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Expanding the Raw Material Base in the Steel Industry

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ABSTRACT

The processes of direct reduction of ores are intensively used worldwide because of the significant amounts of raw materials needed by the steel industry, so that in the future the quantities of iron sponge / by-products used in the processes of developing ferrous alloys.

The paper presents a synthesis of the processes for the direct reduction of iron ores and the processing or transformation into by-products, intended for the steel industry, of small and powdery waste with Fe content, as well as experimental research in the pilot phase, to obtain some by-products from waste.

Iron-containing by-products from waste processing contribute to expanding the base of steel raw materials in the context of sustainable development and circular economy.

1. INTRODUCTION

A significant amount of industrial waste (small and powdery waste containing iron) is generated annually from the steel industry.

Steel companies are those that continuously generate iron-containing waste and in quantities directly proportional to their production. The most common iron-containing waste is the following: dust and sludge agglomeration, dust and sludge blast-furnaces, dust and sludge of converter, steel mill dust, electrofilter dust from electric steel mill, scale (oxide layer on the surface of the steel part heated to high temperatures) and mill scale sludge (mixture of water with fine particles of material) (Popescu D, 2018). Powdered waste results from various exhaust gas and wastewater treatment operations within steel processes (cast iron and steel production) (Socalici A, et al., 2014; Hepuţ T, et al.,2011; Socalici A, 2016; Mititelu C.P., et al., 2015).

In Figure 1 a precise delineation of the above types of waste into two main categories of industrial steel waste is provided.

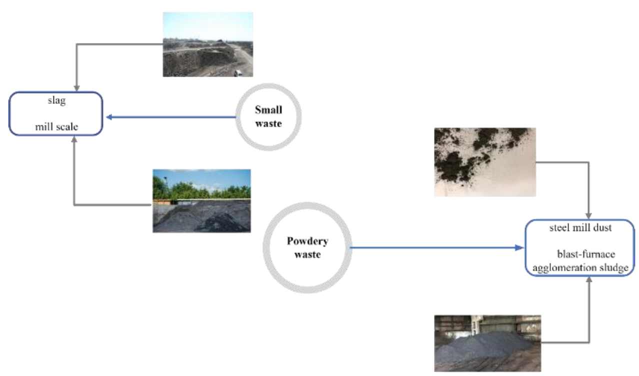

Figure 1. Classification of types of iron and steel waste

Small waste is generated in both steel processes (scale and slag - ferrous fraction) and in the mining industry – preparation of sideritic ores (ferrous concentrate from sideritic waste) (Socalici A, et al., 2014; Hepuţ T, et al., 2011; Socalici A, 2016; Mititelu C.P, et al., 2015).

In the steel industry, small powdery waste with a high content of useful elements (Fe, C, etc.) can be processed or transformed into by-products and

recovered in the processes of developing metal alloys. Worldwide, the processing of waste into by-products is carried out using a series of processes. This paper focusses only on the study and analysis of a single process, namely direct reduction.
Recovery of the useful element (Fe) content of iron ore by exposing it to temperatures below the melting temperature of iron is achieved by means of the direct reduction process. In the process, the amount of oxygen in the ore is reduced by exposing it to low temperatures (500-1100°C) or high temperatures (higher than 1500°C), resulting in the iron sponge, named after its high degree of porosity — Figure 2. (Socalici A, et al., 2014; European Commission, 2001; Steiniger V, 2022; Socalici A, 2024).

Figure 2. Iron sponge or direct reduced iron (FutureX Holding Limited, 2024)

Iron sponge is produced in direct reduction aggregates (bucket ovens, rotary furnaces, tubular furnaces) where a reducing agent is used (natural gas, coal, etc.), the final product being manufactured in the form of irregularly shaped lumps, spherical pellets, iron magnifiers, fine powder (Socalici A, et al., 2014; European Commission, 2001; FutureX Holding Limited, 2024; Cargo Handbook, 2024).
Most commonly, iron sponge or directly reduced iron is used in the load of electric arc furnace and induction furnace in steelmaking (Socalici A, et al., 2014; Steiniger V, 2022). Worldwide, direct reduced iron production (DRI) is increasing due to the need (demand) for by-products used in steel plants as substitutes for iron ore (raw material in pig iron and steel production processes) and scrap metal (secondary raw material).
Figure 3 shows the evolution of iron sponge production worldwide between 2008 and 2022, which reinforces the previous statement. It is worth mentioning that direct reduced iron is manufactured in various forms that will be detailed below.
The variants under which iron sponge is produced are: CDRI (cold direct reduced iron), HDRI (hot direct reduced iron), HBI (hot briquetted iron) (Socalici A, et al., 2014; European Commission, 2001; Păcurar C.D, 2019; Midrex, 2024; International Iron Metallics Association, 2021; Midrex-The world leader in direct reduction technology, 2020).
According to statistics, in 2022 the top five countries in the world producing iron sponge are: India with a production of 43.55 million tones, Iran with a production of 32.90 million tones, Russia with a production of 7.66 million tones., Saudi Arabia with a production of 6.48 million tones, and Mexico which had a production of 5.84 million tones (Midrex-The world leader in direct reduction technology, 2022).

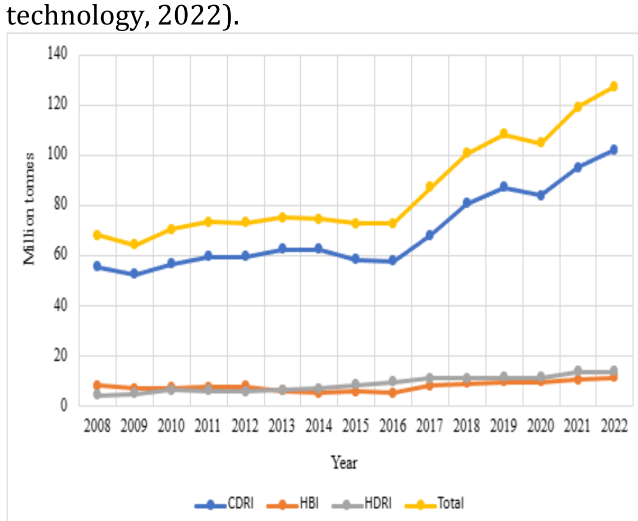

Figure 3. Evolution of iron sponge production worldwide

To directly reduce iron ore and waste from the steel industry, several processes have been developed around the world; therefore, this paper will detail only the most known and used iron sponge manufacturing processes worldwide.

2. METHODOLOGY AND RESEARCH DESIGN

The methodology followed in the paper provides for the description of the most used direct reduction procedures and the presentation of the current stage of research in the field of direct reduction of iron ores and small and powdery waste containing Fe. The aim of the paper was to present the main characteristics of some of the most well-known reduction procedures, while also identifying the stage and applicability of some direct reduction procedures on the territory of Romania. This aspect was achieved by presenting experimental research conducted by a team of researchers made up of professors from important universities in the country and specialists from steel companies.

2.1. Processes for obtaining sponge iron / direct reduced iron, practiced worldwide

2.1.1. Processes for the manufacture of iron sponge from iron ore

A. MIDREX process

The process of reducing iron ore in a bucket oven, where a reforming gas obtained from natural gas is used as fuel, is characteristic of MIDREX process technology (Masaaki A, et al., 2010).

Lower quality iron ores can often be used in MIDREX iron sponge production plants, which is determined by the cost of raw materials and the impact of steelmaking operations, without affecting the quality of the final product (Midrex-Designed for today, Engineered for tomorrow, 2018).

In the direct reduction installation used by MIDREX technology, iron ore, pellets and / or lumps are loaded on top, the reducing gas (H_2, CO) reacts with iron oxide (removing the oxygen content), resulting in the iron sponge that can be evacuated hot or cold (Midrex-Designed for today, Engineered for tomorrow, 2018).

Figure 4 shows the elaboration aggregates in which the different variants of iron sponge produced by the MIREX process technology are used.

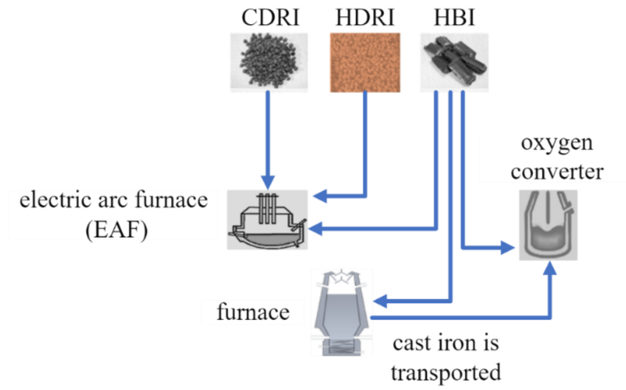

Figure 4. The use of iron sponge in various aggregates according to its physical and chemical characteristics (Midrex, 2024; Midrex-Designed for today, Engineered for tomorrow, 2018)

In the past, the MIDREX process produced only DRI cooled before discharge, but as the benefits of using DRI became more known, the next step was to improve the technology, with the iron sponge being hot-discharged and hot-briquetted in a roller press that shapes the reduced material into dense briquettes, resulting in HBI (Midrex-Designed for today, Engineered for tomorrow, 2018). The process of briquetting the iron sponge, in which no binder is used, is shown in Figure 5.

The improved physical characteristics of the HBI product have proven to be a solution to the handling, shipping, and storage problems associated with DRI. Hot briquetting was the solution found to improve plant losses and expand the potential market for DRI products, through the possibility of using an iron sponge in a blast furnace (Ravenscroft C, et al., 2018).

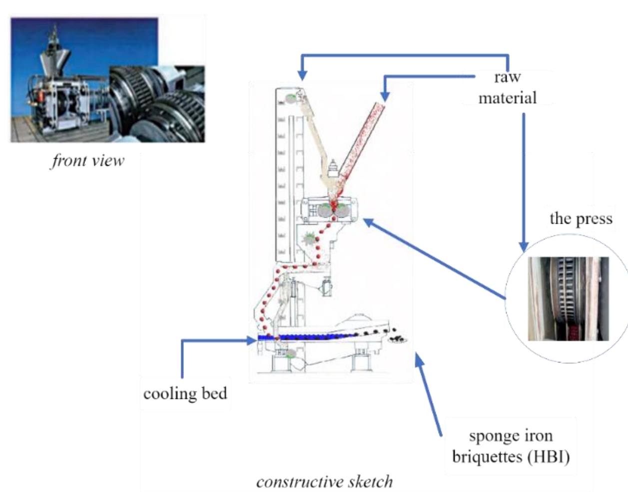

Figure 5. HBI manufacturing plant (Socalici A, 2024; Atsushi M, et al., 2018; Ravenscroft C, et al., 2018)

The combination of hot and cold discharge in a single reduction furnace was a logical advance for MIDREX process technology. Currently, in MIDREX direct reduction installations, the shape of the DRI can be changed without interrupting the flow of products (CDRI to HBI, CDRI to HDRI, or HDRI to HBI), and the iron sponge can be produced simultaneously in any combination (Midrex, 2024; Midrex-Designed for today, Engineered for tomorrow, 2018).

The evolution of iron sponge production through the MIDREX process is shown in the graph in Figure 6 and as can be seen, the quantities of directly reduced iron (DRI) have been increasing. In the coming years, the steel industry is expected to focus exclusively on using iron sponge as a raw material to reduce carbon dioxide emissions.

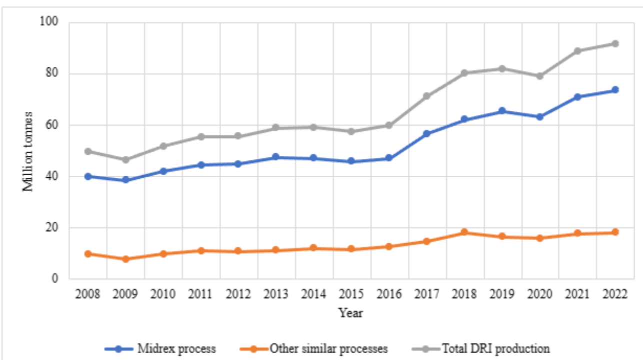

Figure 6. Evolution of iron sponge production worldwide

The technology on which this process is based is considered the most widely used and successful iron sponge manufacturing technology. In 2022, 57.8% of the total iron sponge production (127.36 Mt) was manufactured using the MIDREX process (Midrex-The world leader in direct reduction technology, 2022).

B. HYL / ENERGIRON process

In the HYL process, oxygen from iron ore (initially processed as pellets or lumps) is removed in a retort / reactor facility (Ahmed M.M.I, et al., 2016). The HYL process technology has undergone numerous changes, of which the most representative are mentioned below.

The HYL I generation, which appeared in 1957, consisted of four identical reactors operating simultaneously, each of which was at a different point in the reduction cycle at a particular time (Socalici A, et al., 2016; Lüngen H.B, et al., 2022).

The second generation (HYL II) was a modification of the initial process to improve efficiency and reduce natural gas consumption. At this stage of process development, two significant changes were made, namely: the use of the high temperature alloy tube in the gas reheating furnace, which allowed the gas to be heated to the higher temperature, and the reduction of the number of heating retorts from the original four units to two units (Satyendra, 2017). The HYL II process was never commercialized, as the advent of the HYL III process offered many more significant advantages.

After years of research, the HYL III process, was developed, the third generation of HYL reactors, although II was not a separate process, but was only an improvement over HYL I. The main change was the replacement of the four fixed-bed reactors with a single movable-bed reactor (Dutta S.K, et al., 2016). The new concept of the HYL process (HYL III) has led to higher plant productivity, higher iron sponge quality, lower energy consumption, and simpler plant operation (Satyendra, 2017).

Improvements in the HYL III facility led to the emergence of HYL IV M generation. This facility used a movable bed reactor (like HYL III) to reduce iron ore pellets and iron ore, producing cold / hot DRI (CDRI / HDRI), and hot briquetted sponge (HBI). The first HYL IV M plant began production in 1998 in Monterrey, Mexico (Asia Steel, 1999; Dutta S.K, et al., 2016).

In 1988, the supply of natural gas and the injection of oxygen into the reduction reactor led to the "HYL self-reform scheme", called HYL ZR, which was successfully implemented in 1998, and in July 2001 (Satyendra, 2017).

In 2005, HYL technology was acquired by Techint Technologies, which was later named Tenova HYL. In 2006, Tenova and Danieli formed a strategic alliance for the design and construction of DRI gas-fired plants under the new brand "ENERGIRON".

C. SL/RN process

In the rotary furnace, there are two main temperature zones; the first is the preheating zone where the load is heated to 900-1100°C (the raw materials that make up the load are dried and the volatile substances in the coal are removed) and in the second zone, the temperature is kept constant at 1050-1100°C. After reduction, the material is

cooled in a metal drum sprinkled outside with water, sieved, and magnetically separated to remove tailings (Socalici A, et al., 2014; Lüngen H.B, 2022; Metso, 2024; Kekkonen M, et al., 2000).
Figure 7 shows the sketch of the SL/RN process, together with the elements adjacent to the reduction plant (rotary furnace).

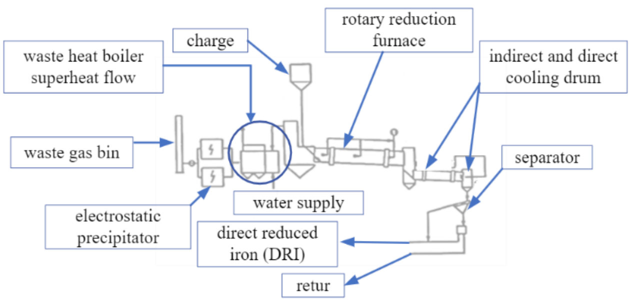

Figure 7. Schematic arrangement of direct reduction installation SL/RN (Socalici A, et al., 2014; Socalici A, 2024; Lüngen H.B, et al., 2022; Kekkonen M, et al., 2000)

Compared to direct reduction shaft furnaces (MIDREX, HYL processes), rotary furnaces are characterized by greater flexibility in the use of iron ores, high energy consumption, and low productivity (Lüngen H.B, et al., 2022). This direct reduction process has gained momentum in India, where hundreds of plants over the past 30 years have used SL/RN technology (Lüngen H.B, et al., 2022).

D. ITmk3 process

This process involves making a mixture of iron ore / fine ore concentrates and non-coking coal, to obtain raw pellets, which are loaded into the rotary hearth furnace and transformed by simultaneous reduction and melting, into granulated iron called "iron nuggets" (Ironmaking process alternatives screening study, 2000; Ghosh A.M, et al., 2021; Ishikawa H, et al., 2008; Satyendra, 2013; KOBELCO, 2023; Kikuchi S, et al., 2010; Upakare R, et al., 2018; Gulhane A, 2017).
The advantages of using ITmk3 are highlighted by the following aspects: (Ironmaking process alternatives screening, 2000; Ishikawa H, et al., 2008; Satyendra, 2013; KOBELCO, 2023; Kikuchi S, et al., 2010; Upakare R, et al., 2018; Gulhane A, 2017; Chatterjee A, 2012):

- granulated iron has small dimensions that facilitate handling and transportation;
- granulated iron can be continuously charged in an electric arc furnace (EAF) just like an iron sponge (DRI) and hot briquetted iron sponge (HBI);
- the process is simple, allowing direct use of low-quality materials and complete separation of hot metal from slag;
- ability to use a wide variety of solid reducers (including antracid);
- most of the equipment involved in the process has been tested and has been industry-proven high reliability;
- the plant is easy to operate without the need to handle molten iron, which is unprecedented in other processes;
- granulated iron melts easily, having a low melting point and high thermal conductivity;
- unlike the iron sponge and the hot-briquetted iron sponge, granulated iron does not contain a sterile constituent;
- in the ITmk3 process, granulated iron, which is equivalent to cast iron, can be produced directly from raw pellets without the need to reduce the pellets.

The first commercial plant where ITmk3 technology was implemented through Steel Dynamics, Inc., (Hoyt Lakes, Minnesota, SUA), started production in 2010 and has a capacity of 500000t/year (KOBELCO, 2023; Kikuchi S, et al., 2010; Gulhane A, 2017).
Such technologies operate at Mesabi Nugget, Minnesota, USA, capacity 500000t/year (Ishikawa H, et al., 2008) in Michigan, USA, in collaboration with Cleveland-Cliffs Inc, as well as in Kazakhstan, India, and Ukraine (Gulhane A, 2017). Itmk3 technology is available in operation, and its implementation is under development in many plants around the world due to its flexibility regarding carbon sources (Ishikawa H, et al., 2008).
The graphs in Figures 8 and 9 show the evolution of DRI production related to the main types of process and the production statistics by geographical region.
It is found that in the field of iron sponge production, three processes predominate (MIDREX, HYL / ENERGIRON, and reduction processes in rotary furnaces) which have been detailed in this paper. According to data provided by MIDREX Technologies, Inc., which were graphically represented and analyzed, the growing need of steel companies for by-products to ensure, diversify, and expand their raw material base. The

MIDERX process holds the largest share of the world's total iron sponge production, with a current goal of improving its technology by using hydrogen, thus limiting gas emissions to zero.
Through the constant improvements made to MIDREX technology, it can be expected that this process will be able to meet the corresponding raw material base needs for the global steel industry, thus occupying a monopoly position on the relevant markets.
Regarding the regions where the largest amount of iron sponge is produced, it was found, according to the data presented in Figure 9, that more than half of the total world production is produced in North Africa (58.48Mt). At the opposite end is Europe with a production of 7.81Mt of total world production (123.36Mt).

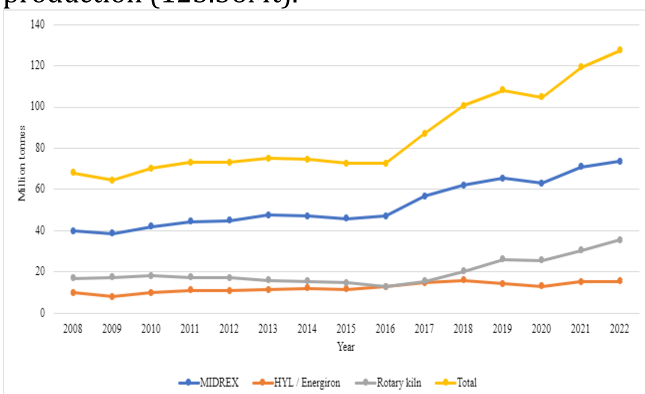

Figure 8. World DRI production according to the technology used

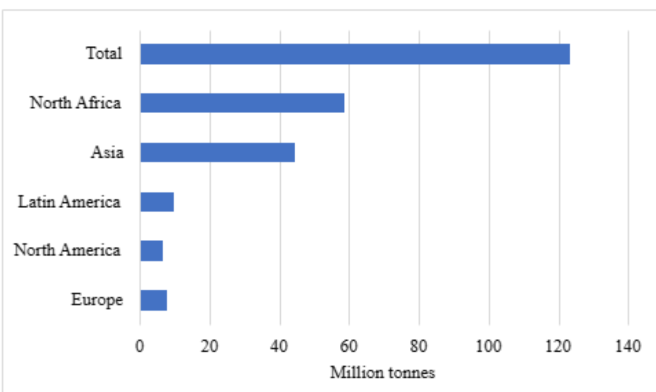

Figure 9. World production of DRI by region

As a result of the findings, it can be stated that the European steel industry has serious deficiencies in terms of expansion, respectively, diversification of the raw material base necessary for steel companies producing Fe-C alloys. It is necessary to increase iron sponge production capacities in several countries in Europe, for example Germany, where CDRI is produced (0.40Mt/year) and Russia, where there are two CDRI production plants (capacity 1.67Mt/year) and HBI (2.08Mt/year) (Midrex, 2024). Currently, iron sponge is considered a by-product of utmost importance for the steel industry, due to the advanced technology of its production in various variants that are adapted to the needs of specific elaboration aggregates (blast furnaces, converters, electric arc furnaces), but also to superior technical characteristics (high iron content, high level of purity, lack of elements harmful to the quality of metal products). For this reason, the popularity of this type of by-product as the main raw material in most production processes is expected to increase.

2.1.2. *Processes for the manufacture of iron sponges from iron ore and / or small and powdery waste with a high iron content*

A. FASTMET process

This process involves loading iron ore and / or small powdered waste containing iron into a rotary hearth furnace, resulting in the production of iron sponge (Lupu O, 2023; Miloștean D, 2024; Socalici A, 2016; Ghosh A.M, et al., 2021; Kekkonen M, et al., 2000; KOBELCO, 2023).
Currently, the installed capacity of DRI plants based on FASTMET technology varies between 16000-190000t/year (Ghosh A.M, et al., 2021; KOBELCO, 2023; Tsutsumi H, et al., 2010).
Small and powdery wastes that are considered as raw materials in this process which also aims to recover the zinc content from them are: blast-furnace dust and sluge, converter dust, agglomeration dust, steel mill dust, mill scale and sluge (Kekkonen M, et al., 2000; KOBELCO, 2023).
As with the MIDREX process, the iron sponge manufactured using the FASTMET process technology is either hot-briquetted direct reduced iron (HBI), hot-discharged direct reduced iron (HDRI) or cooled direct reduced iron (CDRI) or used as a raw material in specific aggregates for the elaboration of metal alloys (blast furnace, converter, or arc furnace) (Lupu O, 2023; Miloștean D, 2024; Socalici A, 2016; Kekkonen M, et al., 2000; KOBELCO, 2023).
The hot discharged iron sponge briquetting plant, located near the rotary hearth furnace, is shown in Figure 10.

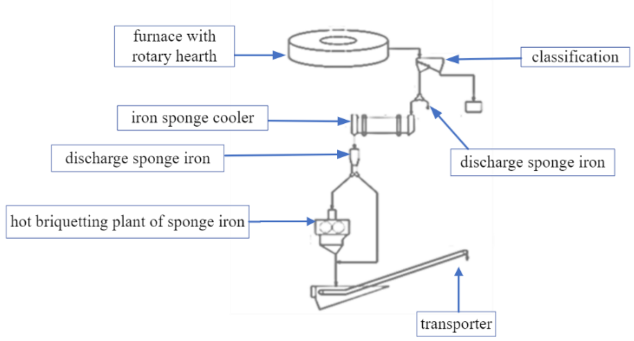

Figure 10. Process flow of the HBI production line of a FASTMET plant (Tsutsumi H, et al., 2010).

The appearance of the briquetted iron sponge is shown in Figure 11.

Figure 11. Lighter made of iron sponge manufactured by the FASTMET process (Tsutsumi H, et al., 2010).

Taking into account the high level of gas emissions generated by the steel industry and the situation of depletion of primary material resources, the FASTMET process represents a solution to the problem of lack of materials, but also significant amounts of small and powdery waste deposited (Tsutsumi H, et al., 2010).

B. FASTMELT process

In this process, the iron sponge is manufactured using FASTMET technology, then this by-product is transformed into a hot metal called FASTIRON (Lupu O, 2023; Miloștean D, 2024; Socalici A, 2016; Ghosh A.M, et al., 2021; Kekkonen M, et al., 2000; Ishikawa H, et al., 2008; Satyendra, 2013).

FASTMELT can be used to convert by-products (waste) such as blast-furnace dust and sluge, converter dust, steel mill dust into high-quality hot metal, and as with the FASTMET process, the aim is to recover the Zn content from waste (Ishikawa H, et al., 2008).

The FASTMET and FASTMELT processes have been developed to provide an economical way to recycle these types of industrial steel waste by manufacturing a valuable steel product (iron sponge, liquid metal).

C. INMETCO process

This process aims to reduce in a rotary hearth furnace pellets obtained from steel waste containing Fe and C (coal and coke dust, agglomeration dust and sluge, steel mill dust and sluge, scale and mill scale sluge), to produce the iron sponge that is subsequently loaded into the electric arc furnace (EAF), obtaining liquid metal (Lupu O, 2023; Miloștean D, 2024; Socalici A, 2016; Ironmaking process alternatives screening study, 2000; Kekkonen M, et al., 2000; Satyendra, 2017).

Subsequently, the liquid metal is poured into moulds, obtaining by-products called “pigs” (Climate policy watcher, 2024).

The efficiency of this process is proven not only by the ability to reintroduce steel waste into manufacturing streams and obtain a new product, but also by recovering significant amounts of Zn, Pb from dust generated by the manufacture of iron sponge (Lupu O, 2023; Miloștean D, 2024; Socalici A, 2016).

D. REDSMELT process

The development of this process involves the manufacture of raw pellets from small and powdery waste, their reduction in the rotary hearth furnace and, lastly, the melting of the iron sponge obtained in the submerged arc furnace (Socalici A, 2016; Kekkonen M, et al., 2000; Satyendra, 2018).

Worldwide, the REDSMELT process is considered an effective option against the long-term disposal of small, powdery waste containing iron.

E. PRIMUS process

The technology underlying this process applies to waste generated by the steel industry (sludge and steel mill dust, mill scale, etc.) and consists in separating the content of non-metallic elements (Zn, Pb) from the ferrous fraction of the waste, which is subsequently processed and transformed into an iron sponge (Miloștean D, 2024; Socalici A, 2016; Rieger J, et al., 2019; Gojiae M, et al., 2006;

Frieden R, et al., 2001).
The aggregate used in the PRIMUS process technology is the storied oven, where the waste is thermally processed, being used as fuel / reducing agent coal (Miloștean D, 2024; Socalici A, 2016).
The PRIMUS process technology was implemented on an industrial scale in 2003, in Luxembourg, to recycle 60000t/year of EAF dust and 15000t/year of mill scale sludge. Six years later, the technology was also adopted in Taiwan to process EAF dust mixed with converter sludge and mill scale, with a maximum processing capacity 120000t/year (Miloștean D, 2024; Rieger J, et al., 2019; Gojiae M, et al., 2006).
The graph in Figure 12 shows the evolution of DRI production within processes that use technologies such as shaft furnaces, fluidized bed furnaces, hearth furnaces, etc. As mentioned before, the popularity of reduction processes in vat, retort, or rotary furnaces prevails today; the production related to fluidized bed reduction processes is not only reduced compared to the total world production of DRIs. The productivity of these types of technologies is decreasing, as shown in the graph in Figure 16 due to technological progress that has led to the emergence of more efficient processes in terms of production alternatives, consumption, quality of by-products, and the aspect of contributing to reducing emissions.

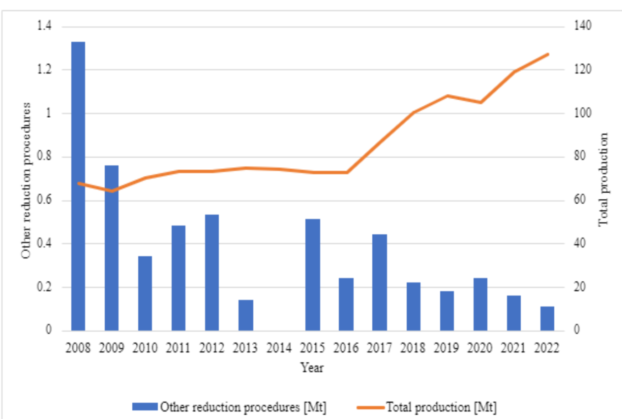

Figure 16. Evolution of the world's DRI production compared to the production of other reduction processes

From the reporting of the quantities of by-products (DIRs) produced under other lesser-known and used types of reduction process to the total world production of DRIs, the quantities produced are part of the total production only in 2008 and 2009 after which the level of production of these processes no longer reaches the threshold of total production.
The main reasons for this sharp and declining decrease may be the popularity of other new or modernised processes, but also the degree of depletion of primary raw materials.

2.2. Unconventional direct reduction procedure

The results of laboratory or pilot phase research and experiments on the application of the direct reduction process to small and powdery iron-containing waste from the steel industry are presented below. The research aimed to highlight the potential of waste processing through it, since iron ore reserves in Romania are being exhausted, some of the largest mining operations in the country located in Ghelari and Teliuc were permanently closed before 2001, due to the depletion of reserves.
Experimental research was carried out under research contracts (Project no. 31-098, 2007; Project no. 233, 2008; Project no. 232, 2008). The main objective of the tests and experiments carried out was to establish the optimal technological flows for the recovery of powdered ferrous waste using the pilot installation of a direct reduction type rotary furnace. The rotary furnace was developed under a research contract (Project no. 31-098, 2007; Project no. 232, 2008; Project no. 233, 2008) at the Faculty of Engineering Hunedoara in collaboration with specialists from the Faculty of Materials Science of the Polytechnic University of Bucharest and S.C CCPPR SA Alba Iulia. The pilot plant is currently operating at S.C CCPPR S.A Alba Iulia — Figure 17 (Hepuț T, et al., 2011; Socalici A, 2016; Project no. 31-098, 2007; Constantin N, et al., 2021)
Various tests and experiments were carried out in the pilot plant. The unconventional technology consisted of introducing into the furnace quantities of powdered ores, ferrous waste / sludge together with coke and coal dust, ceramic balls, and triangular prisms made of refractory steel (Stănăşilă C, et al., 2008). The products obtained were ferrous metal powder, combustion gases, and tailings. After completion of the reduction process, the iron powder obtained was separated from the reducer tailings by magnetic concentration (Constantin N, 2002).
The obtained ferrous metal powder is intended for use in the steel production process, by injecting it

directly into the manufacturing aggregate or by transforming it into by-products (briquettes/pellets) to be inserted into the aggregate charge (Constantin N, 2002).

Figure 17. The experimental installation - rotary tubular furnace (Socalici A, 2016; Constantin N, et al., 2021; Project no. 233, 2008; Project no. 232, 2008)

From the analysis of research on the experimental and unconventional installation of direct reduction compared to the classical procedures presented in this paper, it is considered necessary to highlight the following aspects: the unconventional process has, according to the researchers, a low consumption of solid reducer (coal); heat consumption was low because of the heat dispersers used; the use of heat dispersers is also indicated for other processes; application of the process also to industrial ferrous waste; possibility of obtaining iron powder; the possibility of obtaining iron sponge by reducing pellets.

3. CONCLUSIONS

The global production of iron sponges is increasing due to the demand of the steel industry, and the iron sponge can be considered a replacement for iron ore if it is manufactured from industrial waste, as in the case of the ITmk3 process presented. As a solution to the decrease in iron ore resources, owners of direct reduction technologies (MIDREX, HYL/ENERGIRON, etc.) will have to find replacement materials for iron ore, the handiest being industrial waste containing iron that has intrinsic value. In the future, the direct reduction processes presented will focus on exploiting the intrinsic value of industrial waste, which will favour the reduction of pollution levels caused by the steel industry, together with the activity of replacing solid combustion with hydrogen, which is currently being worked on.

The technology of the ITmk3 process that involves the manufacture of pellets and their reduction in the rotary furnace is also presented by the first detailed experimental research that reaches the applicability of the direct reduction process also on small and powdery waste with iron content, coming from the steel industry.

It is important to mention that in Romania there are no capacities to produce iron sponges from ores or small and powdery waste containing iron, the industrial waste processing activity is carried out by steel plants or waste processing companies using classical recovery processes, especially pelletizing, agglomeration, and briquetting.

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