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# RECOVERY OF POWDERY WASTE WITH IRON CONTENT IN THE STEEL INDUSTRY

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*The steel industry implements sustainable solutions to produce high-quality steel while minimizing environmental impact. The structure of the ferrous raw material base is designed to maximise the use of waste and waste processors are working to ensure the qualities and quantities of waste required by it. The paper presents the experimental industrial research carried out and the results obtained on the use of powdered waste in the load of the arc electric furnace for the production of steel.*

**Keywords**: pulverous ferrous waste, steel, circular economy, environment

## 1. Introduction

Currently, steel production prevails in integrated combinations (primary flux/modern technologies - oxygen-powered steelworks, about 70% from the world production of steel), however, there are also a number of technical constraints, such as, economic and environmental, and in recent years there is an increase in the share of steel elaborated in small plants (modern technologies and steelworks equipped with electric arc-fired ovens, secondary treatment-continuous casting installations, about 30% of world steel production) [1,2,3].

The main technological problems encountered by the steel industry [3]:

- the quality of raw materials used (depleted raw materials, very limited supply or geographically inaccessible, limited flexibility in terms of production, use of very complex complementary gas cleaning systems, etc.);

- the large capital investments (high operational costs, low margins, low efficiency of machinery, etc.);

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- environmental problems (obtaining the authorization for construction and exploitation very difficult; by-products difficult to use; a large amount of wastewater, carbon footprint, etc.).

For the steel industry, the expansion of the raw material base in the context of the circular economy is of importance because the composition of the waste varies depending on the region of origin and the market [1,4]. At present, the requirements regarding the quality and purity of waste used in the production of steels are increasing. It is desirable to use in the metal load of steel-making aggregates suitable waste qualitatively and at competitive prices.

To obtain steel at low cost in the context of sustainable development and circular economy (Fig. 1), steel producers need to take a different approach to the use of metal scrap. Implementation of waste treatment processes and increased flexibility in handling different types of waste, especially iron-containing waste and other elements useful for steel development, become important for maximizing their use and meeting quality requirements [1,5]. Focusing on circularity and adopting new approaches for processing and reuse in the metal load of waste, steel companies can secure the future of their production strategies and add value to a low-carbon and zero-waste economy.

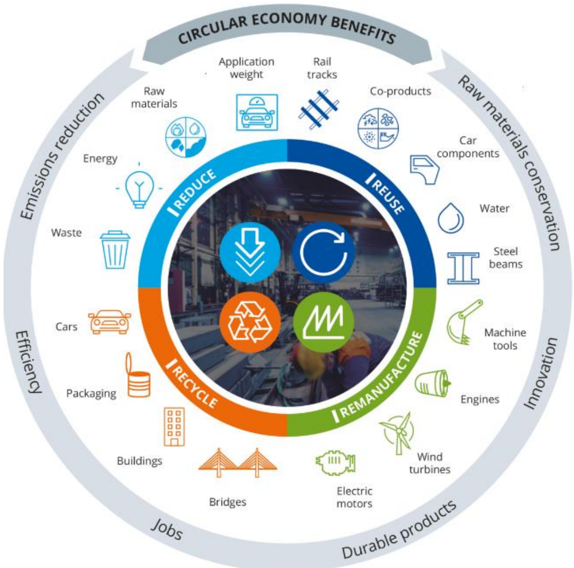


Fig. 1. Circular economy benefits [1].

Small ferrous and powdery waste after processing is a valuable raw material applied in steel manufacturing processes. The efficiency of the use of waste as raw or auxiliary materials is an integral part of the steel manufacturing process [6, 7]. The purpose of the steel industry is to use all raw materials at full capacity, ensuring zero waste from steel production, thus, each co-product resulting from the process of elaboration of cast iron and steel is used in the component of the load of the elaboration agreements. This approach minimises waste sent to landfill, reduces emissions and preserves raw materials [8, 9, 10].

Steel and waste containing recycled iron have a number of advantages. By-products also lose very little of their physical properties, and it is often more affordable to produce steel from recyclable materials than to produce steel from extracted ore - especially then when high strength steel is produced. Steel manufacturers are working to reduce the carbon footprint of steel produced by the traditional integrated steel fabrication. At present, we can consider that they have reached among the lowest levels of carbon emissions possible from a scientific perspective on the flow of steel production. The only available way to further reduce its carbon emissions is to switch to the production of steel developed in electric arc furnaces using alternative metals [11, 12]. In the context of sustainable development and the circular economy, the steel industry must also improve resource efficiency and reduce costs by harnessing waste and reintroducing it into the technological flow of the resulting by-products.

The significant number of wastes, residues and by-products generated in the EAF steel production route can be recovered both internally or externally to the steelmaking process by exploiting different approaches. Competitiveness and resource efficiency of the steel industry are reached in case of recycling residues directly in the EAF, or via new recovery technologies for recovery of ferrous waste [13, 14]. In order to reduce the environmental impact and production costs, while improving the quality of the developed steel, appropriate optimization strategies must be applied throughout the entire technological flow: minimizing energy and raw materials inputs, and, reducing emissions and waste produced, increasing the reuse of ferrous and non-ferrous waste, optimising technological operations and improving the quality of liquid steel [15, 16].

In addition to the ferrous waste from the steel industry, waste from other industries can also be used with good results, for example: pyritic ash from the chemical industry, iron concentrate from thermal power plant ash from the energy industry, red mud from the metallurgical industry. Analyzing the research carried out by different research collectives [7,17,18] regarding the valorization of small and powdery waste through the classic processes, it was observed the obtaining of viable by-products for use in the loading of steelmaking aggregates. Considering the imported quantities of waste still stored, efforts must be made to identify processing solutions for them and introduce them into the economic circuit. The recovery of valuable substances [19] from the waste stored or currently resulting from the manufacturing flows aims to contribute to the expansion of the base of raw materials in the context of sustainable development. The proposed procedure, namely the briquetting processing technology, has the advantage of flexibility, which offers the possibility of choosing recipes that may contain one or more powdery waste [20]. The processing of these types of waste, in order to obtain a suitable product to be recycled in various stages of the technological flow, is based on the idea of the lowest possible costs of treatment operations or at least equal to the costs of controlled storage.

## 2. Industrial experiments

Industrial research on the use of briquetting by-products, obtained from ferrous powder waste, in the load of steel-making aggregates, were carried out at an electric steel plant equipped with an electric arc furnace, a secondary treatment plant of LF-type steel, a VD type vacuum secondary treatment plant and a continuous casting plant [21].

Fig. 2 shows the technological flow of steel production at the level of the organisation. The industrial research was carried out on 5 charges of chromium and molybdenum alloy steel (steel brand 42CrMo4 and 25CrMo4 according to SR EN 10083-1). Elaborated steel barges were subjected to vacuum treatment. The steel was continuously poured in the form of billets.

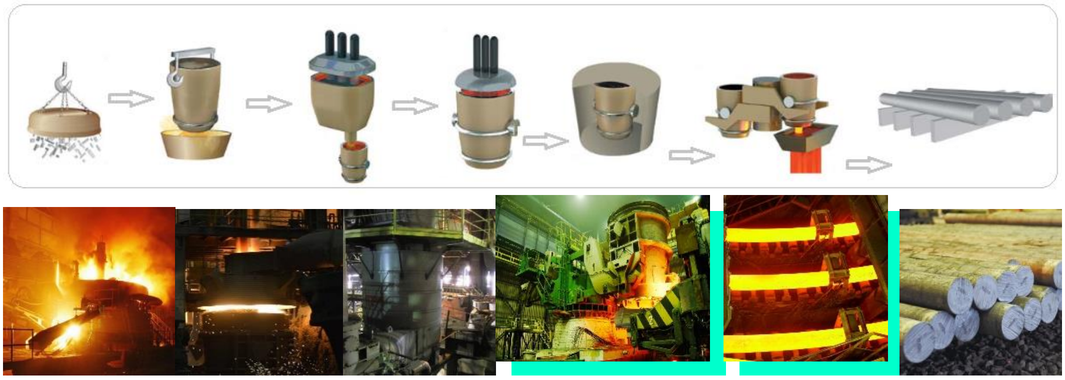

Fig. 2. The technological flow of steel production

Experimental strings were tracked throughout the technological flow, namely:

- elaboration in the furnace: good quality load without scrap with oils, moisture, rust below 2%, freshly burned lime, iron ore calcined, properly heated casting pot;

- treatment of steel in LF and VD installations: compliance with the limits of variation of technological parameters (heating, bubbling), moisture-free additions (for slag formation and alloying), chemical and thermal homogenization by argon bubbling followed by the treatment in the vacuum plant without VD heat input, at casting moulding pot and distributor heated according to technological instructions;

- compliance with the parameters of continuous casting: the casting speed correlated with the casting temperature, the flow rate and the pressure of the cooling water on each cooling area.

The metallic charge of the experimental charges: E1 - Old iron easily processed; E3 - Heavy iron; E40 - Broken scrap; E5 – Steel Span; E6 – Waste metal with small, thin, compressed/balanced residues; F – cast iron waste; A – waste alloy steel; B – Briquettes of small ferrous and powdered waste.

Fig. 3 shows the distribution of the metal load to the elaborated steel charges. In order to highlight the influence of the use in the metallic load of the briquettes' assortment, an analysis was performed on the steel barges and the balance on sequences (electrical furnace elaboration and casting-out). In the analysis carried out were: degree of metallization, dilution of elements and recovery of molybdenum. Fig. 4 and 5 shows the metallic load of the elaborate steel barges with the highlight of the briquettes assortment (B), this assortment being used at a rate of 15-21%. The balance sheet of the metal load is shown in Fig. 6. The methane, oxygen and electricity consumption for the analysed charges are shown in Figs. 7 and 8.

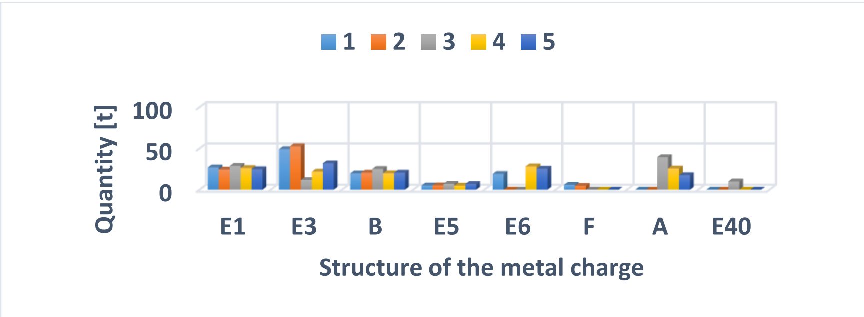


Fig. 3. Metal load distribution

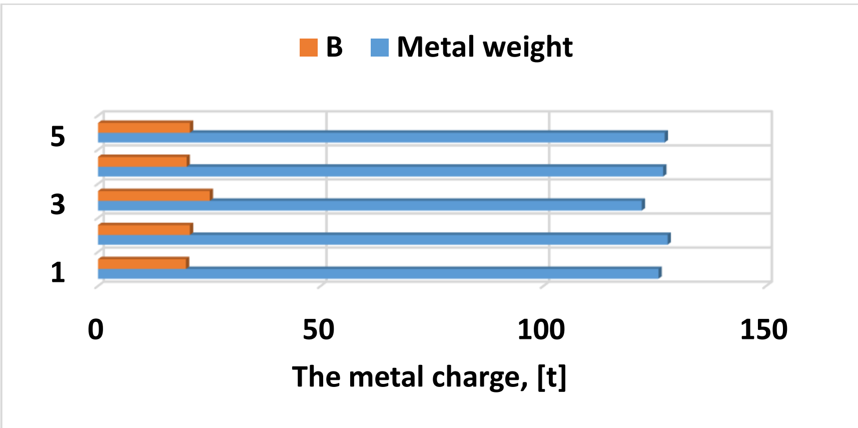


Fig. 4. Highlighting the briquetting assortment related to the total metallic load

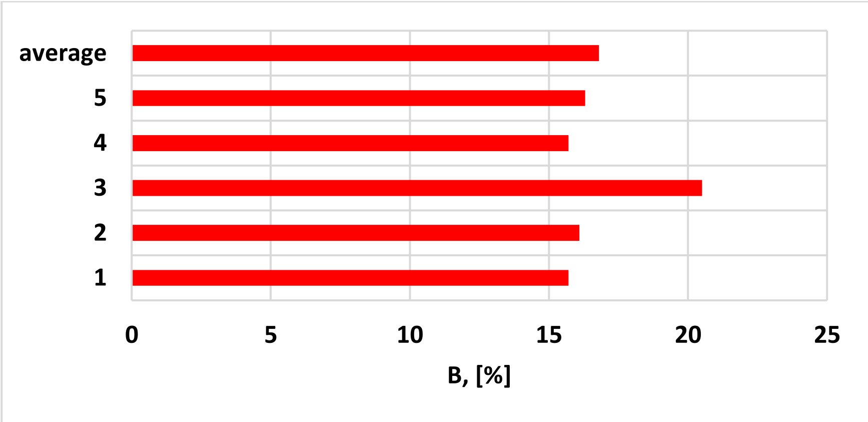


Fig. 5. Assortment of briquettes used in metal load

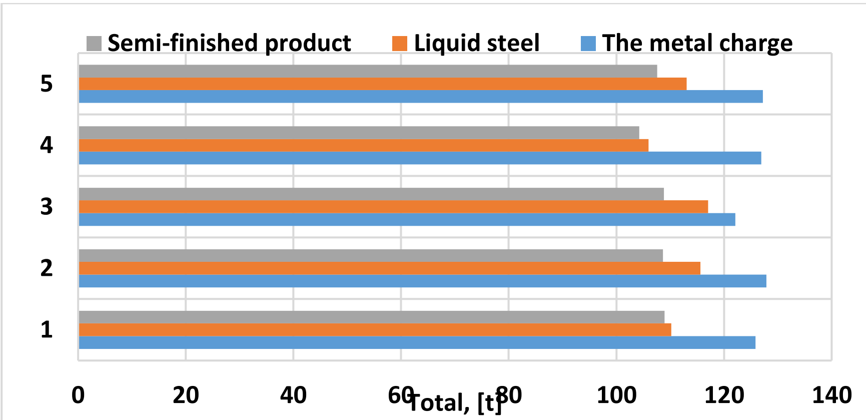


Fig. 6. Balance sheet metal load

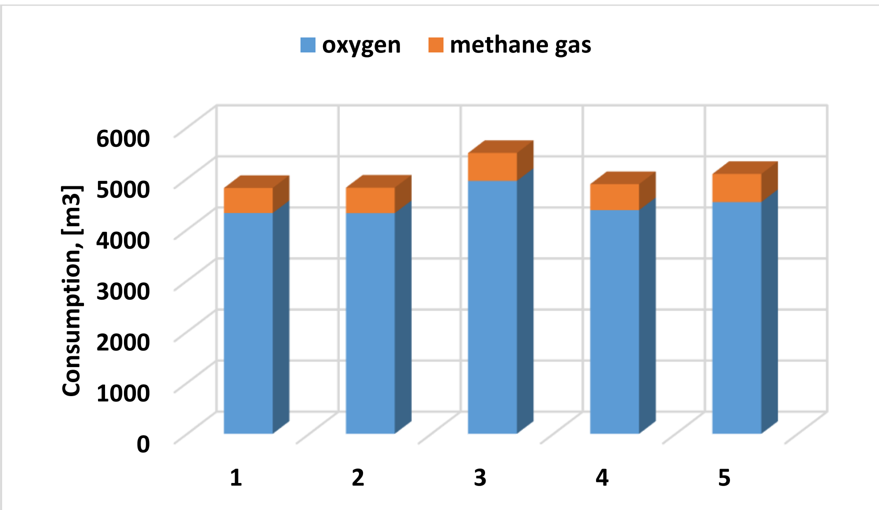


Fig. 7. Consumption of oxygen and methane gas

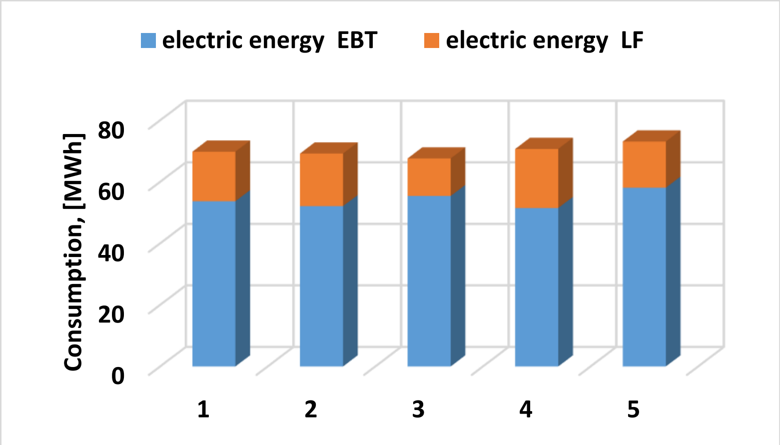


Fig. 8. Consumption of electrical energy in the development of steel

For the accuracy of the experimental data, a number of technological measures were considered:

- verification and calibration, according to the procedures in force, for measuring equipment;
- use only of materials with known physical and chemical characteristics (ferroalloys, slag foaming and carburizing materials, fondants, etc.);
- weighing of the billets, stitches and the rest of the distributor resulting from continuous casting;

weighing the slag and waste resulting from the process.

## 3. Result and discussion

To analyse the influence of the assortment of briquettes in the metal load on the degree of metallization, dilution and recovery of the useful elements in them were made a series of qualitative and quantitative determinations on experimental briquettes, old iron assortments used in the load, auxiliary materials, auxiliary materials, of materials and ferroalloys.

Samples were taken to determine the chemical analysis of steel and slags. Several chemical analyses were carried out on the briquettes to establish the chemical elements, mainly Cu and Mo, to highlight the recovery of molybdenum and the compliance with the product standards of the copper content.

After elaboration, the steel charges are subjected to secondary treatment in the LF installation and then followed the vacuum treatment in the VD installation. The casting of steel was carried out as follows: a sequence of 2 strings/sequences for the 1st and 2nd charge (Ø220mm), a sequence of a charge for the charge 3 (Ø220mm) and a sequence of 2 strings/sequence for the charge 4 and 5 (Ø280mm).

The specific consumption of metal load varied in the range of 1043.21-1160.26 kg/t steel and the degree of metallization 86-95%.

Regarding the copper content, it is higher by about 0.01 – 0.05% than at the end of the steel treatment. For the achievement of a copper content of 0.2 - 0.22% the amount of ferrous waste with low copper content (assortments E2 and E6) must be 40 - 46 t/large, etc, depending on the copper content of E1 (0.30-0.35%).

In the metal load of the chargers was introduced alloyed ferrous waste that bring into the load appr. 0.03%Mo. The melting molybdenum content being on average 0.05% results in the fact that the assortment of briquettes led to an extra 0.02% Mo (equivalent to 35 kg FeMo/charge).

The EAF steel production flow is based on a sustainable production chain, integrated into society in terms of the optimal use of raw materials and resources, including energy and its flow [22,23]. Resource efficiency [24,25] will also play a central role by implementing maximum valorization of residues for both internal and external usage as well as by optimizing utilization of scrap through suitable pretreatment and characterization techniques. The need for alternative sources of iron obtained through the processing of waste arises due to the quantities of scrap iron existing on the market as well as the impurity with unwanted elements in the composition of the steel.

## 4. Conclusions

From the analysis of the experimental data, the following are observed:

- Copper content at melting, at the end of the elaboration and at casting is within the product standard for continuously cast semi-finished products obtained during the experiments;
- The copper content in the melting sample is higher by about 0.01 – 0.05% than at the end of the steel treatment;
- For obtaining the copper content, according to the standard required by the beneficiary, within the limits of 0.2-0.22%With the amount of ferrous waste with low copper content, the E2 and E6 must vary within the limits of 40 - 46 t/large, respectively, considering the E1 assortment which has a copper content of 0,30-0,35%;
- The use of the briquettes' assortment does not lead to an increase in the copper content in the elaborated steel;

As for the molybdenum content, it is melting on average 0.05%, it follows that the assortment of briquettes led to an increase in molybdenum content of 0.02%Mo (equivalent to 35 kg FeMo/charge), so it can substitute some of the ferroalloys used;

- The use in the spring electric furnace load of the briquettes' assortment, on average 16%/charge, leads to the saving of raw materials (can replace the old deficient iron assortments, can, without influence on the quality of the elaborated steel);

- When using the briquettes assortment in load, there were no exceedances of the specific energy, fuel, oxygen consumption, these being within the technological norms in force.

In the case of the recovery of ferrous waste, in the context of the circular economy, by using by-products obtained as raw material, a number of advantages are obtained: technological, economic and ecological. Extending the raw material base in the steel industry by re-introducing small ferrous and powdered waste into the economic circuit leads to savings of raw materials, material, energy and fuel. Also, by-products obtained and used as raw materials from a qualitative point of view are superior compared to some of the old iron categories used in steelmaking aggregates.

Powdery and small waste can be recovered in current practice in the steel industry and it is necessary to continue research in order to establish the most efficient processes, recovery technologies, both from an economic and ecological point of view.

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