resistance to compression after drying, 6,6 kg/pell, the temperature of the «shock» 540 °C) was obtained by adding to IV layer 40 % of clays layer II and 20 % kaolinite. For LebGOK concentrate, the average quality values of raw pellets corresponded to the indicated composition of the mixture of bentonite clays. Pellets of good quality were obtained from LebGOK and CGOK concentrates with the addition of 1 % bentonite clay of the II layer. The addition of a small amount of palygorskite to this clay (20%) does not impair the quality of the pellets from the TsGOK concentrate. Pellets of SevGOK with a bundle of clay of the II layer are characterized by reduced compressive strength after drying. The same applies to pellets from the CGOK concentrate using clay only of the III layer.

Thus, the clay variety of the Cherkassk deposit is most favourable for ensuring the good quality of the raw pellets of the Cherkassky deposit, which are a natural mixture of alkaline earth bentonite of the II layer and palygorskite (III layer) in a variable ratio, from 1:1 to 4:1. The high rates of pellets quality were obtained for clay mixtures of layers II and III (in the range of ratios characteristic for layer IV).

Table 2. Influence of the quantity of iv layers bentonite clay of the cherkassky deposit On the quality of pellets from sevgok concentrate (burning temperature 1350 °c, duration - 7 min)

Name of additive in charge	Raw pellets properties						Burning pellets properties					
	The number of bundles, %	Humidity, %	Compressive strength, kg/pell		The number of drops without destruction, times	The temperature of the «shock», °C	Compressive strength, kg/pell	Drum test		The recovery strength, %		
			raw	dry				+5 mm	-0,5 mm	-0,5 mm	+5 mm	+10 mm
Sarygukh bentonite	0,5	8,4	0,97	3,5	5,0	480	472,7	98,1	1,9	2,8	80,35	66,8
IV layer of Cherkassky dep.	0,5	8,5	1,04	3,5	5,2	550	509,2	97,9	2,0	5,75	76,6	56,1
Sarygukh bentonite	1,0	7,5	1,52	6,3	12,9	470	Not investigated					
IV layer of Cherkassky dep.	1,0	7,7	1,51	5,9	18,8	490						

Table 3. Influence of the charges moisture with various binders on the quality indicators of raw pellets with basicity 0,5 of the concentrate of cgok

Name of additive in charge	The number of bundles, %	Humidity of charge, %	Humidity of pellets, %	Compressive strength, kg/pell		The number of drops without destruction, times	Total porosity, %	The temperature of the «shock», °C
				raw	dry			
Sarygukh bentonite	0,5	8,2	7,7	1,26	2,9	5,6	26,31	460
Same	0,5	9,1	8,7	1,08	2,55	6,3	30,04	480
Same	0,5	9,87	9,65	0,65	2,35	10,6	31,50	500
A mixture of clay II and IV layers	0,5	8,1	8,0	1,04	2,7	5,2	28,28	480
Same	0,5	9,3	9,3	0,82	2,25	5,8	31,80	460
Same	0,5	9,74	9,74	0,68	2,47	10,1	32,45	535

For all types of tested binder additives, calcined pellets were characterized by high physical, mechanical and metallurgical properties (Table 1). The effect of the bentonite type on the properties of the finished calcined pellets is not traced. Pellets with the clay of the IV layer of the Cherkassk deposit had the highest temperature of the «shock». It should be noted that the temperature of the "shock" according to experiments to a large extent also depends on the size of the concentrate. So for a thinner concentrate of SevGOK, it was lower by 45-90 °C in comparison with pellets from CGOK concentrate.

Considering the results of previous studies, further experiments were carried out with bentonites of the IV layer and a mixture of clays of the IV and II layers in a ratio of 1:2. Since clay of the IV layer is a natural mixture of clays of the II and III layers, the addition of clay of the II layer gives a new compositional mixture, which should be considered, also, as a special variety of the IV layer with a high content of alkaline earth bentonite, and as a mixture of clay of the III layer and II layers.

With a consumptions decrease of bentonite from 1 % to 0,5 %, the quality indicators of raw pellets decreased to almost the same level, but acceptable for pelletizing for both types of bentonites: Sarygyuhsky and Cherkassky (IV layer) (Table 2).

Burnt pellets with the addition of Cherkassky bentonite with the same physical and mechanical properties in the cold state showed a slightly greater destructibility during reduction than in experiments with alkaline Sarygyuhsky, although their strength during low-temperature reduction corresponds to modern requirements: abrasion 5,75 %, class output +5 mm – 76,7% (with the required – at least 70 %). The increase in bentonite consumption for SevGOK concentrate did not increase the temperature of the «shock».

Under industrial conditions, significant fluctuations in the humidity of the concentrate entering the pelletizing process can take place. In this regard, we conducted comparative experiments with different a moisture content of the mixture before pelletizing, respectively, at a different moisture content of the pellets, with the addition of 0.5% alkaline and Cherkassky bentonites (a mixture of clays of layers IV and II, Table 3).

In both cases, with an increase in humidity, a similar pattern of changes in the properties of pellets is observed for both Sarygyuhsky and Cherkassky bentonites: the dynamic strength increases from 5.6-5.2 to 10.6-10.1 drops, porosity (in Fig. 1-3, the average values of three parallel experiments are presented) and the temperature of the “shock” of the pellets (Table 3).

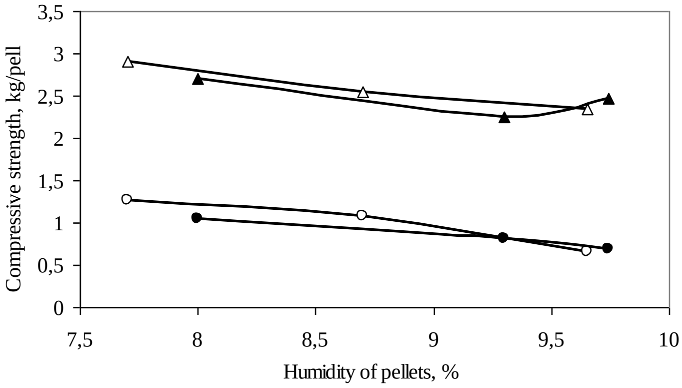

Fig. 1. The effect of humidity of raw pellets on their strength indicators: Δ and ▲ are the strength of dry pellets, ○ and ● are the strength of raw pellets (with the addition of Sarygyuhsky and Cherkassky bentonite IV layer, respectively)

The temperatures of the "shock" of raw pellets with alkaline earth bentonite at the same humidity are approximately equal to the temperatures with alkaline bentonite. With increasing humidity of the raw pellets, the strength of the raw and dry pellets decreases, and the porosity and drop strength increase. An increase in the moisture of pellets above 9,3 % leads to a decrease in the static strength of the pellets below the minimum permissible limit (0,75-0,8 kg/pell) for Cherkassky (0,68 kg/pell with 9,74 % humidity of the pellets), and for Sarygukh bentonite (0,65 kg/pell with the pellet moisture content of 9,65 %). At the same time, at relatively high humidity of pellets 9,3 % with Cherkassky bentonite, their strength (0,82 kg/pell) is not lower than the minimum limit.

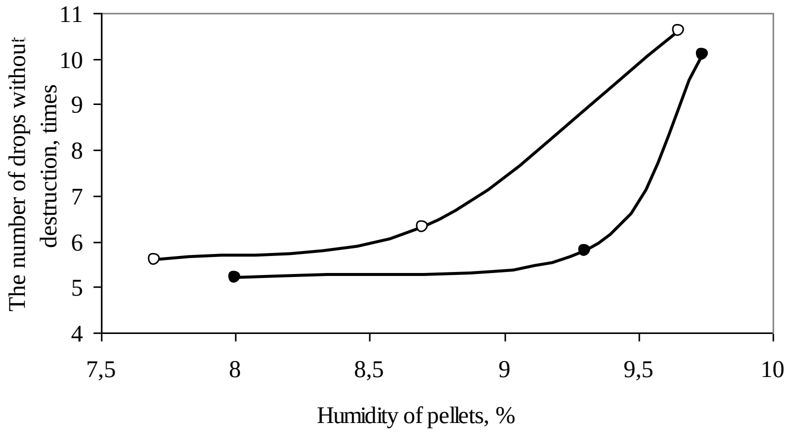

Fig. 2. The effect of humidity of raw pellets on their strength indicators when dropping: ○ and ● – with the addition of Sarygyuhsky and Cherkassky bentonite IV layer, respectively

Graphical analysis of the data given in table. 3 and in fig. 1-3 shows that at the same humidity the porosity of raw pellets with Cherkasy bentonite is about 0,8-1 % higher. Graphical analysis of the data given in table 3 and fig. 1-3 shows that at the same humidity the porosity of raw pellets with Cherkasy bentonite is about 0,8-1 % higher. With increasing humidity of the pellets from 7,7-8,0 to 9,7 %, their porosity increases from 27 to 32 %. %. In this case, the compressive strength of raw and dry pellets with both bentonites is slightly reduced, and the impact strength of raw pellets increases. Thus, according to these tests, when using a mixture of layers IV and II, the quality of raw pellets with Cherkassky bentonite is slightly worse than with Sarygyuhsky, however, the absolute values of the indicators generally satisfy the requirements.

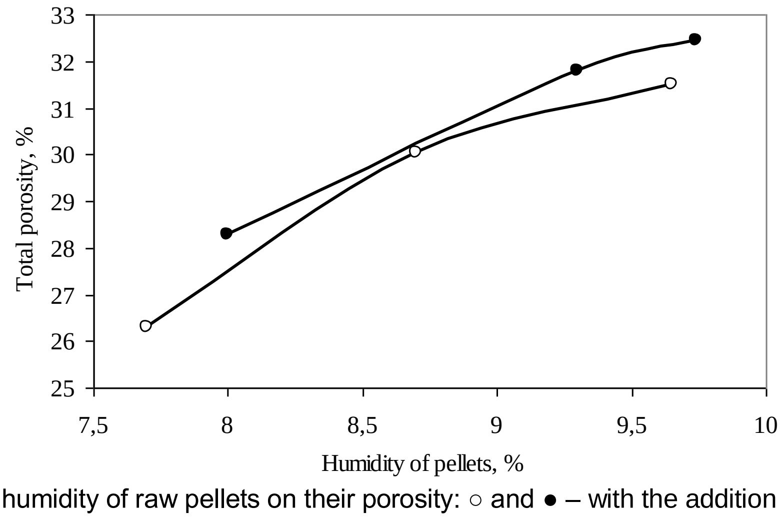

Fig. 3. The effect of humidity of raw pellets on their porosity: ○ and ● – with the addition of Sarygyuhsky and Cherkassky bentonite IV layer, respectively

Laboratory tests showed that, despite the relatively lower performance [3] (determined by existing methods in distilled water) of Cherkassky bentonite, pellets from concentrates CGOK, SevGOK and LebGOK obtained with the addition of clays IV, IV and II, III and II layers, are not inferior or inferior insignificantly in properties in the wet and dried state to pellets with the addition of Sarygyukh bentonite.

When using Cherkasy bentonite, it is possible to obtain pellets in approximately the same humidity range of the concentrate as for Sarygyuh bentonite. To objectively confirm the possibility of using alkaline earth bentonite of the Cherkassky deposit (II-III-IV layers) in the production of pellets, it is necessary to conduct comparative industrial tests at a pelletizing plant (for example, SevGOK) using a concentrate with increased hardness of industrial water.

Conclusions

1. The effect of replacing alkaline bentonite in a mixture for the production of pellets with alkaline earth, palygorskite and their mixtures of bentonite clays has been studied. The possibility of using less scarce and expensive local bentonite clays instead of expensive exported alkaline clays without deteriorating the technology is shown by the example of the properties of raw, dry and calcined pellets.

2. The comparative effect of the moisture content of raw pellets on their porosity and strength characteristics with alkaline and alkaline-earth bentonites in the charge was studied. It is shown that the absolute values of the indicators with both bentonites at all humidity values correspond to the requirements of the technology, however, the strength when dropping pellets with alkaline earth bentonite is lower than with alkaline.

3. With the studied amounts (0,5 and 1,0 %) of bentonites in the charge, the compressive strength of raw and dry pellets with alkaline and Cherkassky bentonite from layer IV (a natural mixture of alkaline earth and palygorskite) was almost the same, and the temperature of the «shock» at second – 20-70 °C higher.

4. An objective conclusion about the suitability of natural (without modification) Cherkassky bentonite clays and their replacement with alkaline can be determined only as a result of lengthy industrial tests with specific concentrates and industrial water.

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Стаття поступила: 17.12.2019