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# Investigation of Acid Electric-Furnace Slag as a Perspective Raw Material for Ceramic Pigment Production. Report 1. Study of Granulometric and Chemical Composition of Slag

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The research results of granulometric and chemical composition of acid electric-furnace slag of Kharkiv Iron & Steel Plant are presented in the paper. Rather high homogeneity of researched waste in relation to grain fineness along with wide variation in the fractional chemical composition is determined, which generates a need for pre-treatment when using in pigmental technology.

Keywords: ELECTRIC-FURNACE SLAG, GRANULOMETRIC COMPOSITION, MAGNETIC PART, NON MAGNETIC PART, FRACTION, CHEMICAL COMPOSITION, NONSTAINING OXIDES, METAL OXIDES OF VARIABLE VALENCY, COLORING, CERAMIC PIGMENTS

**Introduction**

The development of metallurgical branch results in increase of waste amount in the form of various slag concentrated in dirt piles and occupying huge territories.

Meanwhile, reprocessing of such technogenic deposits for many long years will enable to reduce demand for high-priced natural and technically pure raw materials. As a result, usable land areas occupied by waste are liberated, and deleterious effect of industrial regions on adjoining territories is reduced.

Metallurgical slag is a waste product of high-temperature processes formed as a result of metal stock impurity oxidation, melting-down of fluxing components and fracture of furnace lining. Chemical-mineralogical and fractional composition of solid slag is defined by nature of the components participating in the production cycle, by features of the processes that take place at smelting of any metal or alloy, and also depends on cooling conditions. All of this, in turn, has a considerable effect on structure formation and reactive capacity of cooled slag.

The task of present research is investigation of features of granulometric and chemical compositions of acid electric-furnace slag at Iron & Steel Plant named after Malyshev (Kharkiv) as a potential source of low-cost raw materials for ceramic pigment production.

**Results and Discussion**

As a result of visual estimation, it is determined that studied waste is a homogeneous fine-grained material of grey colour with brownish shade and small content of large inclusions.

Classification of averaged sample of electric-furnace slag by grain composition is carried out by fractional method at the first stage of investigations (**Table 1**) with the subsequent chemical analysis of products.

Having analyzed obtained data it is necessary to mention that Kharkiv slag is homogeneous material in relation to grain composition which is proved by fractions not less than 2.5 mm (totally approximately 90 mass. %). And only 4.5 mass. % fall on large inclusions (more than 5.0 mm).

In the process of subsequent slag preparation for chemical analysis it is determined that it contains hard-broken inclusions of various nature. And concentration of such inclusions considerably increases at transition from small slag fractions to larger (**Table 2**, **Figure 1**) prompting suggestions about their metal nature. Magnetic component (92.8 mass. %) quantitatively predominates in solid inclusions of electric-furnace slag.

The most of non-magnetic component is concentrated in the fractions sized from 5.0 to 2.5 mm (totally in the order of 3 mass. %).

Further we carried out fractional chemical analysis of non-magnetic part of the experimental metallurgical slag. The results are shown in **Table 3**, and graphical dependences of content of variable valency metallic oxides and nonstaining oxides on the fractional composition of examined waste are illustrated in **Figure 2**.

Carried out analysis of experimental data helped determine that fractional chemical composition of non-magnetic part of experimental electric-furnace slag differs by inhomogeneous content of basic components. In particular, examined secondary material is enriched with silicon dioxide which concentration largely increases from 56.16 to 85.16 mass. % as slag grains become finer.

The content of aluminum and calcium oxide depending on coarseness of slag fractions has extreme character and is maximum for grains 1.0-2.5 mm (5.71 and 7.21 mass. % respectively), **Figure 2b**.

The similar trend is observed for magnesium oxide, but its maximum amount falls at fraction 2.5-5.0 mm (2.47 - 2.58 mass. %). Total iron concentration in the waste under investigation essentially raises from 4.45 to 25.88 mass. % at increase of its grain size and correlates well with data on magnetic component content (**Table 2**). Also it is necessary to mention that minimum concentration of other staining oxides (manganese, chromium and titanium) – 0.45; 0.17 and 0.15 mass. % respectively is characteristic for studied slag fraction of size less than 1.0 mm.

**Table 1.** Granulometric composition of electric-furnace slag test sample

| Slag | Fraction content, mass. % | | | | |
|---|---|---|---|---|---|
| | > 5.0 mm | 5.0–3.5 mm | 3.5–2.5 mm | 2.5–1.0 mm | < 1.0 mm |
| Electric-furnace | 4.5 | 5.1 | 2.3 | 12.2 | 75.9 |

**Table 2.** Content of hard-broken inclusions (mass. %) in various fractions of Kharkiv electric-furnace slag

| Slag | Proportionated sample | | | Item and grain fineness of samples, mm | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | > 5.0 | | | 5.0–3.5 | | | 3.5–2.5 | | | 2.5–1.0 | | | < 1.0 | | |
| | Total* | Me** | nonMe*** | Total | Me | nonMe | Total | Me | nonMe | Total | Me | nonMe | Total | Me | nonMe | Total | Me | nonMe |
| Electric-furnace | 2.64 | 2.45 | 0.19 | 34.1 | 33.3 | 0.8 | 13.7 | 12.1 | 1.6 | 5.3 | 4.0 | 1.3 | 2.4 | 2.0 | 0.4 | – | – | – |

* - total content of hard-broken inclusions in slag
** - content of magnetic component
*** - content of non-magnetic component

Besides, there is weight loss in the experimental slag during calcination as a whole 3.84 mass. % (**Table 3**) caused by structural moisture in small amount. And, its content in various fractions of electric-furnace slag is directly proportional to concentration of oxides of calcium, magnesium and aluminum which is indicative of formation of hydrosilicates with their participation.

**Table 3.** Chemical composition of electric furnace slag, mass. %

| Fraction size, mm | Item | | | | | |
|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_{tot}$ | $TiO_2$ | $Cr_2O_3$ | CaO |
| Proportionated sample | 80.00 | 3.55 | 6.89 | 0.20 | 0.20 | 2.86 |
| > 5.0 | 56.16 | 4.60 | 25.88 | 0.20 | 0.29 | 4.15 |
| 5.0–3.5 | 57.24 | 5.04 | 21.01 | 0.27 | 0.26 | 5.90 |
| 3.5–2.5 | 63.83 | 5.65 | 13.37 | 0.29 | 0.27 | 6.04 |
| 2.5–1.0 | 64.42 | 5.71 | 11.35 | 0.37 | 0.32 | 7.21 |
| < 1.0 | 85.16 | 3.02 | 4.45 | 0.15 | 0.17 | 1.86 |
| Fraction size, mm | Item | | | | | |
| | MgO | MnO | ZnO | $Na_2O$ | $K_2O$ | П.п.п |
| Proportionated sample | 1.46 | 0.77 | 0.02 | 0.05 | 0.16 | 3.84 |
| > 5.0 | 1.70 | 2.35 | сл. | 0.22 | 0.20 | 4.25 |
| 5.0–3.5 | 2.58 | 1.75 | 0.03 | 0.14 | 0.38 | 5.40 |
| 3.5–2.5 | 2.47 | 1.96 | 0.02 | 0.10 | 0.42 | 5.58 |
| 2.5–1.0 | 2.25 | 1.91 | 0.03 | 0.20 | 0.38 | 5.85 |
| < 1.0 | 1.23 | 0.45 | 0.02 | 0.04 | 0.10 | 3.35 |

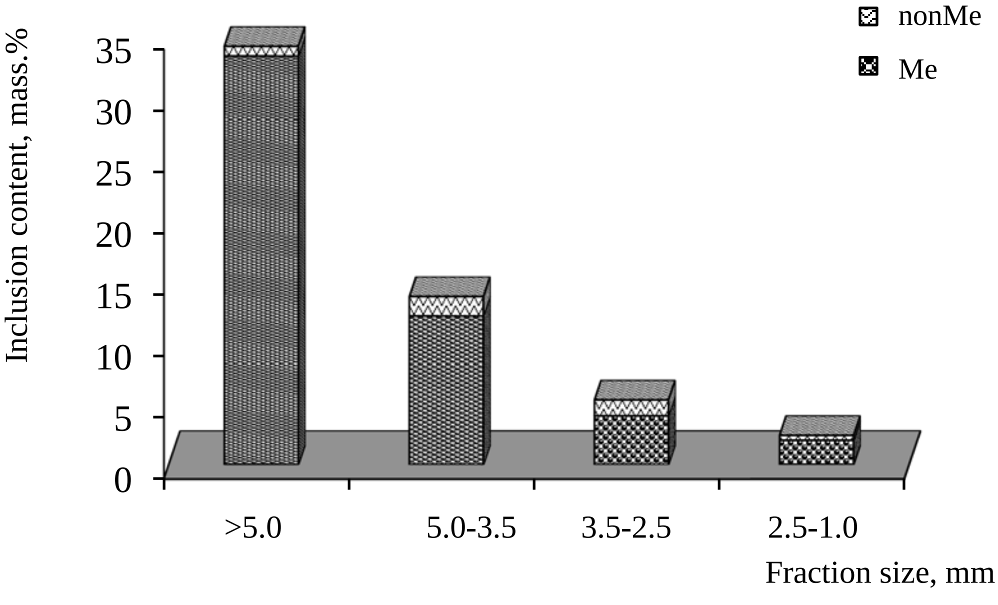


**Figure 1.** Distribution of hard-broken inclusions of various nature on grain composition of experimental slag

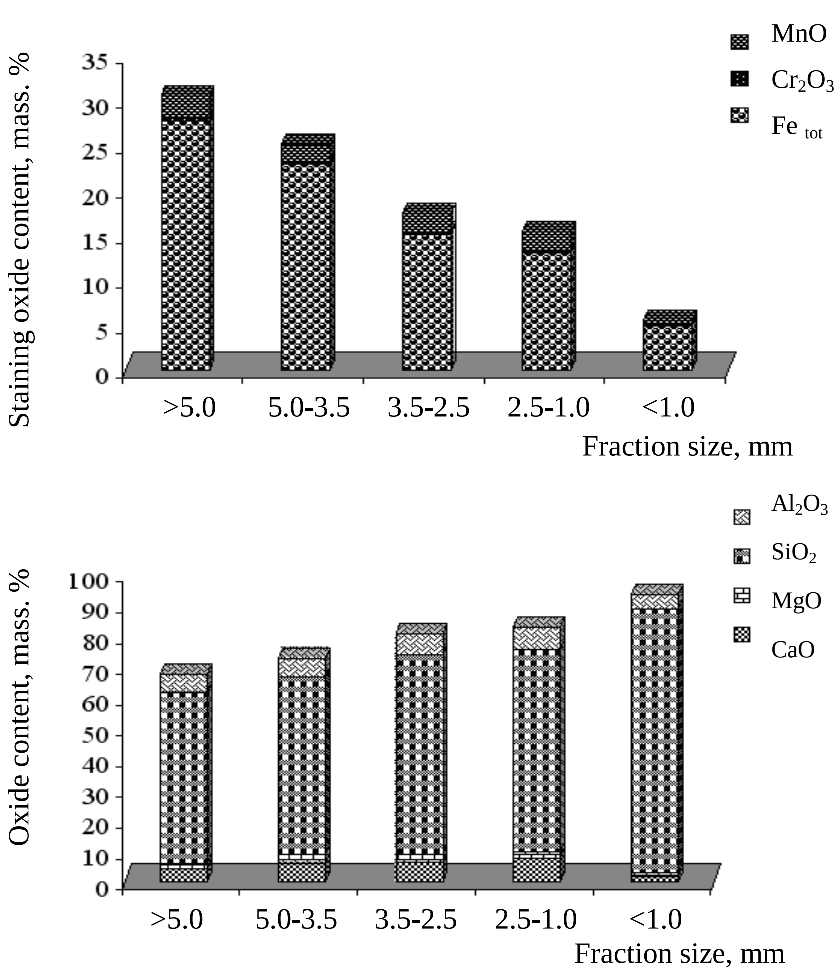


**Figure 2.** Distribution of metallic oxides of variable valency (*a*) and not nonstaining oxides (*b*) in various fractions of Kharkiv slag

## Conclusions

It is important to note that acid electric-furnace slags are granulometric homogeneous materials with primary content of silicon dioxide and rather low concentration of staining components that enables to assume the possibility of their application in ceramic pigment production. However, in view of wide variation in the chemical composition observed for fractions of various graininess as well as considerable content of metal inclusions in such waste large fractions, it is reasonable to carry out their preliminary preparation by joint crushing of slag proportionated samples or by means of separating the finest fraction (less than 1 mm) which differs by the minimum content of staining components and absence of metal inclusions.

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## Исследование кислого электросталеплавильного шлака, как перспективного сырья для производства керамических пигментов. Сообщение 1. Изучение гранулометрического и химического состава шлака

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В статье представлены результаты исследований гранулометрического и химического составов кислого електросталеплавильного шлака металлургического предприятия Харькова. Установлена достаточна высокая однородность изучаемого отхода по зернистости наряду с значительными колебаниями пофракционного химического состава, что определяет необходимость его предварительной подготовки для применения в пигментной технологии.