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DRYING AND AGGLOMERATION OF PELLETS MADE OF RED MUD

Utilization of red mud (RM) is of strategic importance at a scale of a country. It seems to be promising to produce pellets made of red mud. RM pelletizing was carried out with a lab-scale dish pelletizer with a diameter of 30 cm and a side height of 10 mm in rotation at a speed of 30 min^{-1}. Before pelletizing, RM had a moisture content of 10%. Baking was carried out in the oxidizing atmosphere created by the jet feed of a natural gas and oxygen mixture at a ratio of 1 : 1.6 in the reaction cell. In all tests, the gas–air flow rate was 2.5 l/min. The test samples had a weight of 4–6 g. Wet pellets made of RM were placed in a boat and set in a lab-scale tubular kiln. The quality analysis of baked pellets followed a standard flowsheet, with determination of chemical composition, compression strength and reduction strength of pellets in accordance with state standard GOST 19575-84. The baking tests of pellets made of RM were carried out at the varied temperatures in a range of 1000–1400 °C and in the different regimes of heating, dependent on the movement velocity of the tube which pushes the boat with pellets through the reaction zone. The analysis of the result defines the optimal temperature range for baking RM pellets from 1180 to 1250 °C. It is found that for the pellets with the basicity from 1.8 to 3.0, the increase of the heating rate over 20 mm/min leads to a significant decrease in the strength of the test samples. The test pellets baked at the temperature of 1200 °C have a high strength. In reduction, the compression strength is 120–140 kg/pellet. Red mud is found to be well pelletizable. The temperature of fluxing onset and surface melting of the test samples is 1180–1250 °C, and sodium sulfides get totally removed from the composition of the product in this case. For all pellets made of red mud with the basicity from 1.8 to 3.0, the typical fluxing and surface melting temperature ranges from 1180 °C to 1250 °C.

Keywords: *red mud, pellets, decarbonization, nodulization, balling, strength, baking*
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Introduction

Utilization of red mud (RM) is of strategic importance at a scale of a country. A promising trend in this regard is processing of RM with extraction of useful components (alumina) from it [1–3].

In the wasteless technology of RM processing, production of pellets is of particular interest. There is no experience of pellet production from red mud, and the earlier research [4–6] considered RM as a binder in pelletizing of iron ore concentrates and as an intensifier in agglomeration. As a binder in pelletizing, RM successfully replaces expensive bentonite [7–9]. A sample of RM with the iron content to 46% and silica content to 10% was obtained at the Boksitogorsk alumina plant [10–12].

It is known that the increase of the iron content in the furnace feed by 1% allows the increment in iron making by 2.5% at the coke saving by 1%. In this context, the use of the alumina production waste as the feed in iron making validates the relevance of this study [13–15].

The quality of a metallurgical conversion product depends on the quantity of elements in composition of RM. The properties of an end product depend on the impact of such elements as aluminum, silicon, calcium, sodium and titanium [16–18].

The main objective of this study is usability of iron fraction of RM in integrated processing of waste without extra expenses connected with separation of other elements contained in RM and resisting extraction.

This study aims to investigate the behavior of RM in agglomeration with Ca/Si ratio control. Later on, RM can be used as a binder in production of iron ore pellets in view of the fact that RM contains up to 50% of iron oxide while the material is considered as waste.

Table 1. Physicochemical characteristics of RM

Chemical composition, %						Content of sizea <0.50 mm, %	Specific density, g/cm^3	Specific surface, cm^2/g	Total water retention capacity, %	Bulk weight, t/m^3
Al_2O_3	Fe_{total}	FeO	CaO	SiO_2	LoI					
12.90	46.75	6.57	12.58	9.58	12.10	89.63	2.35	159.22	30.40	1.18

Note: LoI — loss on ignition.

Procedure and materials

RM pelletizing was carried out in a dish pelletizer with a diameter of 30 cm and a side height of 10 cm in rotation at a speed of 30 min^{-1}. Before pelletizing, RM was pre-wetted to 10%. The main physicochemical properties of RM are [19–21]:

Bulk weight 1.15–1.21 t/m^3;

Specific density 2.02–2.68 g/cm^3;

Total moisture retention capacity 29.50–30.90%;

Specific surface 158.36–160.54 cm^2/g.

Preliminary baking of wet RM pellets was carried out in lab-scale tubular kiln PT-1.3-20 to examine the process of agglomeration in uniform heating. A sample was an individually lying RM pellet in a ceramic boat. The sample 10–15 mm in size was placed in a tube with a diameter of 300 mm and 1 m long. Then, the tube with the sample was moved through the reaction zone of the kiln at a rate from 5 to 20 cm/min.

Baking was performed in the oxidizing atmosphere by means of feeding natural gas and oxygen mixture at a ratio of 1 : 1.6 in the reaction cell [22–24]. The air–gas mixture flow rate was the same in all tests and equaled 2.5 l/min.

The test sample of RM from the Ural alumina plant had a weight of 25 kg. The main components and physical characteristics of the test RM material are described in **Table 1**.

The qualitative analysis of baked pellets followed a standard flowsheet with the determination of chemical composition, compression strength and reduction strength of pellets as per state standard GOST 19575–84 [25–27].

On the whole, the data on the physical properties of the test material offer grounds for suggesting a high pelletizing capacity of RM, and high dispersiveness and water retention capacity come into notice [28, 29].

Research findings

The research findings show that during pelletizing of RM (pre-wetted to 16.5–17.0%), germs rapidly originate at first and grow to 5–8 mm as the feed material is being added. However, the further growth of the pellets of RM to 12–15 mm proceeds very slowly, and the fed material vividly balls with formation of new germs. An increase in the moisture content by

8–9% results in agglomeration of pellets with formation of aggregates.

Considering different chemical composition and, accordingly, different basicity of red muds from different plants [30–32], the strength of pellets made of RM with different basicities was tested. The pellets with different basicities, manufactured at the moisture content of 16.5–17.0%, demonstrated the higher crushing resistance and plasticity. The pelletizing results are compiled in **Table 2**.

Table 2. Pelletizing of RM with different degree of fluxing

Mixture composition			Moisture content, %	Compression strength, kg/pellet		Drops from height of 0.5 m without failure
RM, %	Limestone, %	CaO/SiO_2		Wet	Dry	
100	0.0	1.8	17.0	4.1	16.5	50
87.6	12.4	2.0	16.8	2.9	14.2	
82.2	17.8	2.5	16.6	3.9	15.3	
77.5	22.5	3.0	16.5	2.58	18.5	

For the pellets made of RM having different basicity, the compression strength of wet unbaked pellets reaches 3–5 kg per pellet [33–35]. Baking was carried out at a temperature of 1240–1300 °C. The baking temperature–strength relationship of RM pellets having different basicity is depicted in **Fig. 1**.

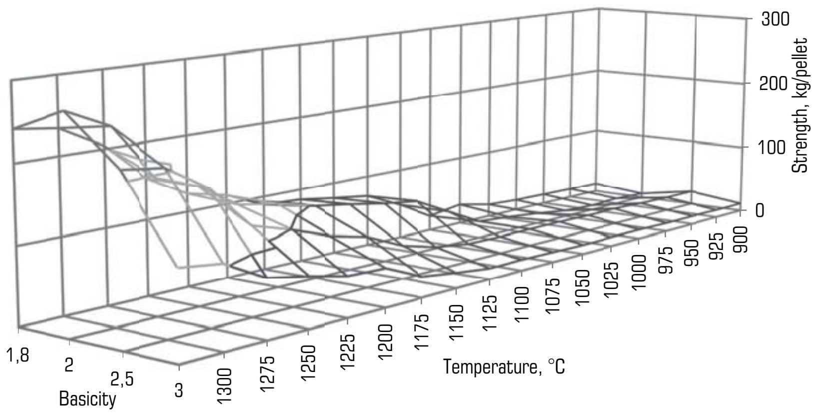

Fig. 1. Temperature dependence of strength of baked RM pellets having different basicity

Basicity of RM pellets was adjusted by addition of calcium oxide, by gradually increasing the content of the active additive with formation of two calcium silicate which strengthened the product. Aside from that, partial surface melting and adhesion of pellets to each other was observed.

Preliminary backing of RM pellets was carried out in a lab tubular kiln in a temperature range of 1000–1400 °C and in different regimes of heating. The velocity of the tube pushing a test sample across the reaction zone was 5, 10 and 20 mm/min. The test pellets had the basicity of 1.8, 2.0, 2.5 and 3.0.

The obtained results correlate with the data on the temperature of fluxing and melting onset in the samples of the same composition (**Fig. 2**).

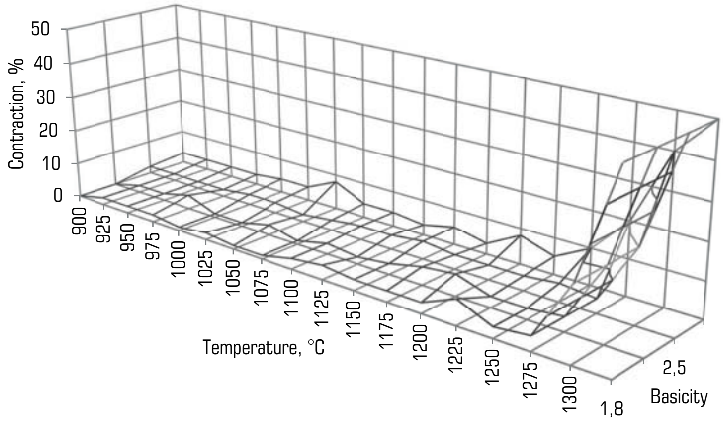

Fig. 2. Contraction versus baking temperature of pellets made of RM having different basicity

The analysis of the results gives a provisional optimal temperature range for baking of pellets as 1180–1250 °C.

It is found that for the pellets made of RM having the test basicity values, the increase in the displacement velocity of the reducible layer at a temperature of 1180–1200 °C to 20 mm/min leads to the decrease in strength, and sensitivity of the pellets to the regime of heating grows with the decrease in basicity (**Fig. 3**).

The preliminary results were used in selecting the main temperature and time parameters for baking RM pellets.

The technological peculiarities of RM pellets described below were also taken into account:

— high moisture content of wet pellets (16.5–17.0%) and low thermal resistance before the first signs of agglomeration (350 °C for basicity of 3.0 and 500 °C for basicity of 2.0);

— higher sensitivity of pellets to change in the rate of heating in case of basicity of 2.0;

— low temperature range of fluxing and surface melting of pellets.

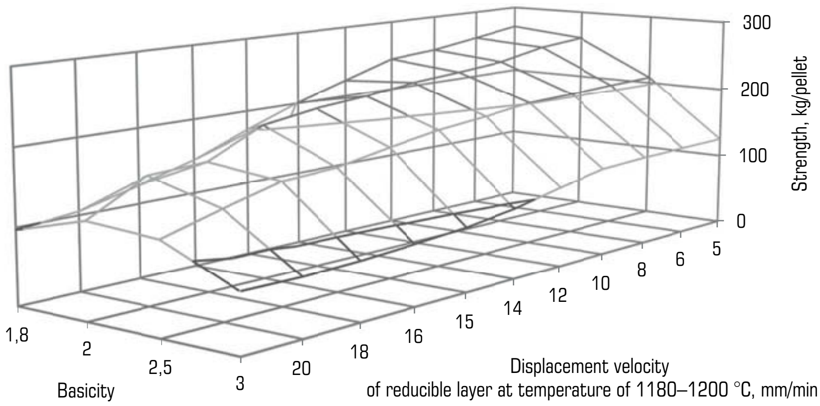

Fig. 3. Temperature–strength relationship of baked RM pellets

The research shows that baked pellets made of RM in the lab tubular kiln have a high strength (120–140 kg/pellets). The research results are described in **Table 3.**

It is planned to continue the studies on a semi-industrial installation of baking a layer of RM pellets to analyze their mutual adhesion which complicates haulage and stockpiling. The baking plant may be equipped with a lined cell with a diameter of 300 mm and 400 mm high, and with three burners for a mixture of natural gas and air. By estimates, the air–gas mixture flow rate can be no higher than 1.4–1.6 m^3/s.

The main technological parameters of the layer baking from the accomplished test results are compiled in **Table 4**.

The furnace cell has nozzles for adjustable air feed. The gaseous fuel may be a mixture of oxygen and natural gas with a calorific capacity of 8000 kcal/m^3, fed via the nozzles under a pressure to 3 atm (0.3 MPa).

Table 3. Quality factors of RM pellets after baking and reduction

Factor	Basicity			
	1.8	2	2.5	3
Specific capacity, t/(m²·h)	0.56	0.53	0.53	0.5
Content, %:				
Fe	40.66	41.10	41.91	42.46
FeO	9.98	10.09	10.29	10.43
Al_2O_3	19.60	19.82	20.21	20.48
CaO	19.12	19.33	19.71	19.97
SiO_2	10.62	9.66	7.88	6.66
Compression strength, kg/pellet	4	6	8	7
Pellets after reduction, %:				
>10	82.9	83.8	87.7	87.4
0.5–5	2.6	1	0.5	0.6
<0.5	2.2	0.8	1.2	1
Rupture factor, %	1.17	1.04	1.00	1.08
Compression strength, kg/pellet	120	135	140	130

Table 4. Main parameters of layer baking of RN pellets in layer of 150 mm

Process, min/°C	Basicity	
	2	2.5–3.0
Drying	7.5/340	10.0/250
Heating	4.0/800–1000	4.0/800–1150
Baking	6.0/800–1000	8.0/1150–1180
Recuperation	2.5/900	2.5/900
Cooling	11.0/20	11.0/20

The temperature in the combustion space is adjusted by changing the gas–air ratio.

The tests use small samples with a weight of 1.5–1.8 kg. Wet pellets made of RM are placed in a perforated refractory-steel glass with a diameter of 14 cm and 25 cm high. The glass with the test pellets is set inside the furnace, on a fill bed 10 cm high made of baked pellets. The unoccupied place between the glass and the lined cell walls is filled with baked pellets of the same size. The layout of the semi-industrial plant is shown in **Fig. 4**.

Conclusion

1. It is found that at an early stage of RM pelletizing, fast formation of agglomerates 5–8 mm in size takes place.

2. It is experimentally proved that the optimal moisture content of RM mixture is 16.5–17.0%.

3. The uniaxial compression strength of wet RM pellets reach 4–6 kg, and their plasticity increases.

4. The temperature of fluxing and surface melting of RM samples, when total removal of sodium sulfides from the product occurs, is 1180–1250 °C.

5. It is found that the increase in the sample displacement velocity over 20 mm/min for RM pellets with the basicity from 1.8 to 3.0 leads to the increase in the adhesion of pellets to each other.

6. The temperature of the first signs of aggregation in wet pellets made of RM having a high moisture content (16.5–17.0%) is 350 °C for the basicity of 3.0 and 500 °C for the basicity of 2.0.

7. Drying of RM pellets is recommended to carry out at a heating rate to 5 °C/min, which allows removal of moisture and prevention of adhesion.

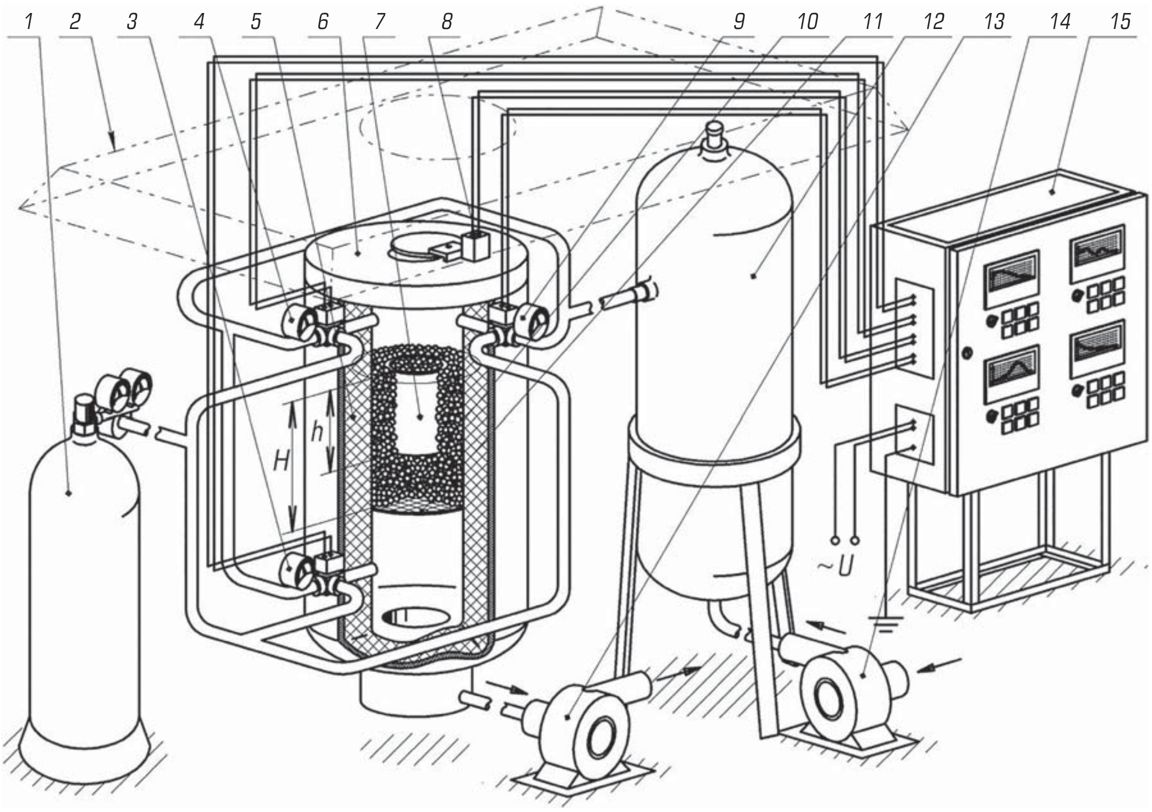

Fig. 4. Layout of semi-industrial plant:

1 – oxygen container; *2* – exit gas outlet; *3*, *4* – gas–air mix feed adjuster to ensure depression cell temperature of 300–500 °C; *5* – furnace; *6* – furnace cover; *7* – small-size sample baking glass; *8* – automated door to organize air flow; *9* – gas–air mix feed adjuster to ensure depression cell temperature of 1000–1400 °C; *10* – fill material for unoccupied space in cell; *11* – grille pan; *12* – gas receiver; *13* – fan to maintain low pressure; *14* – pump to feed natural gas at pressure of 6 atm (0.6 MPa), series BD-07A DC12V; *15* – control cabinet

8. For all pellets made of RM with the basicity from 1.8 too 3.0, a typical range of the fluxing and surface melting temperature is from 1180 to 1250 °C.

9. The test results show that baked pellets made of red mud have a high strength (120–140 kg/pellet).

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