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METHODS OF PELLETIZING FINE CHROMIUM RAW MATERIALS, KEMPIRSAY DEPOSIT, USING POLYMERIC BINDER

Abstract. This article describes the existing methods of pelletizing crude ore materials. Their main methods and mechanisms have been considered. The technologies of formation of briquettes and brexes have been described in detail. In the work, fine chromium raw materials from Kempirsay deposit are used as materials under study. The material is a loose substance obtained after drying chrome ore. The chemical and particle size distribution composition of fine chromium raw materials is given. The binder is polyacrylamide. A comparative analysis and differences between the methods of pelletizing have been carried out. The methods of pelletizing have been described, and the results of laboratory research on pelletizing have been obtained. The qualitative indicators of the obtained pelletized products were evaluated. The recipe for the optimal composition of the mixture for pelletizing has been selected. The factors affecting the quality of briquettes and brexes have been determined.

Key words: *polyacrylamide, chrome ore, briquetting, pelletizing, semi-dry molding, brexes, extrusion.*

Полимерлі байланыстырушы реагентті пайдалана отырып, Кемпірсай кен орнының ұсақ дисперсті хром шикізатын кесектеу тәсілдері

Аңдатпа. Бұл мақалада кен шикізатын өңдеудің қолданыстағы әдістері сипатталған. Олардың негізгі әдістері мен механизмдері қарастырылады. Брикеттер мен брекстерді қалыптастыру технологиялары егжей-тегжейлі сипатталған. Жұмыста зерттелетін материалдар ретінде Кемпірсай кен орнының ұсақ дисперсті хром шикізаты пайдаланылды. Материал-хром кенін кептіргеннен кейін алынған сусымалы зат. Ұсақ дисперсті шикізаттың химиялық және гранулометриялық құрамы келтірілген. Байланыстырушы материал ретінде органикалық зат, қатты және аморфты материал полиакриламид қолданылады. Бұл акрил қышқылының амидіне негізделген полимер, иіссіз, ұнтақ мөлшері 1 мм-ден аз болып келеді. Салыстырмалы талдау жасалды, кесектеу брикеттер мен брэкстер арасындағы айырмашылықтар талқыланады. Брикеттер мен брекстер қаттылық қасиетін аңықтау үшін, беріктігін анықтауға арналған қондырғыда, арнайы соққыда және барабанда сыналды. Кестеде көрсетілген брикеттер мен брекстердің беріктігін аңықтау нәтижелері келтірілген. Алынған өнімдердің сапалық көрсеткіштері және тасымалдауға төзімділігі және көптеген құймалар бағаланды. Қоспаның оңтайлы құрамының рецепті таңдалады. Брикеттер мен брекстердің сапасына әсер ететін факторлар анықталды.

Түйінді сөздер: *полиакриламид, хром-рудалық шикізат, брикеттеу, кесектеу, жартылай құрғақ қалыптастыру, брекстер, экструзия.*

Способы окускования мелкодисперсного хромового сырья Кемпирсайского месторождения с использованием полимерного связующего реагента

Аннотация. В данной статье описаны существующие способы окускования рудного сырья. Рассмотрены их основные методы и механизмы. Подробно описаны технологии формирования брикетов и брэксов. В работе в качестве исследуемых материалов использованы мелкодисперсное хромовое сырье Кемпирсайского месторождения. Материал представляет собой сыпучее вещество, получаемое после сушки хромовой руды. Приведены химический и гранулометрический состав мелкодисперсного хромого сырья. Связующим материалом выступает органическое вещество, твердый и аморфный материал полиакриламид, представляющий собой полимер на основе амида акриловой кислоты, без запаха, порошок крупностью менее 1 мм. Был сделан сравнительный анализ и отличия между способами окускования. Расписаны методика проведения окускования, а также получены результаты лабораторных исследований по окускованию. Брикеты и брэксы были испытаны на сброс, на установке по определению прочности на сбрасывание, на удар и истирание. Приведены результаты испытания брикетов и брэксов на прочность, которые представлены на графике. Оценены качественные показатели полученных окускованных продуктов и устойчивости к транспортировке и многочисленных пересыпок. Подобрана рецептура оптимального состава смеси для окускования. Определены факторы, влияющие на качество брикетов и брэксов.

Ключевые слова: *полиакриламид, хроморудное сырье, брикетирование, окускование, полусухое формование, брэксы, экструзия.*

Introduction

Metallurgical practice has three most common methods of pelletizing fine materials: sintering, granulation (pelletizing) and briquetting. The main task of pelletizing is to produce a quality pelletized product with the necessary strength for transportation and loading into the melting unit, to ensure sufficient gas permeability of the batch layer, as well as to reduce dust entrainment in the pyrometallurgical process.

The pelletizing methods can be divided into two groups: high-temperature and cold-temperature. The high-temperature methods include, first of all, sintering, and the second method is pelletizing followed by hardening calcination. In both cases, the desired strength of the lumpy product is achieved through exposure to high temperatures at which partial submergence and solid-phase sintering of the material occurs.

The group of cold pelletizing methods includes briquetting, extrusion with the production of extrusion briquettes (the brexes) and non-fired pelletizing. In these cases, the necessary strength of briquettes is provided by adding the binders in the composition of the material under pelletization.

The share of fine ore materials and concentrates, which are products of deep enrichment, recycled materials, and technogenic waste not previously involved in processing, is critically increasing in the metallurgical industry at the present time. The need to use these materials is based on the quantitative content of valuable components in the materials and the deterioration of the raw material base as the deposits are depleted. Traditional methods of pelletizing raw materials by agglomeration and pelletizing have largely exhausted their reserves and possibilities. Therefore, scientific developments aimed at providing the metallurgical industry with first-grade high-quality batch mixture seem to be very relevant, and the direction of development of briquette production is promising [1].

Feeding materials in their compact form into the metallurgical unit prevents their removal with the exhaust gases, and in the case of reduction smelting provides gas permeability of the batch materials column. In addition, briquetting reduces material losses during transportation [3].

The process of briquetting fine-grained materials has a number of the following advantages [2]:

- *strength and better transportability of briquettes;*
- *briquettes have the same regular shape and weight;*
- *briquettes have a higher specific gravity, can concentrate maximum useful components in the minimum volume;*
- *the possibility of obtaining complex briquettes consisting of several batch components in different proportions;*

- the possibility of using fine-grained materials of wide particle size distribution, while for pelletizing it is preferable to use the particles smaller than 74 microns.

In the metallurgical industry, a variety of briquette press designs are used for briquetting fine materials: stamping, belt, table, and ring presses. At the moment in the metallurgical industry, briquetting in roll briquetting presses is the most widespread, due to a number of advantages over presses of other designs [2]. The advantages are: continuity of the process, high productivity, ease of operation, lack of dynamic loads, relatively low wear of working surfaces and low energy consumption. Leading companies specialized in the development and series production of roll presses are: K.R. Komarek, Inc. (USA), Köppern (Germany), Sahut-Conreur (France), Spidermash (Russia).

Each briquetting process has its own specifics of preparation of fine fractional materials, consisting in the number and sequence of operations. Preparation of raw materials for briquetting is a combination of mechanical and thermal processes. The technological process of briquetting consists of:

- preparation of raw materials for briquetting (crushing, classification, drying, dosing and mixing components);

- pressing of briquette batch;

- briquette processing operations to separate fines and hardening.

A number of requirements are imposed on the binder materials. Firstly, the binder for briquetting must provide the necessary strength properties of the briquette both in the cold state and at the temperature of the metallurgical process. At the same time, the binder must not let harmful and ballast impurities into the material.

Briquetting of fine materials using binders, in contrast to briquetting without them, allows to obtain high-quality briquettes from almost any material at relatively low pressures pressing. When choosing binders, one should take into account not only their good binding properties, on which the strength characteristics of briquettes depend, but also the level of moisture and heat resistance provided by binders, the absence of harmful impurities in their composition, and environmental safety [4]. Binders have the following specific requirements:

- high surface activity and good wetting of the surface of the material under briquetting;

- the presence of plastic properties;

- resistance to atmospheric precipitation, temperature, oxidation by atmospheric oxygen, etc;

- absence of substances that contaminate the finished product;

- high soaking rate;

- no occurrence of high internal stresses in the hardened binder, which can destroy the adhesive bond;

- absence of volatile compounds that are toxic to the human body;

- cheapness and availability;

- ease of use;

- durability during storage and transportation.

If until recently inorganic binders such as cement or bentonite were widely used in ferrous metallurgy, nowadays polymeric organic binders are gaining popularity and can partially or completely replace inorganic ones [5-8]. As a rule, polymeric binders decompose at high temperatures without release of dangerous decomposition products and completely volatilize.

The aim of the work is to study the applicability of the polyacrylamide, polymeric agent, in the pelletizing of fine chromium raw materials as a binder. Development of pelletizing technology for processing in different metallurgical units, as well as the choice of rational consumption of the binder to reduce costs. Briquetting in a hydraulic press (roll-type press) and extrusion were chosen as the main methods of pelletizing.

Methodology of the study

Fine chromium raw materials from Kempirsay deposit were used as the material for pelletizing. The chemical composition of the sample is presented in Table 1. The used material was determined by tetrametric methods with the materials converted to a solution. The material is a loose substance obtained after drying of chrome ore. The particle size distribution of the sample is shown in Table 2. This material is valuable as a chrome ore raw material, as its chromium oxide content is about 43-49%. In industry, such raw materials are mostly pelletized and used as an additive in the batch during melting of ferroalloys [9-11].

The binder chosen was organic substance polyacrylamide (hereinafter PAA) which is a polymer based on the amide of acrylic acid. PAA is a solid, amorphous crystalline substance, white or partially transparent, odorless, powder with a coarseness of less than 1 mm. It is soluble in water, glycerol, ethylene glycol, glacial acetic acid; it swells in propionic acid, dimethyl sulfoxide and propylene glycol.

Chromium raw materials were pre-dried in a desiccator until constant weight. The materials were weighed on electronic scales KERN EW 3000-2M.

Raw mixes for briquetting and extrusion were prepared according to the same technique. For mixing, a laboratory single-blade mixing machine with adjustable speed of the rotating blade was used. Mixing of materials in it is done in a horizontal plane with concentric movement of the axis of the rotating blade. Dry mixing in the mixer was carried out for 10

Table 1

Chemical composition of fine chromium raw material from the Kempirsay deposit №1

Кесте 1

№1 Кемпірсай кен орнынан алынған ұсақ дисперсті хром шикізатының химиялық құрамы

Таблица 1

Химический состав мелкодисперсного хромового сырья из Кемпирсайского месторождения №1

Moisture	$Cr\ O_{23}$	SiO_2	CaO	MgO	$Al\ O_{23}$	FeO	C	S	P	PPP
0,34	48,81	7,80	0,51	19,71	7,13	12,24	0,49	0,024	0,002	3,793

minutes. The addition of water is required to impart adhesive qualities to the PAA, which leads to its dissolution and good volumetric distribution. Water was added to the dry mixture and stirred until the mixture became homogeneous. IP-1000 hydraulic laboratory press and a steel mold with a 30 mm cylindrical hole diameter were used for molding briquettes. The flow of the binder was chosen in accordance with the instructions for use, as well as on the basis of literature and experimental data [5-8]. The briquette forming force was 7 kN/cm^2. Table 3 shows the ratio of the components of the briquettes.

Table 2
Particle size distribution of the material
Кесте 2
Материалдың гранулометриялық құрамы
Таблица 2
Гранулометрический состав материала

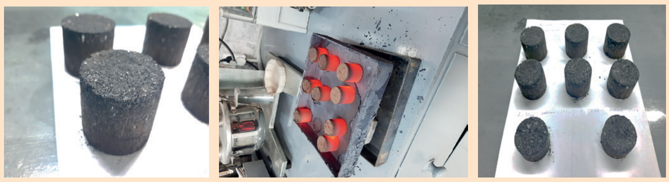
Sieve under laboratory conditions, wt,%			
-0.2+0.1 mm	-0.1+0.071 mm	-0.071+0.040 mm	-0.040 mm
1,15	1,89	21,47	7 5.48

Table 3
Composition of experimental briquettes
Кесте 3
Тәжірибелі брикеттердің құрамы
Таблица 3
Состав опытных брикетов

Option	Binder, mass/%	Moisture over dry weight, wt/%
Briquette 1	3	5
Briquette 2	2	6
Briquette 3	1	6
Briquette 4	3	4
Briquette 5	2	4

The obtained briquettes were cylinders of 30 mm in diameter and 30 mm high, weighing 60 g each. Drying of briquettes was performed under different conditions. For each type of drying, three briquettes were used. Drying under natural conditions took place at 20 °C for 2 days. Forced drying was carried out in Nabertherm TR 420 desiccator operating in the mode of volumetric drying with hot air. Drying in the desiccator was carried out at 120 °C for 180 minutes. The appearance of the briquettes is shown in Figure 1.

For briquetting, various types of extruders can also be used. At present, extruders are widely used in various industries. Extrusion is the process of extruding material through a forming hole [12]. For extrusion of the mixture, FSh-004RK02 screw pelletizer was used, on which a die with one molding channel of circular cross-section with diameter of 16 mm was pre-installed. In the process of extrusion at the outlet of the die the brexes were broken down manually into pieces 60-70 mm long (Fig. 1), weighing 80-90 g. Table 4 shows the ratio of components of raw brexes.



a b c

Figure 1. Appearance of briquettes.
a – raw briquettes; b – hot briquettes; c – dried briquettes.
Сурет 1. Брекеттердің сыртқы түрі.
а – шикі брикеттер; б – ыстық брикеттер; в – кептірілген брикеттер.
Рис. 1. Внешний вид брикетов.
а – сырые брикеты; б – горячие брикеты; в – высушенные брикеты.

Figure 2. Extrusion on a screw pelletizer.
Сурет 2. Бұрандалы түйіршікті экструзия.
Рис. 2. Экструзия на шнековом грануляторе.

Table 4
Composition of experimental brexes
Кесте 4
Тәжірибелі брэкстердің құрамы
Таблица 4
Состав опытных брэксов

Option	Binder, mass/%	Moisture above dry weight, wt/%
Brex 1	3	10
Brex 2	3	12
Brex 3	2	10
Brex 4	2	12
Brex 5	1	12
Brex 6	0,5	12

The obtained briquettes were placed in metal trays, and then some of them were dried in natural conditions at 20 °C with measuring their strength after 1 and 4 days. The rest of the brexes were force dried under the same conditions as the briquettes.

Part of the briquettes after forced drying was subjected to a test to determine the hot strength. The dried briquettes were placed in a muffle furnace heated to 1000 °C and kept the briquettes in it for their maximum complete heating in volume. After 30 minutes, the briquettes were removed and the compressive strength was tested while hot.

Strength was measured on automatic test press RB-1000, IP-1000 and on the installation to determine the dropping strength (Fig. 3). The compression force in the strength test was applied in the radial direction of the briquette/brex perpendicular to its forming force. The punch of the test press was a steel bar with a diameter of 20 mm.

a *b* *c*

Figure 3. Hydraulic press:
a – IP-1000, b – RB-1000, c – installation to determine the drop strength.
Сурет 3. Гидравликалық пресс:
a – IP-1000, b – RB-1000, c – қалпына келтіру беріктігін анықтау бойынша орнату.
Рис. 3. Гидравлический пресс:
a – ИП-1000, b – RB-1000, c – установка по определению прочности на сбрасывание.

Briquettes/brexes were tested for dropping, impact and abrasion. To determine the impact and abrasion resistance AP50B 3MT UZ (GOST 15137-77) drum type was used. The amount of material for determination of impact and abrasion resistance is not less than 15 kg. The material is loaded into the drum and after locking it the drum starts rotating up to 200 revolutions.

To determine the dropping strength, we used an installation for determining the dropping strength (GOST 25471-82), according to which the batch of briquettes/breaks are dropped on a metal surface from a height of 2000 mm with determination of the output of the formed fines (grain-size class less than 5 mm). The number of dropping is only 3 times. It is considered that briquettes/brexes meet the drop strength requirements if the amount of fines formed does not exceed 5...10 or even 15%. This means that transportation of large briquettes/brexes can be ensured only under logistic conditions, which exclude multiple dropping.

Results of the study

The results of the briquette strength test are shown in the graph in Figure 4.

The highest compressive strength is shown by briquettes №4 after forced drying at a temperature of 120 °C soaking for 3 hours with 3% binder content. The highest compressive strength of 50 kgf/briquette is shown by briquette No.1 with 3% binder content. With the exception for samples No.4 and No.5, the hot strength of other briquettes is comparable. Based on the graph in Figure 3 of all options for briquettes it is possible to accept that the most optimal option by all strength characteristics is briquette No.2, as all strength indicators are higher against other compositions of the briquette. Figure 5 shows the results of measuring the strength of the brexes.

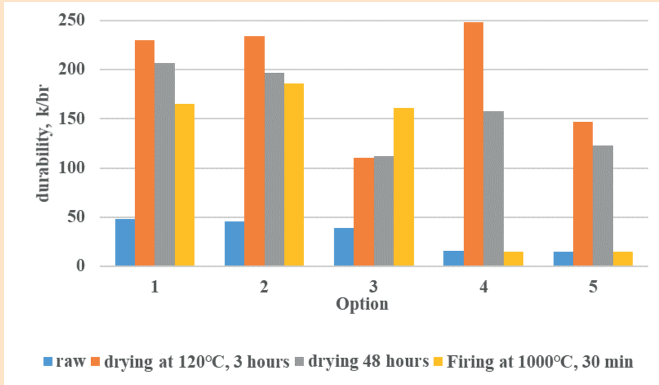


Figure 4. Test results of strength characteristics of briquettes.
Сурет 4. Брикеттердің беріктік сипаттамаларын сынау нәтижелері.
Рис. 4. Результаты испытания прочностных характеристик брикетов.

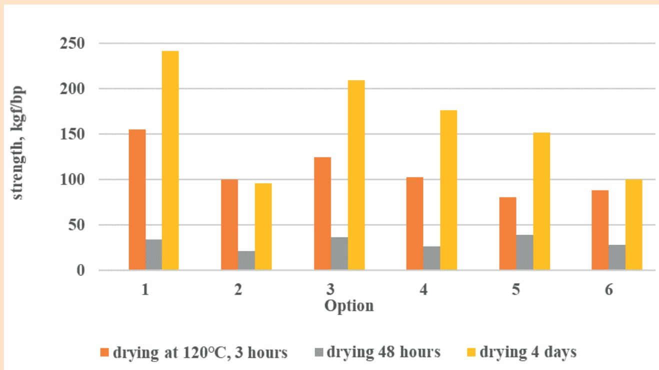


Figure 5. Test results of the strength characteristics of the brexes.
Сурет 5. Брэкстердің беріктік сипаттамаларын сынау нәтижелері.
Рис. 5. Результаты испытания прочностных характеристик брэксов.

Table 5
Impact and abrasion resistance
Кесте 5
Соққыға және тозуға төзімділік
Таблица 5
Прочность на удар и на истирание

Option	Strength, kgf/br		Durability of dry product for 3 times dropping from a height of 2000 mm/%	
	impact	abrasion	>5	<5
Briquette 1	96,1	3,9	98,85	1,15
Briquette 2	92,33	7,67	96,54	3,46
Brex 5	95,8	2,3	97,33	2,66
Brex 6	42,4	45,3	93,19	6,81

The strength of the raw brexes did not reach the values of 20 kgf/brex. The highest strength is in the brexes after natural drying for 4 days, a strength of 242 kgf/brexes has been achieved. Brexes after forced drying at 120 °C for 3 hours also show high compressive strength, up to 155 kg/brex. To determine the resistance to impact and abrasion (GOST 15137-77) and to dropping (GOST 25471-82), 1, 2, 5 and 6 briquettes options were selected. The choice of options of briquettes to determine the strength was due to the fact that these options have the highest strength values. As for the briquettes, they were chosen in terms of reducing the cost of the binder. The test results are presented in Table 5.

As can be seen from Table 5 briquettes are stronger than brexes on average by 25%, 18.02% and 2.4% in terms of impact strength, abrasion strength and drop, respectively. But it should be noted that the consumption of the binder in briquettes is 1 and 2% more against for brexes.

Results and conclusion

Based on the laboratory studies on pelletizing, the following conclusions can be made: when using polyacrylamide as a binder, briquettes and brexes showed relatively high strength. In the case of briquetting fine chromium raw materials, addition of polyacrylamide up to 3% is enough to obtain briquettes with high strength. In obtaining extruded briquettes (brexes) high strength is achieved by adding polyacrylamide up to 1%. On the basis of analyses of laboratory studies it was found that:

Mechanical strength of briquettes and brexes required for transportation and multiple shipment in this case is achieved by forced drying and soaking in natural conditions for 2-4 days. Regarding the choice of the type of pelletizing in terms of resistance to transportation and multiple reloading, the production of briquettes is preferable to brexes.

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