

# Elaboration of steelmaking slag processing scheme for resource-saving

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**Abstract.** The paper proposes a method for processing steelmaking slag for the purpose of resource saving. The authors propose to include partial granulation of steelmaking slag in the processing scheme. This embodiment includes draining of molten slag from the steelmaking unit in the bucket and separation of the molten slag into two parts, one of which is enriched in iron. With the use of statistical processing dependence for determination of content of FeO content in the converter slag was received. The resulting granulated product can be recommended for use in construction, in agriculture as a fertilizer, as well as a slag-forming flux in steelmaking.

## 1. Introduction

Now in the Russian Federation in dumps and tailings there are about 80 billion tons of waste from production and processing of mineral resources. In [1] it is noted that in 12 billion tons of accumulated solid waste content of valuable components is often higher than in natural ore deposits. In areas of placement of the metallurgical enterprises huge amounts of waste from various engineering procedures of a metallurgical complex (mining and enrichment of raw materials, production of cast iron, steel and, rolled products, coal combustion) which can be referred to technogenic deposits accumulated. The most significant number of technogenic fields was created in the Urals. In [2] it is noted that for the 300-year period of intensive mining and metallurgical production in the Urals billions of cubic meters of waste are saved up. In the late eighties PGO "Uralgeologiya" performed work on compiling geological and economic overview with assessment of possible use of waste of mining, metallurgical and fuel industry of the Ural economic region for receiving building materials. According to data of the overview, amounts of an annual output of waste in the Ural economic region as of 1986 were as follows: the overburden and host rock – 159.7 million m<sup>3</sup>, coal mining waste – 73.2 million m<sup>3</sup>, waste coal – 2.8 million m<sup>3</sup>, tailings of dry magnetic separation – 7.6 million m<sup>3</sup>, tailings of wet magnetic separation – 20.8 million m<sup>3</sup>; metallurgical slag – 21.9 million tons, ash and slag wastes from TPPs– 17.9 million tons [3].

## 2. Theoretical part

With transition to the market relations in many factory cities of the Urals primary conversion of slag dumps started. Generally it is sorting and magnetic separation for the purpose of metal extraction (content of iron in slag of about 1.5 %) and sieving on screens for receiving slag crushed stone. Cost of slag crushed stone is 1.5-3.0 times lower than that of crushed stone from natural raw materials.



In large enterprises the current slag blast-furnace production at present is almost entirely processed, technologies of deep processing applied [4]. After granulation of fiery molten slag it is used as raw material for the production of slag Portland cement (SPC) and calcareous binders, can be fine aggregate of concrete and mortars based on these binders. The granulation step is required since the rapid freezing of the melt is formed the desired mineralogical composition of the material comprising the maximum number of active glassy phase. Shpts is made by joint grinding of PC clinker, granulated slag and gypsum or by carefully mixing these materials, crushed separately. The cost of shpts when introduced into a mixture of 30 to 60 % of granulated slag is 1.5-2.0 times lower than the SPC from mineral raw materials.

Slag of the current steel production is processed generally into crushed stone. More advanced processing, it isn't exposed. This is due to the high melting point of steelmaking slag and its rapid solidification after the flush from the kiln. Therefore, it isn't possible to granulate it similarly as blast furnace slag.

Development of technologies for deep processing of dump and steelmaking slag will create the conditions for full processing slag current production and reduction of the area of slag dumps, which will improve the environment. On the other hand it will solve the problem of cementing materials in places where there are slag heaps, but no natural raw materials.

Now in our country and abroad works on research of rational ways of processing of steelmaking slag in liquid state by granulation are carried out. For this purpose the most various designs of installations, using water, steam and air to cool the melt and as the energy source are applied [5-7].

It is experimentally proved that the steelmaking slag which passed a granulation stage sharply reduces hydraulic activity and tendency to self-disintegration. On chemical and mineralogical composition, the steelmaking slag which underwent thermocrushing is closer to the Portland cement than blast furnace slag, and can serve as raw material for production of cementing materials.

The main difference of steelmaking slag from Portland cement is the content of iron and manganese oxides, and also sulfur availability. Thus, in case of decrease of oxidation and reduction of the sulfur content in steelmaking slag possibilities of their application extend: as bases for slag-forming mixtures in ferrous metallurgy; for production of Portland cement and other cementing materials as well as fertilizers or active filters of sewage.

Various ways of granulation of steelmaking slag have been analyzed.

Granulation of steelmaking slag in the kiln hasn't found application due to the high concentration of the metal in slag flushed from a furnace. It led to unstable granulation process: claps and sharp emissions of steam gas mixture in case of metal contact with water. The second negative factor was the constant metalling of the oscillating screen grid. The third and main negative factor is the considerable difficulties of placement of the pool with water in direct proximity to the steelmaking unit.

Granulation on the special installations remote from steelmaking units at a distance from 1.5 to 5 km hasn't found application because of a low overheat of slag fusion over temperature of the beginning of solidification. Temperatures of final slag flush amounted to 1530-1550 °C during that period, and the beginning of solidification of slag -1350-1280 °C [8].

Currently, the process of tapping steel and slag from the melting units is carried out at temperatures of 1600-1650 °C. Slag is discharged into slag ladles at temperatures of 1600-1650 °C, and modern steel-making process is characterized by high intensity: the discharge of metal and slag is made practically at once after the oxygen lancing of the melt. The separation of the molten metal and slag is not perfect - slag-metal emulsion gets into the slag bowl. Further sludge is separated into hot metal that settles on the bottom of the bowl, and the molten slag. The practice of processing steelmaking slag of Magnitogorsk Iron & Steel Works shows that the slag in the slag bowls, received for processing in 60-80 minutes. after the flushing from the furnace keeps the ability to provide a flush.

### 3. Experimental part

After the conducted analysis of variants of granulation of steelmaking slag, it was decided to carry out the granulation in the laboratory. The study was carried out in the laboratory of the Department of metallurgy of ferrous metals of the Nosov Magnitogorsk State Technical University in the furnace of resistance of Tamman.

The steelmaking slag sulfur content is from 0.7 to 1 %. In case of water granulation of slag irrespective of a design of aggregates process happens by sharp chilling of the melted slag with water. Upon contact of the melt with water there is its intensive evaporation.

The smell of hydrogen sulfide during the granulation was felt. But the water the slag was poured into, did not change an indicator pH. This is due to the fact that parallel with the formation of acidic products of H<sub>2</sub>S and SO<sub>2</sub> it occurs the hydration of CAO, followed by neutralization of acidic compounds with alkaline.

As a result of the experiment the product in black was received, which crumbled under slight mechanical action. The resulting product can be recommended for use in construction, as a result of hydration it is more resistant to degradation, in agriculture it can be used as a fertilizer and as a slag-forming flux in steelmaking.

Thus, it is proposed to include partial granulation of steelmaking slag in the scheme of processing.

Fluid steel slag in the ladles is delivered to installation of granulation in 40-60 minutes after discharge from the melting unit. This time is sufficient to separate slag-metal emulsion, but at the same time, the melt fluidity is maintained. After installing it's time to turn slag ladles over, and it is necessary to discharge only 30-40 % of the fusion which was in the ladle with melt to the pool. This will avoid discharging the metal into the pool that will affect the quality of the received granulated product. The remainder of the slag melt and deposited metal is sent for further processing. The iron concentration in the residue of the slag melt is increased, that will improve the recoverability of the metal in the processing.

The product (the granulated steelmaking slag) after a granulation and drying contains the minimum quantity of sulfur, iron and manganese, besides, it turns out without crystal structure therefore it can be used as lime containing material to slag in metallurgical process and for production of slag Portland cement and other cementing building materials.

For catching steam-gas emissions we suggest to establish the shelter with a general steam-gas withdrawal and to guide it to system of organizational cleaning in oxygen and converter shops. The shelter needs to be equipped with slide gates with electric drive [9].

Thus, we propose a method for processing steelmaking slag for the purpose of resource saving. This version includes discharge of slag melt from steelmaking unit into ladles and separation of the slag melt into two parts, one of which is enriched in iron. The discharge is performed at a temperature of over 1600 °C, which produces blowing of the jet of slag melt by air with an air flow rate 4.5 m / min, after discharge ladles are carried to the granulation installation where the mentioned separation of the slag melt into two parts by discharging 30-40 % of slag melt from the ladle into the pool to obtain a granulated product, and then the remaining part of the ladle enriched with iron, is carried to further processing to extract iron, while the slag melt in the ladle after discharge from the steelmaking unit before separating it into pieces is allowed to settle with in 40-60 min.

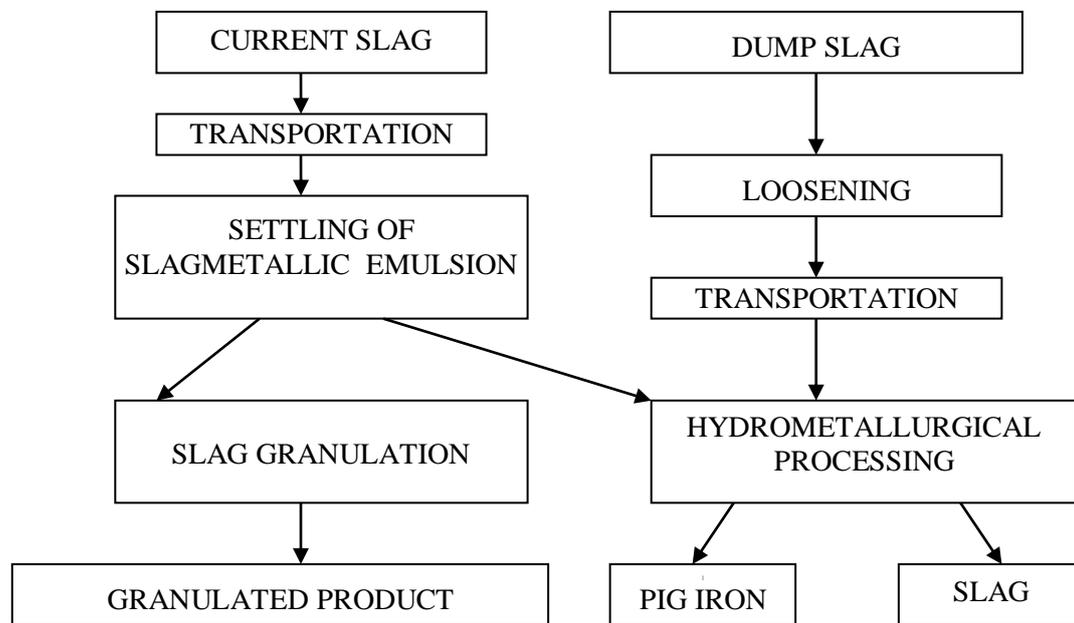
The results of experiments of converter slags does not allow to make an unambiguous conclusion about the decrease influence of the delay time of the melt slag on the recovery percentage of magnetic product. The experimental results are processed using the statistical method of analysis "steepest ascent" [8].

The following relationships were obtained to determine the content of FeO for converter slag:

$$\eta_{FeO} = 25,25 - 0,9 \cdot \tau - 0,015 \cdot T + 0,001 \cdot \tau \cdot T,$$

$\tau$  – is exposure time, [min];  $T$  – is melt temperature, [°C].

The proposed scheme for processing and use of metallurgical slag in the conditions of the existing production is shown in figure 1.



**Figure 1.** The proposed scheme for processing of slag.

The type of granulation installation has to provide utilization of the water vapor containing large amounts of sulfide compounds. A drum granulation method conforms to this requirement.

Dump slag after loosening by special crawler type machines is routed to the pyrometallurgical processing after which a melt and restored slag is obtained.

Thus, the inclusion of steel making slag in the scheme of partial granulation processing will produce more integrated processing of steelmaking slag, significantly reducing negative impacts on the environment and involvement of more man-made materials in the processing. Furthermore, the crushing stage is abandoned, that simplifies the procedure of steelmaking slag processing and reduces economic cost.

## References

- [1] Kozlovski I A 2003 *Mining Journal* **10** 4–9
- [2] Zorya V N 2015 *Research of Technogenic Waste of Ferrous Metallurgy, Including Waste from Enrichment and Combustion of Coal, and Development of Technologies of their Processing* thesis for a degree of Candidate of Technical Sciences (Novokuznetsk) p 18
- [3] Cherchintsev V D et al O B 2010 *Ecology and Industry of Russia* **2** 52–4
- [4] Shatokhin I M et al 2016 *Int Conf-School on Chem. Tech.* (Volgograd: VSTU) pp 351–352
- [5] Volkova E A, Sviridova T V and Bobrova O B 2015 *Integrated Use of Metallurgical Production Waste in Metallurgy: Technology, Innovation, Quality* ed E V Protopopov (Novokuznetsk) pp 361–364
- [6] Drobniy O F, Harlov A A and Proshkina O B 2009 *Mineralogy Tehnogeneza* **10** 228–34
- [7] Senik A I, Miliukov S V and Proshkina O B 2008 *Ecology and Industry of Russia* **9** 22–3
- [8] Sviridova T V, Bobrova O B and Volkova E A 2016 *Materials Science Forum* **870** 466–70
- [9] Akhmedjanova Z I and Bobrova O B 2016 *Actual Problems of Modern Science, Engineering and Education* (Magnitogorsk: Nosov MSTU) pp 228–230