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Metallurgy

An annealing-free method for processing high-moisture iron-containing sludge of metallurgical production

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ABSTRACT

The purpose of this study was to study the possibility of producing high-strength briquettes from high-moisture iron-containing slimes by hydration with quicklime (chemical dehydration) in combination with dolomite dust from a degusting system and carbon-containing pulverized materials and developing a drainless technology for the production of complex self-healing briquettes. The physicochemical conditions of the hydration process, temperature and time parameters of the process were studied, and the choice of active dehydrating materials significantly increased the degree of hydration of the composite system and their optimal ratios, and the period of the beginning and end of self-hardening were determined. The conditions of combining the processes of dehydration, and self-hardening with the processes of melding, when applying external pressure to a hardening mixture in a meld to obtain a coated material in the form of a briquette in one technological cycle are considered, which is one of the main provisions of the scientific novelty of the proposed method. Optimal conditions for the production of high-strength briquettes suitable for metallurgical production technologies, excluding the stages of thermal drying and firing, have been established, and a set of strength properties occurs in the air. The method allows obtaining a self-healing dipped material by introducing a carbon-containing reducing agent into a slurry-lime self-hardening mixture. Cheap waste pulverized limestone and dolomite roasting wastes are used as a dehydrating material, and pulverized carbonaceous materials (coke and coal screenings) are used as a reducing agent. Unlike well-known technical solutions, the proposed technology and the method incorporated in it eliminates the storage of iron-containing sludge in a sludge storage facility and allows you to organize a drainless scheme of non-annealing and the production of complex self-healing iron-containing material for the production of steel and rolled products. The technology will make it possible to organize production for the processing of high-moisture iron-containing sludge, pulverized calcium- and magnesium-containing and carbon-containing pulverized waste and also solves the problems of environmental pollution and land allocation for the storage of industrial waste.

Keywords: sludge, dust, processing, dehydration, pelletizing, briquetting.

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Introduction

The "Green Industry" is becoming a new trend that ensures the implementation of the concept of sustainable development [[1], [2]]. Despite the popular opinion that metallurgy is a "dirty" industry, large companies, over the past decades, have been implementing and developing new environmentally friendly solutions, improving production processes. Today, two main directions can be identified in which metallurgy is moving towards increasing the environmental friendliness of production:

- development of technologies aimed at reducing harmful emissions and cleaning production processes;

- closure of the production cycle, when various materials and resources are used several times or sold for further processing.

Creation of a closed cycle, in terms of emissions into the atmosphere and wastewater or secondary raw materials. The transition to low-waste technologies within the framework of the closed-loop concept is the most difficult and most important part of the "green industry" [[1], [2], [3],

[4]]. The metallurgical industry is one of the largest sources of formation of significant volumes of large-tonnage mineral waste with various compositions and is accompanied by the formation of a significant amount of various wastes, reaching 30% of steel production. It consists of about 80% slag and about 20% dust and other waste. At the same time, waste is often technologically superior to iron ore materials extracted from the subsurface. However, despite its high resource potential, waste from the mining and metallurgical industries in Kazakhstan is mainly used as raw materials for the construction industry, but even here the volume of recycled material does not reach 10% of the annual volume of education. The utilization of man-made waste can not only contribute to saving resources, i.e. obtaining an alternative source of raw materials, but also reduce environmental pollution. In addition, the integrated use of man-made waste can potentially reduce production costs and increase economic benefits.

One of the most problematic areas is the technology of storing high-moisture waste from metallurgical production in tailings dumps. For example, iron-containing sludge is sent through multi-kilometre sludge pipelines to a tailings dump in the form of pulp with a solid: liquid 1 mass ratio: 2. The technology requires significant costs for transporting the pulp to the tailings pond and returning the clarified water after settling into the technological cycle [[5], [6], [7], [8]]. Due to the lack of effective dewatering and fumigation technologies, these materials are usually stored in tailings dumps, where they are mixed with other slurries and dust and their metallurgical value is lost. On the other hand, at full-cycle metallurgical enterprises, when calcining limestone and raw dolomite, a large amount of finely dispersed calcium and magnesium-containing waste is formed in the form of lime and dolomite dust, which are excellent dehydrating and binding materials and, as a rule, these materials are not in demand and are stored in ash and sludge storages. Taking into account the emerging trend of reducing the total iron content in natural iron ore concentrates (45-50%), an alternative secondary raw material can be an iron-containing oxidized material obtained from high-moisture iron-containing sludge and pulverized waste from lime production and firing of crude dolomite to partially replace iron ore concentrate. This approach will reduce the need for natural iron ore and flux materials. This is possible if there is a technology for preparing sludge for metallurgical processing. In Kazakhstan, millions of tons of ash and sludge waste from various industries are deposited in sludge storages, forming man-made deposits of iron-containing and fluxing materials that can serve as secondary metallurgical raw materials and a partial substitute for natural iron ore raw materials. In addition, they are usually located near metallurgical enterprises.

Literature review

Until now, tailings disposal has remained the only common treatment option for this sludge other than recycling, but if recycled, these iron oxides have the potential to provide significant economic benefits. The technology under consideration for storing “liquid” waste from metallurgical production has several disadvantages: high one-time capital costs for the construction and operation of slurry pipelines and tailings dumps; there is a high probability of migration of harmful chemicals into groundwater if the protective screens of the base and sides of the tailings dump are damaged.

The known technology for storing ore enrichment waste in underground workings and tailings with the use of a hardening agent additive allows the use of underground workings of the enterprise with production capacity for storage [[5], [6]].

Reducing the risk to the environment by storing high-moisture metallurgical waste in underground goaves and tailings with the addition of a hardener solves important scientific, practical and social problems. This is achieved by hardening hazardous ingredients, selecting the compositions of hardening mixtures and converting them into a solid state [[6], [7], [8]].

In world practice, technologies for agglomerating mineral sludge by cold briquetting under pressure are known, based on the use of binders made of powdered materials [[9], [10], [11], [12], [13], [14], [15], [16]]. The wet sludge is mixed with suitable binding materials to obtain a homogenized mixture. The finished mixture is fed into a briquette press and after applying pressure to the mold, a briquette is obtained, which is subjected to heat treatment and firing.

Briquetting provides wide opportunities for recycling fine waste; it is also promising from the point of view of obtaining a metallized product since reducing agents can be introduced into the briquetted charge [[19], [20], [21], [22], [23], [24], [25], [26], [27]].

The advantages of briquetting are that this method makes it possible to obtain standard products with adjustable sizes and technological properties from the waste of various chemical compositions and properties, increase the density of bulk materials, prevent freezing and caking of finely dispersed waste in bins and dosing equipment, and reduce dust during transportation and use. The efficiency of using useful components in briquettes is significantly higher than in any other state (in a fine or polydisperse fraction, in sorted form). Compared to agglomeration and pelletizing, briquetting of iron-containing waste has several advantages:

- briquettes have the same shape and weight, are characterized by a high iron content, density and strength, and better transportability;
- all the oxygen in the briquette remains active, while in the agglomerate it is in a bound state (in the form of silicates), which is especially important for blast furnace production;
- environmental safety of briquetting: waste-free, no high temperatures during production;
- the possibility of using carbon-containing filler in a briquette in any ratio to activate processes in a metallurgical furnace (carburizing, reducing agent, energy carrier);
- the possibility of recycling all types of fine waste from metallurgical production.

To reduce moisture when processing sludge, thermal drying is traditionally used, which quickly reduces the moisture content in the sludge [[10], [15], [21], [27]]. Sludge dewatering by hydration of calcium and magnesium-containing materials (chemical dewatering), as a new processing technology, has the advantage of energy saving and environmental protection and its ability to reduce the volume and quantity of sludge. This method makes it possible to obtain hardened material without thermal firing [[28], [30], [31], [32]].

There are known studies on the hardening of sludge from wastewater treatment plants by hydration using cement and lime [[28], [29], [30], [31], [32]]. Cement and lime are mixed with the sludge in certain proportions to dewater the sludge and harden it. It was established that the rate of sedimentation and dewatering of the hardened sediment depended on the ratio of hardener to sludge. The higher the ratio, the more obvious the dehydration effect, and the maximum dehydration reduction value is 13%.

Currently, chemical curing is a more advanced sludge treatment method. The method eliminates the problems of low efficiency and severe pollution of traditional methods of storing sludge in a sludge reservoir or sludge fields [[28], [29], [30], [31]]. The principle of hydration of wet tailings with cement was incorporated in the above-mentioned technology of storage in abandoned mines [[5], [6], [7], [8]].

When disposing of man-made waste from metallurgical production, non-firing methods of agglomeration are increasingly effective, which have fundamental advantages in comparison with high-temperature methods of thermal drying. This is expressed in high technical and economic indicators (cost, capital and current costs, energy consumption, etc.) and environmental indicators (3-5 times reduction in the degree of environmental pollution) [[17], [18], [19], [21], [26]].

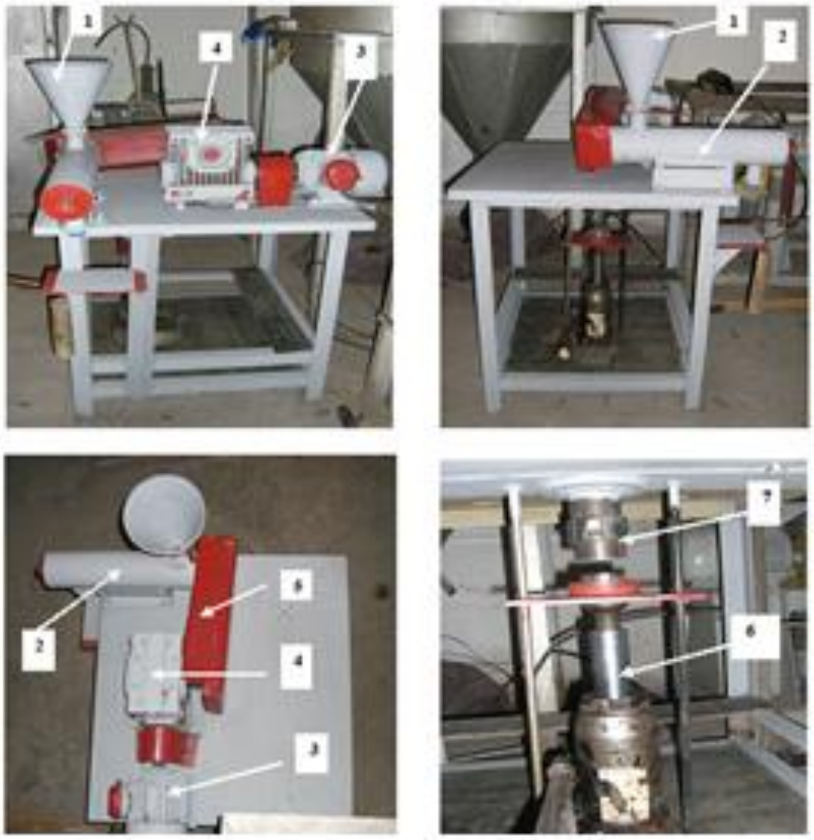
Once cured, the product must have mechanical resistance to allow some basic work such as transport and oven loading and the type of binder plays an important role. Regardless of the chosen binder, a reliable briquette should retain all of the above-mentioned properties as much as possible.

The purpose of this study was to study the possibility of producing high-strength briquettes from high-moisture iron-containing slurries by hydration with quicklime powder (chemical dehydration) in combination with dolomite dust from the dust removal system and carbon-containing dust materials and developing a drainless technology for the production of complex self-healing briquettes.

Research Methodology

When carrying out this work, we proceeded from the condition of developing a technology for the chemical dehydration of iron-containing sludge with a moisture content of 60-90%, obtaining sludge-lime mixtures without the use of complex equipment and the use of lime and dolomite dust, which are secondary material resources.

To study the processes of combining the operations of dewatering, self-hardening and agglomeration of iron-containing sludge, a laboratory installation was developed (Fig. 1) and experiments were carried out to study the conditions that ensure the production of iron-containing briquettes suitable for use in steel production.



1-receiving hopper (funnel); 2 - screw mixer (activator); 3 – electric drive; 4 - reducer;
5 - belt drive; 6 - hydraulic press; 7 - cylindrical mold

Fig. 1 - Scheme of a laboratory plant for cleaning converter gas-rich, briquetting iron-containing sludge

Table 1 - Fractional composition of components

Component	Content, % by fraction, mm							
	>2.5	1.6-2.5	1.0-1.6	0.63-1.0	0.1-0.63	0.063-0.1	0.05-0.063	<0.05
Converter sludge	-	-	-	7,8	27,2	2,8	1,2	61,0
Lime dust	15.8	11.9	10.7	7.9	23.7	11.9	13.8	4.3
Dolomite dust	-	2.0	3.3	4.0	16.0	34.0	13.3	27.4

Mixing was done manually, and the volume of materials used was measured using measuring containers. During the mixing and holding process, the temperature was measured, the time was recorded and the rate of dehydration of the mass was calculated. The mixing process lasted 5-10 minutes until a homogeneous mass was obtained.

Molding was carried out on a laboratory hydraulic press with a force of 125, 180 and 280 kN.

As source material for the preparation of slurry-lime mixtures and briquettes, converter sludge with a moisture content of 60-90% was used, taken from the slurry pipeline at the time of its pumping from radial settling tanks to the ash and sludge storage tank.

For chemical dehydration of the initial sludge, lime dust from gas purification of the KS-1000 furnace and dolomite dust from a rotary kiln were used. In the process of research in laboratory conditions, the physicochemical properties of converter sludge taken from the slurry pipeline at the time of pumping, lime and dolomite dust, and lime-slurry mixtures were studied (Table 1, 2).

When preparing experimental mixtures, the volumetric ratio of converter sludge, lime and dolomite dust varied from 0.5 to 2.0 parts by volume (Table 3).

Table 2 - Average chemical composition of components, %

Component	$C_{общ}$	$Fe_{общ}$	CaO	$CaO_{акт}$	SiO_2	MgO	MnO	AL_2O_3	P	S	п.п.п	Прочие
Converter sludge	2.60	55.60	16.40	-	2.10	2.05	1.27	1.87	0.60	0.25	10.50	7.79
Lime dust	-	-	84.90	68.0	-	0.77	-	-	-	0.02	11.0	3.31
Dolomite dust	-	5-6	44.50	-	3.71	26.52	-	1.74	-	-	15.00	7.77

Table 3 - Composition of sludge-lime mixtures

Mixture number	Content, volume fractions		
	Converter sludge	Lime dust	Dolomite dust
1	1.0	1.0	-
2	0.5	1.5	-
3	0.5	-	1.5
4	1.0	1.0	0.5
5	1.0	1.5	0.5
6	1.0	2.0	0.5
7	0.5	1.0	-
8	0.5	1.5	-
9	0.5	2.0	-

After mixing these components, various technological parameters of the resulting mixtures were determined: humidity, temperature, dehydration rate, and hardening time.

Briquettes with a diameter of 50 mm and a height of 60 mm were prepared from slurry-lime mixtures using a mechanical press at loads of 125, 180 and 280 kN/briquette. After keeping the briquettes in natural conditions for 1.5 and 15 days, their strength was assessed by crushing in a press.

Research results

The process of chemical dehydration (hydration) of converter sludge with lime and dolomite dust is characterized by an exothermic reaction between active CaO and excess moisture in the sludge. The process was accompanied by an increase in system temperature. As the research results have shown, the change in the rate of dehydration is directly proportional to the change in temperature during the process of mixing sludge pulp with dewatering components and holding, which made it possible to develop a new method for assessing the degree of chemical dehydration. The technique makes it possible to study the mechanism and kinetics of the chemical dehydration process based on the nature of changes in the temperature of the mixture.

According to the colloid-chemical theory of hardening, the chemical transformations that occur when mixing lime with sludge of high humidity are described by the following reaction:

$$3CaO \cdot SiO_2 + 4{,}5\ H_2O = CaO \cdot SiO_2 \cdot 2{,}5H_2O + 2Ca(OH)_2 \quad (1)$$

The curing process of the system is purely physical and mechanical. Calcium hydrosilicate is very slightly soluble in water, and remains in a colloidal state for a long time, gradually recrystallizing, and then compacting and strengthening. The cement paste acquires cohesion and strength and turns into a solid monolithic body. Chemical processes are completed sometime after the interaction of the binder, in our case pulverized lime, with sludge water to form a fragile loose mass.

Its transformation into a stone-like body occurs due to the formation of a crystalline intergrowth of calcium hydroxide and hydrosilicates. The hardening period is the longest and is characterized by a slight release of heat.

When the binder, in our case pulverized lime, comes into contact with excess moisture from the sludge, there is a so-called preparatory period, during which a saturated solution is formed. The heating of the mixture at this moment is insignificant, since the dissolution process is endothermic. Upon reaching saturation, the cement paste quickly heats up due to the hydration reaction.

It has been established that chemical dehydration of sludge pulp occurs through a two-stage mechanism. The first stage the process is characterized by an exothermic reaction of interaction of the dehydrating component with water with the formation of calcium hydroxide with water according to reaction (2) and occurs in the kinetic region, accompanied by an increase in temperature and rate of dehydration.

$$CaO + H_2O = CaO(OH)_2 \quad (2)$$

It has been established that the first stage of chemical dehydration, i.e. chemical binding of moisture ends with a maximum increase in temperature (Fig. 2).

Depending on the mineralogical and dispersed composition, the initial moisture content of the sludge and the mixing speed, the intensity and speed of hydration changes.

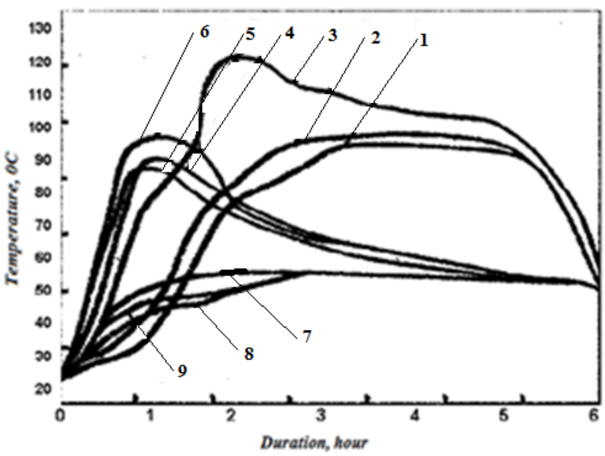


Fig. 2 - The nature of the temperature change during solidification of the slurry-lime mixture

The heat released as a result of the exothermic reaction goes to evaporate moisture. As the research results have shown, at this stage the bulk of the moisture is removed and an increase in the rate of dehydration is observed, which ends when the maximum temperature of the mixture is reached (Fig. 2). The intensity of this chemical interaction depends on the degree of mixing and the maximum area of contact of the reacting substances and the activity of CaO. In this case, the surface of the adsorbed layer of lime particles is deformed, and a more durable crystalline structure of Ca(OH)2 is formed, which cements the resulting sludge-lime mass, and also makes it possible to obtain strong briquettes from this mass. At this point, the moisture content of the mixture is 15-25% and a further decrease in the moisture content of the mixture occurs according to the law of molecular diffusion with a falling rate of dehydration and temperature of the mixture.

Further binding of residual moisture is controlled by the diffusion transport of water molecules through a thin diffusion boundary layer that forms on the surface of the dehydrating material particles. The surface, boundary layer consists of crystallized calcium hydroxide and carbonate, formed as a result of the reaction of calcium hydroxide absorbing carbon dioxide from the surrounding atmosphere according to reaction (3)

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O \quad (3)$$

At the second stage of dehydration, hardening of the mixture begins, caused by supersaturation of the wet mixture with calcium hydroxide. Crystallization centers are metal particles of sludge (iron oxides). Crystals of calcium hydroxide and calcium carbonate coalesce with other oxides present in the sludge into a relatively strong and hard mass.

Thus, the second stage of chemical dehydration generally determines the total duration of obtaining a semi-dry solid mass of sludge-lime mixture suitable for transportation and further disposal in the charge of the sintering or converter process. It has been established that the intensity of chemical dehydration, i.e. the duration of the first and second stages depends on the type of dehydrating materials, the activity of CaO, MgO in it, its fractional composition, as well as the degree of mixing of the main components.

The use of pure pulverized lime as a dehydrating component with a CaO content of at least 60% (compositions No. 7-9) is characterized by a low dehydration rate (Fig. 2). The residual moisture after the first stage is (35-40%), and hardening of this mixture continues for more than 12 hours.

The use of one pulverized lime with active CaO (75-80%) is characterized by a higher rate of dehydration (compositions No. 1-2) and a residual moisture content of 20-30%. The total time for dehydration and hardening of the mixture is 6 hours, obtaining a residual moisture content of 18-20%.

Treatment of slurry pulp with pure dolomite dust, although it reduces the duration of the first stage of dehydration to 2 hours and the residual moisture before the hardening process to 15-17%, but the sludge-lime mixture turns out to be selfdisintegrating. After 24 hours it crumbles with subsequent dusting and cannot be used in metallurgical production technology.

The best results were obtained when treating slurry pulp with a moisture content of 60-90% with a mixture of pulverized lime and dolomite (compositions No. 4-6). This reduces the duration of the main stage of dehydration until the beginning of the hardening period of the mixture. The total duration of dehydration and hardening is 3 hours. получением влажности твердой массы 10-15 %.

Treatment of sludge with lime and dolomite dust intensifies the process of chemical dehydration, which is confirmed by a higher level of temperature rise and rapid hardening of the sludge-lime mixture. This is explained by the presence of dolomite dust, in addition to CaO (45%) and the presence of MgO in it up to 27%. In addition, in dolomite dust, in addition to CaO and MgO, there are clay components - AL_2O_3, SiO_2, and Fe_2O_3, which form silicates with CaO and MgO, aluminates and ferrites of calcium and magnesium, which have high astringent properties. These compounds, when in contact with water, quickly harden in air and contribute to the formation of a fast-hardening slurry-lime mixture.

Since after the completion of the first stage of dehydration a paste-like mass with a residual moisture content of 16-30% is obtained, the possibility of combining the stages of dehydration, self-hardening and agglomeration in one technological cycle was studied

The compressive strength of briquettes produced by pressing with a force of 125, 180 and 280 kN had 94, 265 and 505 kN/cm2, respectively, and density, respectively, 2.7 kg/cm3. The number of fines less than 5 mm falling onto a steel plate from a height of 2 m was 0.6%.

Moreover, those made using dolomite dust (compositions No. 4 and No. 5) were distinguished by increased strength compared to briquettes using pure lime dust.

The humidity of the briquettes after 24 hours was 9%, and after 15 days it was in the range of 0.3-0.5% and did not lose their shape. Moreover, the strength of the briquettes practically did not change during their ageing process, and they turned out to be quite suitable for transportation via conveyor systems and transfers of charge supply paths.

If we consider the economic aspect of the proposed technology, then the most acceptable for production are compositions No. 4 and No. 5, which do not require large amounts of lime and dolomite dust.

Discussion of the research results

As shown by the results of experiments on combined chemical dehydration, self-hardening and molding processes, the strength of the resulting briquettes is affected by the heat release process in the first stage of hydration. It has been established that the maximum strength of briquettes is obtained by pressing the sludge-lime dough at the moment the mixture reaches its maximum temperature. Briquettes made earlier than this moment had low strength, which, apparently, is explained by their destruction under the influence of thermal stresses and steam release during the period of intense heating. An even greater decrease in the strength of briquettes is observed during pressing much later than the maximum heat release, probably due to the loss of thixotropic properties by the hydration products.

Research results have shown that the optimal moisture content of the charge required for the production of high-quality briquettes from iron-containing sludge should not exceed 15-20%.

A distinctive feature of the proposed method of agglomeration from all known ones is the use of the synergistic effect of moisture hydration by active calcium and magnesium oxides, accompanying self-hardening of lime paste sludge and combination with the briquetting process. New patterns have been established that have made it possible to develop a non-firing method for obtaining agglomerated material in the form of self-healing briquettes from iron-containing sludge and waste dusty materials (lime and dolomite dust and carbon-containing dust).

The proposed technology does not require drying or firing, and strength properties are gained when the material is cooled in air for 24 hours.

The established patterns of chemical dewatering of iron-containing sludge with dust-like waste from the production of lime and dolomite made it possible to develop a drainless technological scheme for the production of iron-containing briquettes (Fig. 3).

A closed sludge recycling cycle is envisaged, in which the water will be drained for reuse, and the condensed sludge will be used in full to prepare a sludge-lime mixture.

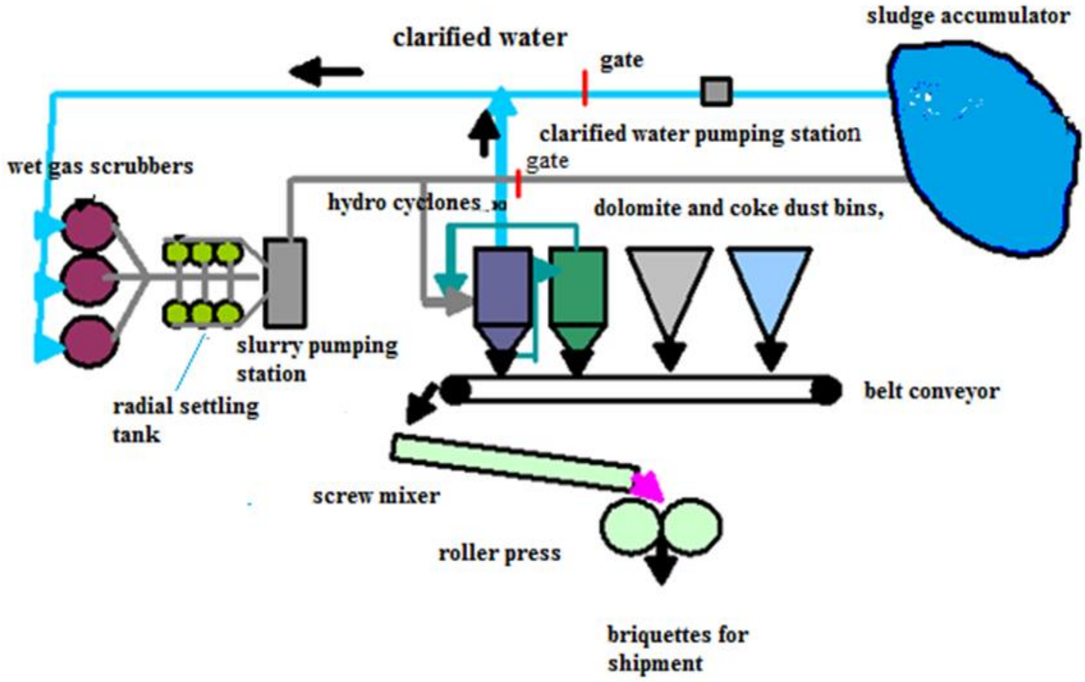


Fig. 3 - Technological scheme for the production of sludge-lime briquettes for converter production
Note: The drawing was created by the author

Currently, pumps pump converter sludge from radial settling tanks to the ash and sludge storage tank three times a day, 650 m3 each, which is about 2000 m3 per day. The interval between pumping sludge is 5-7 hours. The main technological operations will take place in this interval.

The positive side of this method is that there is no need to wait for the sedimentation of solid particles of sludge, as is used in settling tanks; the entire technological process of preparing for sludge disposal occurs while pumping the sludge through the sludge pipeline. The estimated moisture content of sludge after hydrocyclones is about 50%.

Drainless technology is carried out as follows. Slurry from wet gas cleaning technology or systems is pumped directly to the proposed installation (Fig. 2), to a dewatering unit, where the slurry is dewatered in pressure hydroclones GNS-500 and GNS-250, to a moisture content of 40-50%. The condensed sludge is sent to a conveyor, where pulverized lime and/or pulverized dolomite, as well as screening of coke breeze or pulverized coal, are dosed. Materials from the conveyor are fed into a two-roll screw mixer-activator, where the processes of mixing and chemical dehydration are carried out. From the mixer, the dehydrated heated sludge-lime mixture enters a press (roller or vibropress), where the processes of final hardening and molding occur and at the output we obtain agglomerated material in the form of a briquette with a moisture content of 5-9%. Briquettes are stored on pallets for cooling at ambient temperature. Clarified water from the hydrocyclone is pumped out and returned to the technology.

The performed technical and economic calculations showed that the construction of the site and the use of the slurry-lime mixture in the sinter production charge according to the proposed method of chemical dehydration of waste from the production of lime and dolomite, with the disposal of 70 thousand tons of converter sludge, will save 52.5 thousand tons of iron ore annually, 2. 8 thousand tons of manganese ore, 7.0 thousand tons of fuel equivalent and 21.0 thousand tons of limestone. The effect is achieved by saving iron ore materials and replacing them partially with iron contained in sludge and lime, as well as by reducing budget payments for environmental pollution.

The proposed technology makes it possible to create a closed water supply system not through a purification pond (sludge reservoir), but through the proposed installation, which significantly reduces water consumption, labor and energy costs for transporting the pulp through many kilometres of slurry pipelines to the sludge reservoir and returning clarified water to the technology, as well as the costs of maintaining slurry pumps, slurry pipelines and sludge accumulators.

Thus, iron ore slurry in the form of agglomerated composite material can be used as a substitute iron ore concentrate in end-to-end technology for smelting steel and cast iron. There is no need to allocate land for sludge storage and achieve more complete recycling of industrial waste.

The proposed project is the basis for the creation of closed metallurgical environmentally friendly resource-saving processes that solve not only the problems of raw materials and maximum involvement of waste in economic circulation but also environmental problems of production.

The competitiveness of the proposed technology compared to other analogues is as follows:

- transportation and storage of sediments in a sludge storage tank is eliminated;
- labour and energy costs for transportation and storage of sludge, maintenance of slurry pumps, slurry pipelines and sludge accumulators are reduced;
- there is no need to dry the sludge before agglomerating and firing iron ore briquettes;
- organizing a one-stage process of dehydration, self-hardening and molding to produce complex iron-carbon-containing agglomerated material in one production cycle;
- dispose of waste dusty waste from burning lime and dolomite, as well as screenings of coke or coal.

This version of the technology was introduced at ArcelorMittal Temirtau JSC in the water supply shop for the dewatering of oil-containing and iron-containing waste from rolling production (oily scale) using powdered lime and dolomite dust to produce lime scale for sintering production [33].

Conclusion

The study of the physicochemical conditions of hydration processes, temperature and time parameters of the process made it possible to select active dehydrating materials and their optimal ratios, which significantly increase the degree of hydration of the composite system and the period of the beginning and end of self-hardening. The conditions for combining the processes of dehydration, and self-hardening with molding processes when applying external pressure to the hardening mixture in a mold with the production of agglomerated material in the form of a briquette in one technological cycle are considered, which is one of the main provisions of the scientific novelty of the proposed method. Optimal conditions have been established for the production of high-strength briquettes suitable for metallurgical production technologies, excluding the stages of thermal drying and firing, and the development of strength properties occurring in air.

The method makes it possible to obtain self-healing agglomerated material by introducing a carbon-containing reducing agent into a self-hardening slurry-lime mixture. Cheap waste materials are used as dewatering material dusty waste from burning limestone and dolomite, and dusty carbon-containing materials (coke and coal screenings) as a reducing agent.

In contrast to known technical solutions, the proposed technology and the method incorporated in it eliminates the storage of iron-containing sludge in a sludge storage facility and makes it possible to organize a drainless scheme of non-firing agglomeration and the production of complex self-healing iron-containing material for the production of steel and rolled products. The technology will make it possible to organize production for the processing of high-moisture iron-containing sludge, dusty calcium- and magnesium-containing and carbon-containing dusty waste and also solve the problems of environmental pollution and land acquisition for storage of production waste.

The proposed technology solves not only technological, but also environmental problems: reducing environmental pollution and land allocation for storage of industrial waste, reducing environmental charges for waste storage, as well as pollution of off-balance and groundwater.

The self-hardening properties of sludge when treated with dewatering materials based on industrial waste can also be implemented for the disposal of hazardous sludge waste, for example in abandoned mines. This will prevent contaminated water from entering water bodies while eliminating the need for the construction and maintenance of ash and sludge storage tanks without the danger of breaking dams and flooding adjacent arable lands.

Ash and sludge waste dewatered using the proposed method can be used for landscape work, as well as in the industry for the production of various building materials.

Conflict of interest. The authors declare that they have no conflict of interest about this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this paper.

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Металлургиялық өндірістегі ылғалдылығы жоғары темірі бар шламды күйдірмей өңдейтін әдіс

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ТҮЙІНДЕМЕ

Бұл зерттеудің мақсаты шаңды кетіру жүйесіндегі доломит шаңымен және құрамында көміртегі бар шаң материалдарымен үйлесімде сөндірілмеген әк ұнтағымен гидратация (химиялық сусыздандыру) арқылы ылғалдылығы жоғары темірі бар шламдардан беріктігі жоғары брикеттерді алу мүмкіндігін зерттеу және осы негізде өздігінен қалпына келетін кешенді брикеттерді өндірудің ағынсыз технологиясын жасау болды. Гидратация процесінің физика-химиялық жағдайлары, процестің температуралық-уақыттық параметрлері зерттелді, композиттік жүйенің гидратация дәрежесін айтарлықтай арттыратын белсенді сусыздандыру материалдарын таңдау және олардың оптималды арақатынастары, басталу мен аяқталу кезеңі және өздігінен қатаюы анықталды. Бір технологиялық циклде брикет түріндегі агломерацияланған материалды өндірумен қалыптағы қатайтатын қоспаға сыртқы қысым түсіру кезінде сусыздандыру, өздігінен қатаю процестерін қалыптау процестерімен біріктіру шарттары қарастырылады, бұл ұсынылған әдістеменің ғылыми жаңалығының негізгі ережелерін құрайды. Термиялық кептіру және күйдіру кезеңдерін қоспағанда, металлургиялық өндіріс технологияларына жарамды беріктігі жоғары брикеттерді өндіру үшін оңтайлы жағдайлар белгіленді және беріктік қасиеттерінің жиынтығы ауада қалыптасады. Әдіс құрамында көміртегі бар тотықсыздандырғышты өздігінен қататын суспензия – әк қоспасына қосу арқылы өздігінен түзілетін агломерацияланған материалды алуға мүмкіндік береді. Құрғататын материал ретінде әктас пен доломитті күйдіргеннен қалған ұнтақталған арзан қалдықтар, ал тотықсыздандырғыш ретінде құрамында көміртегі бар материалдар (кокс және көмір скринингтері) пайдаланылады. Белгілі техникалық шешімдерден айырмашылығы, ұсынылған технология мен оған енгізілген әдісте шлам қоймасында темірі бар шлам сақталмайды және күйдірмейтін агломерацияның ағынсыз схемасын ұйымдастыруға және болат пен прокат өндіруге арналған құрамында темірі бар өздігінен қалпына келетін материалды өндіруге мүмкіндік береді. Технология ылғалдылығы жоғары темірі бар шламды, құрамында кальций мен магнийі және көміртегі бар шаңды қалдықтарды өңдеу бойынша өндірісті ұйымдастыруға мүмкіндік береді, сонымен қатар қоршаған ортаны ластамау және өндірістік қалдықтарды сақтау үшін қажетті жерді алу мәселелерін шешеді.

Түйін сөздер: шлам, шаң, өңдеу, сусыздандыру, агломерация, брикеттеу.

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Безобжиговый способ переработки высоковлажных железосодержащих шламов металлургического производства

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АННОТАЦИЯ
Целью данного исследования было изучить возможность производства высокопрочных брикетов из высоковлажных железо-содержащих шламов гидратацией негашеной пылевидной известью (химическое обезвоживание) в комбинации с доломитовой пылью из системы обеспыливания и углеродсодержащих пылевидных материалов и разработки на этой основе бессточной технологии производства комплексных самовосстанавливающих брикетов. Исследованы физико-химические условия процесса гидратации, температурно-временные параметры процесса, определен выбор активных обезвоживающих материалов значительно повышающих степень гидратации композитной системы и их оптимальных соотношений, период начало и конца самоотвердения. Рассмотрены условия совмещения процессов обезвоживания, самоотвердения с процессами формования при приложении внешнего давления к твердеющей смеси в пресс-форме с получением окускованного материала в форме брикета в одном технологическом цикле, что составляет одно из основных положений научной новизны предложенного способа. Установлены оптимальные условия получения высокопрочных брикетов пригодных для технологий металлургического производства, исключающих стадии термической сушки и обжига, а набор прочностных свойств происходит на воздухе. Способ позволяет получать самовосстанавливающий окускованный материал введением в шламоизвестковую самотвердеющую смесь углеродсодержащего восстановителя. В качестве обезвоживающего материала используются дешевые бросовые пылевидные отходы обжига известняка и доломита, а в качестве восстановителя пылевидные углеродсодержащие материалы (отсевы коксика и угля). В отличие известных технических решений предлагаемая технология и способ заложенной в ней исключает складирование железосодержащих шламов в шламохранилище и позволяет организовать бессточную схему безобжигового окускования и производство комплексного самовосстанавливающего железосодержащего материала для производства стали и проката. Технология позволят организовать производство по переработке высоковлажных железосодержащих шламов, пылевидных кальций- и магнийсодержащих и углеродсодержащих пылевидных отходов и решает также проблемы загрязнения окружающей среды и отвода земель для хранения отходов производства.
Ключевые слова: шлам, пыль, переработка, обезвоживание, окускование, брикетирование.

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