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Yuri Zakharovich Drachuk[1], Elena Stalinskaya[2], Elizaveta Snitko[3], Evgeniya Zavgorodnyaya[4], Monika Jaworska[5], Larisa Savyuk[6], Dmitry Cheylyakh[7]

Slag waste of metallurgical production. Environmental and economic justification of their use in industry in Ukraine

Abstract: The relevance of the study is due to the need to identify the problems, features and consequences of strategic transformations in the metallurgical industry of Ukraine in the context of reviewing the circular process of organization of the economy, where the blast furnace, open-hearth and rol-

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✉ Corresponding Author: Yuri Zakharovich Drachuk; e-mail: drachuk.yuriy@gmail.com

[1] Institute of Economics Industry of the National Academy of Sciences of Ukraine, Kiev, Ukraine; ORCID iD: 0000-0003-3858-6548; e-mail: drachuk.yuriy@gmail.com

[2] Department of International Economic Relations, Vasyl Stefanyk Precarpathian National University, Ukraine; ORCID iD: 0000-0001-8944-6102; e-mail: stalinskaya.elena@gmail.com

3 Department of Management, Lugansk National Taras Shevchenko University, Ukraine; ORCID iD: 0000-0003--3583-6900; e-mail: esnitko@gmail.com

[4] Department of Management, Lugansk National Taras Shevchenko University, Ukraine; ORCID iD: 0000-0001--5197-2385; e-mail: yevheniiazavhorodnia@gmail.com

[5] Akademia Humanistyczno-Ekonomiczna w Łodzi. APEIRON Wyższa Szkoła Bezpieczeństwa Publicznego i Indywidualnego w Krakowie, Poland; ORCID iD: 0000-0003-3887-294X; e-mail: mjaworska@spoleczna.pl

[6] Ivano-Frankivsk Legal Institute of Odessa National Law Academy, Ukraine; e-mail: novicecuratorslo@gmail.com

[7] Institute of Industrial Economics of the National Academy of Sciences of Ukraine, Ukraine; ORCID iD: 0000--0002-8638-1443; e-mail: ddchl@ukr.net

ling production waste are of a high potential. The reuse of metallurgical waste has a number of economic advantages in terms of the chemical composition of the product life cycle. Blast furnace slag is suitable as a raw material in cement production and can be used as fillers in the construction of roads, hydraulic and environmental facilities, during reclamation works, etc. Agriculture actively uses slag as a fertilizer that contains potassium, magnesium, phosphorus, magnesium, boron – as an additive that reduces soil acidity. Currently, all slag can be processed into fertilizers or building materials. The economic effect of the use of slag in construction is accounted for in the relatively low cost of products, improvement of the quality and durability of the structures. The main positive consequences of smartization of the metallurgical industry are increase of its resource efficiency and environmental friendliness, negative – the low level of blast furnace slag use in various sectors of the economy compared to the experience of developed countries, an insufficiently developed legal framework. The mechanism of state management of the use of secondary raw materials, especially metallurgical origin, in conditions of shortage of energy resources and the intensive use of non-renewable natural resources remains an important scientific problem and requires further research.

Keywords: slag waste, industries, metallurgical production, ecological expenditure

Introduction

The relevance of the study is due to the need to identify problems, features and consequences of strategic transformations in the metallurgical industry of Ukraine in the context of reviewing the circular process of organization of the economy, where the blast furnace, open-hearth and rolling production waste are of a high potential. The reuse of metallurgical waste has a number of economic advantages in terms of the chemical composition of the product life cycle. Blast furnace slag is suitable as a raw material in cement production and can be used as fillers in the construction of roads, hydraulic and environmental facilities, during reclamation works, etc. Agriculture actively uses slag as a fertilizer that contains potassium, magnesium, phosphorus, magnesium, boron – as an additive that reduces soil acidity. At present, all slag can be processed into fertilizers or building materials. The economic effect of the use of slag in construction is accounted for in the relatively low cost of products, improvement of the quality and durability of the structures. As a result of the problem analysis of the smartization of metallurgy in the country, the directions for strategy formation of the use of metallurgical production waste, their involvement in secondary production are determined, innovative processes for the expert training of the metallurgical branch as a basis for circular technology development, features of blast furnace slags use in the production activity of industrial enterprises, the state of metallurgical slag production in the country.

The main results. The historical antecedents for the metallurgical industry smartization are the successful development during all industrial revolutions, as well as the fact that metal remains one of the main structural materials. The urgency of smartization is related to the efficiency improvement of metallurgical enterprises and the need to meet the modern requirements of contractors. The need for the smartization of metallurgical industries is confirmed by the rapid development of new technologies in the world, which leads to the need for strategic transformations in the industry through the use of "smart" solutions and technologies (Amosha and Nikiforova 2019, p. 84).

The need for smartization is going to be seen in the future progressive development of the industry, where the main goal of the formation of metallurgical smart industries is to increase the adaptability of the industry to dynamic changes in the external environment. The national economy has significant untapped inner potential for intensification, production development and improvement of the economic and technological structure to the level of world achievements. Obviously, it is impossible to prevent the formation of technological waste with the most advanced technologies. Therefore, the task is to substantiate the institutional prerequisites for the creation of the blast furnace slag processing industry in metallurgical production on the basis of neo-institutional economic theory, systematic analysis of European and domestic experience in the development of the metallurgical slag processing industry. In this regard, it is important to assess the directions of strategy formation for the use of metallurgical waste, involving them in secondary production, identifying innovative processes for training experts in the metallurgical industry as a basis for circular technology, features of blast furnace slags use in the production activity of industrial enterprises, the state of metallurgical slag production in the country.

Compared to world analogues, only a part of smart technologies known in the leading metal-producing countries is used in the Ukrainian metallurgical industry. However, the main trends in the smartization of the industry are to increase efforts for the better treatment of slag, that allows for compliance with the strict environmental standards of the EU, on which the legislation of European countries and the European Union places an emphasis.

The main positive consequences of smartization of the metallurgical industry are the increase of its resource efficiency and environmental friendliness, negative – low level of blast furnace slag use in various sectors of the economy compared to the experience of developed countries, an insufficiently developed legal framework. The mechanism of state management of the use of secondary raw materials, especially metallurgical origin, in conditions of shortage of energy resources and the intensive use of non-renewable natural resources remains an important scientific problem and requires further research. Referring to the analysis of existing technologies in the metallurgical industry, the level of use of secondary resources is not high at present. The main reason for their unsatisfactory use is the lack of waste disposal facilities, often the lack of recycling technologies and a non-integrated approach. At the same time, the processing and recycling of technological waste into a production business process is the only long-term opportunity to solve the problem of raw material sources.

Hence the most important technological task of modern production is the comprehensive and rational use of raw materials at all stages of processing. One of the most significant sectoral problems is technological waste (slag), which during many years of economic activity in the territories of metallurgical enterprises has accumulated into multimillion ton dumps. And the relevance of the effective recycling of ferroalloy slag is growing every year. The depletion of ore reserves, alongside with the decrease of world prices for ferroalloys are forcing companies to look for ways to reduce production costs. It is also important to improve the environmental component which is associated with the integrated processing of slag. There is a tendency to increase the volume of the use of secondary raw materials, obtained through the efficient processing of industrial waste, in production in the developed countries of the world.

Areas of further research. The problems that require further research include the determination of long-term factors in the development of Ukrainian metallurgy and the substantiation of strategic transformations in the industry in terms of the reassessment of the objectives and prospects of industrial development in Ukraine and the world in the context of new challenges of the fourth industrial revolution.

1. The features of the use of blast furnace slag in production activities of industrial enterprises

One of the leading budget-generating industries of Ukraine is the mining and metallurgical complex, which determines the growth rate of the national economy. Since Ukraine became an independent state, the metallurgical industry has undergone an important path of change and restructuring. According to the Association of Enterprises Ukrmetalurgprom metallurgical enterprises of Ukraine produced 20.82 million tons of steel in 2019, which equals 98.69% of the volume of production in 2018. According to the same business association, last year the production of pig iron fell to 20.05 million tons or 97.53% of figures in 2018. Rolled production amounted to 18.16 million tons or 98.87% of production figures in 2018. Despite the important role in the economy and the high export potential the situation in the industry is complicated by the fact that the environmental and social policy of Ukrainian metallurgical enterprises does not meet the criteria achieved in economically developed countries: the emissions per ton of finished products are significantly higher and workers' wages and the cost of social activities in the structure of gross expenditures is significantly lower (Stalinska 2012). According to literature and statistics, about 36 billion tons of various man-made wastes have been accumulated in Ukraine. And the amount of ash and slag materials (SSM) accumulated in the dumps, solid products of coal combustion from CHP – more than 250 million tons, metallurgical slag – more than 160 million tons. In fact, all the by-products are valuable and universal building materials and can improve the environmental situation as noted by investment experts ArcelorMittal Kryvyi Rih (Shaposhnikova 2019).

The manufacturers of slag in Ukraine are all Ukrainian metallurgical enterprises where the largest among them are Metinvest Holding, ArcelorMittal Kryvyi Rih, Dnieper Metallurgical Plant, the Interpipe company. The most important suppliers of slag for recycling include ArcelorMittal Kryvyi Rih and Recycling Solutions, which was founded by SCM in 2012 to manage waste and by-products. By means of the best practices the company seeks to ensure the cyclical use of natural resources and industrial waste, caring for the environment and improving the ecological conditions. Today the company is a comprehensive operator for the management of by-products and waste for the coal, metallurgical and thermal industries of Ukraine. The main types of secondary materials used by Recycling Solutions (Recycling Solutions 2020): ash and slag materials, metallurgical slags, rare and technical gases, ammonium sulfate and mine methane. Since its foundation the company has attracted more than USD 16 million of investment for business development and the implementation of processing technologies. In 2018, 1.8 million tons of secondary resources of TPPs and metallurgical plants were sold, which allowed to reduce the use of natural materials by 1.9 million tons/year and by 1.09 thousand cubic meters. m/year of area under the dumps of these by-products.

The volume of metallurgical slags processing in Ukraine has been increasing in recent years because slags allow manufacturers of dry construction mixtures, cement, pavements to reduce the cost of their products and improve their quality. But it should be emphasized that man-made waste, as a resource, is still underestimated. Although Ukraine still lacks the tools to stimulate the use of waste as a raw material or material to replace depleted natural resources, there is a lack of cooperation between government and business in slag disposal.

Slag of metallurgical production stems from the following: blast furnace, steelmaking and ferroalloy. The most popular in Ukraine is blast furnace slag – a by-product of pig iron smelting in the blast furnace, as a valuable raw material that is actively used in the cement industry. The main consumers of metallurgical slag in Ukraine are cement producers: CRH companies (Podilsky Cement in Kamianets-Podilskyi, Cement in Odessa, Mykolayivcement in Mykolayiv, Lviv Region), Dyckerhoff Cement Ukraine (Volyn-Cement in Zdolbuniv, Rivne region and Yugcement in Olshanske, Mykolaiv region), HeidelbergCement Ukraine (plants in Kryvyi Rih and Kamyansky, Dnipropetrovsk region), Ivano-Frankivskcement and others. The processed slags are used in road construction: the Mariupol–Zaporizhia, Zaporizhia–Dnipro, Dnipro–Kryvyi Rih routes and highway H-31 (R-52) Dnipro–Tsarychanka–Kobeliaky–Reshetylivka were built using blast furnace slag. Slag is widely used in road construction in the United States, Japan, Brazil, where it can be used both in the base and in the non-seeded layers of roads. According to the учзукеы of the Zaporizhia Iron Ore Plant (Shaposhnikova 2019), which is a consumer of granulated slag, the Zaporizhstal company buys slag and uses it for stowage work in mines. In recent years, the demand for slag has been growing at Zaporizhstal due to the increase in production and accordingly to the volume of stowage work in which slag is used to prepare mixtures.

According to technological processes (Bolshakov and Tovarovskiy eds. 2006), slag formation begins with the sintering of the iron ore part of the charge, from which the iron has already been partially recovered. When heated in the solid phase, oxides can form chemical compounds, the melting point of which is lower than the melting point of the oxides that make them up. When the ore part of the charge is heated to a temperature of 1100–1200°C, and sometimes to lower temperatures, the chemical compounds can form a liquid phase, while all the material is in solid form. It is believed that the field of primary slag formation consists of partially reduced iron ore materials associated with the recovered metal and slag.

Primary slag is the first liquid melt formed on the surface or inside pieces of different iron ore materials during the melting of the most fusible chemical compounds of eutectic composition. The main slag-forming oxides SiO_2, $A1_2Oz$, CaO in any ratio cannot form mobile slag even at temperatures of 1300–1400°C.

The slag formation process begins with the sintering of the iron ore part of the charge, from which the iron has already been partially recovered. Thus, the field of primary slag formation consists of partially reduced iron ore materials associated with the recovered metal and slag.

In Ukraine, priority measures have been given to restrictive measures for the implementation of which there is a legal framework. However, in the current economic and social conditions they are inefficient as companies are not interested in implementing measures to minimize the generation and accumulation of wastesince their cost far exceeds environmental payments, fines, etc. for environmental waste pollution.

In recent years, the world practice has formed fundamental ideas about the direction of resource and environmental policy, the most important part of which is the management of generated waste. The management of secondary resources as a system consisting of two subsystems: the subsystem of management, public administration bodies that organize, stimulate, plan, control and coordinate the process of obtaining secondary resources and their reuse is proposed. The subsystem is controlled, which is the same control object, which is, in turn, influenced by the control system. Subjects of the economic system whose activities are related to the environmentally sound recovery of waste resources act as the object of the controlled system.

In domestic practice, ArcelorMittal Kryvyi Rih, which has already built such an experimental road and tested it, emphasizes the question – "Is it possible to build roads from blast furnace waste in Ukraine?"

In the United States, China, Brazil, Japan and many other countries, slag has long been used in road construction. In Ukraine, the road base from slag is 2.5–3 times less expensive than from granite rubble, which is extracted in quarries.

According to expert estimates, modern concrete roads are less expensive than asphalt. In addition, they are more resistant to wear. If asphalt requires repair after 4–7 years of operation, the service life of concrete is from 20 to 30 years. Over time, the concrete only gets stronger, while the asphalt on the road, on the contrary, melts in the heat and collapses under the wheels of weightlifters. It is no coincidence that the World Bank recommends to firstly build cement concrete roads. Their advantage has long been appreciated by developed countries. In the USA about 60% of all highways in the country are concrete, in Europe – 40%, in Ukraine – less than 1%. Earlier, ArcelorMittal Kryvyi Rih launched an initiative to change the legal framework of Ukraine. A number of standards have been updated which now allow the use of ferrous metallurgy slag in the production of heavy concrete. In particular, a new state standard for road design was issued, thanks to which the construction of concrete roads with the use of slag was actually legalized.

According to the Deputy Director of the Investment and Engineering Department of ArcelorMittal Kryvyi Rih (Andriy Babenko) the company plans to use large and small fractions of recycled slag to prepare concrete to be used in domestic construction in investment projects, thereby reducing the cost of domestic construction. Apart from this, earlier at dismantling of buildings and constructions reinforced concrete was taken out and stored on landfills. Now the sorting of the waste and the removal of the metal parts to be sent to the dill shop, and the crushing of concrete to be used in construction is planned. Firstly, this is economically feasible, and secondly, it will reduce waste.

As for the use of metallurgical slag in the country, the prospects, in experts' opinion, are huge – at ArcelorMittal Kryvyi Rih alone there is 50 million cubic meters of slag in the dumps. All that is needed is a substantive interest from the state and private developers who will respond and support such an initiative. For starters, it would be useful to simplify the procedure for issuing various permits for the reconstruction of roads with the replacement of asphalt pavement with concrete in Ukraine and to prepare standard projects. Additionally equal opportunities for participation in the repair of roads of local importance should be provided not only to road, but also to construction companies and even to private entrepreneurs who have experience in working with concrete. Such steps at the state level are real reforms for the people.

The world has long found a rational use of waste metallurgical production, but we are just taking the first steps. In particular, ArcelorMittal Kryvyi Rih offers steelmaking slag in the form of an ameliorant to increase soil fertility in agriculture, to use blast furnace slag in railway ballast instead of gravel.

2. Innovative processes of training metallurgical industry experts as the basis for the development of a circular technology

The transition from the old linear model of the economy to a circular one, as noted in the work *Circular Economy and Benefits for Society* (Wijkman and Skånberg 2017), promises to create new market niches as well as new business models. Ukraine can become an Eastern European hub in this new reality by joining its construction at an early stage. But to reach this qualitatively new level of resource efficiency technological innovation and editing of behavioral patterns together with large-scale investments and special packages of government incentives will be required.

According to the Global Environment Forum data (2014, Tokyo), the circular economy (closed-loop economy) is defined as a concept aimed at eliminating the material loop and extending the life of materials through longer use and the use of secondary raw materials (The concept... 2019).

The World Steel Association has prepared an information guide illustrating the principles of the circular economy by the example of the ferrous metallurgy (Petrov 2017). Steel is known to be the most relevant material in the global economy, and metallurgy clearly demonstrates how the effect of circular technologies can be achieved. The basic principle of a circular economy in metallurgy is to ensure the maximum efficiency of each process in the life-cycle of goods and services. The circular economy is based on the implementation of the 4R principle providing circular chains of added value of steel products as follows: secondary use (Reuse) – recovery (Remanifacture) – recycling (Recycle) – reducing the use of resources in production (Reduce) (Petrov 2017).

Each of the principles requires the implementation of high-tech operations and the availability of highly qualified experts for their design and implementation but their implementation has undoubted advantages in economic and environmental terms. World experience confirms that steel products are easily recovered while achieving a high quality of recycled products such as car engines and wind farms. The production of these goods saves up to 83%, reduces CO_2 emissions by 87% and reduces the cost of new engines by up to 53%. The technology of using new lightweight high-strength steels makes it 25–40% lighter and stronger. This new steel help other branches decrease the environmental footprint.

Steel is a material of long-term use, allows for almost infinite recycling without loss of properties, and magnetic separation and sorting of scrap metal allow for employment generation. Studies have shown that the processing of 1 ton of steel saves an average of 1.4 tons of iron ore, 740 kg of coal and 120 kg of limestone.

Innovative technologies in metallurgy are widely used in developed countries. In the field of educational services, the sphere of education which should provide industry with highly qualified and competitive professionals in innovative branches is at the stage of post-industrial development of the world economy . At the same time, knowledge carries out an independent economic motion, and is used in the form of intellectual capital and an effective element of productive forces (Savyuk 2018).

In June 2019, with the support of Metinvest Holding LLC, as part of the new project "Examination Centers", a meeting "Open platform for mining and metallurgical industry" was held. The meeting was held to discuss key needs and expected results from future cooperation between stakeholders (employers) and higher education institutions in the mining and metallurgical industry. Within the framework of the adopted resolutions a decision was made to openly form new curricula where, in our opinion, a new profession of engineer in the sphere of circular metallurgy should be included.

3. Domestic realities of metallurgical slag production in the country

The national economy has significant untapped domestic potential to intensify production and improve its economic and technological structure to the level of world achievements. On the principles of analysis of the results of interaction and interconnection of the components of the mining and metallurgical production complex – raw materials (iron ore, ferrous scrap, coke, coking coal), energy of various kinds and auxiliary materials, landmarks of strategic development – the efficiency and competitiveness levels of enterprises in this industry are increased on the grounds of the introduction of new technologies of metallurgical production (Povazhny et al. 2012, p. 5).

The most important technological task of modern production is the comprehensive and rational use of raw materials at all stages of processing. One of the most significant sectoral problems is man-made waste (slag), which for many years of economic activity in the territories of metallurgical enterprises has been accumulated into multimillion-dollar dumps. Therefore, the relevance of the effective recycling of ferroalloy slag is growing every year. The depletion of ore reserves along with the fall of world prices for ferroalloys are forcing companies to look for ways to reduce production costs. It is also important to improve the environmental component, which is associated with the integrated processing of slag. It should be noted that in the developed countries in the world there is a tendency to increase the use of secondary raw materials obtained through the efficient processing of industrial waste.

The possibilities of the utilization and use of metallurgical production waste, possible consumers of blast furnace slag are considered further. Thus, the Donetsk region, according to Ukravtodor, became the first in Ukraine to start using slag rubble for road repairs. The priority is the Zaporizhia and Dnipropetrovsk regions that possess a large amount of industrial waste. In particular, industrial waste includes ash slags, metallurgical slags, and coal waste.

According to the scientific research of famous scientists, young researchers and statistics data the need for processing of the secondary waste of metallurgical production and the use of blast furnace slag when, taking technological features within the production tasks of iron-containing blast furnace, open-hearth and rolling production waste into account, the task is to offer a multilevel classification of types of technological waste (rejects), methodical and applied approaches to determine the sludge content of iron-containing products of the processing of metallurgical slags and scrap which are formed in the production process and resources offered for recycling.

Obviously, the most advanced technologies cannot prevent the formation of technological waste, previously known technical and economic indicators which were used to characterize production efficiency, the assessment of technological and economic parameters of the product life cycle are not enough. The theory of classification of technological business processes, including the recycling of iron-containing production waste as part of the international quality system is still under development. According to the analysis, process management is aimed at the efficiency of technological waste of sinter domain redistribution (Rashchupkina et al. 2017). Based on the above and on the diversity of business processes in the blast furnace and steelmaking technological redistribution, an attempt to substantiate the scientific and methodological and some applied aspects of the implementation of business processes in this area is being made. Therefore, for the accurate accounting of iron-containing redistribution, in accordance with the requirements of the standard of the international quality system (ISC), products must be classified as: suitable products accepted from the first presentation, which meet all the requirements of the order; non-conforming products that have deviations from the requirements of the ISC and technological waste – and part of the products that due to the technological process conditions inevitably turn into industrial recycling within the parameters set by internal regulations. It should be noted that in various methods of obtaining iron-containing alloys formed in the process, industrial recycling includes: blast furnace and open-hearth slag, sludge sinter, sludge from blast furnaces and open-hearth furnaces, furnace dust, scale of primary and secondary settlers, welding tongue as well as materials of natural origin, such as ore fines, screening of fine agglomerate and oxidized pellets and iron of direct reduction, iron ore concentrate and mixtures thereof. Reuse of iron-containing waste has a number of economic advantages in terms of the chemical composition of the product life cycle. The technological waste of industrial recycling in the steel casting using a continuous casting machine includes: regulatory metal residues in steel and intermediate ladles; part of the first and last workpieces cast and rolling within the established expense coefficients; the rest of the metal in the intermediate bucket; head and tail trim of metal; metal, poured into a slag bowl, from the gutters and scrap on the gutter; a normalized part of the workpiece before and after the defect "belt", formed as a result of the replacement of immersion cups and intermediate buckets; blanks of immeasurable length (the length of which is less than the allowable for rolling on their own mills). The technological waste of iron-containing rolling production includes final trimming; samples; welding slag; cinder; deficiencies in the adjustment of the condition (by varietal condition), calculated for each type of rental. Also, the internal recycling of technological waste includes the rejects of:

1) steel production: a) emergency scrap obtained as a result of burnout of the converter lining, burnout of steel ladle lining, ladle overload, in the form of emissions during the melting period as well as other technological losses of metal due to the converter shop; b) emergency scrap (when pouring steel on the caster) as a metal residue in the ladle and metal in the slag bowl more than a technologically justified amount, metal poured into the emergency bowl, scrap formed during breakthroughs; workpieces that have insurmountable surface defects, deviations in the size and shape of the cross section from the requirements established by regulatory documentation and are not suitable for further processing; part of the workpiece that exceeds the normalized according to the technical conditions; part of the workpiece before and after the defect "belt", which was formed in any cases;

2) rolling production: the rejects include – rejects of heating; rejects of rental, rejects of heating in surface overheating, surface defects and deviations in size and shape of the cross section from the requirements established by the regulatory documents, excessive deficiencies in the adjustment of the condition.

According to research (Nedava 2018b; Gasik et al. 2004; Nedava 2018a) an example of the essence of slag recycling technologies at JSC *Nikopol Ferroalloy Plant* and the identification of effective areas of the use of ferroalloy slag production is given. The annual output of slag, which is formed in the conditions of the Nikopol Ferroalloy Plant, is 1.2–1.5 million tons. The general scheme of slag processing at the plant includes the following:

1) crushing of solid slag to obtain lump slag of different fractions and slag sand;
2) granulation of liquid slag;
3) extraction of metal-containing inclusions from slags;
4) processing of slag into slag products.

Slag from smelting shops is transported in slag bowls by rail to the slag processing site.

The formed slag is taken out to the slag dump by means of special slag trucks where it hardens and waits for further processing.

The priority of the considered scientific direction consists in classification and introduction of low-waste and waste-free technological business – processes of sinter production and management of these processes for the achievement of efficiency of activity. Referring to the analysis of existing technologies in the metallurgical industry the level of use of secondary resources is not high at present. The main reason for their unsatisfactory use is the lack of waste preparation facilities, often the lack of recycling technologies and a non-integrated approach. At the same time, the processing and recycling of technological waste into a production business process is the only long-term opportunity to solve the problem of raw material sources. Given that only 2% of consumed natural resources are converted into final products and the rest goes into waste, waste recycling becomes a priority, the basis for solving the problem of resource conservation. It will allow companies of any level of complexity to build an effective management system for each business process, to link individual sub-processes into a single system, and to integrate the existence of business processes that reduce the consumption of natural resources limiting emissions and removing the harmful effects of landfills on the environment, rational use of material resources into this system, within one company (Nedava 2018a, b).

One of the characteristic features of ferroalloy production is the formation of huge slag dumps, which occupy industrial areas and have a negative impact on the ecological situation of the surrounding areas. And the annual increase in their volume indicates the urgency of the slag recycling problem. The slag processing system at JSC *NZF* meets all the main points that are inherent in most recycling areas of such enterprises and has technologies that may further improve and enhance the productivity not only of the presented area, but also of the enterprise as a whole.

Conclusions

The Ukrainian experience shows a low level of use of blast furnace slag in various sectors of the economy compared to the experience of developed countries. In addition, there is an underdeveloped legislative framework. The best option for the development of blast furnace slag in Ukraine should be the integration of successful experience of the EU and the United States.

The most important technological task of modern production is the comprehensive and rational use of raw materials at all stages of processing. One of the most significant sectoral problems is man-made waste (slag) which for many years of economic activity in the territories of metallurgical enterprises has been accumulated into multimillion-dollar dumps. The depletion of ore reserves alongside the fall of world prices for ferroalloys is forcing companies to look for ways to reduce production costs. It is also important to improve the environmental component which is associated with the integrated processing of slag. There is a tendency to increase the volume of use in the production of secondary raw materials obtained through the efficient processing of industrial waste In the developed countries of the world.

Slag waste is considered to be technically and economically the most viable alternative to the materials used in construction and repair work. The gradual reduction of waste from the metallurgical industry, expanding the possibilities of utilization, disposal, environmentally safe disposal for reuse in road construction helps to increase the level of environmental safety – the release of land and replacement of natural materials with alternatives.

the determination of long-term factors in the development of Ukrainian metallurgy and justification of strategic changes in the industry in terms of reassessing the objectives and prospects of industrial development in Ukraine and the world in the context of new challenges of the fourth industrial revolution are among the problems that require further research.

The problem of waste disposal and recycling can be solved centrally – by means of cooperation between government and business, which will result in new economic opportunities and the creation of new high-tech industries with strong potential, solving environmental problems and GDP growth.

Steel is a material of long-term use, allows for almost endless processing without the loss of properties and magnetic separation and sorting of scrap metal allow for creation of new workplaces. Innovative technologies in metallurgy are widely used in developed countries. Ukraine must focus on world experience to achieve sustainable economic development and overcome the crisis.

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Yuri Zakharovich Drachuk, Elena Stalinskaya, Elizaveta Snitko, Evgeniya Zavgorodnyaya, Monika Jaworska, Larisa Savyuk, Dmitry Cheylyakh

Odpady żużli w produkcji hutniczej. Środowiskowe i ekonomiczne uzasadnienie ich wykorzystania w przemyśle Ukrainy

Streszczenie

Powodem realizacji prezentowanych badań jest konieczność zidentyfikowania problemów i ich cech wynikających z przemian strategicznych w przemyśle metalurgicznym Ukrainy w kontekście cyklicznego przeglądu procesu organizacji gospodarki, w którym odpady wielkopiecowe, paleniskowe i walcownicze mają duże znaczenie. Ponowne wykorzystanie odpadów metalurgicznych ma wiele zalet ekonomicznych ze względu na cyklu życia produktu. Żużel wielkopiecowy nadaje się jako surowiec do produkcji cementu i może być stosowany jako wypełniacz przy budowie dróg, obiektów hydrotechnicznych, środowiskowych, podczas prac rekultywacyjnych itp. Rolnictwo wykorzystuje żużel jako nawóz zawierający potas, magnez, fosfor, magnez, bor – jako dodatek zmniejszający kwasowość gleby. Obecnie cały żużel można przerobić na nawozy lub materiały budowlane. Efekt ekonomiczny stosowania żużla w budownictwie przekłada się na relatywnie niski koszt wyrobów, poprawę jakości i trwałości konstrukcji.

Głównymi pozytywnymi efektami takiego inteligentnego wykorzystania odpadów z przemysłu metalurgicznego są wzrost efektywności wykorzystania zasobów i poprawa jego oddziaływania na środowisko. Cechy negatywne to niski poziom wykorzystania żużli wielkopiecowych w różnych sektorach gospodarki w porównaniu z doświadczeniami krajów rozwiniętych i niedostatecznie opracowane ramy prawne. Ważnym problemem naukowym i wymagającym dalszych badań pozostaje mechanizm państwowego zarządzania wykorzystaniem surowców wtórnych, zwłaszcza pochodzenia metalurgicznego, w warunkach niedoboru surowców energetycznych i intensywnego wykorzystania nieodnawialnych zasobów naturalnych.

Słowa kluczowe: odpady żużlowe, przemysł, produkcja metalurgiczna, wydatki ekologiczne