RECOVERY OF SIDERITIC WASTE AS A CARBOFER BY-PRODUCT IN THE STEEL INDUSTRY

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The approach and implementation of waste recycling technologies with iron content depend on the nature of the secondary materials that must be recycled and on the form of the by-product resulting from their processing. The Carbofer process is a possibility of valorizing powdery waste, obtaining a mechanical mixture of the carbofer type usable in the process of making cast iron as well as steel. The applied procedure offers the possibility of choosing some recipes that can contain several pulverulent wastes chosen depending on the chemical composition and the available quantities of these wastes. The work presents the results obtained in the laboratory regarding the obtaining of carbon steel by-product obtained from pulverulent waste and usable in steelmaking as an agent for foaming slag.

Keywords: pulverous waste, carbofer, steel, circular economy, environment

1. Introduction

With the increase in income levels and living standards, the global consumption of raw materials and energy is rising, placing significant pressure on natural resources and the environment [1]. At the same time, we must reduce the quantities of waste disposed of by reintegrating it into the economic cycle. Many wastes containing iron, carbon, and other elements useful in the steel industry, present in the form of sludge and dust, need to be recycled. The CARBOFER process represents a viable solution for utilizing powdery wastes (tailings from the mining industry, sludges and dust from the steel industry, slags resulting from secondary steel treatment, etc.) generated by the steel and mining industries. The steel industry produces significant quantities of powdery wastes rich in iron and carbon, a substantial portion of which is still being landfilled. Some of these wastes can be successfully used to produce the carbofer by-product [2-5]. This product is

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used as a foaming agent for slag in steel production, thereby recycling the waste in a manner that is environmentally, technically, and economically sustainable. The carbofer product is also effectively used in blast furnaces for pig iron production [6-9].

Slag foaming in steelmaking aggregates plays a significant role in reaction kinetics, maintaining furnace temperature, preventing energy losses, and protecting their refractory linings. Slag foaming is used to increase the thermal efficiency of the furnace during refining, as the sidewalls are fully exposed to the radiation of the electric arc. Foaming slag rises and covers the electric arc, enabling greater heat transfer without increasing the thermal load on the furnace walls. During the refining process, slag foaming is achieved by continuous oxygen injection and intermittent injection of calcined petroleum coke or a coke mixture for slag foaming. Numerous studies have been conducted on slag foaming [10-19]. The foaming behaviour of slag is indirectly evaluated in terms of the foaming index, which can be correlated with the physical properties of the slag (viscosity, surface tension, and density) [17-19]. Despite these limitations, the steel industry remains interested in the slag foaming process during steel manufacturing.

2. Experiments in the laboratory phase

The applied process, namely the processing technology, offers the advantage of flexibility, allowing for the selection of recipes that can include one or more types of powdery waste. This is based both on the chemical composition required by the recycling site for the resulting product (its technological destination) and on the quantity of waste generated over a specific period. In addition to the wastes commonly generated in the technological flow, we also considered wastes stored in decantation ponds and deposits, as well as wastes resulting from the mining and steel industries in the Hunedoara region).

For the purpose of conducting laboratory-scale experiments, samples of powdery waste were collected from various sections of steel plant platforms and from decantation and storage ponds. Representative samples were obtained from the following types of waste [9,20]:

- Sideritic waste;
- Ferrous sludge;
- Scale sludge;
- Sintering-blast furnace sludge;
- Electrode scraps;
- Lime dust.

For the production of CARBOFER, a powdery mechanical mixture, processing was carried out according to the technological flow shown in Fig. 1.

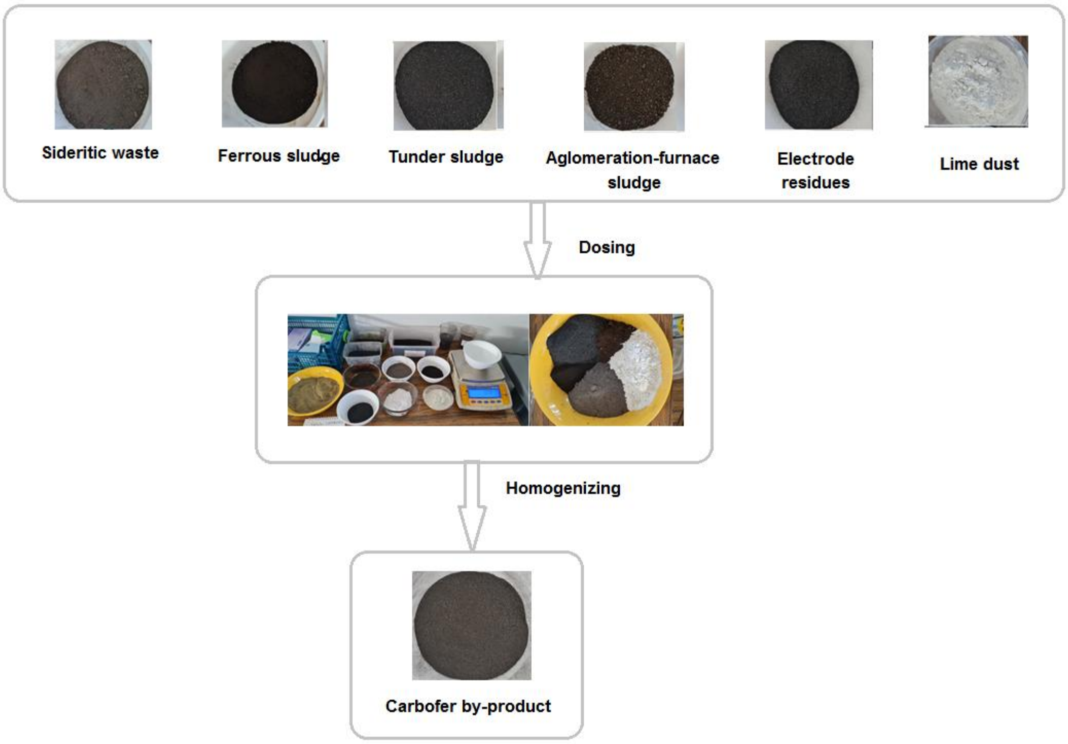

Fig. 1. Technological flow of waste processing

The chemical composition of the components in the experimental recipes is presented in Fig. 2.

A total of 10 experimental recipes were tested, with their components and chemical composition shown in Figs. 3 and 4.

The processed materials contain elements that are useful for the processes carried out in steelmaking aggregates.

Technology for producing the CARBOFER foaming material:

- Raw materials used: sideritic waste, ferrous sludge, electrode scraps, and lime dust;
- Determination of the qualitative characteristics of raw materials: chemical composition, granulation, moisture content, sterile content, foreign bodies;
- Homogenization: obtaining a mechanical mixture;
- Determination of the qualitative characteristics of the Carbofer by-product.

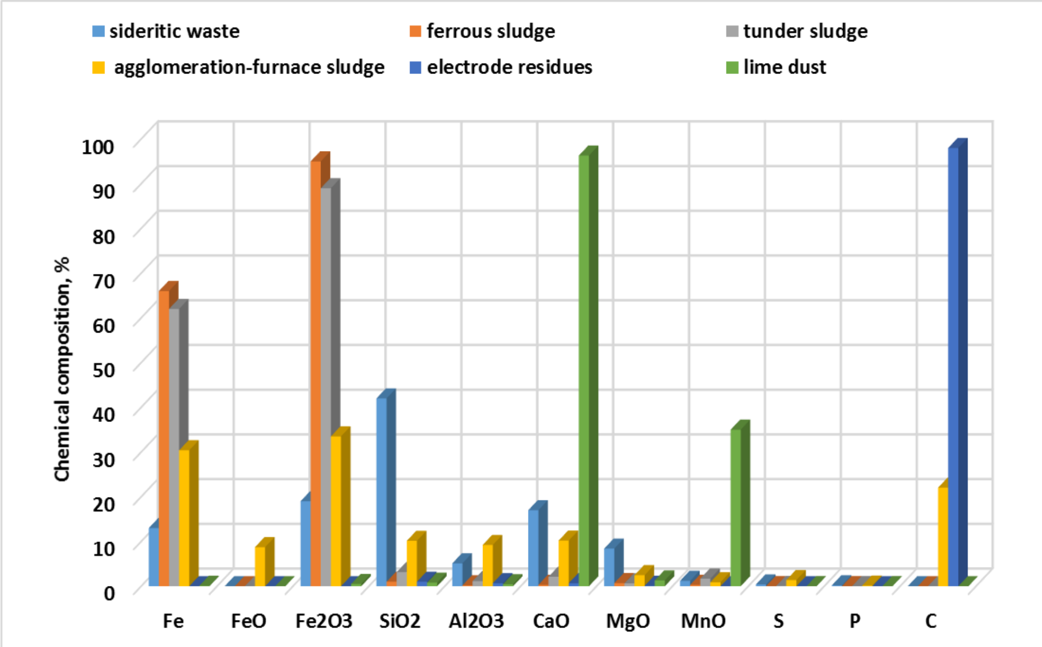

Fig. 2. Chemical composition of the components of experimental recipes

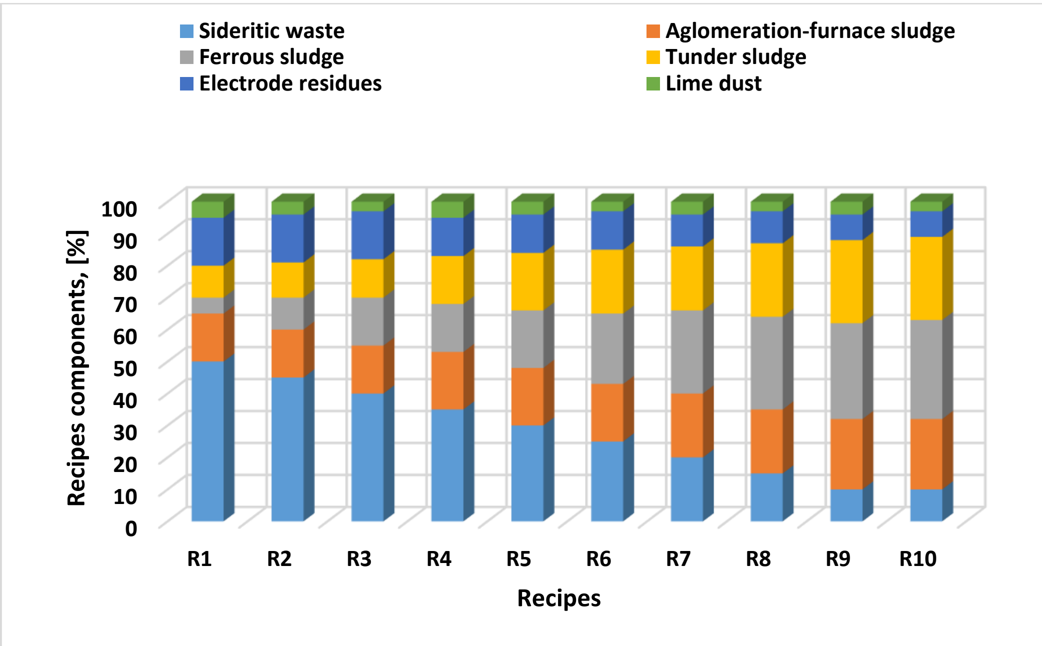

Fig. 3. Recipe Components

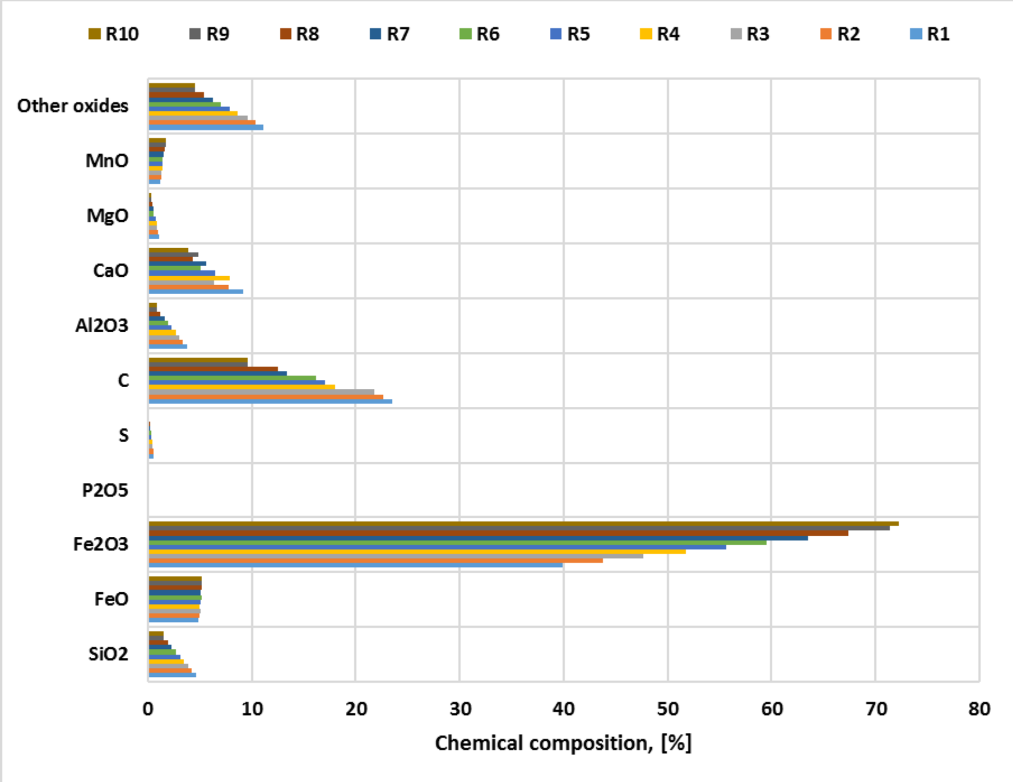

Fig. 4. Chemical Composition of the Carbofer Recipes

The experiments and tests were conducted in the laboratories of the Faculty of Engineering in Hunedoara. The resulting Carbofer by-product is a material used for slag foaming in the steelmaking process within electric arc furnaces. Working with foaming slag is a common practice in electric furnaces.

The experimental tests conducted in the laboratory aimed to highlight the phenomenon of slag foaming. The Carbofer by-product obtained (Fig. 5) was tested through a slagging process (Fig. 6). For this, a graphite crucible and an induction melting system were used, with the process temperature reaching 1350-1400°C.

Fig. 5. Carbofer by-product

Fig. 6. Testarea Carbofer by-product

3. Result and discussion

To determine the foaming capacity, the slag samples collected were investigated in terms of their macroscopic appearance (Fig. 7) using a stereomicroscope. A spongy material was observed, with uniform porosity, and pores with a diameter of 2.5 mm accounted for approximately 50% of the total pore volume.

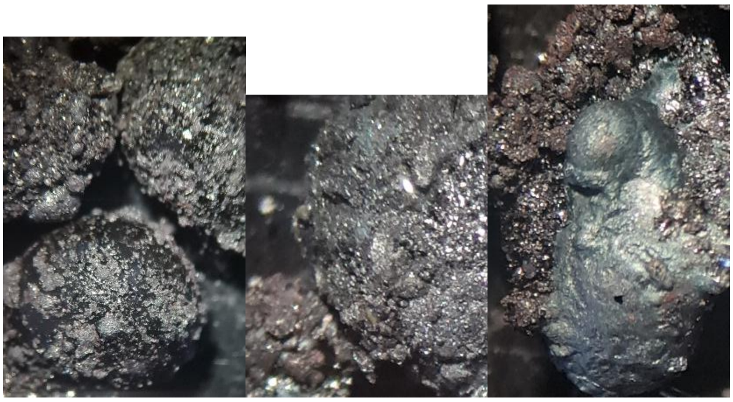

Fig. 7. Sample analysis with a stereomicroscope

In industrial practice, the use of foaming slag in steelmaking within electric arc furnaces originated from the desire to improve the thermal efficiency of the electrode-melt bath, especially under conditions where the furnace operates as a melting machine. Thus, towards the end of the melting process, long arcs are no longer surrounded by scrap metal, and their radiation severely affects the furnace walls and roof. To shorten the arcs, the secondary voltage is reduced, and to maintain electrical power, the current intensity is increased, leading to significant wear of the graphite electrodes. Therefore, slag foaming was implemented to allow for the use of long arcs even during the hot period of the manufacturing cycle.

4. Conclusions

Analyzing the results obtained from the production of the experimental Carbofer by-product and its testing, the following observations can be made:

- The Carbofer by-product has an appropriate content of FeO and CaO;
- The slagging time is 8-12 minutes;
- A satisfactory foaming of the slag is achieved.

To produce the Carbofer by-product, a series of wastes are used. By reusing these wastes in the steel production flow, economic, technological, and ecological advantages are obtained (reducing the quantities of waste landfilled).

In industrial practice, in steelmaking aggregates, the use of the Carbofer by-product, which has a high content of C and Fe, ensures a good dissolution of FeO in the slag. This results in a good oxidation of carbon in the molten bath and an intense foaming of the slag, thus ensuring the operation with a covered arc.

The use of foaming slag in steelmaking offers a number of advantages:

- Rapid increase in temperature and, consequently, in the productivity of the aggregate;
- Reduction in specific electricity consumption due to improved heat transfer efficiency from the arc to the molten bath;
- Reduction in the consumption of refractory materials due to decreased thermal radiation to the walls and roof;
- Lower specific electrode consumption due to operation with lower intensities.

The laboratory results regarding the production of the Carbofer mechanical mixture support its viability as an optimal recycling solution for the analyzed powdery wastes in the steel industry. The best results were obtained for recipes 1 and 5.

The foaming mass product obtained from the experimental recipes can be used under optimal conditions for slag foaming, ensuring an appropriate composition for this purpose in the steelmaking process within electric arc furnaces.

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