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COMPLEX ADDITIVES ON THE BASIS OF RED MUD FOR INTENSIFICATION OF IRON-ORE SINTERING AND PELLETIZING

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Abstract

Currently, production of stable pelletized materials for blast furnace remains a major challenge for iron and steel metallurgy. The use of red mud with a low content of alkaline elements allows intensifying sintering processes of agglomerate and making pellets from ores and concentrates of ferruginous quartzite. Structural studies have shown that the beneficial effect of low alkaline red mud occurs at the stage of melts in high temperature sintering zone.

RUSAL ETC in cooperation with MISIS develops a process for introduction into sintering mixture of sintering aids on the basis of red mud to improve the agglomerate quality and to raise capacity of sintering machines. For the production of pellets a process is in development for activation of bentonite clay with Bayer red mud aimed to raise iron content in sintered pellets, to reduce consumption of expensive natural bentonite and to improve quality of sintered pellets.

A complex of laboratory and plant investigations has been conducted; the results obtained testifying viability of introduction of sintering aid and complex binding agent on the basis of red mud at enterprises of iron and steel metallurgy for the production of agglomerate (sinter) and iron ore pellets.

1. Introduction

In the metal industry of Russia (like in many other countries of the world) the main ore constituent of the feed for ore sintering and pelletizing are ferruginous quartzites, mostly hardly beneficiated and hard melting ores. Basic silicate of gangue in their structure is high-melting quartz, melting temperature1710 °C. Since ores and concentrates of ferruginous quartzite are major components of the feed, sintering requires additional heat and time to complete the process of melt formation with liquid binding of ore grains. Hence, for intensification of melt formation process it is advisable to introduce ore-forming additives into the feed. The additive should contain a certain amount of mineral ore to compensate the iron in the feed composition and should have the ratio of oxides of silicon, calcium and aluminum, corresponding to the composition of low temperature mineral components of ferrosilicate melt. The addition should contain minimum of harmful impurities (S, Na, K, P, Zn, etc.) and, most importantly, meet particle size distribution of the finest reactive fraction of the charge to participate in the processes of primary melt formation. Red mud with low content of alkalis may serve as such additive. Previous studies on the introduction of red mud into the charge of sinter and pellets dealt mainly with untreated red mud from residue disposal areas [1].

2. Agglomeration

Laboratory agglomerate sintering tests were performed at a constant composition of the ore part of the feed: 57% of ferruginous quartzite concentrate and sinter ore from Michaylovskoye and Lebedinskoye deposits and 29 % of Bakalsk sinter ore, the rest being metallurgical wastes: blast furnace dust, slag, blast furnace sludge, agglomerates and pellets screenings. In all experiments of sintering the CaO / SiO_2 ratio in the feed was 1.6 ± 0.2-0.3%. The content of coke breeze in the mixture was 4.2%. Red mud from Ural smelter treated with lime in a reactor to reduce alkali content was used as an intensifying additive. Chemical composition of low alkali red mud (LARM) is presented in Table 1.

Table 1. Low Alkali Red Mud chemical analysis, mass %

Fe_2O_3	SiO_2	CaO	Al_2O_3	MgO	K_2O	Na_2O	TiO_2	P_2O_5	LOI
36.8	7.9	21.9	10.8	0.8	0.15	0.85	3.8	0.75	2.8

LARM additive was introduced in amount of 1, 3, 5 and 7 % relative to the iron-ore component of the feed. Strength of the sintered agglomerate was determined according to GOST 15137-77 RF (Strength - drum sample 5 mm, attrition - drum sample - 0.5 mm). Basic parameters of sintering are shown in Table 2.

Table 2. Key parameters of sintering (agglomeration)

Key parameters	Red mud dosage, % of iron-ore component of the feed				
	0	1	3	5	7
Height of sintering layer, mm	290	290	290	290	290
Relative reduction of layer, %	17.59	18.28	19.66	19.66	20.69
Sintering rate, mm/min	9.35	9.67	10.36	10.36	10.74
Useful agglomerate from sinter, kg (>5mm)	23.72	23.67	24.59	25.65	24.50
Yield of useful agglomerate, %	70.50	71.10	75.80	76.90	74.40
Specific production of useful agglomerate Q, $t/m^2 \cdot h$	1.208	1.245	1.386	1.446	1.432
Strength (drum sample +5 mm)	61.62	63.53	66.09	74.33	69.11
Attrition (drum sample -0.5 mm)	7.59	7.88	6.61	4.33	5.83

As follows from the data in Table 2 as addition of LARM increases to 5% the increase of impact strength as compared to the base agglomerate is 12.71 abs. % (20.5 relative %), and the abrasion resistance increases by 3.26 abs. % (41.4 relative %). With further increase in the amount of the additive the strength characteristics of sinter begin to decline.

Changes in the strength of the agglomerate, in our opinion, are determined by the formation of the mineralogical composition of the sinter, depending on the amount of low alkaline red mud introduced into the feed. Samples of basic sinter (without LARM) represented virtually a two-phase system: ore phase hardened with glass phase with no signs of decrystallization. Ore phase consisted of magnetite and hematite grains, where the latter were confined to the conductive pores, cracks and surface volumes of the agglomerate (Figure 1).

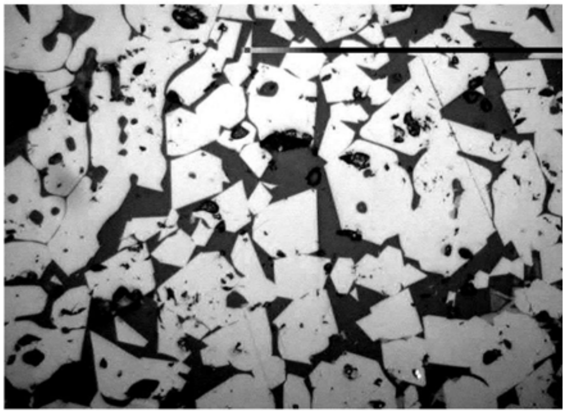

Figure 1. Microstructure of the basic agglomerate. Magnetite – white, glass phase – grey. Reflected light, magnification × 500

At the minimum addition of LARM to charge in amount of one percent two-phase composition of ore and silicate phases is maintained in the agglomerate. Changes concern only microstructure of the silicate phase itself. Upon cooling of the agglomerate tiny needles of ferrite phase precipitate from ferrosilicate melt, and in the volume of silicate binder there are no contacts of ferrite crystal with the ore phase, so the strength carrier of sinter is glass phase reinforced with acicular ferrite crystals (Figure 2).

Figure 2. Microstructure of sinter with 1 % LARM. Glass phase – grey, needle crystals of ferrite – light grey. Reflected light, magnification × 500

Increase in red mud content in sintering mix to 3% changes significantly mineral formation in the sinter as a whole. Agglomerate is converted into ternary mineral composition consisting of magnetite, ferrite, and glass phase. The role of ferrite phase is modified. Its scaly crystals formed on magnetite contact with ferrosilicate melt, become the main bunch of ore grains. The amount of residual melt in the form of glass phase is observed in loops of ferrite crystals (Figure 3).

Microstructure of agglomerates changes fundamentally with the increase of LARM content to 5 and 7%. In this case, the components of red mud become defining in the process of melt formation in the areas of liquid-phase sintering of the agglomerate. The amount of silicate forming components increases in the melt. At agglomerate cooling stage, at contact of ferrosilicate melt and magnetite grains that are oxidized at the surface, crystals of Al-Si ferrite phase nucleate and grow performing in this case the role of binding of ore grains (Fig. 4).

Figure 3. Microstructure of sinter with 3 % LARM. Ferrites – light grey scaly crystals, glass phase – dark grey. Reflected light, magnification × 500

Figure 4. Microstructure of sinter with 5 % LARM. Residual grains of magnetite– white, ferrite – grey, glass phase – dark grey. Reflected light, magnification × 500.

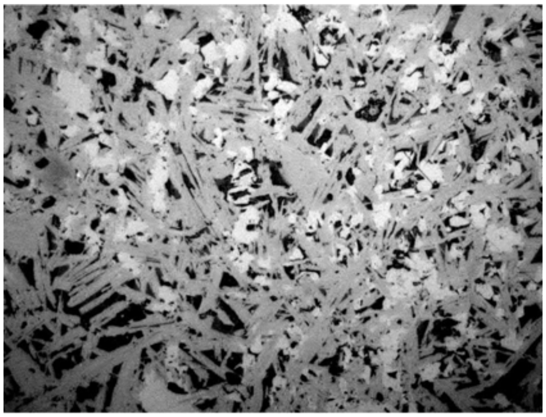

Figure 5. Microstructure of sinter with 7 % LARM Residual grains of magnetite– white, ferrite – grey, glass phase – dark grey. Reflected light, magnification × 500.

The ratio of the magnetite, Al-Si ferrite and glass phase in agglomerates with 5 and 7% LARM, depends on composition and structure of granulated volumes of the charge. However, in all studied samples of agglomerates total number of ferrite binding dominates over glass phase (Fig. 5).

Qualitative and quantitative changes in microstructure of the agglomerates with addition of a low alkaline red mud are confirmed by analysis of mineral composition by the method of Mössbauer spectroscopy (Fig. 6). Established optically, phase transformations of ore, ferritic and silicate phases with the increase of LARM in the charge are definitely confirmed. The process of ferrite formation in the bundles of agglomerates already at 1% LARM is accompanied by reduction in magnetite content, as far as for the formation of Al-Si ferrite the iron of magnetite is consumed. The increase in ferrite phase content in bundles is the reason of glass phase reduction in sinter. This is due to the fact that silica of industrial wastes is present in Al-Si ferrite up to 10 % (by mass).

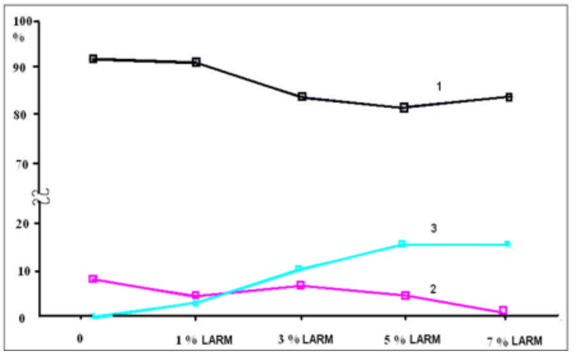

Figure 6. Main phase components of agglomerate (sinter), % vs percentage of introduced LARM : 1 – iron ore phase (magnetite +hematite), 2 –glass phase, 3 –Al-Si ferrite

Thus, during sintering of a multicomponent charge based on sintered ore and iron quartzite concentrates hardening mechanism of agglomerates with the addition of low alkali red mud is determined by the fact that the fine particulate mass of low alkali red mud in the high temperature sintering zone is transferred into ferrosilicate melt of agglomerates reverses mineral formation, resulting in replacement of silicate binding by stronger ones – ferrite. Increased content in agglomerates bonds of Al-Si ferrites and reduced amount of glass phase is accompanied by enhancing of strengthening properties of the finished product.

3. Pelletizing and baking of pellets

The studies of the impact of low alkaline red mud on pelletizing and sintering of non-fluxed pellets were carried out at Kostomuksha GOK - OJSC "Karelian Pellet", Russia, the ores of which are ferruginous quartzite. Into the charge (concentrate) low alkaline red mud was added instead of bentonite. Also mixtures of low-alkaline the red mud with bentonite (2% LARM and 0.3% bentonite and 1% LARM and 0.5% bentonite) were tested. As base case the bentonite was used. In the experiment with addition of 1% LARM and 0.5% bentonite initially the additive was mixed in a ball mill, and then introduced into the charge, followed by mixing. Experimental pellets were compared to pellets, pelletized with bentonite only. The green pellets were prepared in a laboratory drum-pelletizer, and then the pellets were placed in a steel mesh basket (probes). The probes were placed on a pallet of an industrial baking machine OK-520/536 before a roller stacker, and removed in the end part of the baking unit before receiving hopper of burnt pellets.

To determine the strength of baked pellets for compression the probe was divided into three equal portions - top layer, middle layer and bottom layer.

Table 3 shows properties of green pellets. As can be seen from the below data, the addition of LARM leads to deterioration of the strength properties of raw pellets, but adding a mixture of LARM 1% + 0.5% bentonite makes properties sufficient to transport the pellets to the baking unit. The obtained results are not final and there is a way to further improve creation of red mud based products including by addition of polymer compounds.

Table 3. Properties of green pellets

Parameter	Additive			
	LARM	LARM +Bentonite	LARM +Bentonite	Bentonite (base)
Charge, %				
concentrate	98.0	97.7	98.5	99.18
bentonite		0.3	0.5	0.82
Red mud	2.0	2.0	1.0	
Mass portion in green pellets, %				
class +20 mm	6.3	3.4	4.2	0.0
class +16 mm	15.1	19.1	14.8	2.9
class 8-16 mm	77.5	76.7	79.1	96.7
class 0-8 mm	1.1	0.8	2.8	0.4
Av. diameter, mm	13.0	13.2	12.9	12.0
Compression strength, kg/pel.				
green	0.63	0.80	0.790	1.04
dry	0.68	1.28	2.349	2.22
Dropping strength				
green, time	1.9	2.7	3.1	4.8

The baking of experimental pellets (Table 4) demonstrate that the most effective impact on the strength properties of baked pellets has the mixture of LARM 1% and 0.5% bentonite, which considerably increases the strength of the bottom layer, that cannot be achieved by conventional methods of intensification of baking.

Table 4. Properties of baked pellets

Parameter	Addition			
	LARM	LARM + Bentonite	LARM + Bentonite	Bentonite (base case)
Charge, %				
concentrate	98.0	97.7	98.5	99.18
bentonite		0.3	0.5	0.82
Red mud	2.0	2.0	1.0	
Compression strength				
Baked pellets, kg/pel	234	275	313	223
top	270	283	232	253
middle	258	291	341	239
bottom	173	251	366	177

Table 4. Properties of baked pellets (cont-ed)

Parameter	Addition			
	LARM	LARM + Bentonite	LARM + Bentonite	Bentonite (base case)
Chemical composition, average % of baked pellets				
Fe	65.33	65.14	65.64	65.34
S	0.003	0.004	0.010	0.005
CaO	0.61	0.53	0.38	0.54
SiO_2	5.60	5.76	4.99	5.74
MgO	0.19	0.19	0.2	0.19
K_2O	0.040	0.043	0.055	0.041
Na_2O	0.104	0.104	0.100	0.102

Using scanning electron microscopy (SEM) we investigated the structure of the bottom layer of baked pellets from the point of view of melt formation. Figure 7 shows a typical structure and elemental composition of the melt in the pellet with bentonite (base case).

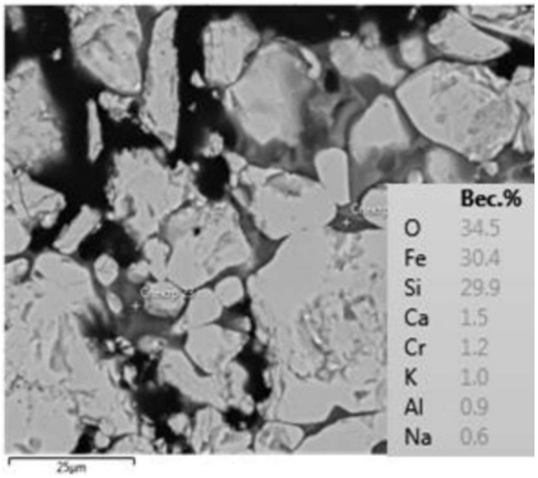

Figure 7. Structure and elemental composition of pellet melt with bentonite

The volume of melt in the structure is low and since the melt can be described as fayalite, then its viscosity is high enough.

Baking of pellets with 2% LARM leads to the formation of more melt but temperature level does not allow to make full interaction between the LARM and concentrate. Figure 8 shows the result of interaction of LARM with the ore portion of a pellet and elemental composition of the resulting melt.

Use of a low alkaline red mud and bentonite mixture, as follows from the analysis of the elemental composition of the melt in the pellets with the composition "1% LARM + 0.5% bentonite" (Figure 9), forms lower-melting melt involving a portion of the surrounding rocks of the concentrate as well.

Thus, pre-mixing of a low alkaline red mud bentonite allows during baking process to obtain a melt having a relatively low melting point thus intensifying sintering of pellets.

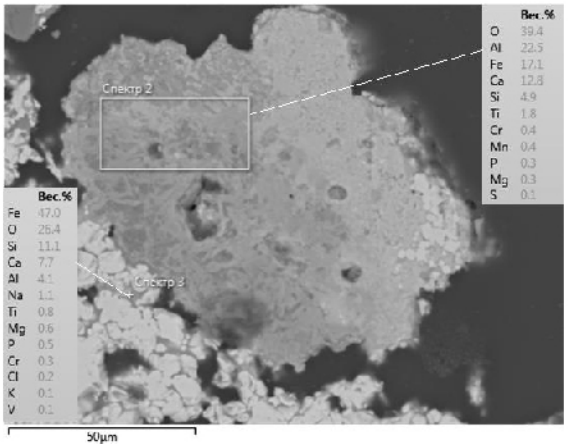

Figure 8. Structure and elemental composition of pellet melt with 2% LARM

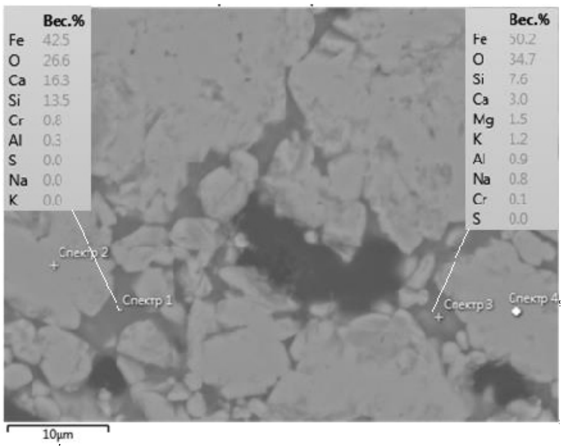

Figure 9. Structure and elemental composition of pellet melt with 1% LARM + 0.5% bentonite

4. Conclusions

1. Addition of low alkaline red mud into iron ore sinter charge initiates formation of ferrite in the sintering process and transforms a binder of ore grains from glass phase to the crystal ferritic phase, which explains the increase in strength and decrease of agglomerate attrition.

2. Low alkaline red mud can be effectively used in the production of pellets. The compositions of low alkaline red mud and bentonite allow in the baking process to produce a melt with a relatively low melting point and intensify sintering of pellets. Increase in calcium alumoferrite phase content in the liquid phase and reduction in fayalite phase improve the strength properties of the baked pellets.

3. The results of the study create conditions to apply treated red mud as commercial product in iron and steel metallurgy.

5. Acknowledgment

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6. References

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