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DEVELOPMENT AND IMPLEMENTATION OF AN EFFECTIVE TECHNOLOGY FOR PROCESSING DEPLETED CHROMIUM TAILINGS USING JIGGING COMPLEXES

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Abstract. The article presents the results of comprehensive studies and pilot-industrial trials aimed at the development and implementation of an efficient technology for processing low-grade chromium tailings from the Donskoy Mining and Processing Plant using KPFSH-50 type jigging complexes. The accumulated chromite ore beneficiation tailings, amounting to approximately 3 million tons with a Cr_2O_3 content of 15–25%, are considered a significant source of secondary raw materials while simultaneously posing a serious environmental burden on adjacent territories.

In order to enhance chromium recovery efficiency, the main technological parameters of the jigging process were optimized, including an increase in pulsation frequency to 2.0–2.5 s^{-1}, replacement of standard screens with slotted screens featuring a 3 mm slot width, and adjustment of process water consumption. Pilot-industrial trials were conducted at the Aktobe Ferroalloy Plant with processing of tailings in the 5–10 mm size fraction. As a result, chromium oxide recovery of up to 73.1% was achieved, producing a concentrate containing 35–51% Cr_2O_3, meeting the requirements for charge materials used in ferroalloy smelting operations.

To assess the reproducibility of the developed technology, validation trials were carried out at the Aksu Ferroalloy Plant, where Cr_2O_3 recovery reached 66.7%. The estimated economic effect from industrial implementation of the technology exceeds USD 21 million. The proposed technology enables the conversion of technogenic waste into a category of strategic mineral raw materials and complies with the principles of resource efficiency and the circular economy.

Key words: chromium tailings, jigging, mineral beneficiation, chromium recovery, secondary resources, technogenic waste, KPFSH-50.

Introduction

The accumulation of technogenic waste generated by mining and processing plants (MPPs) represents one of the key challenges at the intersection of environmental protection and the economic sustainability of the metallurgical industry [1]. Large volumes of beneficiation tailings stored in tailing ponds lead to land withdrawal, landscape degradation, dust generation, and contamination of surface and groundwater, thereby creating long-term environmental risks for industrial regions [2, 3].

In the Republic of Kazakhstan, this issue is of particular relevance due to the scale of ferroalloy production and the high concentration of mining and metallurgical enterprises. One of the most problematic facilities is the Donskoy Mining and Processing Plant (DMPP), where approximately 3 million tons of low-grade chromium tailings with an average Cr_2O_3 content of 15–25% have accumulated over a prolonged period of operation [2]. Despite the relatively low content of the valuable component, these materials possess considerable resource potential and may be regarded as a source of secondary chromium raw materials.

At the same time, depletion of high-grade chromite ore reserves, increasingly complex mining and geological conditions, and growing demand of the ferroalloy industry for chromium-bearing materials necessitate the involvement of technogenic resources into economic circulation [4]. In this context, processing of beneficiation tailings becomes not only an environmental priority but also a strategic economic objective aimed at expanding the raw material base and reducing production costs.

For the processing of relatively coarse chromium tailing fractions (3–10 mm), gravity beneficiation methods represent a promising approach. Among them, jigging occupies a special position due to its high throughput, technological reliability, and comparatively low operating costs [5, 6]. However, the

efficiency of the jigging process strongly depends on the proper selection and optimization of technological parameters, as well as on the adaptation of equipment to the specific characteristics of technogenic raw materials.

In this regard, the development and industrial validation of an adapted technology for processing low-grade chromium tailings from DMPP using jigging complexes under operating conditions of ferroalloy enterprises is of particular relevance. The aim of this study was to develop, optimize, and pilot-test a technology for processing low-grade chromium tailings from DMPP at the jigging complexes of the Slag Processing Shop of the Aktobe Ferroalloy Plant (AktFP).

Materials and methods of research

Industrial KPFSH-50 jigging complexes operated at the Slag Processing Shop of the Aktobe Ferroalloy Plant (AktFP) were used as the main process equipment [7]. The initial material for the study consisted of low-grade chromite ore beneficiation tailings from the Donskoy Mining and Processing Plant, represented by 0–10 mm and 5–10 mm size fractions with an average chromium oxide content of 15–25%. Prior to feeding into the jigging machines, the material was classified by size in order to stabilize the particle size distribution of the feed.

To achieve maximum efficiency of the jigging process, a set of measures aimed at optimizing the operating conditions of the equipment was implemented, based on the analysis of preliminary industrial observations and literature data.

Optimization of the kinematic regime. The pulsation frequency of the jigging bed was increased from 1.5–2.0 to 2.0–2.5 s^{-1}, which intensified the loosening of the material layer and improved particle segregation by density within the pulsating flow.

Modernization of the screen deck. Standard screens with a 2 mm slot width were replaced with slotted screens featuring a 3 mm slot width. This modification reduced clogging by fine particles (0–1 mm), stabilized the hydrodynamic regime, and ensured a uniform distribution of the upward water flow across the entire bed area.

Adjustment of the hydraulic regime. The supply of under-screen water to the jigging machines was increased to reduce pulp viscosity, decrease friction forces between particles, and enhance their mobility under pulsation conditions, thereby improving density-based mineral separation.

Pilot-industrial trials (PIT) were conducted in June 2023 at two production sites: the Aktobe Ferroalloy Plant (for the 0–10 mm and 5–10 mm fractions) and the Aksu Ferroalloy Plant (AksFP) to assess the reproducibility of the developed technology. Monitoring of technological parameters, sampling of beneficiation products, and their analysis were carried out in accordance with the requirements of the temporary technological regulation VTR 04.02.07-09-2025 and the applicable enterprise standards [7].

The efficiency of the process was evaluated based on Cr_2O_3 recovery to the concentrate, chromium oxide content in the beneficiation products, and the operational stability of the equipment under prolonged continuous operation conditions.

The results and its discussion

The results of the pilot-industrial trials confirmed the high efficiency of the optimized technology (Figure 1).

The highest recovery rate (73.1%) was achieved for the more homogeneous 5–10 mm fraction, which can be explained by the optimal conditions for gravity separation. The obtained concentrate fully meets the technological specifications for charge materials used in ferroalloy smelting shops (not less than 32–35% Cr_2O_3). A comparable result obtained at the Aksu Ferroalloy Plant (66.7%) demonstrates the reproducibility and versatility of the developed technology.

In addition to the concentrate, the process allows the production of an intermediate product (Cr_2O_3 content of 32–40%), which can be subjected to further beneficiation or directly used in the charge mixture. Two types of tailings are also generated: low-grade tailings (3.17–5.25% Cr_2O_3), requiring the

development of utilization routes (for example, in the construction industry), and slime tailings (22.95–36.09% Cr_2O_3), which are planned to be involved in the production cycle after drying and mixing with filter-press cake as a charge component [7].

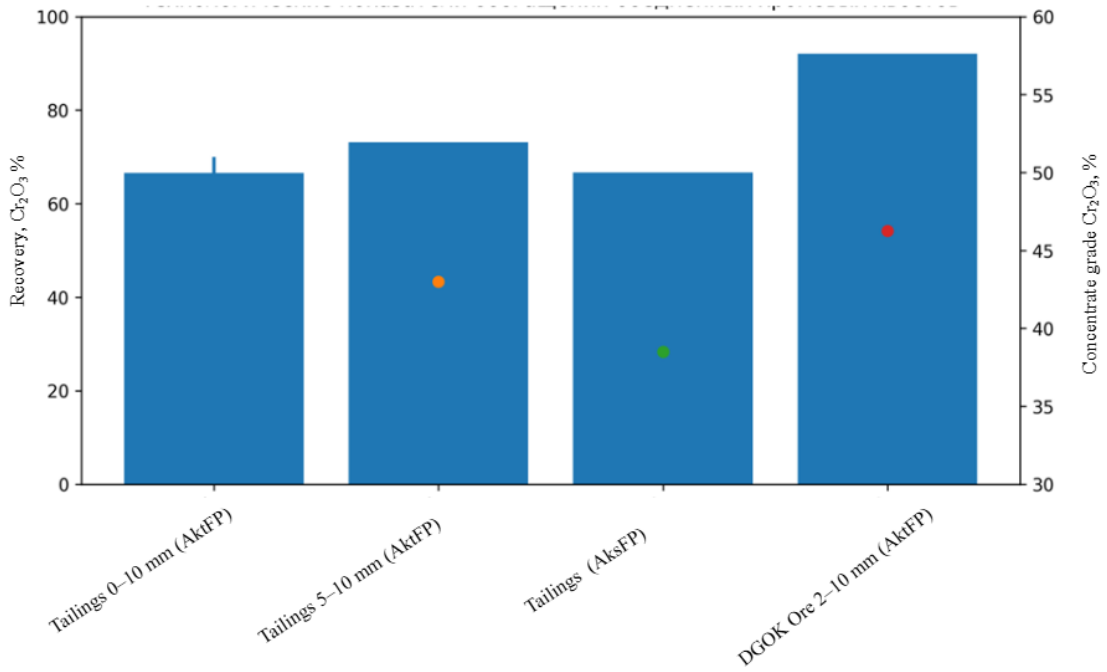

Figure 1 – Technological performance indicators for the beneficiation of low-grade chromium tailings

Conclusion

The implementation of the technology ensures a significant multiplicative effect:

• Economic: The creation of a stable source of secondary raw materials reduces dependence on the purchase of primary concentrate. The preliminary assessment of the total economic effect for the Aktobe and Aksu Ferroalloy Plants amounts to USD 21 million (USD 15 million and USD 6 million, respectively).

• Environmental: Systematic processing of accumulated tailings makes it possible to reduce the area of tailing storage facilities and minimize dust generation.

• Resource-related: The technology transforms technogenic waste from a category of environmental hazard into a strategic raw material reserve.

Based on the positive results of the pilot-industrial trials, the management of JSC “TNK Kazchrome” decided to organize regular shipments of low-grade raw materials from the Donskoy Mining and Processing Plant to the Aktobe and Aksu Ferroalloy Plants for continuous processing. To regulate the process, the Temporary Technological Regulation VTR 04.02.07-09-2025 was developed and implemented [8].

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ОТСАДКАЛЫҚ КЕШЕНДЕРДЕ КЕДЕЙЛЕНГЕН ХРОМДЫҚ ХВОСТАРДЫ ҚАЙТА ӨҢДЕУДІҢ ТИІМДІ ТЕХНОЛОГИЯСЫН ӘЗІРЛЕУ ЖӘНЕ ӨНДІРІСКЕ ЕНГІЗУ

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Аңдатпа. Мақалада Донской тау-кен байыту комбинатының (ДГОК) кедейленген хромдық хвостарын КПФШ-50 типті отсадкалық кешендерді қолдана отырып қайта өңдеудің тиімді технологиясын әзірлеу және өндіріске енгізу бойынша жүргізілген кешенді зерттеулер мен тәжірибелік-өнеркәсіптік сынақтардың нәтижелері келтірілген. Хромит кендерін байыту нәтижесінде жинақталған көлемі шамамен 3 млн тоннаны құрайтын, құрамында Cr_2O_3 мөлшері 15–25 % болатын хвостар екінші реттік шикізаттың маңызды көзі ретінде қарастырылумен қатар, іргелес аумақтарға

елеулі экологиялық жүктеме түсіреді.

Хромды бөліп алу тиімділігін арттыру мақсатында отсадка процесінің негізгі технологиялық параметрлері оңтайландырылды, оның ішінде пульсация жиілігін 2,0–2,5 $с^{-1}$ дейін арттыру, стандартты електерді саңылау ені 3 мм болатын саңылаулы електерге ауыстыру, сондай-ақ технологиялық судың шығынын реттеу жүзеге асырылды. Тәжірибелік-өнеркәсіптік сынақтар Ақтөбе ферросплав зауыты базасында фракциялық құрамы 5–10 мм болатын хвостарды өңдеу арқылы жүргізілді. Зерттеу нәтижесінде Cr_2O_3 оксидінің алынуы 73,1 %-ға дейін жетіп, құрамында Cr_2O_3 мөлшері 35–51 % болатын, ферросплав өндірісінің балқыту цехтарының шихта талаптарына сәйкес келетін концентрат алынды.

Әзірленген технологияның қайталанғыштығын бағалау мақсатында Ақсу ферросплав зауытында бақылау сынақтары жүргізіліп, онда Cr_2O_3 алынуы 66,7 % деңгейінде қамтамасыз етілді. Технологияны өнеркәсіптік ауқымда енгізуден күтілетін есептік экономикалық тиімділік 21 млн АҚШ долларынан асады. Ұсынылып отырған технология техногендік қалдықтарды стратегиялық минералдық шикізат санатына көшіруге мүмкіндік беріп, ресурсты үнемдеу және циркулярлық экономика қағидаттарына толық сәйкес келеді.

Түйін сөздер: хромдық қалдықтар, отсадка, байыту, бөліп алу, екінші реттік ресурстар, техногендік қалдықтар, КПФШ-50.

РАЗРАБОТКА И ВНЕДРЕНИЕ ЭФФЕКТИВНОЙ ТЕХНОЛОГИИ ПЕРЕРАБОТКИ ОБЕДНЕННЫХ ХРОМОВЫХ ХВОСТОВ НА ОТСАДОЧНЫХ КОМПЛЕКСАХ

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Аннотация. В статье представлены результаты комплексных исследований и опытно-промышленных испытаний по разработке и внедрению эффективной технологии переработки обеднённых хромовых хвостов Донского горно-обогатительного комбината с использованием отсадочных комплексов типа КПФШ-50. Накопленные хвосты обогащения хромитовых руд в объёме порядка 3 млн тонн при содержании Cr_2O_3 15–25 % рассматриваются как значимый источник вторичного сырья, одновременно представляющий серьёзную экологическую нагрузку на прилегающие территории.

С целью повышения эффективности извлечения хрома выполнена оптимизация основных технологических параметров процесса отсадки, включающая увеличение частоты пульсации до 2,0–2,5 $с^{-1}$, замену стандартных сит на щелевые с шириной щели 3 мм, а также корректировку расхода технологической воды. Опытно-промышленные испытания проведены на базе Актюбинского завода ферросплавов с переработкой хвостов фракционного состава 5–10 мм. В результате достигнуто извлечение оксида хрома до 73,1 % при получении концентрата с содержанием Cr_2O_3 35–51 %, соответствующего требованиям шихтовых материалов плавильных цехов ферросплавного производства.

Для оценки воспроизводимости разработанной технологии выполнены контрольные испытания на Аксуском заводе ферросплавов, где достигнуто извлечение Cr_2O_3 на уровне 66,7 %. Расчётный экономический эффект от промышленного внедрения технологии оценивается более чем в 21 млн долларов США. Предлагаемая технология обеспечивает перевод техногенных отходов в категорию стратегического минерального сырья и соответствует принципам ресурсосбережения и циркулярной экономики.

Ключевые слова: хромовые хвосты, отсадка, обогащение, извлечение, вторичные ресурсы, техногенные отходы, КПФШ-50.