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ANALYSIS OF THE SYSTEM PROCESSING WASTE PRODUCTS IN ENERGY AND METALLURGICAL INDUSTRY

23.1 INTRODUCTION

Due to the increasing global development of materials used in the manufacture of everyday goods and their impact on broadly understood human environment, all elements of potential hazards must be considered in the product lifecycle and arrangement of the waste disposal process.

Because there are a variety of issues to be addressed in the design, logistics, production, operation and disposal processes that should be taken into account to minimize the adverse impact of the products, we can use here a vast array of factors for technological and organizational analysis.

Innovative products manufactured in heavy industry require the use of high-quality production processes and organizational systems.

Innovation in case of products of this type means interfering with the chemical composition (the possibility of using new compounds and chemical elements), a microstructure which, apart from the chemical composition, is one of the most important determinants of properties (mechanical, physical, utility, etc.), hence also application of the material in question.

Demand for modern, advanced products requires manufacturers to make technical, infrastructural, organizational and logistical changes. The process approach plays an important role here [2]. Of course, this is often associated with financial expenses.

This publication contains information on the problems of processing and utilization of products of metallurgical and power industry.

Significant development challenges include work on the disposal of by-products of industrial processes. Of particular interest is the use of slag with Zn-Pb content, due to a number of harmful compounds, constituting a continuing technological and utilitarian challenge.

23.2 POST-MANUFACTURING SLAGS

Power generating and metallurgical activity contributes to the production of two types of slags:

- blast furnace slag formed in the production of pig iron
- converter slags (steelmaking) formed during melting of steel, which after manufacture are stored and sold to customers as a whole [1].

Once the manufacturing process is complete, we can distinguish: Blast furnace slag.

In the old days, after melting of pig iron in a blast furnace, the slag in liquid state was drained into a ladle and dumped into a dump where it was poured down the slopes and was subjected to cooling in the air.

During cooling, a number of minerals are crystallized, mainly:

- magnesium and calcium silicates
- magnesium and calcium aluminosilicate
- oxides of iron, manganese and magnesium.

Converter-steel slag is a product of steel smelting. Liquid slurry from the converter is granulated to slowly solidify, during which the two- and three-calcium silicates, calcium ferrite, wustite and impurities from the batch are crystallized in the hot slag.

POSSIBILITIES OF USING SLAGS

Below, we briefly describe the possibility of reuse of slags:

- In the first stage of steel slag processing the iron contained therein is recovered, which may be present in free form as drops of metal retained in the cooling slag or as chemical compounds formed as a result of steelmaking process. Technology consists of two basic operations: slag crushing and magnetic separation. Crushing of slag is carried out in several stages, using crushers of various types and is a high energy consuming operation and causing rapid consumption of equipment [3].
- Use of slags for the production of road construction materials – non-magnetic fraction is segregated on sieves into different grain fractions according to the requirements of the customer and used in road, housing and other construction.
- Use of slags to produce binding materials – the ability to use slags is related to the properties of chemical compounds in their composition, which, when mixed with water, create hydrates with high mechanical strength. Such compounds, when mixed with sand or other filler and with water, form casting slip which, after some time, hardens and forms a mould.

In the process of blast furnace slag production, technology has been developed involving mixing with certain amounts of clinker, Portland cement and gypsum. The so-called metallurgical cement is obtained, which after hardening is resistant to high temperatures and water. These cements are most commonly used for the construction of large concrete structures [5].

Currently, the mass of slag in the steel industry worldwide is about 300 kg per

ton of pig iron, and in individual steelworks ranges from about 180 kg/t to over 400 kg/t. In Poland until 1980 this share was around 700 kg/t and currently ranges between 300 and 400 kg/t of pig iron. Blast furnace slag is an alloy of (in decreasing order) CaO, SiO₂, MgO and Al₂O₃ – the proportion of the latter two components varies in particular steel mills, the MgO content may be greater or less than the Al₂O₃ content. These four components account for about 95% of the slag mass.

The iron contained in the slag can occur either in free form as metal clots retained in the cooling slag or in the form of chemical compounds. The most valuable component of steel slags is metallic iron (its content is at a level of 5÷15%) [4]. Iron is recovered by using several levels of fragmentation and magnetic separation. The purpose of the first separation is the recovery of metallic iron. The degree of recovery depends primarily on the particle size of the material separator. It has been found that reduction of slag grading from 1 to 0.25 mm leads to an increase in the amount of iron in the concentrate from 25 to 90%, whereas the complete separation of the metallic iron from the slag phase is only possible with the grinding of the slag to the grain of 0.1 mm.

Recovering scrap metal from slags brings a double advantage. On the one hand, there are obtained metallurgical aggregates cleaned in majority of magnetic inclusions, which greatly improves their quality; on the other hand scrap is obtained, deficit of which the steelworks experience.

Wcisło Z., Stachura et al. in the paper entitled "The use of selected metallurgical wastes for batch components for metallurgical and cement production processes" [8] presented the possibilities of using selected waste containing a significant proportion of iron oxides in the composition such as scale, slag of pig iron desulphurization, sludge and filter cake, magnetic fraction of slag, blast furnace dust. Based on the analysis of their chemical composition and grading, they assessed their suitability for reduction and cement production.

Using their own computer program used to compile the sintering load of the sintering belt the Arcelor Mittal Steel Kraków Branch made the calculations of the sinter feedstock taking into account the use of sludge and filter cake, magnetic fraction from the slag landfill. Calculations have shown that it is possible to manage sludge and filter cake at 15 kg per ton of sinter, magnetic fraction – 14 kg per ton of sinter and slag from pig iron desulphurization of 8 kg per ton of sinter (alkali content of 1,5 kg/t sinter, zinc content – 0,21 kg/t sinter). The above weight of the waste materials does not affect the quality of the sinter and does not contribute to the deterioration of blast furnace and the quality of the pig iron [7].

The use of metallurgical ferrous scrap for clinker production should be preceded by an analysis of their fulfilment of criteria to ensure that the required mineral components in the clinker will be achieved which is decisive for the hydraulic properties of the finished product, and to ensure the appropriate cement performance such as specific strength, proper binding time or volume constant. The components used for cement production are primarily evaluated for their chemical

composition.

The scope of use of ferrous waste is limited by the presence of harmful admixtures. In the cement mix of raw materials the MgO content is limited to 2.5% by weight. Alkali and sulphur content should not be greater than 1% by weight and the amount of phosphorus in clinker must not exceed 2% by weight, equivalent to about 1.3% by weight of P₂O₅ in a mixture of raw materials.

These slags in the form of loose granules, with a content of %: 0,5-5 Cu; 0,1-1,0 Pb; 15-25 C (coke); 0,5-6,5 g/t Au; 100-450 g/t Ag, with the following grain composition:

Fraction, mm	+10	-10÷+5	-5÷+3	-3
Content, %	15-20	45-50	8-10	40-50

were sent to copper smelters where they were melted in shaft furnaces together with copper raw materials.

In order to improve the slag processing from slab furnaces with relatively low content of copper and precious metals, a new technology was developed and tested in the pilot plant, based on the fluidising chlorinated roasting of slags with hydrometallurgical processing of the roasting product. The technology includes the below operations:

- chlorinated roasting,
- absorption of metal chlorides in acid chloride solutions.

The assumed aims have been achieved in the studied technologies, i.e.:

- recovery of valuable metals in useful products such as raw lead, raw copper, copper stone, Zn-Pb dust,
- conversion of unreduced residue into mineral material – non-leachable in water silicate slag with low content of heavy metals [6].

With the use of an electric furnace, it is possible to recover Pb and Fe in metallic form and to preserve sulphur in copper stone. The TSL reducer allows for the production of low zinc end slags, the direct production of metallic copper and sulphur transfer to the process gases for desulphurisation. Specialized research has confirmed the ability to use silicate slags in construction as aggregate, bituminous fillers and for concrete production.

The basic directions for use of this slag are as follows:

- as a hydraulic filling component for filling voids,
- production of abrasive for abrasive blasting,
- reclamation work.

23.3 PROBLEM OF MAGNETIC SEPARATION OF POST-MANUFACTURING SLAGS

Tests of magnetic separation of slags were carried out in a DAVIS large scale laboratory magnetic analyser.

The test slag was milled in a ball mill and sieved to receive a powder of particle size < 0.2 mm, from which an aqueous dispersion was prepared, dispensed with

continuous stirring to a magnetic separator. The separated fractions were filtered and dried to give a magnetic fraction and a non-magnetic fraction.

The results of the magnetic separation tests of the slags presented in Table 2 are arithmetical mean values of three experiments carried out under identical conditions.

Studies have shown that the magnetic separation method can separate the slag with an initial content of 34.5% Fe and 8.29% C into a magnetic fraction with 44.6% and a non-magnetic fraction enriched in carbon suitable for recycling in the blast furnace.

Average iron yield to magnetic fraction $U_{Fe} = 70,1\%$; and average yield of carbon to non-magnetic fraction $U_C = 93,9\%$. It has been shown that the zinc passes along with the iron into the magnetic fraction. Based on the research carried out, the concept of slag utilization technology from blast furnaces was developed. The essence of this is the magnetic separation of ground slags.

23.4 SUMMARY

The presented problems require the use of innovative solutions in the field of technology and organization, allowing for a comprehensive solution in the aspect of the management of metallurgical products and the power industry.

The in-depth part of the article is a review of the achievements in the process of utilizing post-manufacturing slag waste, which is a significant part of products in the manufacturing process. The presented types and most important properties of post-production slag waste can be used for further research aimed at selecting the most effective methods of processing and utilization of waste.

The analyses and observations in the paper on post-production waste handling problems can serve as a basis for further research and industrial deployment. The magnetic separation method is a good basis for the isolation and processing of magnetic and non-magnetic materials in order to use them in a wide range in metallurgical, power and other industries.

REFERENCES

1. J. Bendkowski, M. Wengierek. *Logistyka odpadów*. Tom I. Wydawnictwo Politechniki Śląskiej. Gliwice 2002.
2. M. J. Ligarski. *Podejście systemowe do zarządzania jakością w organizacji*. Monografia. Wydawnictwo Politechniki Śląskiej. Gliwice 2010
3. I. Jonczy. Charakterystyka mineralogiczno-chemiczna szkliw z żużli hutniczych. *Gospodarka Surowcami Mineralnymi*, 2011, tom 27, nr 1, s. 155.
4. A. Konstanciak, W. Sabela. Odpady w hutnictwie żelaza i ich wykorzystanie. *Hutnik-Wiadomości Hutnicze*, 1999, nr 12, s. 572.
5. J. Sitko. Problems of materials management in the casting industry. *Arch. Foundry Eng.* 2008 vol. 8 iss. 3, s. 217-220.
6. J. Sitko. The problem of quality thermoinsulation products in selected company. *Zesz. Nauk. AM Szczecin* 2010 nr 24, s. 100-104.
7. M. Rzeszowski, K. Zieliński i in. Metody odzysku żelaza z żużli hutniczych i możliwości jego wykorzystania. *Hutnik-Wiadomości Hutnicze*, 2004, nr 1, s. 15.

8. Z. Wcisło, R. Stachura i in. Wykorzystanie wybranych odpadów metalurgicznych na komponenty wsadowe do procesów hutniczych i produkcji cementu. *Hutnik-Wiadomości Hutnicze*, 2010, nr 9, s. 476

Date of submission of the article to the Editor: 04.2017

Date of acceptance of the article by the Editor: 05.2017

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**ANALYSIS OF THE POST-PRODUCTION WASTE PROCESSING SYSTEM IN THE
METALLURGICAL AND ENERGY INDUSTRIES**

Abstract: *The article presents an overview of selected issues related to the problem of processing and utilization of slags from the power industry and the Zn-Pb metallurgy. The varied chemical composition and structure creates for disposal technologies a number of difficulties that must be overcome to enable a wide use of slags in industry. Innovative approach to the disposal process increases the chances of solving many technological and organizational problems in the energy and metallurgical industry.*

Key words: *process, recycling, slag, energy*

**ANALIZA SYSTEMU PRZETWARZANIA ODPADÓW POPRODUKCYJNYCH
W BRANŻY ENERGETYCZNEJ I HUTNICZEJ**

Streszczenie: *Artykuł prezentuje przegląd wybranych zagadnień związanych z problemem przerobu i wykorzystaniem żużli z przemysłu energetycznego oraz hutnictwa Zn-Pb. Zróżnicowany skład chemiczny oraz struktura stwarza dla technologii utylizacji szereg trudności, które należy pokonać aby umożliwić szerokie wykorzystanie żużli w przemyśle. Innowacyjne podejście do procesu utylizacji zwiększa szanse na rozwiązanie wielu problemów technologicznych i organizacyjnych w branży energetycznej i hutniczej.*

Słowa kluczowe: *proces, recykling, żużel, energia*