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МЕТАЛЛУРГИЯ
МЕТАЛЛУРГИЯ
METALLURGY

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ТРАНСПОРТ
TRANSPORT

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DETERMINATION OF OPTIMAL PARAMETERS OF SINTERING OF ROLLING SCALE

This article presents the results of studies conducted to determine the optimal parameters of sintering of rolled scale in a mixture with iron-containing steelmaking waste. The conducted studies of sintering of rolled scale have shown that the gas permeability of the charge depends on a number of physical properties, the size and shape of the grains, the amount of return, the height of the charge layer, and the moisture content of the charge. The initial gas permeability strongly depends on the degree of humidification of the agglomeration charge, especially when sintering small classes of materials under study. The maximum gas permeability of the charge is ensured with an optimal granulometric composition of the charge, which is characterized by an average equivalent diameter: the higher this indicator, the higher the gas permeability of the charge. The value of the surface tension reaches its maximum at a certain moisture content of the charge, which is the optimal moisture for this charge. By increasing the amount of return during agglomeration, the vertical sintering rate increases and the quality of the agglomerate improves. These factors lead to an increase in the productivity of sintering plants. According to the results of the study, the optimal parameters of the sintering sintering process of rolled scale in a mixture with iron-containing steelmaking waste were worked out. It is established that the optimal amount of return is the use of 20 % of the mass of the sintering charge at the optimal height of the sintered layer of 300 mm. As a result of the conducted research, the following optimal indicators were achieved: mechanical strength – 70.2 %, sintering rate – 28.7 mm/min, specific productivity – 1.75 t/m2 ·hour.

Keywords: Rolling scale, agglomeration, optimal parameters, sintering, return, layer height.

Introduction

Currently, two large electric steelmaking enterprises KSP Steel LLP and PB Casting LLP operate in Kazakhstan (Pavlodar). The production complex of KSP Steel LLP includes a steelmaking workshop, pipe rolling production and pipe finishing lines. The products of the second PB Casting LLP plant are steel billets, grinding balls and rods, as well as reinforcing bars [1].

In rolling production, as a result of metal compression on rolling mills (blank, long-range, hot and cold rolling), a large amount of rolling scale is formed. The formation of scale is associated with high temperatures. At high temperatures, an active chemical interaction of steel with surrounding gases occurs, as a result of which the surface layers are oxidized. The oxidized layer is scale, formed as a result of the diffusion process of oxidation of iron and impurities that make up steel [2].

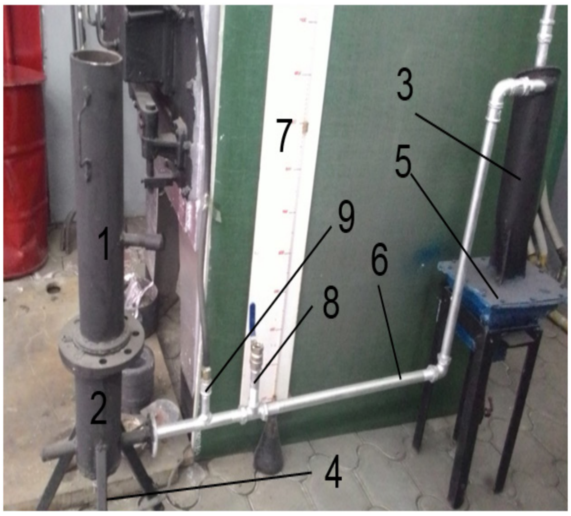
Currently, a situation has formed in the metal charge market of Kazakhstan, which has led to a significant increase in scrap metal prices, which has prompted commercial and technical services of enterprises using mainly scrap metal in steelmaking to search for alternative materials. For such electric steelmaking enterprises as KSP Steel LLP and Casting PB LLP, which have limited scrap metal resources, this problem is one of the most urgent.

World experience shows that the world pays great attention to the disposal and use of man-made waste in metallurgical processing [2]. In foreign countries, rolled scale and all waste generated at metallurgical plants are used in sintering and other industries [3, 6]. The authors of the works [7] present the results of the use of agglomerate in blast furnace production, in the production of ferroalloys, the use of which makes it possible to improve the technological and physico-chemical parameters of the process.

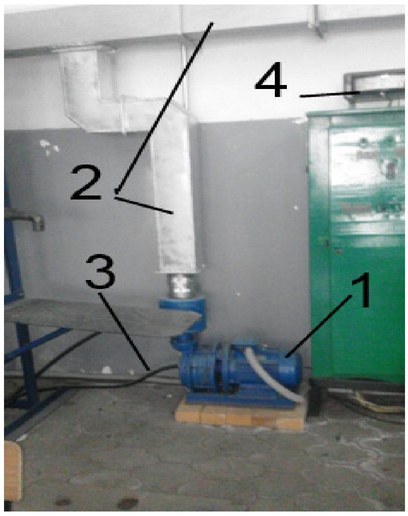
Materials and methods

Laboratory studies of the sintering of steelmaking waste mill scale were carried out using the methodology adopted in the university laboratory on an agglomeration plant. The general appearance of the agglomeration bowl is shown in Figure 1. Parameters of the agglomeration plant: diameter 100 mm, bowl height 500 mm. The agglomeration plant is equipped with a VP-1.5 vacuum pump, chromel-aluminum (CA) and vanadium-rhenium (VR) thermocouples and an automatic multi-channel temperature recorder (AMTR-6) of the sintering process (recording the temperature of the gas outlet and the layer of sintered batch).

During the research, rolling scale of a fraction of 10 – 0 mm was used as the main material. Which is represented by iron oxides Fe_2O_3, Fe^3O^4 and FeO. The chemical composition of the mill scale of materials used as additives is presented in tables 1 and 2 according to GOST 53657-2009. The chemical composition was determined in the accredited laboratory of Casting LLP and the Chemical and Metallurgical Institute named after J. Abishev.



a



b

a) 1 – Bowl; 2 – Gas receiver; 3 – Cyclone (gas cleaning); 4 – CAT Thermocouple; 5 – Dust collector; 6 – Gas pipelines; 7 – Pressure gauge; 8 – Slide gate; 9 – Connecting fitting of the pressure gauge;

b) 1 – Pump VWP-1-1.5; 2 – The chimney; 3 – Water supply; 4 – Measuring equipment.

Figure 1 – Agglomeration plant

Table 1 – Chemical composition of rolled scale, %

Name	Fe_{total}	FeO	Fe_2O_3	SiO_2	MnO	C
Scale	76.4	45.3	58.8	0,6	1.7	0.11

Aspiration dust (AD) was used in an amount of 5-10 %. This dust was used as an iron-containing additive. The final steelmaking slags of the ladle furnace unit (LFU slags) were used as a fluxing additive, in an amount of 5-10 %. Coke screenings of the 0-5 mm fraction in the amount of 5-12 in the charge were used as fuel %.

The total weight of the moistened agglomeration batch of one sintering was 3 kg. In total, 20 sinterings were carried out.

The fractional composition of the materials was determined according to GOST 27562-87. The results of the fractional composition are shown in Table 3.

Table 2 – Chemical composition of materials used as additives

Name of the material	Fe_{total}	SiO_2	MnO	Al_2O_3	MgO	CaO	S	P	C
Aspiration dust	50.4	1.2	2.3	3.3	2.7	3.6	0.02	0.002	2.9
LFU slags	1.2	22.7	1.3	2.4	3.7	54.9	0.78	-	-

It is known from the pelletizing theory [8] that grains of 0.4–1.6 mm are poorly involved in pelletizing, since on the one hand they are too large to roll, and on the other hand they are too small to serve as germ centers. During granulation, agglomeration charges are divided into three parts: lumpy (> 0.4 mm), lumpy (particles > 1.6 mm) and an intermediate fraction (grains 0.4 – 1.6 mm), located between the formed lumps of the agglomeration sheet layer. Table 3 shows that most of the rolled scale fraction is in the intermediate class (grains 0.4 – 1.6 mm). Therefore, to improve the pelletizing process of the charge, aspiration dust was used, which is included in the range of the lumped fraction. The final slags of the bucket furnace unit (LFU slag) were originally used as a fluxing additive. However, the use of these wastes also makes it possible to significantly improve the clumping ability of the agglomeration charge, since grains of less than 0.4 mm predominate in LFU slags, similar to aspiration dust.

Table 3 – Fractional composition of materials

Material	Fractional composition, %											
	-0.05	0.05	0.10	0.16	0.2	0.31	0.4	0.63	1.0	1.6	2.0	Σ, %
Rolling scale	0.7	1.9	5.0	7.2	25.7	1.5	28	12	6.1	5.7	6.9	100
Aspiration dust	0.2	0.6	2.1	26.3	38.7	2.1	9.6	8.1	0.8	0.5	11	100
LFU slags	63.5	15.2	6.3	2.5	4.3	-	2.0	1.4	0.9	1.2	2.7	100

The research was carried out according to the methodology adopted in the university laboratory. After the weight dosage of the components, the charge was thoroughly mixed, moistened and pelletized (4 min) in a disc granulator with a diameter of 1.0 m. The moisture content of the charge materials was preliminarily determined according to GOST 12764-73.

Results and discussion

During agglomeration, the initial gas permeability of the charge is of great importance, the value of which determines the entire course of the agglomeration process and, consequently, the physico-chemical properties of the resulting agglomerate and the specific productivity of the installation [9,10].

The number of returns is strictly regulated in agglomeration factories. Return is a waste product that is not included in the finished products of the factory, therefore, the greater the relative share of return in daily production, the less usable agglomerate is produced. Therefore, the development of sintering modes with a share of return in the charge plays an important role, i.e. how much return is applied to the sintering charge, so much agglomerate must be obtained from sintering. Otherwise, the balance of the agglomeration process is disrupted by the amount of return on production. If there is not enough return, the use of fuel increases, which leads to an increase in the cost of the agglomerate. With a large amount of return at the sintering plant, an excess of waste is generated that will require disposal.

The return practically does not contain carbonates and hydrates, since reactions and restorations have already partially passed in it. Hence, it follows that there is less heat demand for return than for waste and ore materials. It should also be noted that with the use of a return, the bulk weight of the charge increases and the water consumption per 1 ton of charge decreases, and the mechanical strength of the agglomerate also increases.

Thus, with an increase in the amount of return during agglomeration, the vertical sintering rate increases and the quality of the agglomerate improves. These factors lead to an increase in the productivity of sintering plants.

According to the research data presented in Figures 2 and 3 and in summary table 4, it is possible to notice a change in the main sintering parameters depending on the amount of return to the sintering rate of the sintering charge, the productivity of the installation, the strength of the agglomerate and the yield of the suitable agglomerate.

With an increase in the number of returns from 5 to 15 %, there is an increase in sintering speed and productivity. It should be noted here that in all the experiments the amount of fuel used was 10 %, because in previous sintering tests to determine the optimal amount of fuel, it was found that 10 % of coke should be considered optimal. Based on the data in Figure 2, it can be seen that with an increase in the number of returns from 25 to 35 %, there is a decrease in the sintering rate and plant performance.

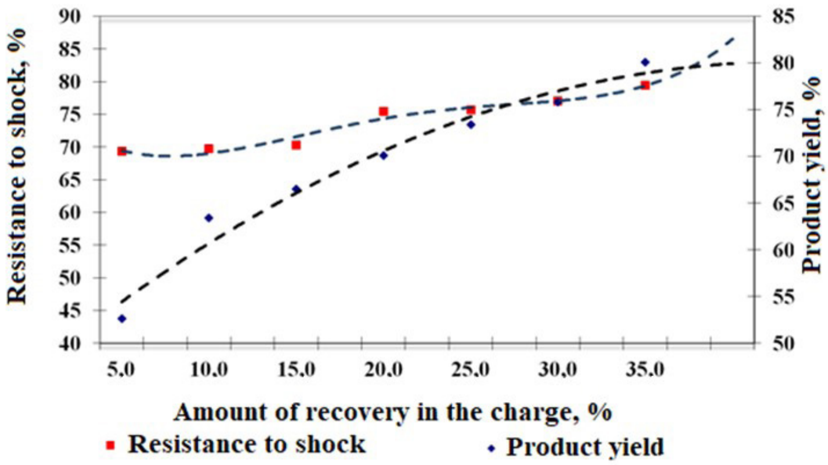


Figure 2 – The effect of changing the amount of return on the strength and yield of the suitable agglomerate

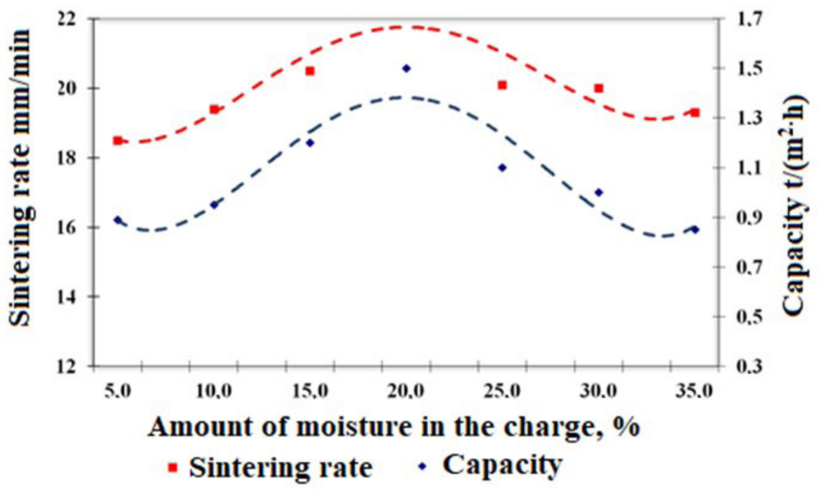


Figure 3 – The effect of changing the amount of return on sintering speed and productivity

This phenomenon can be explained by the fact that more melt is formed in the sintering charge and parameters such as sintering speed and productivity begin to decrease somewhat. It follows that a further increase in the return in the sintering charge reduces the technological parameters of sintering and cannot cover the production costs from an increase in scrap, i.e. return. As for the increase in strength and yield (Figure 3), it initially increases along with the increase in the amount of return in the charge. This is natural, since a significant mass of the charge undergoes repeated sintering. The return particles do not contain a sufficient amount of fuel, and the heating process occurs due to the fuel of the agglomeration charge. When there is too much return, which is observed in the curves of Figure 3. this circumstance begins to negatively affect the technological parameters of sintering. However, according to [9, 44 s.], if the amount of fuel is increased, the strength and yield of the fuel will increase. However, a further increase in the amount of fuel with an optimal fuel consumption of 10 % does not make sense [9, 49 s.], since the cost of the agglomerate begins to rise in price.

Table 4 – Sintering indicators when changing the amount of return

The amount of charge return, %	Sintering speed, mm/min	Productivity, $t/m^2 \cdot hour$	Strength according to GOST – 15137-87, (X)	Output of suitable, %
5	18.5	0.89	69.3	52.6
10	19.4	0.95	69.7	63.4
15	20.5	1.20	70.3	66.5
20	22.7	1.50	75.4	70.1
25	20.1	1.10	75.7	73.4
30	20.0	1.00	77.0	75.8
35	19.3	0.85	79.4	80.1

Visually, such an agglomerate with a return rate of 20 % has a fairly good porous structure. Metallized particles are observed on a piece of agglomerate, and the agglomerate is dense in structure.

Thus, according to the results of the study, it was found that the optimal amount of return is considered to be 20 % of the mass of the agglomeration charge at a fuel consumption of 10 %. The results on the optimal amount of fuel are presented in [10, 564 s.].

Another important parameter in agglomeration is the height of the sintered layer. Depending on the growth of the sintered charge layer, a decrease in the amount of sucked air is inevitably formed, i.e. there is a decrease in the vertical sintering rate. However, there is such a concept, the higher the sintered layer, the higher the air is heated before entering and into the combustion zone of solid carbon. gorenje With the best heated air, the thermal level of the agglomeration process increases, the quality of the agglomerate significantly improves, the yield of suitable agglomerate increases, and fuel consumption decreases.

Thus, an increase in the height of the agglomeration charge layer leads to a double effect, the first is a decrease in the vertical sintering rate, the second is an increase in the yield of suitable agglomerate. Therefore, as a result of experiments to determine the optimal height of the sintering layer, it is necessary to determine such a height of the sintering layer that would satisfy all the requirements of the agglomeration process.

The optimal height of the charge layer ensures the best technological sintering performance [10, 566 s.]. During agglomeration, gorenje moves downwards at a certain speed to the grate. During the heating process, the gorenje products, which have a high temperature, transfer their heat to the underlying layers. In the process, the moisture of the charge evaporates, the charge is heated to high temperatures. The sucked air is heated by passing through a molten layer of agglomerate, which is usually located in the combustion zone. Gorenje. Hence, the solid carbon in the charge and the sucked air interact. The interaction occurs due to the development of high temperature and the agglomeration process takes place quite quickly.

The optimal sintering height also depends on the physico-chemical properties of the agglomerated material and their fractional composition. Therefore, only by conducting special studies can the optimal height of the sintered layer be determined.

During the experiments, the height of the sintered layer was changed at parameters from 200 to 400 mm. Sintering parameters when changing the height of the charge layer are shown in Table 5.

When conducting studies to determine the optimal height of the sintering layer of the sintering charge, the discharge under the grate was maintained within 900-1100 mm of water. The height of the sintering layer was changed at 200, 250, 300, 350 and 400 mm.

From Figures 4 and 5, changes in technological parameters are observed when the height of the sintering layer changes. Analyzing the data in Figures 4 and 5, the best best performance was achieved at a sintered layer height of 300 mm. At a height of 300 mm, the sintering rate is 28.7 mm, productivity is 1.75 t/m3 ·hour, the strength of the agglomerate is 70.2, the yield of the usable agglomerate is 75.2 %.

An increase in the height of the charge layer to 400 mm leads to a slight decrease in the sintering rate (20.3 mm/min) and productivity (1.21 t/m2 · hour) with a slight increase in the mechanical strength of the agglomerate (75.7 %), and a suitable yield (75.4).

Visually, the agglomerate has a moderately fused structure, although it contains a few more semi-fused inclusions of rolled scale. The temperature of the gas outlet with a change in the height of the sintered layer changed from 560 °C to 620 °C. Such an increase in the temperature of the gases under the grate indicated a higher temperature in the combustion zone due to a change in the height of the layer.

Таблица 5 – Sintering parameters when changing the height of the sintering layer

The height of the charge layer, mm	Sintering speed, mm/min	Productivity, $t/m^2 \cdot hour$	Strength according to GOST – 15137-87, (X)	Output of suitable, %
200	19.6	1.09	69.3	62.8
250	22.7	1.16	69.7	67.7
300	28.7	1.75	70.2	75.2
350	22.7	1.21	75.4	75.5
400	20.3	1.10	75.7	75.4

Thus, based on the conducted research, it was found that the optimal height of the sintered charge layer is 300 mm. At the height of the sintered layer of 300 mm, the following results were obtained: mechanical strength – 70.2 %, the maximum sintering speed was reached – 28.7 mm/min, and the installation capacity was 1.75 t/m2 ·hour.

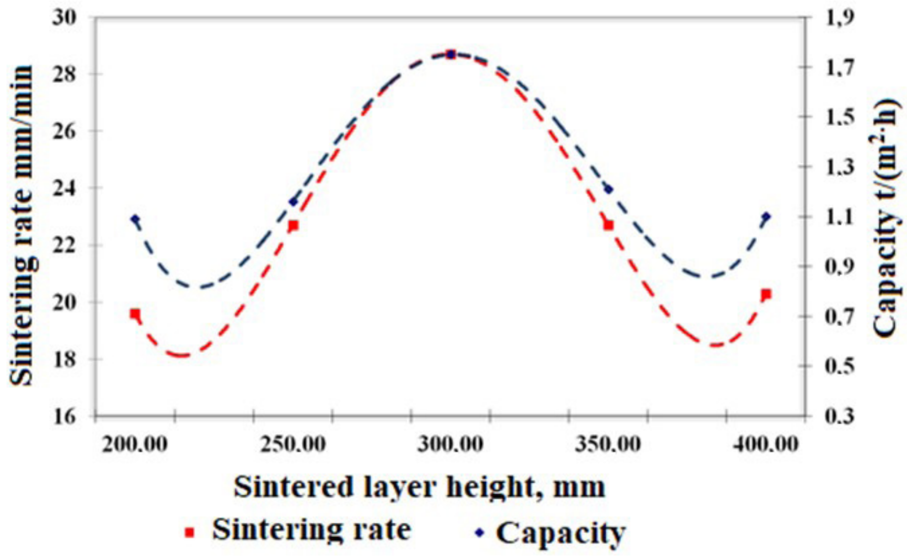


Figure 4 – Influence of the height of the sintered layer on the strength and yield of the suitable agglomerate

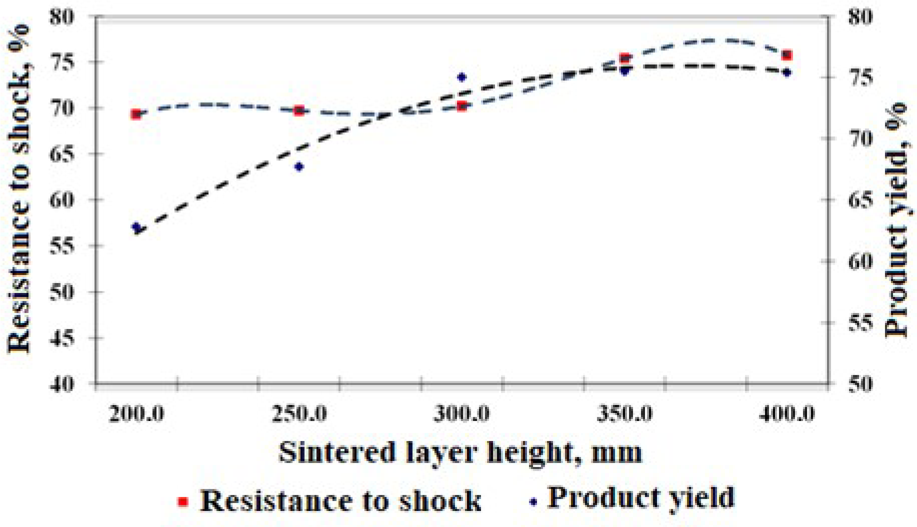


Figure 5 – Influence of the height of the sintered layer on the strength and yield of the suitable agglomerate

Conclusions

The conducted studies of sintering of rolled scale have shown that the gas permeability of the charge depends on a number of physical properties, the size and shape of the grains, the amount of return, the height of the charge layer, and the moisture content of the charge. The initial gas permeability strongly depends on the degree of humidification of the agglomeration charge, especially when sintering small classes of materials under study. The maximum gas permeability of the charge is ensured with an optimal granulometric composition of the charge, which is characterized by an average equivalent diameter: the higher this indicator, the higher the gas permeability of the charge. The value of the surface tension reaches its maximum at a certain moisture content of the charge, which is the optimal moisture for this charge. By increasing the amount of return during agglomeration, the vertical sintering rate increases and the quality of the agglomerate improves. These factors lead to an increase in the productivity of sintering plants.

Thus, according to the results of the study, the optimal parameters of the sintering sintering process of rolled scale in a mixture with steelmaking waste were worked out. As a result of the conducted research, it was found that the optimal amount of return for agglomeration of rolled scale mixed with iron-containing steelmaking waste is 20 % of the mass of the agglomeration charge at a height of the sintered layer of 300 mm. With the optimal parameters worked out, the following results were achieved: mechanical strength – 70.2 %, the maximum sintering speed was reached – 28.7 mm/min, and the installation capacity was 1.75 t/m2 ·hour.

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ОПРЕДЕЛЕНИЕ ОПТИМАЛЬНЫХ ПАРАМЕТРОВ СПЕКАНИЯ ПРОКАТНОЙ ОКАЛИНЫ

В данной статье приводятся результаты проведенных исследований по определению оптимальных параметров спекания прокатной окалины в смеси с железосодержащими сталеплавильными отходами. Проведенные исследования спекания прокатной окалины показали, что газопроницаемость шихты зависит от целого ряда физических свойств, величины и формы зерен, количества возврата, высоты слоя шихты, влажности шихты. Начальная газопроницаемость сильно зависит от степени увлажнения агломерационной шихты, в особенности при спекании мелких классов исследуемых материалов. Максимальная газопроницаемость шихты обеспечивается при оптимальном гранулометрическом составе шихты, которая характеризуется средним эквивалентным диаметром: чем выше этот показатель, тем выше газопроницаемость шихты. Величина поверхностного натяжения достигает своего максимума при определенной влажности шихты, что является оптимальной влагой для данной шихты. Увеличением количества возврата при агломерации возрастает вертикальная скорость спекания и улучшается качество агломерата. Эти факторы приводят к увеличению производительности агломерационных установок. По результатам исследования были отработаны оптимальные параметры агломерационного процесса спекания прокатной окалины в смеси с железосодержащими сталеплавильными отходами. Установлено, что оптимальным количеством возврата является использование 20 % от массы агломерационной шихты при оптимальной высоте спекаемого слоя 300 мм. В результате проведенных исследований достигнуты следующие оптимальные показатели: механическая прочность – 70,2 %, скорость спекания – 28,7 мм/мин, удельная производительность – 1,75 т/м2·час.

Ключевые слова: прокатная окалина, оптимальные параметры, спекание, возврат, высота слоя.

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ИЛЕМ ОТҚАБЫРШАҒЫН ЖЕНТЕКТЕЛУДІҢ ОҢТАЙЛЫ ПАРАМЕТРЛЕРІН АНЫҚТАУ

Бұл мақалада құрамында темір бар болат балқыту қалдықтарымен қоспада илем отқабыршағын жентектеудің оңтайлы параметрлерін анықтау бойынша жүргізілген зерттеулердің нәтижелері келтірілген. Илем отқабыршағын жентектегенде жүргізілген зерттеулер шикіқұрамның газ өткізгіштігі бірқатар физикалық қасиеттерге, дәндердің шамасы мен пішініне, қайтарылу санына, шикіқұрам қабатының биіктігіне, шикіқұрамның ылғалдылығына байланысты екенін көрсетті. Бастапқы газ өткізгіштік агломерациялық шикіқұрамның ылғалдану дәрежесіне өте тәуелді, әсіресе зерттелетін материалдардың ұсақ кластарын жентектеу кезінде. Шикіқұрамның ең жоғары газ өткізгіштігі шикіқұрамнының оңтайлы гранулометриялық құрамы кезінде қамтамасыз етіледі, ол орташа баламалы *диаметрмен сипатталады: бұл көрсеткіш неғұрлым жоғары болса, шикіқұрамның газ өткізгіштігі соғұрлым жоғары болады. Беткі тартылу шамасы шикіқұрамның белгілі бір ылғалдылығы кезінде өзінің максимумына жетеді, бұл осы шикіқұрам үшін оңтайлы ылғал болып табылады. Агломерация кезінде қайтару санының ұлғаюымен пісірудің тік жылдамдығы артады және агломераттың сапасы жақсарады. Бұл факторлар агломерациялық қондырғылардың өнімділігін арттыруға алып келеді. Зерттеу нәтижелері бойынша құрамында темір бар болат балқыту қалдықтарымен қоспада илем отқабыршағын жентектеудің агломерациялық процесінің оңтайлы параметрлері пысықталды. Жентектелген қабаттың оңтайлы биіктігі 300 мм болған кезде агломерациялық шикіқұрамның массасы 20 % -ын пайдалану қайтарудың оңтайлы мөлшері болып табылады. Жүргізілген зерттеулер нәтижесінде мынадай оңтайлы көрсеткіштерге қол жеткізілді: механикалық беріктігі – 70,2 %, жентектеу жылдамдығы – 28,7 мм/мин, меншікті өнімділігі – 1,75 т/сағ.*

Кілтті сөздер: илем отқабыршағы, оңтайлы параметрлері, жентектеу, қайтару, қабаттың биіктігі.

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