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Prospects for using bentonite-polymer composites to improve the strength and stability of iron ore pellets during granulation

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Abstract. The article investigates the application of bentonite-polymer composites (BPC) in the process of granulation of iron ore concentrates to increase the strength and stability of iron ore pellets. The purpose of the study was to optimize the physical and mechanical properties of the pellets using BPC as a binder. The relevance of the work is associated with the growing demand for more efficient pelletizing technologies capable of ensuring high-quality pellet production while reducing binder consumption and improving process stability. During the experiments, laboratory tests were performed with various dosages of bentonite and BPC, achieving a stabilized granulometric composition and improved strength characteristics of green pellets. The results showed that BPC added to the batch promoted a significant increase in compressive strength and a decrease in the abrasion of calcined pellets. In addition, binder consumption was found to be connected with the quality indicators of the product, enabling the optimization of the technological process and the achievement of target parameters. The paper stressed the importance of using high-quality binders to improve pellet efficiency and stability, which has significant implications for metallurgical production. Recommendations for the use of BPC can be applied in the development of new methods for the production of iron ore pellets with improved performance.
Keywords: bentonite-polymer composite, iron ore concentrate, pelletizing technology, charge, granulation process, iron ore pellets

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1. INTRODUCTION

The expansion of the market for iron ore raw materials raises the need to increase product quality, meaning the improvement in the consumer properties of iron ore pellets [1]. Better strength properties, or the ability of pellets to resist destruction, can be achieved, among other things, leveraging the

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quality of charge components when preparing raw materials for metallurgical conversion [2]. Such control can be executed through a number of technological techniques during charge preparation and heat treatment, as well as by changing the composition of the charge by introducing certain additives [3].

Green pellets are formed through the pelletization of fine iron ore concentrate in special installations – pelletisers.

In addition to dynamic loads in the pelletizer, the process of obtaining green pellets is defined by two main types of forces – molecular and capillary. These same forces determine the patterns of impregnation of the concentrate layer.

The mass of finely graded concentrate is a loose body penetrated by capillaries, which are formed by small pores – gaps between the concentrate particles [4]. Depending on the pore size and porosity of the concentrate layer, the same amount of water in contact with the concentrate moistens different volumes of the concentrate and strengthens the moistened lumps of concentrate in different ways. The volume of capillary moisture may reach as high as 50% or more, depending on the porosity of the solid and the particle size. Pore sizes and the overall porosity of the concentrate layer depend on both the particle size distribution of the concentrate and on the binder component.

One characteristic parameter of the pelletizing process is the pelletizing ability coefficient of the charge [5]. The effective radius and, consequently, the pelletizing ability of the concentrate influence the emergence, formation, and growth of pellets during pelletizing.

The pelletizing process [6] associated with the rate of granule formation and growth is characterized by the adhesion strength of particles within the granule, which is contingent on the factors presented in Fig. 1.

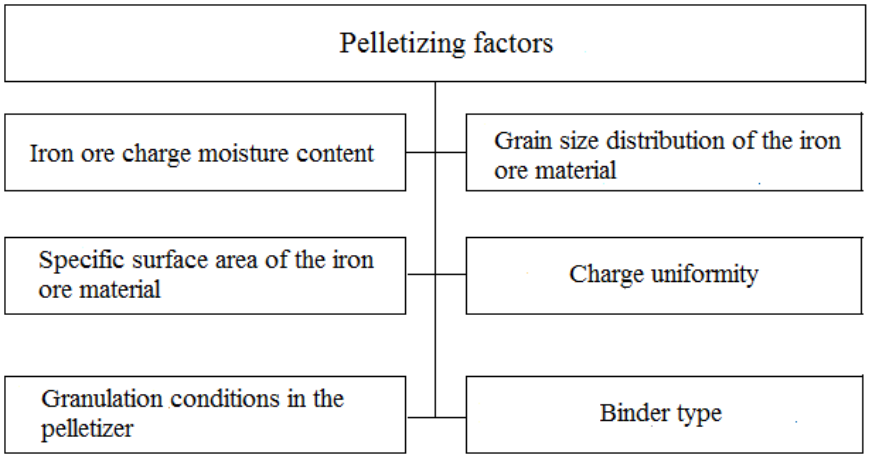

Fig. 1. Factors in the pelletizing process.

Pelletizing ability reflects the ability of fine materials to form strong granules. The higher the pelletizing ability of the charge, the more uniform the size of the resulting green pellets, which helps to increase the yield of the desired diameter class (10-14 mm) in the total mass of the obtained granules.

Binding additives are used to increase the strength of green and especially dry pellets, improve their impact strength under rapid heating, intensify drying in induration machines, and improve the metallurgical properties of the pellets [2, 7].

The role of binders is to ensure the strength of not only green pellets (sufficient to transport them from the pelletizer to the calciner) but also dry pellets (particularly important for intensifying the drying process). In the production of pellets from highly enriched concentrates, binding additives actively participate in the formation of the optimal structure of pellets, which ultimately determines their quality and metallurgical properties.

A characteristic property of binders is their small particle size and colloidal nature [8]. Bentonite is the most common binder in pellet manufacturing. The main component of bentonite clays is

montmorillonite Al_2O_3 x $4SiO_2$ x $3H_2O$, a natural mineral that remains unaffected in the course of processing [9].

Bentonite is a highly dispersed clay that swells in the presence of water and provides colloidal adhesion (adhesive properties) due to the ability of the clay to form a gel and group together a large number of fine particles interacting with concentrate particles [10].

After moistening, bentonite particles form a film with a large surface area, which envelops the concentrate particles and connects them with each other. The strength of green and, most importantly, dried pellets increases with the addition of bentonite due to the mutual attraction of bentonite particles and the attraction of bentonite and magnetite particles. Importantly, the binding effect persists even after the water is removed through drying. The strength of dry pellets is determined by the energy of interfacial interactions in the concentrate–bentonite system.

Bentonite improves pelletizing ability, increases the plasticity of green pellets to dynamic loads, and regulates the rate of dehydration of pellets and the release of moisture when the pellets are dried by heating, which protects them from destruction and ensures the required quality of calcined pellets [11].

As a result of the formation of molten slag, the compressive strength of the calcined pellets increases.

The addition of bentonite-polymer composites (BPC) to the charge is a promising method in the production of iron ore pellets for improving the technical and economic performance of induration machines and increasing the strength properties of pellets [8, 12-16].

A bentonite-polymer composite is a combined mixture of an organic polymer and the inorganic part (bentonite clay), which determines its exceptional properties and increases the functionality of both binding and strengthening additives [14].

The advantages of this additive stem from the fact that when it interacts with water in the charge, it forms a polymer-bentonite gel with increased binding ability, resulting in a structure of green pellets that is more resistant to dynamic and static loads.

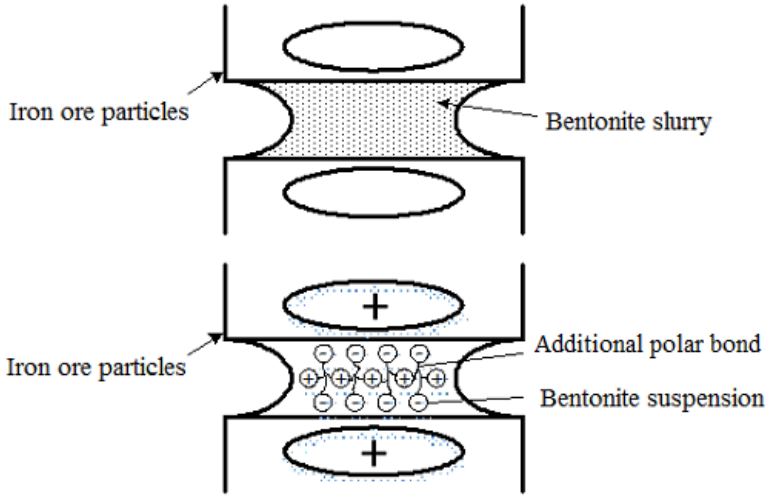

Fig. 2. Interaction of bentonite-polymer slurry with concentrate particles.

Research goal: The purpose of the article was to determine the prospects for the use of bentonite-polymer composites to improve the strength and stability of iron ore pellets during the granulation process.

Key research objectives:

1. To develop mixture formulations to produce calcined pellets with improved physical and mechanical properties.
2. To conduct tests to determine an alternative binder with optimal bentonite consumption.
3. To determine the impact of new types of binders on the quality of green and calcined pellets.

4. To evaluate the properties of iron ore pellets with the new charge composition during subsequent metallurgical conversion.
5. To justify the optimal choice of binder for industrial tests.

2. METHODS AND MATERIALS

2.1. General Characteristics of Studies

2.1.1. Study Design

Charge pelletizing tests were carried out in accordance with the methodological instructions of the laboratory of Altai Geological and Ecological Institute (AGEI), LLP, and the methodology of similar studies in the field of metallurgy and construction. Fig. 3 shows the scheme of the conducted tests.

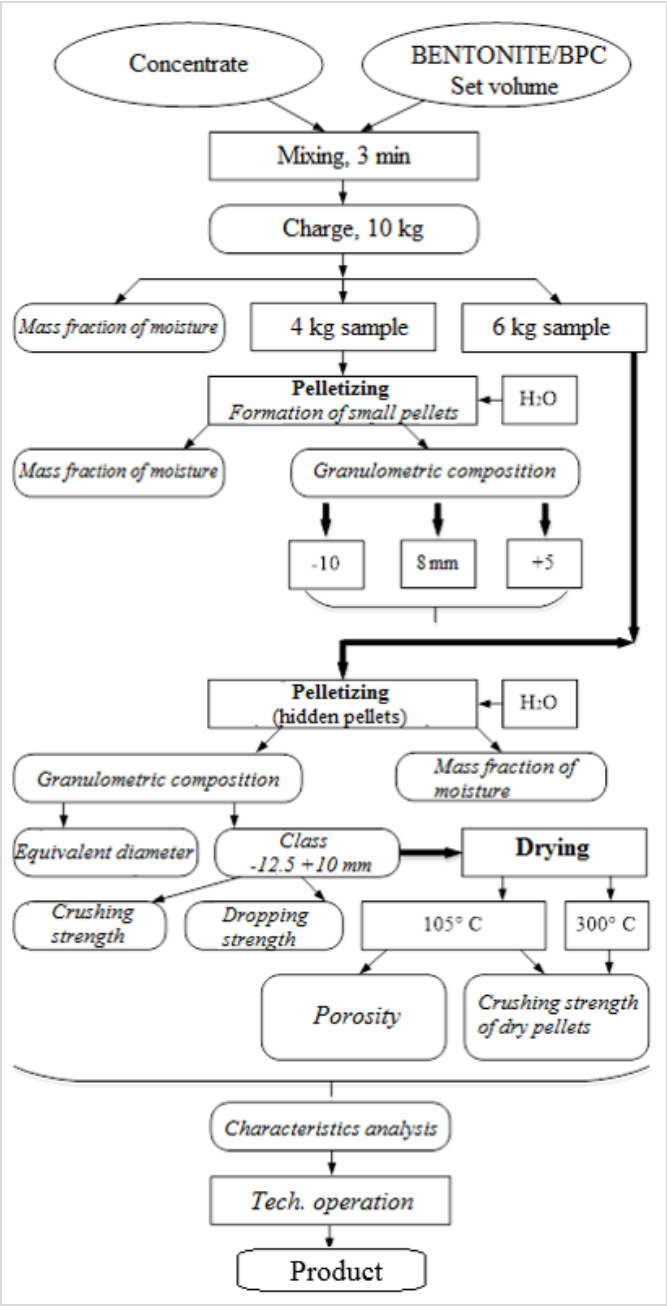

Fig. 3. Pelletizing process flow chart.

The first stage of work before the "pelletizing" stage, involving the determination of charge quality indicators, was carried out in 2024 in a laboratory of AGEI, LLP (Ust-Kamenogorsk, Republic of Kazakhstan; geographical coordinates: 49°58′ N, 82°37′ E). A 100 kg sample of iron ore concentrate for laboratory testing was sourced from the Sokolov-Sarbai Mining Production Association (SSMPA), JSC.

At the second stage, laboratory studies were carried out to determine the physical and chemical characteristics of charge components: iron ore concentrate, bentonite clay, and the bentonite-polymer composite (BPC). The purpose of these studies was to ensure the reliability of data on the quality of the starting material and the predicted behavior of the charge during granulation.

2.1.2. Studied Samples

The following components were used as starting materials:

1. **Iron ore concentrate by SSMPA, JSC** – a highly enriched material with 68.5% mass fraction of iron, 9.2% humidity, and 85.2% content of fractions below 0.045 mm. The iron ore concentrate produced by SSMPA, JSC, was chosen due to its stable grain size and high iron content, making it a great reference material to study the effects of various binders on the granulation process and the properties of the resulting pellets.
2. **Bentonite clay** – natural mineral with a montmorillonite content of 83%, a 21.9% moisture content, and a swell index of 75 ml/2 g.
3. **Bentonite-polymer composite (BPC)** – composite material containing a montmorillonite base (75.5%) and an organic polymer that enhances the adhesion of concentrate particles.

2.1.3. Sample Preparation

For laboratory studies, 1 kg samples were taken from a 100 kg batch of concentrate. The samples were pre-dried to constant weight at (105 ± 5)°C in a Memmert UF110 oven (Germany), cooled in a desiccator, and mixed thoroughly for homogeneity.

Charge samples for chemical analysis were collected and prepared, preserving the representativeness and uniformity of the material. Each sample was ground to a uniform fraction, sieved through laboratory sieves, and mixed thoroughly. The weight of each sample met the requirements for chemical analysis, and all operations were performed under conditions that excluded the loss of volatile components and changes in humidity. This approach ensured high accuracy and reproducibility of the results of tests determining the chemical composition and physicochemical characteristics of charge components.

Sample preparation included grinding, sieving, and homogenizing the material to a homogeneous mixture fit for further physicochemical and technological testing. All operations were performed in ways that ruled out changes in the structure of particles and their moisture capacity, which is especially crucial to correctly determine the true density, specific surface area, and quality parameters of binders.

The results of the chemical analysis of the concentrate are shown in Table 1.

Table 1. Quality parameters of the concentrate by SSMPA, JSC.

Mass fraction of moisture, %	Mass fraction of Fe_{total}., %	Mass fraction of particle size class (mm), %	
		-0.071 mm	-0.045
9.20	68.7	95.0	85.2

Full chemical analysis of charge materials was conducted prior to laboratory tests (Table 2).

Table 2. Chemical composition of charge materials.

Material	Mass fraction, %							Montmorillonite, %
	Fe_{total}	FeO	SiO_2	CaO	MgO	Al_2O_3	LOI	
Concentrate	68.5	28.9	2.38	0.76	0.61	0.83	0.51	-
Bentonite	4.29	0.097	61.0	0.83	2.99	14.96	6.80	83.0
BPC	3.70	1.65	60.8	1.37	2.33	18.3	8.4	75.5

2.2. Quality Parameters of the Iron Ore Concentrate

To assess the quality of the iron ore concentrate, the main physical and chemical indicators characterizing its suitability for subsequent metallurgical processing were determined.

2.2.1. Definition of Pelletization Ability

The moisture content of the iron ore concentrate is a critical determinant of its pelletizing ability in the production of pellets. Concentrate moisture content was measured by drying the sample to constant weight at a controlled temperature. This indicator provides information on the amount of free and particle-bound water in the concentrate, which is important for the granulation and pelletizing processes.

Pelletizing ability was determined as per the methodological instructions of AGEI, LLP, developed based on experimental studies at mining enterprises.

The method consists in determining the velocity of capillary distribution of water in a layer of dry, finely dispersed bulk materials.

Pelletizing ability influences the grain size distribution of green pellets. The higher the pelletizing ability index of the charge, the more uniform the green pellets in size, meaning that the yield of the suitable size class in the range of 10 ÷ 14 mm in the total mass of green pellets increases.

In addition to dynamic loads in the pelletizer, the process of obtaining green pellets is influenced by two main types of force – molecular and capillary. The same types of forces determine the patterns of impregnation of the concentrate layer. Fig. 4 shows the distribution of water in the concentrate layer.

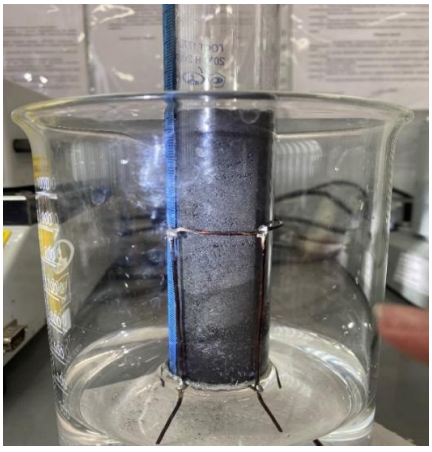

Fig. 4. Distribution of water in the concentrate layer.

Pelletizing ability was determined by the method of capillary water absorption. Dry concentrate was placed into a glass tube (1 cm in diameter, 15 cm in length), lowering the lower end into the water and recording the time of the liquid surface rising.

Effective radius (r) in μm was calculated by formula (1):

$$r = \frac{4 \cdot v \cdot l}{\delta_t} \cdot \eta \cdot 1000 \quad (1)$$

where: r – capillary radius, μm;
υ – capillary suction rate, cm/sec;
l – height of the liquid column in the capillary (11 cm);
δ_t – water surface tension coefficient ($72.86 \cdot 10^{-3}$ N/m);
η – water viscosity coefficient (1.005).

2.2.2. Determination of the Bulk Density of the Concentrate

Bulk density determined by freely filling a standard cylindrical vessel with the concentrate and measuring the mass per unit volume. This indicator reflects the packing of particles and affects the transport and dose properties of the material and the uniformity of its supply to the pelletizing units.

The tests were performed in an air-dry state without mechanical compaction. Measurements were taken using a cylindrical vessel with a volume of 5 dm³, which corresponded to the optimal ratio between the size of the vessel and the size of the material (0-1 mm). The concentrate was freely poured into the vessel, after which the mass of the substance per unit volume was measured.

This method assesses the natural packing of particles characteristic of the technological state of the material during storage and transportation. The bulk density index is an important criterion for calculating charge compositions, dosing in granulators, and assessing the uniformity of particle distribution in the pelletizing layers.

The obtained bulk density values showed high reproducibility in repeated measurements, confirming the reliability of the chosen determination method and its suitability for the technological analysis of iron ore concentrate.

2.2.3. Determination of the True Density of the Concentrate

True density was determined by the pycnometric method, which accurately estimates the density of a mineral particle excluding pores and voids. This index is critical for calculating charge structure and determining sinter or agglomeration product yield.

The determination was performed using an ATS pycnometer. Concentrate samples were carefully prepared to eliminate the effects of air and moisture on the measurements and obtain the accurate density of the solids.

The true density of a pellet reflects the density of its mineral structure, which is determined by the chemical-mineralogical composition of the material, particularly the content of total iron and related compounds. This indicator is important for analyzing particle structure, calculating charge mixtures, and modeling pelletizing processes since it reflects the physical basis of the mass and the volume of particles, excluding porosity and intergranular gaps.

Repeated measurements proved the high accuracy of the method and produced stable values, allowing the data to be used for the comparative analysis of different concentrate batches and the assessment of the technological characteristics of the material.

2.2.4. Determination of the Specific Surface Area of the Concentrate

The specific surface area of the concentrate was measured by the adsorption method, which establishes the active surface of the particles involved in contact processes during granulation and sintering. Large specific surface area enhances particle bonding and the formation of dense pellets during pelletization.

The research was carried out using a PSH-12 M computer device, which provides high measurement accuracy and automatic data processing.

Specific surface area is a key factor in particle adhesion and the strength of green pellets. It is directly linked to the granulometric composition of the material: the higher the share of fine fractions, the greater the total surface of the particles per unit mass of concentrate.

It should be emphasized that specific surface area considers only the outer area of the particles and does not include the surfaces of the pores, be they closed or open. This indicator reflects the physical activity of particles upon interaction with each other and with astringents, which makes it an important parameter for modeling pelletizing processes and assessing the technological properties of the concentrate.

Repeated measurements demonstrate the stability and reproducibility of the results, which allows using these data to optimize the particle size distribution and predict the quality of the pellets.

The physical properties of the concentrate sourced for the study from SSMPA, JSC, were determined in the laboratory of AGEI, LLP. The physical properties of the concentrate are presented in Table 3. All the indicators were determined by repeated measurements and averaged, ensuring a high accuracy and reproducibility of the results.

Table 3. Physical properties of the concentrate (SSMPA, JSC).

Mass fraction, %		True density, g/cm^3	Bulk density, t/m^3	Specific surface area, cm^2/g	Capillary radius, μm	Capillary suction rate, cm/sec
moisture	cl. -0.040 mm					
8.94	82.6	4.905	2.0	1,421	4.41	0.008

The studied concentrate manufactured by SSMPA, JSC, has a high capillary radius (4.41 μm) and a significant capillary velocity of water (0.008 cm/sec), which indicates a good pelletizing ability of this concentrate, which, in turn, affects the emergence, formation, and growth of pellets during pelletizing.

2.3. Quality Parameters of Binders

The main binders used in the pelletizing process are bentonite clay and BPC. Their properties directly determine the strength and uniformity of the pellets. The quality characteristics of the binders (bentonite clay and BPC) were determined by the following procedures:

- The mass fraction of the sand fraction was determined by sieving through a set of calibrated sieves, making it possible to determine the number of large inert particles that reduce the binding capacity.
- The clay component was measured using water dispersion, which allows quantifying the active particles involved in the formation of the pellet structure. Higher clay content improves the adhesion between the grains of the concentrate and the binder.
- Colloidal properties were determined by the ability of the material to spread evenly in water and be retained in the slurry. High colloidity improves the plasticity of the mixture and increases the strength of green pellets.
- The mass fraction of moisture was determined by drying the samples to a constant weight. This indicator allowed us to establish the water-holding capacity of the binder and its effect on granulation.

Significance of quality indicators

Together, these indicators make it possible to fully assess the suitability of the iron ore concentrate and binders for the pelletizing process. The mass fraction of moisture and specific surface area of the concentrate are responsible for the optimal adhesion of particles, and the physical and chemical properties of binders contribute to the formation of strong, homogeneous pellets resistant to mechanical and technological influences.

The swell index was determined according to the methodological instructions of the laboratory of AGEI, LLP.

- Swelling ability according to the methodological instructions of the laboratory of AGEI, LLP
- Effective viscosity of 10% suspension according to the guidelines of the laboratory of AGEI, LLP

Particular effort was made to maintain the initial ratio of particle size fractions and humidity, since these parameters directly affect the adhesion of particles and the formation of a strong pellet structure during pelletizing.

The effective viscosity of the 10% suspension was determined on a FANN 35 SA viscometer. The suspension was premixed with a Hamilton Beach mixer for 10 minutes at a speed of 10,000 min^{-1}.

The results on the quality parameters of binders used in the preparation of experimental batches of iron ore pellets are given in Table 4.

Table 4. Quality parameters of binders.

Binder	Mass fraction, %			Colloidity, %	Swell index, ml/2g	Swelling, times	Effective viscosity, mPa·
	moisture	sand fraction	clay component				
bentonite	21.91	1.5	98.0	75.0	52.4	15.3	90.0
BPC	20.96	0.2	96.5	61.7	37.9	10.2	67.0

Before pelletizing, the composition of charge components for each formulation was determined as shown in Table 5.

Table 5. Charge components composition.

Parameter	Binder									
	bentonite						BPC			
1 Binder consumption, %	0.30		0.40		0.50		0.30		0.40	
2 Mass fraction of moisture, %	C	B	C	B	C	B	C	BPC	C	BPC
	8.94	7.85	8.94	7.85	8.94	7.85	8.94	8.15	8.94	8.15
3 Dry weight dosage, %	99.70	0.30	99.6	0.40	99.50	0.50	99.70	0.30	99.60	0.40
4 Wet weight dosage, %	99.70	0.30	99.60	0.40	99.49	0.51	99.70	0.30	99.60	0.30

Note: C – concentrate, B – bentonite.

The resulting pellets were unloaded from the pelletizer for further physical and mechanical testing.

2.4. Determination of Parameters in the Samples of Green Pellets

The parameters determined in green pellets included the following.

The mass fraction of moisture in concentrate samples was determined by thermal drying to constant weight. The samples were weighed first, then dried at a controlled temperature, and then weighed again. Based on the difference in weight, the moisture content of the material could be established with high accuracy. This parameter is critically important, since it determines the adhesion of particles during the formation of pellets and the behavior of the material throughout further agglomeration.

The granulometric composition of the concentrate was determined by consecutive sieving through a set of sieves of different size categories. Each fraction was weighed, and the proportion of each particle size was calculated relative to the total weight of the material. Particle size distribution allows predicting the specific surface area, particle adhesion, as well as the strength of pellets and the uniformity of their formation.

These methods provide a full understanding of the physical and technical characteristics of the concentrate and indicate optimal pelletizing conditions and binder dosage to obtain a product of high technological and metallurgical value.

- the crushing strength of green pellets and pellets dried in a drying cabinet at 105°C and 300°C was determined with an IPG-1 pellet strength meter;
- dropping strength was measured by dropping from a height of 500 mm on rubber and metal surfaces;
- The porosity of dry pellets was established by measuring the volume and weight of the dry samples. First, pellet samples were weighed carefully, then their volume was determined using methods that ruled out compaction to preserve the internal structure of the pores. Using these data, porosity was calculated as the ratio of pore volume to total pellet volume in percentages.

Porosity is a critical factor affecting the mechanical strength and gas permeability of the pellets. High porosity contributes to the adhesion of particles to additives, improves gas penetration during agglomeration, and improves the uniformity of heating during the metallurgical process. Low porosity, on the contrary, increases the density and strength of the pellets but can impair gas permeability and the uniformity of heat treatment.

Thus, porosity control optimizes pellet formation technology by balancing the strength and structural permeability of the product.

2.5. Tests on Calcined Pellets

After heat treatment, calcined pellets were subjected to comprehensive tests to assess their strength and structural characteristics.

Compressive strength was determined using an ITS-8313-1.0 test machine. The pellet samples were placed between the press plates, and the exerted load was recorded until the sample was destroyed. This indicator reflects the ability of pellets to withstand mechanical loads during transportation, storage, and loading into metallurgical units.

Impact strength and abrasion were determined using a mini-drum. The samples were placed in a drum that rotated at a set speed, simulating real conditions of mechanical stress and friction. The loss of mass of the material after the test served as the indicator of abrasion, and resistance to destruction upon impact characterized the impact strength of the pellets.

The porosity of calcined pellets was determined by the density method on a VIBRA AJH 420 CE laboratory scale using an AJDK volume meter. Porosity was calculated as the ratio of pore volume to the total volume of the pellet, which made it possible to assess the internal structure and degree of sintering of the material. This indicator is vital for ensuring gas permeability and the uniform heating of the pellets in metallurgical processes.

This set of tests provided a comprehensive assessment of the quality of calcined pellets and their compliance with the requirements of the technological process, ensuring a balance between strength, structural integrity, and functional porosity.

- Determination of chemical composition (Fetotal, FeO, SiO2, CaO, MgO, Al_2O_3, LOI).

Fig. 5 shows a laboratory installation used to sinter the test pellets under isokinetic conditions. The heat treatment of test samples in this installation was close to the conditions of the existing conveyor-type induction machines.

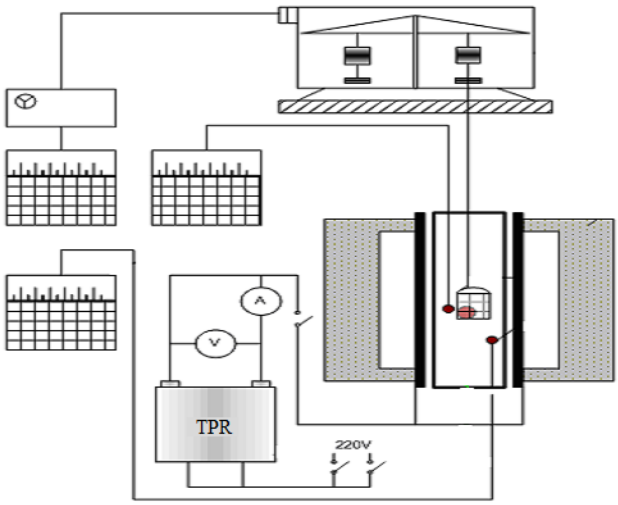

Fig. 5. Diagram of the laboratory unit for sintering pellets under isokinetic conditions.

2.6. Experimental Data Processing

The experimental data were processed through standard statistical methods using Microsoft Excel to organize the data and plot graphs.

3. RESULTS AND DISCUSSION

The results of laboratory studies of pellets obtained by pelletizing a high-quality concentrate with the addition of different binders at varying dosages are presented in Table 6 and Figs 5 and 6.

Table 6. Results of laboratory tests on pellets from the SSMPA concentrate made with different binders.

Parameter	Binder				
	Tagbent, LLP (bentonite)			BPC	
Binder consumption, %	0.30	0.40	0.50	0.30	0.40
Mass fraction of moisture, % - green pellets	8.20	8.31	8.27	8.14	8.19
Mass fraction of size class (mm), % +16 -16 +14 -14 +12.5 -12.5 +11.2 -11.2 +10 -10 +8 - 8 +5 - 5 +0	 0.2 1.2 8.2 34.2 25.0 27.2 4.0 0.0	 0.8 2.6 21.2 43.4 20.3 10.4 1.3 0.0	 0.4 5.3 28.4 45.1 14.0 6.0 0.8 0.0	 0.0 1.4 6.7 34.2 30.5 23.5 3.7 0.0	 0.0 3.4 18.4 41.9 22.1 12.1 2.1 0.0
Diameter of green pellets, mm	10.34	11.28	11.68	10.40	11.15
Porosity of dry pellets, %	32.1	31.7	30.8	31.5	30.2

The obtained data show that the highest yield of a suitable class of pellets (size class -12.5 mm + 10 mm) at a consumption rate of 0.3-0.4% is obtained with BPC. Meanwhile, the mass fraction of moisture in green pellets remains at the level of 8%.

Importantly, the yield of a suitable class with the addition of 0.3% binder in the case of BPC was 4.2% higher compared to pure bentonite powder.

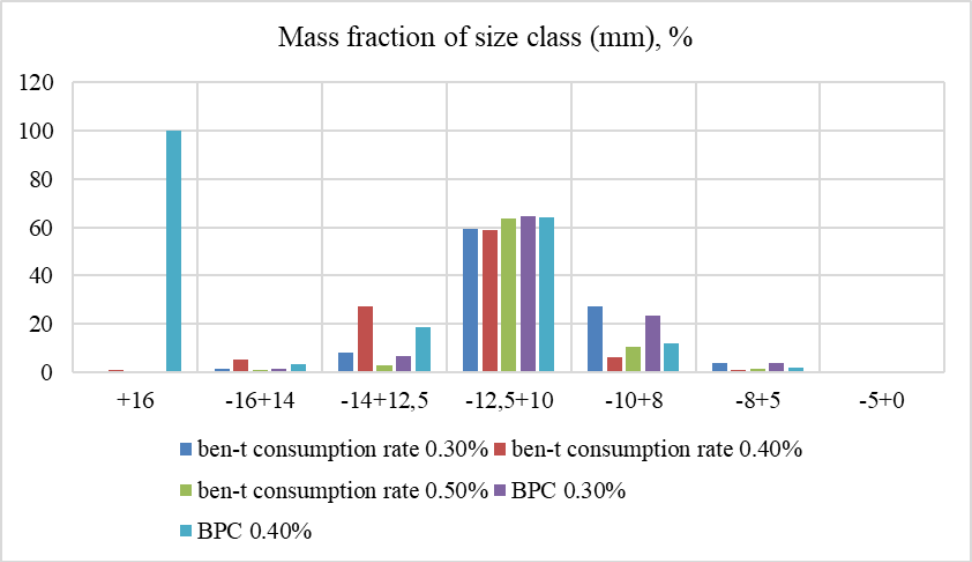

Fig. 6. Particle sizes of green pellets.

The results of porosity tests conducted on dry pellets show the predominance of open pores distributed uniformly in volumes.

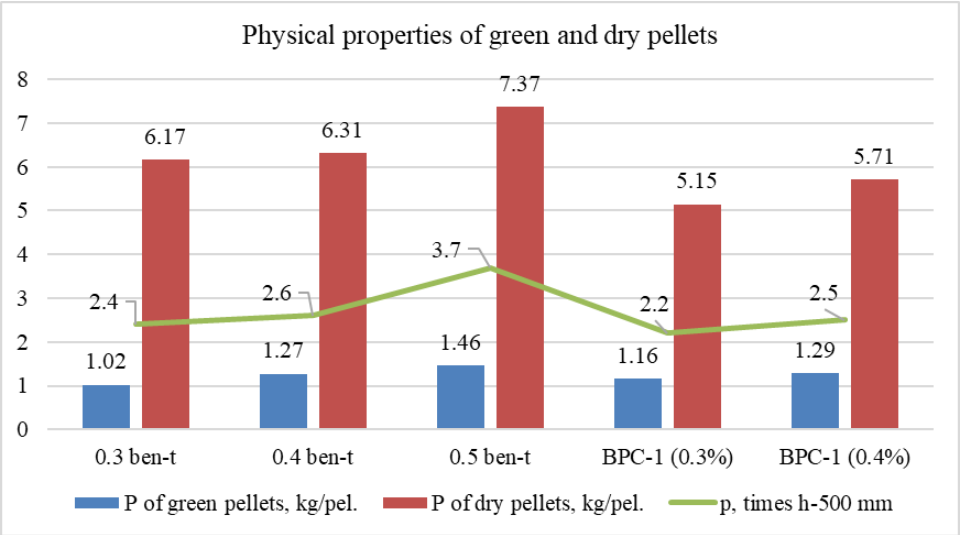

Fig. 7. Strength characteristics of green and dry pellets.

The laboratory pelletizing process with BPC was stable. The content of water in the components of the charge and additives is enough to achieve the necessary viscosity and for the pelletizing process to proceed (to form pellets with a uniform and strong structure).

Since the consumption of bentonite/BPC (0.5/0.4%) meets specifications for the strength properties of green pellets (Fig. 7), higher binder consumption was impractical.

The heat treatment of the test samples was approximated to the conditions of the existing conveyor-type calciner for the production of DR pellets. The maximum temperature in the furnace reached 1,300°C.

The physical and chemical properties of the calcined pellets obtained after calcination are detailed in Table 7.

Table 7. Physical and chemical characteristics of calcined pellets.

Binder	Binder consumption, %	Strength characteristics of calcined pellets			Porosity, %	Chemical composition, %							
		toughness (B^{+5}), %	abrasion resistance ($B^{-0.5}$), %	compressive strength, kg/pel.		Fe_{total}	FeO	SiO_2	CaO	MgO	Al_2O_3	S	LOI
Bentonite	0.30	97.5	2.5	306.0	22.6	66.55	0.72	2.61	0.55	0.71	0.96	0.0022	0.23
	0.40	98.0	2.0	314.0	21.7	66.44	0.66	2.70	0.51	0.71	0.99	0.0018	0.19
	0.50	98.2	1.8	392.0	21.2	66.34	0.82	2.72	0.55	0.71	1.00	0.0017	0.22
BPC	0.30	97.6	2.4	279.0	23.3	66.60	0.82	2.61	0.49	0.70	0.99	0.0021	0.23
	0.40	98.1	1.9	318.0	22.8	66.34	0.94	2.68	0.52	0.70	0.99	0.0022	0.20

During calcination, pore formation processes occur as a result of the release of gases during the decomposition of hydrates and carbonates. At the same time, the original voids are destroyed or redistributed around the contacts of the pellet grains. Some of the pores are fused closed, others are enlarged by fusing with smaller ones, and more pores appear on the surface of the pellets.

By controlling calcination temperature and accounting for the melting of the charge components and the amount of gases emitted, it is possible to obtain a structure with higher or lower porosity.

Calcination temperature has the greatest influence on the porosity of the pellets during the solid phase sintering period and the transition to liquid phase sintering. In the absence of a liquid phase in solid-phase sintering, the number of contacts of ore grains increases, and porosity decreases as a result.

In turn, porosity directly contributes to:

- the improvement of recovery capability;
- the simplification of gas discharge during firing;

- the preservation of mechanical properties.

The analysis of the strength characteristics of calcined pellets shows that optimal binder consumption, provided that the remaining charge components are constant, falls in the range of 0.3-0.4%. Moreover, at a consumption rate of 0.4%, the cold strength of calcined pellets using BPC is 2.2% higher than when using bentonite clay.

The assessment of the strength properties of dry and calcined pellets revealed a linear relationship between the consumption of binder and the characteristics of the pellets. With an increase in the optimal specific consumption of the binder, the strength of the calcined pellets increases while the desired quality of the pellets is maintained. Overall, the research results show that the physical and mechanical properties of calcined pellets depend on the quality of green pellets, which, in addition to a complex of other factors, are influenced by the properties of the binder.

The recommended binding additives, i.e., bentonite powder by Tagbent, LLP, and BPC, at a consumption rate of 0.4%, stabilize the granulometric composition of green pellets, improve the strength characteristics of green, dry, and calcined pellets, and increase the abrasion resistance of calcined pellets.

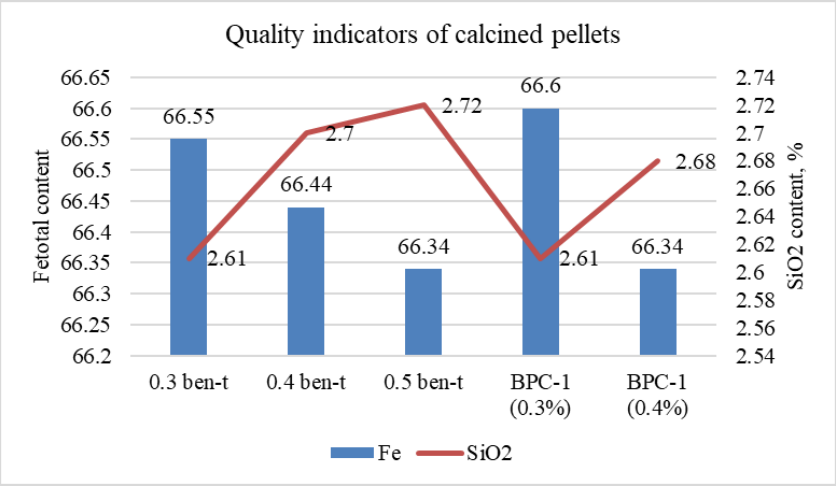

Fig. 8. Quality characteristics of calcined pellets.

The analysis of the obtained calcined pellets shows that at the optimally selected specific consumption of bentonite, not only does the strength of the calcined pellets increase, but the content of harmful SiO_2 impurities decreases and the content of the valuable –Fe component rises.

4. CONCLUSIONS

The study has determined the role of the proposed binders, bentonite and BPC by Tagbent, LLP, in the composition of charge of the corresponding type and dosage in the production of iron ore pellets from high-quality concentrate (SSMPA, JSC).

Laboratory tests established the composition and dosage of binding components in the charge.

The strength of calcined pellets was found to be directly dependent on the strength of dry pellets. However, pilot tests under production conditions should consider that the movement of the layer on the induration machine generates high layer loads and causes a greater deformation of pellets that received "unhealed" internal defects during transportation and storage compared to laboratory conditions.

It has been shown that to obtain the required viscosity (for the adhesion of pellets) of the gel-like mixture (colloid) of bentonite and water (to form a uniform and strong structure of green pellets), the mixture supplied for raw pelletizing has to have a sufficient amount of water. This factor contributes to the stability of the pelletizing process and the retention of most of the moisture, resulting in a smooth pellet surface.

The study has established that high-quality binders allow producing iron ore pellets with high compressive strength, low abrasion resistance ($B^{-0.5}$), and the specified quality parameters.

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