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Valorification of Ferrous Sludges Resulting from the Steel Industry

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A R T I C L E I N F O

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A B S T R A C T

A particular interest is represented by the unconventional processes of recycling of powdered ferrous waste in order to obtain a product with a high content of metallic iron. The work presents the results obtained from the processing of powdered ferrous waste by briquetting / agglomeration / pelletization as well as the possibility of valorization of the by-products obtained in the steel industry. This study also evaluates the potential of these valorification processes in significantly reducing the ecological footprint of the steel industry, aligning with global environmental sustainability goals and contributing to a greener industrial future. Furthermore, this investigation highlights the role of these processes in fostering a circular economy, where waste is transformed into valuable resources, promoting a sustainable industrial model.

1. INTRODUCTION

In order to apply the concepts of sustainable development, a balance must be established between the volume of raw materials used and the volume of waste that can be recovered, with positive effects on reducing the degree of pollution. It is necessary to pay particular attention to the technologies for processing recoverable waste, resulting from the current manufacturing flows and those deposited. The issue of waste management through recovery is an environmental and economic priority (Matei E., Râpă M, et al., 2021). The circular economy (Figure 1) stimulates the growth of economic value while decreasing the consumption of natural resources.

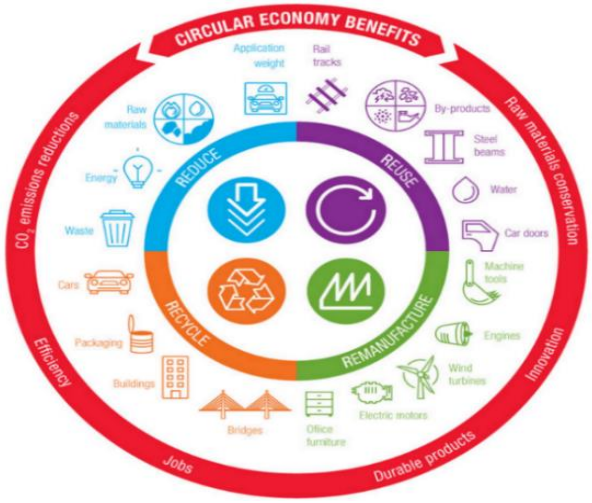


Fig.1. Circular economy in the steel industry

The strategy for the development of the metallurgical industry consists in the development of high-performance technologies in order to reduce emissions and increase the recovery and recycling yields of by-products (Ardelean E, et al., 2022).

Fig.2 presents examples of applications of by-

products in the steel industry.

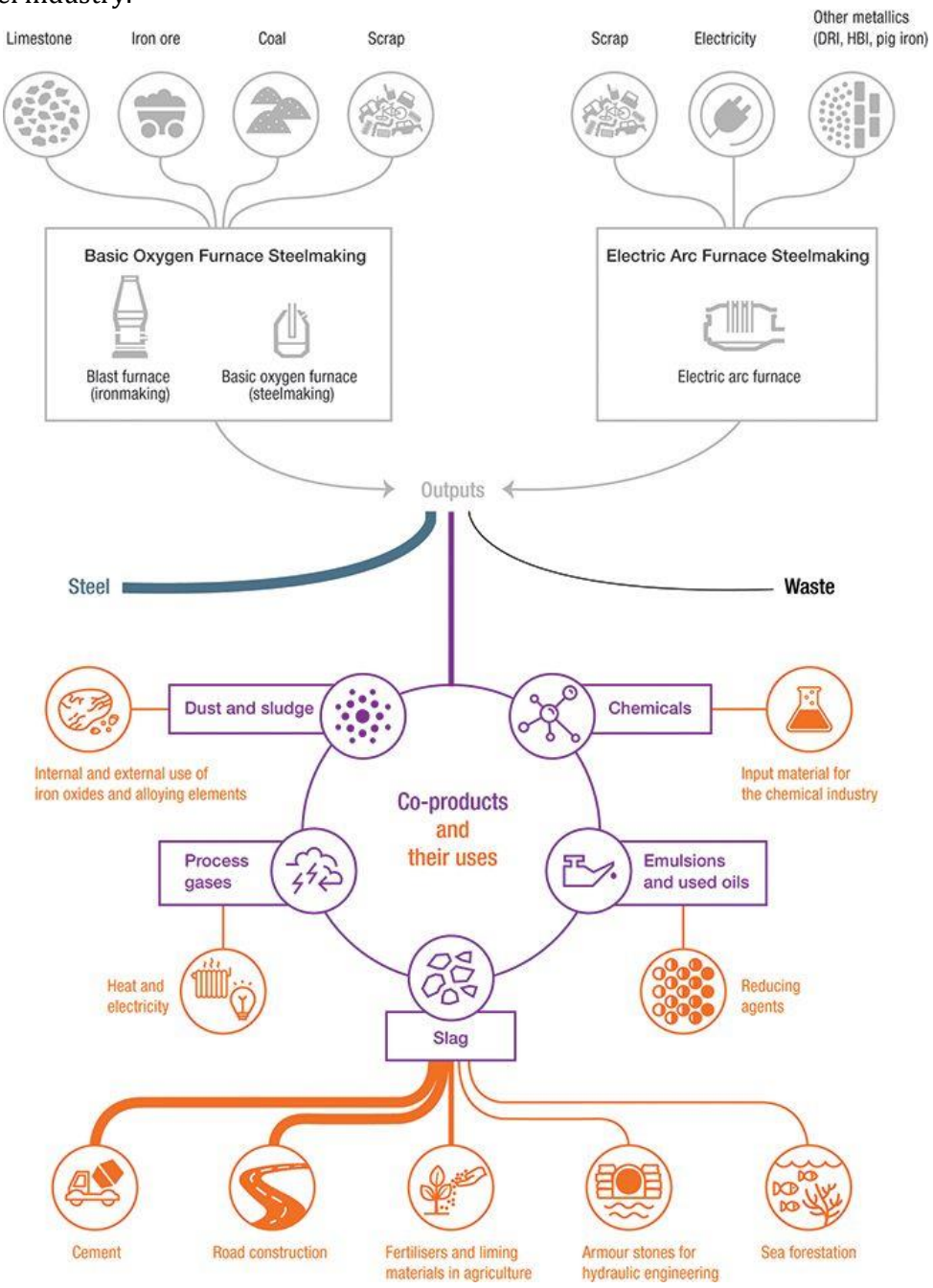


Fig.2. Applications of by-products in the steel industry

The waste resulting from all stages of steel production starting from the sectors of transport (Somova Y.V. et al., 2021), storage and preparation of raw materials to those of finishing the products on the agglomerator -furnace-converter-continuous casting-rolling mill or electric arc furnace–continuous casting–rolling mill, due to the possibilities of recovery through recycling and/or reuse, falls into the category of by-products (de Buzin P, et al., 2014; Lupu, O & Zgripcea, et al., 2018). By-products, together with scrap metal, are mainly sources of iron for the steel industry (Liu J, Liang D, Chen Y, Gao Y, Kong F, Zhu S, Wang L, 2023). Powdered ferrous waste comes from the processes of treatment of flue gases and wastewater resulting from steel processes (Garole, et al., 2012; Xiaolong L, et al., 2017). Depending on the processes used, the resulting waste is presented in a dry or wet state (slurry/sludge) and therefore their way of preparing for re-use differs

from case to case (Branca T.A, et al., 2020; Rieger, Johannes, et al 2021). The procedures applied worldwide for the recovery of powdered waste are pyrometallurgical, hydrometallurgical type processes, as well as other processes, such as hydrocyclone, pelletization, hot briquetting (LIS T., NOWACKI K, et al., 2015). To contextualize the importance of recycling ferrous sludges, we contrast the environmental impacts of traditional disposal methods, such as landfilling, with the more sustainable recycling alternatives, highlighting the need for a shift in waste management practices within the steel industry (GRABOWSKA S, et al., 2015). This section also delves into the latest advancements in waste recycling technologies (Vilarinho I.S., Lopes A.L, et al., 2021), discussing their potential to revolutionize waste management in the steel industry and reduce the overall environmental impact (Kanari N, et al., 2019).

2. METHOD AND EXPERIMENT DETAILS

The work presents the possibilities of processing and capitalizing on ferrous slurries using classical processing technologies (briquetting, agglomeration and pelletization). For the experiential researches, the following were used: ferrous sludge, agglomeration furnace sludge and sludge mill scale

When choosing the recovery process and technology, it must take into account: the characteristics of the waste, the destination of the finished product and the existing processing facilities (Law of waste, 2013). The work presents the obtained results and the final products resulted using the technologies for processing powdered ferrous waste by briquetting / agglomeration / pelletization. During the experimental phase, we adhered to stringent environmental safety protocols, assessing potential hazards and devising strategies to mitigate them (Li D., Hou H, et al., 2018). Additionally, we discuss the practical challenges and considerations for scaling up these processes for industrial applications.

The technological flow of ferrous sludge processing is shown in Figure 3.

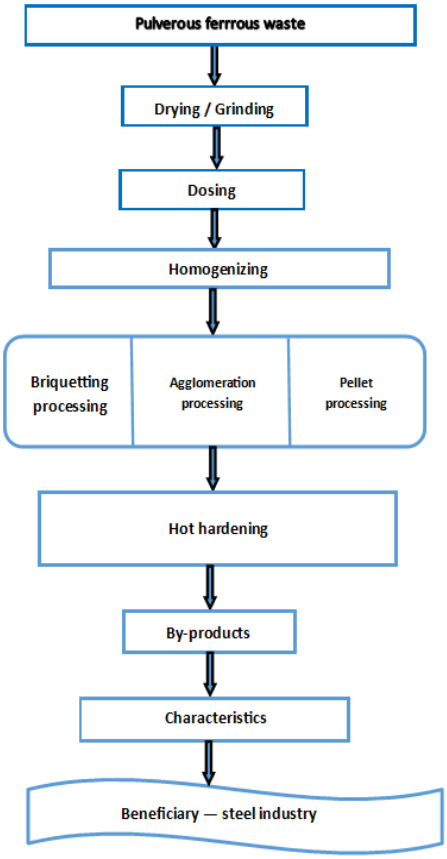


Fig.3. Technological flow of ferrous sludge processing

Their granulometric composition being shown in figures 4-6.

The SEM images for the processed waste are presented in fig.7-8.

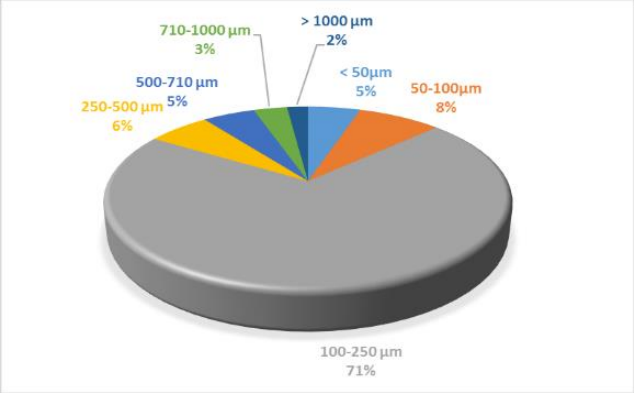


Fig. 4. Ferrous sludge analysis

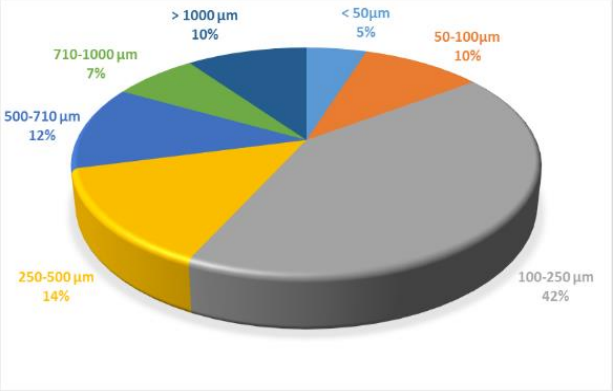


Fig. 5. Sludge mill scale analysis

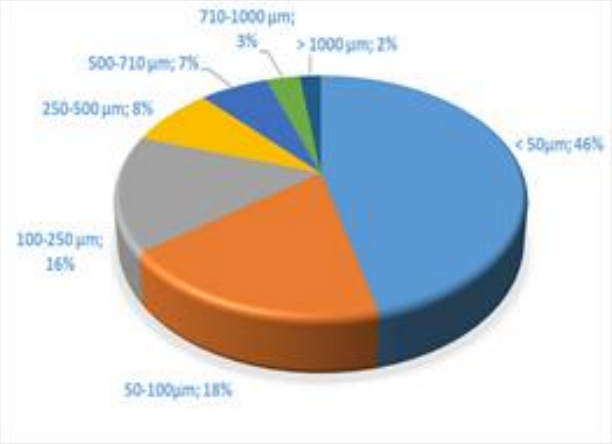


Fig. 6. Agglomeration-furnace sludge analysis

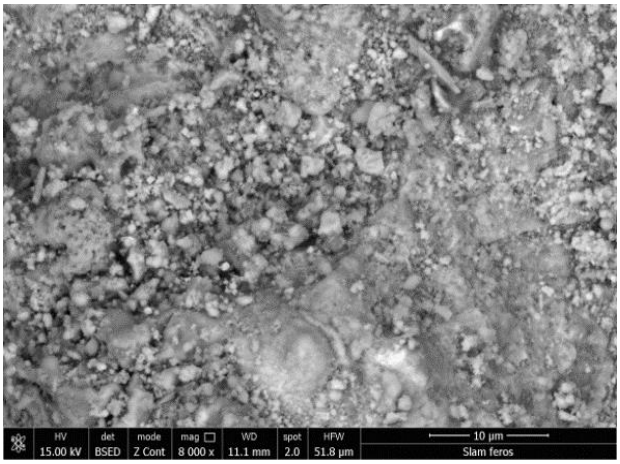


Fig. 7. SEM image for ferrous sludge

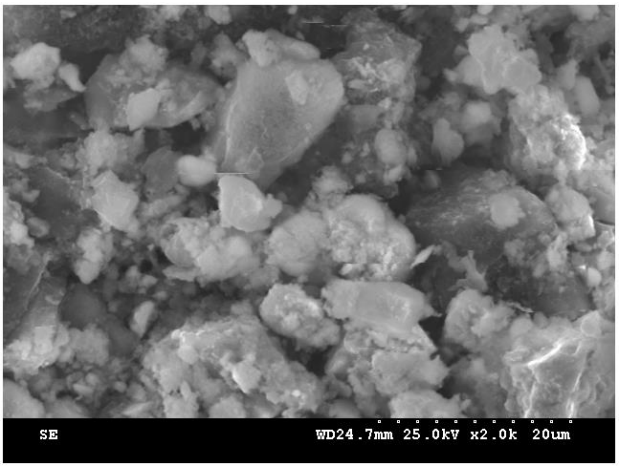


Fig. 8. SEM image for agglomeration-furnace sludge

Experimental technologies for the processing of ferrous sludges:

- Preparation of powdery ferrous sludge (ferrous sludge, sludge mill scale and agglomerating furnace sludge) for the formation of raw charge;
- Determination of the chemical and particle size composition on the group of materials subjected to processing;
- Dosing the materials according to the established recipe;
- Homogenization of materials;
- Briquetting / Agglomeration / Pelletization;

- Hardening of by-products;
- Determination of qualitative characteristics.

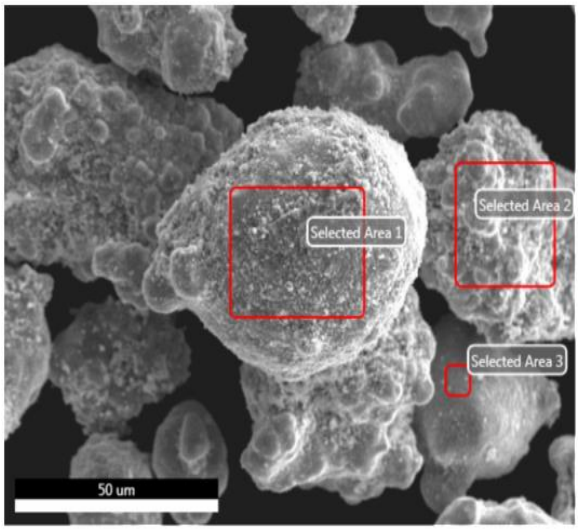
We also incorporate a comparative analysis of the environmental impact of each valorification process, using life cycle assessment methodologies to provide a holistic view of their sustainability.

3. RESULTS AND DISCUSSION

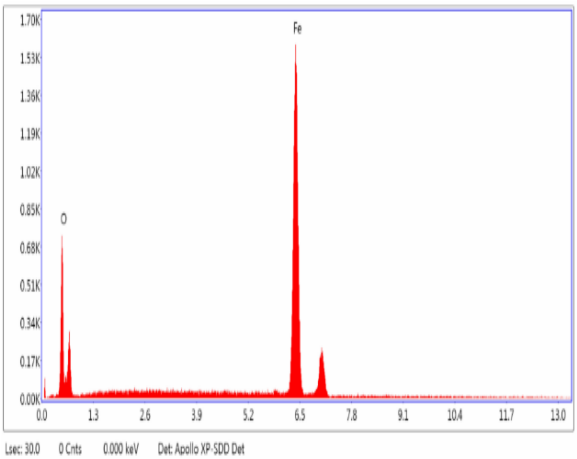
The by-products (figure 9) obtained are subject to handling and transport operations. It is necessary that the resulting by-products (pellets, briquettes and agglomerates) have a certain strength during handling and transport operations, a shredding of these products would lead to the non-fulfilment of the processing conditions in view of the extraction of iron.

The obtained experimental by-products have an iron content of 52-78%Fe. Morphological and microscopic EDS analysis is shown in Figure 10.

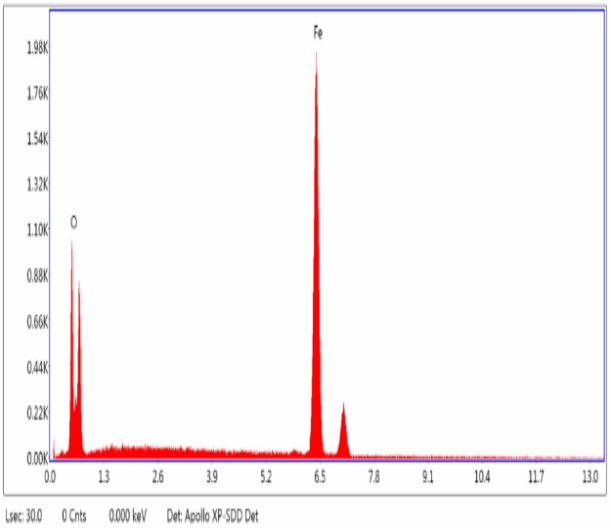
Figure 9. By-products



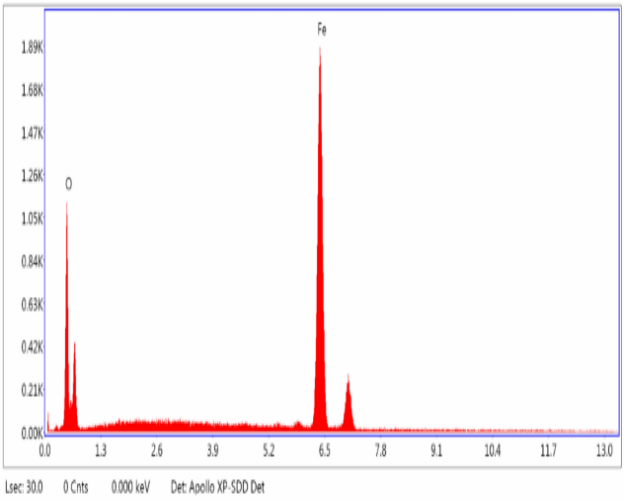
(a) Image SEM experimental lighter



(b) EDS – spectrum zone 1 (65,6%Fe)



(c) EDS – spectrum zone 2 (62,24%Fe)



(d) EDS EDS – spectrum zone 3 (59,92%Fe)
Figure 10. EDS analysis for the experimental lighter

In order to determine the possibilities of recovery of iron and other accompanying elements in the steelmaking process further experiments were carried out with the resulting by-products of elaboration of steel batches. The experiments were carried out in an induction furnace. The degree of recovery of iron varied between 88-98%. The by-products obtained from ferrous slurries, by burning can be metallized, which allows their use as a component in the load of furnaces for the elaboration of steels. The results are further analyzed for their economic implications, revealing the potential cost-effectiveness and financial benefits of adopting these recycling methods. We discuss how these methods could lead to significant savings and efficiency improvements in the steel industry. The discussion further explores the implications of these findings for environmental policy and industry standards, suggesting ways these processes could be integrated into existing regulatory frameworks for greater impact.

4. CONCLUSION

The by-products obtained are intended for use as a raw material in the elaboration of steel in electric arc furnaces and have an iron content of 52-78%. It is necessary to intensify the process of recovering this waste for economic, technological and environmental reasons. In conclusion, our findings underscore the crucial role of innovative waste management solutions in industrial processes. We recommentded that the study's insights could be applied to other industries facing similar waste management challenges, paving the way for broader environmental and economic impacts. We advocate for increased industry collaboration and government support in adopting these innovative recycling methods, emphasizing their potential in contributing to global environmental sustainability goals.

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Law of waste (Dz. U. 2013, 21)

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