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Metallurgy

Research of the production of iron ore sinter from bauxite processing waste

Zhunussova A.K., Bykov P.O., Zhunusov A.K., *Kenzhebekova A.Ye.

Torayghirov University, Pavlodar, Kazakhstan

**Corresponding author email: kenzhebekova_psu@mail.ru*

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ABSTRACT

This article presents the results of a study of the agglomeration of waste alumina ferrous sands and the use of sinter as a substitute for metal charge in steelmaking. At this time, in the process of processing bauxite, JSC "Aluminium of Kazakhstan" produces a large number of fines, which is of great interest to ferrous metallurgy. Wastes from alumina production include a variety of waste sludge, including red, gray sludge, and ferrous sands. According to the chemical composition, ferrous sands can be attributed to iron ore material with a high content of alumina. Most of these problems are eliminated by preliminary agglomeration of fines. In this work, agglomeration studies made it possible to establish the optimal parameters for sintering ferrous sands. When using 10% fuel, the best sintering performance is achieved. The optimal parameters for sintering ferrous sands mixed with other metallurgical wastes are such as productivity - 0.92 t / m^2 h, mechanical strength - 80.0%, sintering speed - 19.3 mm/min, yield - 82.0%, the maximum temperature in the layer is 1340 °C. The results of laboratory melt carried out in an induction melting furnace indicate the possibility of using a sinter as a substitute for metal charge in iron and steel smelting. The conducted melting confirms the fundamental possibility of using a sinter, made from waste products of alumina production of ferrous sands, is a man-made charge material that is suitable for use as a 5% additive to the metal charge in the smelting of iron-carbon alloys similar in composition to cast irons.

Keywords: Ferrous sand, agglomerate, sintering, charge gas permeability, sintering rate, metal charge, smelting.

Information about authors:

Zhunussova Aygul Kairgeldinovna	*Student Ph.D., Department of "Metallurgy", Torayghirov University, 140008, Lomova Street 64, Pavlodar, Kazakhstan. Email: zhunusova.aig@mail.ru*
Bykov Petr Olegovich	*Candidate of Technical Sciences, Professor,* Department of "Metallurgy", *Torayghirov University, 140008, Lomova Street 64, Pavlodar, Kazakhstan. Email: bykov_petr@mail.ru*
Zhunusov Ablay Kairtassovich	*Candidate of Technical Sciences. Professor, Department of "Metallurgy". Torayghirov University, 140008, Lomova Street 64, Pavlodar, Kazakhstan. Email: zhunusov_ab@mail.ru*
Kenzhebekova Anar Yerbolatovna	*Student Ph.D., Department of "Metallurgy", Torayghirov University, 140008, Lomova Street 64, Pavlodar, Kazakhstan. Email: kenzhebekova_psu@mail.ru*

Introduction

At this time, in the process of processing bauxite, JSC "Aluminium of Kazakhstan" produces a large number of fines, which is of great interest to ferrous metallurgy. Wastes from alumina production include a variety of waste sludge, including red, gray sludge, and ferrous sands. Iron sands are formed as a result of the leaching of bauxites according to the Bayer scheme. When bauxite is leached at JSC "AK", a scheme has been developed for removing the iron component of bauxite (ferrous sands) [1]. The formed ferrous sands contain over 50% Fe_2O_3, which, by their chemical composition, are suitable for use in the production of ferrous metals. According to preliminary estimates, more than 500 thousand tons of such waste are generated per year. This is only in Kazakhstan. And according to [2], more than 2.7 billion tons of bauxite waste have accumulated in the world, and annually its amount only increases by 120 million tons.

Currently, the world has a wide variety of works on the processing of bauxite waste from alumina production. However, the ongoing research is not all of the interest from the side of metallurgy. Many technologies for processing wastes from alumina production are expensive for the implementation of the presented studies, and most of them are accompanied by complexity and multi-stage processing processes. According to its composition, bauxite waste can be used in various industries [[3], [4], [5], [6], [7]].

At present, a large number of different methods for processing sludge waste from alumina production have been developed in the world [[8], [9]]. In the works [[10], [11], [12], [13]], the technologies for extracting valuable rare earth metals and components from alumina production sludge are considered.

In [[14], [15]], the technology of processing wastes from alumina production (red mud) by agglomeration was studied. In this direction, many years of great work have been done on the processing of red mud by agglomeration, and positive results have been obtained. It follows that ferrous metallurgy seems to be the most promising for the processing of ferrous sludge (ferrous sands).

In Kazakhstan, the research, presented in [16], is devoted to the study of ferrous sands. The analysis of the physicochemical data on the composition of ferrous sands shows that they can be considered a potential raw material for the production of pigments and cast iron. In [[17], [18]], a method was developed for the processing of alumina production waste - red mud by reduction smelting to produce cast iron and slag containing rare earth elements and titanium dioxide. The work [[19]. [20]] shows the possibility of hydrochemical enrichment of ferrous sands by leaching with alkali-aluminate solutions of alumina production.

Industrial waste is often used in metallurgy as cheap substitutes for iron ores. As a rule, technogenic wastes have a fractional composition of less than 5 mm. When working on a fine charge in a blast furnace, the blast pressure on the tuyeres and the loss of blast pressure in the charge column increase significantly. All this leads to the hanging of the mixture, and gas permeability deteriorates. There is a deterioration in the degree of use of chemical and thermal energy. Under such conditions, it is not necessary to operate the furnaces normally and achieve the productivity of the workshops. It is obvious that most of these difficulties are eliminated by preliminary agglomeration of fines.

The agglomeration of ore materials makes it possible to involve various technogenic wastes in metallurgical processing [20], such as screenings of ores, sludge, mill scale, flue, and aspiration specks of dust [21], and pyrite cinders. The agglomerated high-quality charge prepared for smelting will make it possible to utilize existing waste, improve the operation of furnaces, reduce dust removal, reduce the specific consumption of coke, and increase metal smelting.

Experimental part

Ferrous sands were used as the material under study. Ferrous sands are waste products of alumina production, as are waste sludges, including red, gray sludge, and ferrous sands. According to the chemical composition of the studied material presented in Table 1, ferrous sands can be attributed to iron ore material with a high content of alumina.

When conducting experiments on the agglomeration of alumina production waste, iron sands of a fraction of 0-5 mm were used as a charge in a mixture with mill scale, in a ratio of 70:30. Screenings of coke were used as fuel. The fraction 0.1–1.6 mm has the most unfavorable effect on pelletization [20]. It is in this fineness range that many man-made wastes and the material under study (iron sands) fall, the granulometric composition of ferrous sands is presented in Table 2. The aspiration dust of steelmaking was used as a clay component to improve the compressibility of the charge [21]. The use of aspiration dust had a favorable effect on pelletization, which accelerates with an increase in the number of nuclei in the charge. Pelletization was also facilitated by the use of return in the charge, in which the bulk has the presence of the smallest particles [[20], [21], [22]].

Table 1 – Chemical composition of materials

Materials	Fe_{gen}	SiO_2	MnO	Al_2O_3	MgO	CaO	S	P	C
Ferrous sand - waste of alumina production	61.0	7.8	-	19.0	0.5	5.7	0.2	-	-
Rolled scale from mill	76.8	0.8	1.7	-	-	-	-	-	0.10
Aspiration dust	50.9	1.7	2.0	3.5	2.0	3.0	0.021	0.002	3.2

Table 2 - Granulometric composition of iron sands

Fraction, mm	-0.06	-0.2-0.06	-0.5-0.2	-1-0.5	-3-1	-5-3
Unit. %	2.0	14.7	43.2	20.5	6.8	12.8

Table 3 - The chemical composition of the ash and the technical composition of screening coke fraction 0-10 mm, %

SiO_2	CaO	MgO	Al_2O_3	Fe_2O_3	A	V	W
47.2	10.9	7.0	10.2	11.6	23.0	4.8	6.2

Mixing of the mixture was carried out in a drum mixer. The optimal moisture content of the charge was selected empirically, by a gradual increase from 5 to 10%. The use of clay components contributed to the improvement of the properties of the mixture during its preparation before sintering, it turned out to be friable, and the improvement in gas permeability reduced the sintering time. The experiments were carried out on a laboratory sintering plant, according to the established methodology in the laboratory of the Department of Metallurgy, Toraighyrov University (Pavlodar).

Before pelletizing, iron sand was subjected to pre-drying at 100-150 °C in a drying oven, since after leaching evaporators, iron sands have a high humidity (70-80%). The moisture content of the material was reduced to 5-15%.

The following seeds were used as sintering charge: iron sand, scale (20%), coke breeze (5-10%), return (20%), and aspiration dust. Mixing and pelletizing was carried out in a drum mixer. For better pelletization of iron sand in the mixture, aspiration dust of a fraction of 0-5 mm was used, since this material in the composition has a finely dispersed clay part. Due to the use of waste sludge as part of the sintering charge, the degree of pelletization of the material under research is improved. Screenings of PRC Coke were used as fuel (Table 3). The return was used from the previous sinter. Agglomerate was used as a bed. The incendiary mixture consisted of a mixture of sawdust and coke breeze, lightly moistened with water. Ignition mixture - wood shavings moistened with kerosene.

Bowl parameters: diameter 100 mm, bowl height allows sintering charge up to 500 mm. The sinter plant is equipped with a VVN-1.5 vacuum pump, a TXA, BP thermocouple, and a multi-channel automatic temperature recorder (ART-2) of the sintering process (fixing the temperature of the gas outlet, charge layer at different heights).

The charge was loaded using a special device, which makes it possible to significantly reduce the segregation and compaction of the charge. Ignition was carried out for one minute at a rarefaction of 300-350 mm wg. incendiary and ignition mixture. Sintering was carried out at a constant vacuum under a grate of 1000 mm of water column. The thermocouple readings - the temperature in the bed, and the temperature of the exhaust gases, were recorded on ART-2. The start of sintering was determined by the moment of ignition of the coke, and the end of the process was determined by the time of reaching the maximum temperature of the exhaust gases. The flue gas temperature was measured with a thermocouple (TCA) installed on the gas outlet pipeline. After the end of sintering, the cake was unloaded from the bowl, cooled for 10 minutes in the air, weighed on a laboratory balance, then dropped from a height of 2 m onto a steel plate according to GOST 25471 - 82, after which the yield of classes was determined (including the good fraction +8 mm). Further samples of the agglomerate fraction +5 - 40 mm were subjected to the determination of mechanical strength according to GOST 15137 - 77.

The discussion of the results

During the research, the amount of coke was changed from 5 to 10%. Figures 1, 2, and Table 4 present the results of laboratory studies. From the figures and tabular data (table 4), it can be seen that the amount of fuel has a positive effect on the sintering performance. At 3–5%, the sintering rates are quite low. Changes are observed with an increase in the amount of fuel from 6%. At 7 - 8% fuel, the sintering speed increases slightly to 16.3 – 16mm/min, the plant productivity increases to 0.69 - 0.70 t / m2 h, mechanical strength 75.0 - 77.3%, the yield of suitable sinter is 66.9 - 70%.

A noticeable change is observed with an increase in the amount of fuel in the sinter charge by 9–10%. Changes are visible in the sintering speed, there is an increase from 18.4 to 19.3 mm/min, the productivity of the plant increases from 0.86 to 0.92 t/m^2 h, mechanical strength is 79.0 - 80.0%, and yield 79 - 82%.

The best results in terms of strength and yield of suitable sinter were obtained with an increase in the amount of fuel by up to 11%. However, there is a slight decrease in the sintering speed and productivity of the sinter plant. This is obvious since the carbon of the fuel during combustion releases the heat necessary for the sintering of the charge. If there is not enough fuel in the charge, then the temperature required for sintering (at which liquid phases begin to form) will not be reached and physicochemical transformations in the charge will be poorly developed. The mixture with insufficient fuel will not sinter to the end (a sufficient amount of bonding of all particles among themselves is not formed throughout the entire layer), which will lead to a weak strength of the resulting sinter, which is demonstrated by the data in Figures 1 and 2.

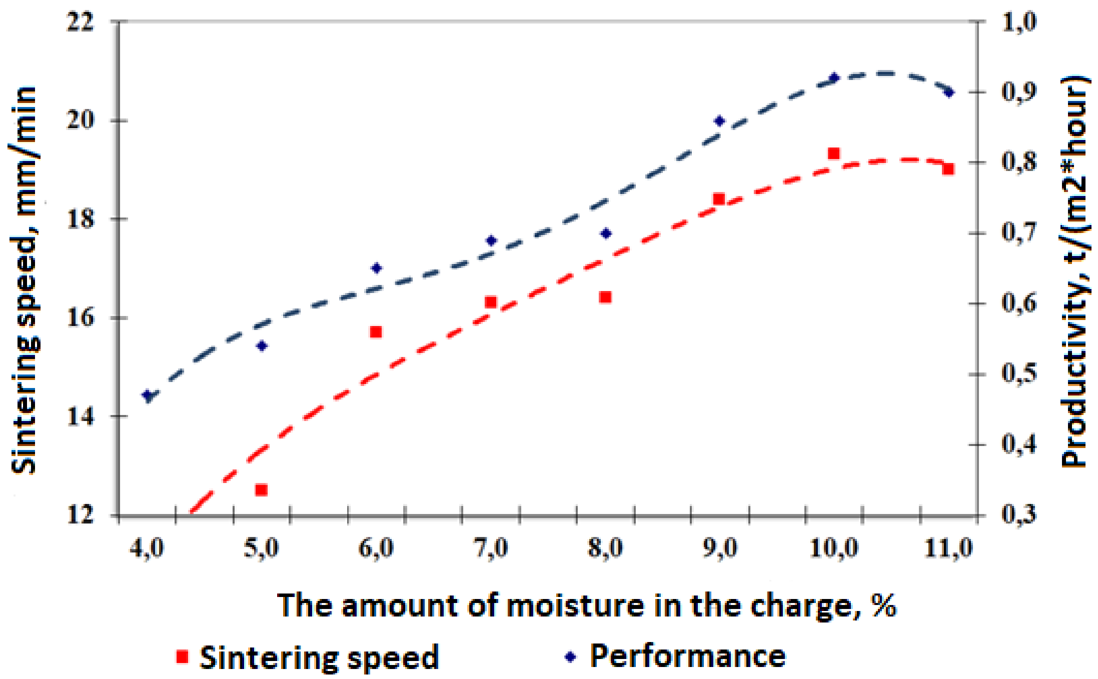

Figure 1 – Influence of the amount of fuel on the sintering performance in terms of productivity and sintering speed

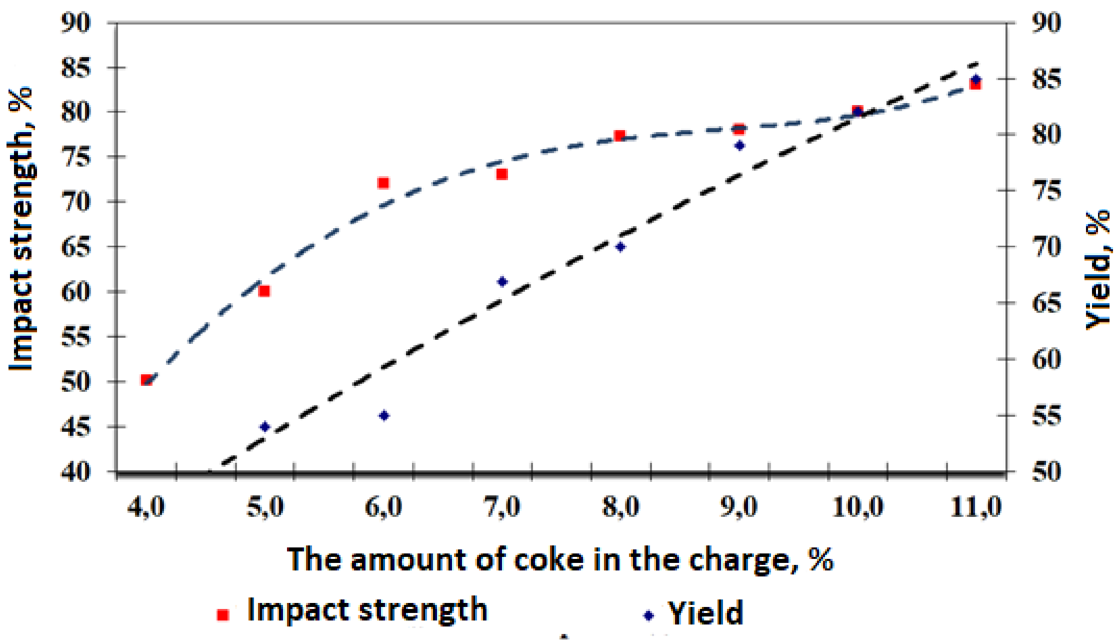

Figure 2 – Influence of the amount of fuel on the sintering performance in terms of strength and yield of suitable sinter

On the other hand, excessive consumption of fuel causes the development of high temperatures, which will cause excessive melting of the sinter and a decrease in mechanical strength, such as with an increase in fuel up to 11%. It is necessary to have such a fuel consumption at which the agglomerate would have good mechanical strength and would not be strongly melted [[21], [22]]. These studies were carried out in order to determine the appropriate fuel consumption for such a sinter.

Thus, the use of 10% fuel should be considered the optimal parameter for sintering iron sands in a mixture with other metallurgical waste, since the best indicators of the sintering process were achieved: productivity - 0.92 t/m^2 h, mechanical strength - 80.0%, speed sintering - 19.3 mm/min, good yield - 82.0%, maximum temperature in the layer - 1340 °C. Figure 3 shows photographs of iron sand (a) and iron ore sinter (b).

The chemical composition of the produced iron ore sinter is shown in table 5.

Further research work was carried out to assess the possibility of using iron ore sinter as a substitute for metal charge in steelmaking. For this purpose, induction melting was carried out in an ITP-0.005 furnace. The agglomerate was loaded into pre-molten metal. The melting of the metal was carried out according to the basic technology of melting steel grade St40. The average specific power consumption in melts using a sinter is higher by 0.52 kW/t than in base melts, which is 0.2%, i.e. the average specific power consumption is practically at the same level. The outlet metal temperature was 1450–1500°C. The temperature was measured using a tungsten-rhenium thermocouple (VR) and an MRT-6 multichannel temperature recorder. The average duration of the melts was 1 hour 30 minutes. Data on the chemical composition of the metal are presented in Table 6.

Table 4 – Sintering performance with changes in fuel consumption

№ of Experiment	The amount of coke in the charge, %	Sintering speed, mm/min	Productivity, t/m^2 hour	Strength according to GOST - 15137-87	Yield, %
1	3	10.4	0.38	-	-
2	4	11.3	0.47	50.1	47.2
3	5	12.5	0.54	68.0	54.0
4	6	15.7	0.65	72.0	55.0
5	7	16.3	0.69	75.0	66.9
6	8	16.4	0.70	77.3	70.0
7	9	18.4	0.86	78.0	79.0
8	10	19.3	0.92	80.0	82.0
9	11	19.0	0.90	83.0	85.0

Table 5 – Chemical composition of iron ore sinter.

Material name	Chemical composition, %						
	Fe_{gen}	Al_2O_3	SiO_2	CaO	MgO	S	P
Iron ore sinter	53.0	15.82	11.36	4.96	4.86	0.59	0.066

Figure 3 – Iron sand (a) and iron ore sinter (b)

Table 6 – The chemical composition of the metal

№ of smelting	Content of elements, %				
	C	Si	Mn	S	P
1	4.70	0.200	0.250	0.020	0.020
2	3.20	0.004	0.015	0.008	0.020
3	0.20	0.009	0.010	0.009	0.008

Table 7 – Chemical composition of the metal part of the charge, %

C	Mn	Si	S	P	Cu	Al
0.40	0.45	0.25	0.020	0.015	0.10	0.020

Table 8 - Chemical composition of the resulting ingots, %

C	Mn	Si	S	P	Cu	Al
0.45	0.20	0.15	0.020	0.015	0.08	0.08

The analysis showed that the obtained alloys have a low content of harmful impurities: the content of sulfur and phosphorus is not more than 0.02%. When conducting experimental heats, steel scrap of steel grade St-40 was used as the metal part of the charge and iron ore agglomerate in the amount of 0.80 kg.

The chemical composition of the metal part of the charge is presented in Table 7.

The total weight of the mixture was 5.8 kg. The average duration of heat is 1 hour 30 minutes, and the temperature of the metal at the outlet is 1600 °C. During melting, slag was induced by the following composition of materials:

- quicklime (CaO) - 45%;
- silica (SiO_2) - 25%;
- metallurgical alumina + fluorspar (CaF_2) - the rest.

During the melting process, the formation of foamy slags was observed. Foamy slags affect the process of oxidation of solid carbon particles in the sinter with the formation of carbon dioxide. Under production conditions, when using agglomerate, it will allow obtaining a reduction in the specific consumption of electricity and reducing agents. This statement is confirmed by individual heats, where the specific consumption was 480−510 kW in terms of a ton of good products.

The resulting iron-carbon alloy was deoxidized with aluminum and cast into cast iron molds. As a result of experimental melting in an induction furnace, 5 ingots of 5 kg each were obtained, the chemical composition of which is presented in Table 8.

The yield of suitable metal was 95.0%. Estimating the content of permanent impurities in obtained samples, the following conclusions can be drawn:

- low content of sulfur and phosphorus due to the use of iron ore sinter containing a minimum amount of harmful impurities;
- the use of iron ore sinter as part of the charge leads to an increase in the carbon content in excess of the calculated amount. This means a higher degree of carbon uptake when using iron ore sinter compared to using carbonaceous materials added during carburization smelting.

The results of melting with the use of iron ore sinter obtained in this work indicate their successful application as a substitute for the metal part of the charge for steel melting. In the process of research in laboratory conditions, 20 kg of steel and iron-carbon alloys were smelted using a sinter of various compositions.

Thus, the fundamental possibility of steel smelting using a sinter is shown. A carbonaceous reducing agent, which is part of the sinter, has a positive effect on the reduction process of steelmaking. It should also be noted that the most important thing is that the agglomerate allows you to partially replace cast iron and steel scrap, significantly reducing the cost of metal.

Conclusions

1 Agglomeration makes it possible to involve in the metallurgical process of various production wastes, such as ferrous sands, sludge, mill scale, flue, and aspiration dust. The high-quality agglomerate charge prepared for smelting in the form of iron ore will make it possible to dispose of existing waste, improve the operation of furnaces, reduce dust removal, reduce the specific consumption of coke, and increase metal smelting;

2 Sintering studies made it possible to establish the optimal parameters for the sintering of ferrous sands. When using 10% fuel, the best sintering performance is achieved. The optimal parameters for sintering iron sands mixed with other metallurgical wastes are: productivity - 0.92 t / m^2 h, mechanical strength - 80.0%, sintering speed - 19.3 mm/min, yield - 82.0%, the maximum temperature in the layer is 1340 °C;

3 The results of laboratory melts carried out in an induction melting furnace indicate the possibility of using a sinter as a substitute for metal charge in steelmaking;

4 The results of the melts carried out in the ITP-0.005 induction furnace in order to assess the effectiveness of replacing scrap iron showed that the resulting iron-carbon alloy is similar in chemical composition to gray cast iron SCH15 GOST 1412-85;

5 Conducted smelting confirms the fundamental possibility of using an iron ore sinter, made from waste products of alumina production of iron sand, is a man-made charge material that is suitable for use as a 5% additive to a metal charge in the smelting of iron-carbon alloys similar in composition to cast iron. The content of harmful impurities in the resulting alloys is minimal and is: 0.009-0.026% sulfur and 0.008-0.022% phosphorus. Yield of suitable metal during melting in an induction furnace is 95.0%.

Conflict of interest. On behalf of all authors, the correspondent author declares that there is no conflict of interest.

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Бокситтерді қайта өңдеу қалдықтарынан темір кені агломератын алуды зерттеу

Жүнісова А.Қ., Быков П.О., Жүнісов А.Қ., Кенжебекова А.Е.

Торайғыров университеті, Павлодар, Қазақстан

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ТҮЙІНДЕМЕ

Бұл мақалада темірлі құм алюминий қалдықтарының агломерациясын зерттеу және болат балқыту кезінде агломератты металл шикіқұрамының орнына қолдану нәтижелері келтірілген. Қазіргі уақытта "Қазақстан алюминийі" АҚ-да бокситтерді қайта өңдеу процесінде көп мөлшерде ұсақ-түйіектер түзіледі, олар қара металлургия үшін үлкен қызығушылық тудырады. Химиялық құрамы бойынша темірлі құмдарды, құрамында алюминий мөлшері жоғары темір кенді материалға жатқызуға болады. Аталған мәселелер ұсақ-түйіекті алдын ала кесектеу – агломерациялау арқылы шешіледі. Бұл жұмыста агломерациялық зерттеулер темірлі құмдардың күйежентектеудің оңтайлы параметрлерін анықтауға мүмкіндік берді. Отынның 10 % пайдаланған кезде, агломерацияның ең жақсы көрсеткіштеріне қол жеткізілді. Басқа металлургиялық қалдықтармен қоспада темірлі құмдардың күйежентектеудің оңтайлы параметрлері келесідей болды: өнімділік - 0,92 т/ м2·сағ., механикалық беріктігі – 80,0 %, күйежентектеу жылдамдығы-19,3 мм/мин., жарамдылық түсімі – 82,0 %, қабаттағы максималды температура - 1340 °C. Индукциялық балқыту пешінде жүргізілген зертханалық балқытулардың нәтижелері шойын мен болатты балқыту кезінде металл шикіқұрамының орнына агломератты қолдану мүмкіндігін көрсетті. Жүргізілген балқытулар техногендік шикіқұрам материалы болып табылатын темір құмының алюминий өндірісінің қалдықтарынан жасалған агломератты пайдаланудың мүмкіндігін растайды, құрамы бойынша шойынға жақын темір-көміртекті қорытпаларды балқыту кезінде металл шикіқұрамға 5% қоспа ретінде пайдалануға жарамды.

Түйін сөздер: Темірлі құм, агломерат, күйежентектеу, шикіқұрамның газ өткізгіштігі, күйежентектелу жылдамдығы, металл шикіқұрамы, балқыма.

Авторлар туралы ақпарат:

Жүнісова Айгүл Қайыргелдықызы — *Докторант, Металлургия кафедрасы, Торайғыров университеті, Павлодар, Қазақстан. Email: zhunusova.aig@mail.ru*

Быков Пётр Олегович — *Техника ғылымдарының кандидаты, профессор, «Металлургия» кафедрасы, Торайғыров университеті, Павлодар, Қазақстан. Email: bykov_petr@mail.ru*

Жүнісов Абылай Қайыртасұлы — *Техника ғылымдарының кандидаты, профессор, «Металлургия» кафедрасы, Торайғыров университеті, Павлодар, Қазақстан. Email: zhunusov_ab@mail.ru*

Кенжебекова Анар Ерболатқызы — *Докторант, Металлургия кафедрасы, Торайғыров университеті, Павлодар, Қазақстан. Email: kenzhebekova_psu@mail.ru*

Исследование получения железорудного агломерата из отходов переработки бокситов

Жунусова А.К., Быков П.О., Жунусов А.К., Кенжебекова А.Е.

Торайгыров университет, Павлодар, Казахстан

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АННОТАЦИЯ

В данной статье приводятся результаты исследования агломерации отходов глиноземного железистых песков и использовании агломерата в качестве заменителя металлошихты при выплавке стали. В данное время в АО «Алюминий Казахстана» в процессе переработки бокситов образуется большое количество мелочи, представляющий для черной металлургии большой интерес. К отходам глиноземного производства относятся разнообразные отвальные шламы, среди которых красные, серые шламы и железистые пески. По химическому составу, железистые пески можно отнести железорудному материалу с повышенным содержанием глинозема. Большая часть перечисленных проблем устраняется предварительным окускованием мелочи - агломерацией. В данной работе агломерационные исследования позволили установить оптимальные параметры спекания железистых песков. При использовании 10 % топлива достигнуты наилучшие показатели спекания. Оптимальными параметрами спекания железистых песков в смеси с другими металлургическими отходами являются: производительность - 0,92 т/м^2·час, механическая прочность – 80,0 %, скорость спекания – 19,3 мм/мин, выход годного – 82,0 %, максимальная температура в слое – 1340 °С. Результаты лабораторных плавок, проведенных в индукционной плавильной печи, свидетельствуют о возможности применения агломерата в качестве заменителя металлошихты при выплавке чугуна и стали. Проведенные плавки подтверждают принципиальную возможность использования агломерата, изготовленных из отходов глиноземного производства железистого песка, является техногенным шихтовым материалом, который пригоден к использованию в качестве 5 %-ной добавки к металлической шихте при выплавке железоуглеродистых сплавов, близких по составу к чугунам.

Ключевые слова: Железистый песок, агломерат, спекание, газопроницаемость шихты, скорость спекания, металлошихта, плавка

Информация об авторах:

Жунусова АйгульКаиргельдиновна — *Докторант. Кафедра «Металлургия», Torayghirov University, Павлодар, Казахстан. Email: zhunusova.aig@mail.ru*

Быков Петр Олегович — *Кандидат технических наук, профессор. Кафедра «Металлургия», Torayghirov University, Павлодар, Казахстан. Email: bykov_petr@mail.ru*

Жунусов АблайКаиртасович — *Кандидат технических наук, профессор. Кафедра «Металлургия», Torayghirov University, Павлодар, Казахстан. Email: zhunusov_ab@mail.ru*

КенжебековаАнарЕрболатовна — *Докторант. Кафедра «Металлургия», Torayghirov University, Павлодар, Казахстан. Email: kenzhebekova_psu@mail.ru*

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