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Effective Use of Steelmaking Dust and Sludge by Use of Rotary Hearth Furnace

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Abstract

In order to effective collection of valuable metals and to promote zero-emission, needs for treatment of dust and sludge in steel making process has been raised. The Plant & Machinery Division of Nippon Steel Corporation has introduced DRyIron process, rotary hearth process from MR&E in USA in consideration of increased needs for treatment of dust and sludge and for production of direct reduced iron. This paper describes outline of DRyIron process and the actual plant constructed in our Hikari Works for treatment of stainless steel dust and sludge.

1. Introduction

For the purpose of promoting efficient recovery of valuable metals and zero-emission plant operation, effective methods to treat the dust and sludge produced from the steelmaking process are increasingly demanded.

At present, dust and sludge from an integrated steelworks is recycled as raw material for sintering. However, due to the limitations of the amount of zinc charged into a blast furnace (limited to 150-200 g/t-pig iron in Japan[1]), total recycling of dust high in zinc content is difficult, resulting in a landfill disposal of the remaining volume. Under the circumstances, methods to treat such dust with high zinc content, mainly dezincification, are believed to contribute a lot in reducing landfilling cost or saving plant operation cost by providing an alternate blast furnace material.

Most of stainless dust and sludge contain many valuable metals (such as Nickel and Chromium), so it brings substantial benefit of recovery of valuable metals and reduction of landfilling cost if rotary hearth furnace is introduced.

Electric furnace dust of ordinary steel is designated as specially controlled waste in Japan and hazardous waste (K061) in the USA[2]. At present, the substance is processed at a processing cost (150-250 $/t in the USA[2] and almost the same in Japan) by an industrial waste disposal contractor. The cost will presumably rise further as a result of much more tightened regulation (such as prohibition of landfilling, limited transportation of the waste, or the like) in the future. In addition, because of a high content of zinc in electric furnace dust, the benefit of zinc material recycling merit will be available by means of a reduction method.

As a processing method for these types of steelmaking dust and sludge, rotary hearth furnaces are attracting the most attention these days.

Rotary hearth furnaces were originally developed as a direct reduced iron manufacturing process. While the Midrex Method and HyL Method are currently used in the industries as methods depending upon natural gas, the rotary hearth furnace process uses fine coal, which makes it possible to produce direct reduced iron cheaply even in a region yielding no natural gas. In the long run, constant shortage of quality scrap and lowered quality of scrap are expected to be problems with respect to the increased demand for iron sources along with the growth of steelmaking by electric furnaces. Consequently, direct reduced iron which has fewer tramp elements is expected to serve as a high-quality iron source in place of scrap.

In 1999, the Plant & Machinery Division of Nippon Steel Corporation introduced the rotary hearth furnace process, " DRyIron™ Process " , of Maumee Research & Engineering Inc. (referred to as MR & E hereinafter), USA into the production facilities in consideration of the need for the treatment of dust and sludge produced from the steelmaking process as well as the need for the manufacturing of direct reduced iron.

This paper introduces the characteristics of the DRyIron™ Process and the actual facilities installed for the treatment of stainless dust and sludge at Nippon Steel's Hikari Works.

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Table 1 Comparison of steel mill waste treatment process [3]

	Rotary hearth furnace	Waelz kiln	Melt kiln	Electrical furnace type	Shaft furnace type
Zinc removal rate	90 - 97%	75 - 90%	99%	99%	99%
Maximum design capacity (10^3 t / y)	400 - 500	80	60	30 - 50	50 - 80
Investment cost per capacity	1	3	3 - 4	4 - 8	3 - 4
Operation cost	1	1.5 - 2.0	1.5 - 2.0	2 - 3	2 - 3
Others		Sticking problem on kiln wall			
Total evaluation	Superior	Base	Base	Base	Base

2. Comparisons between steelmaking dust treatment processes

Table 1 shows the comparisons between existing steelmaking dust treatment processes.[3] Rotary hearth furnaces are superior to other processes on the basis of the following facts and will be used in a lot more applications.

- The equipment investment and running cost are lower than other processes.
- The processing capacity is higher than other processes.
- The dezincification rate is higher than Waelz kiln.
- This process is free from adherents that are generated in a Waelz kiln or Melt kiln.

3. DRyIron™ Process

MR & E was founded in 1985 by the engineers who developed a rotary hearth furnace in Midland-Ross in 1960s. The company has proved its ability in the field. For example, it served such customers as AmeriSteel and Rouge Steel in the USA by constructing DRyIron™ Process-based facilities for the treatment of dust from an electric furnace and dust from an integrated steelworks respectively.

The DRyIron™ Process is characterized in that it uses a dry briquette technique for agglomerating a mixture of powdered iron oxide and fine coal and a special vibrating feeder for feeding briquettes into the furnace. The company has obtained the patents for the techniques mentioned above.

3.1 Principle of reduction in a rotary hearth furnace

Fig. 1 shows the reaction process of briquettes charged into the furnace. The briquettes charged into the furnace are heated by radiant heat in the furnace atmosphere whose temperature is raised by burners. The iron oxide, zinc oxide, and carbon contained in the briquettes react for reduction as shown below. As a result, iron oxide in the briquettes is reduced to metallic iron and the reduced zinc is gasified to be discharged from the system. The zinc contained in the exhaust gas is collected at baghouse as secondary dust.

$$Fe_nO_m + mC \rightarrow nFe + mCO$$
$$Fe_nO_m + mCO \rightarrow nFe + mCO_2$$
$$ZnO + C \rightarrow Zn + CO$$
$$ZnO + CO \rightarrow Zn + CO_2$$
$$C + O_2 \rightarrow CO_2$$
$$C + CO_2 \rightarrow 2CO$$

Because the reaction occurs between the iron oxide, zinc oxide, and carbon contained in briquettes, high densities of these elements in each briquette are important. It is also necessary to place briquettes evenly in the furnace as they are heated by radiant heat from the upper space in the furnace.

3.2 Characteristics of DRyIron™ Process

The DRyIron™ Process has the following characteristics.

(1) Low costs (equipment investment and running cost) and high reactivity with dry briquette method employed

The conventional pellet method requires addition of 8-13% water in the agglomerating process and also requires a dryer and fuel after the material agglomerating process for the prevention of explosion of pellets. In contrast to this, the DRyIron™ Process with the use of dry briquettes does not require a dryer or fuel after the material agglomerating process as demonstrated in **Fig. 2**.

The conventional pellet method employs the rolled agglomerating method, which results in pellets of different sizes and densities to cause undesirable reduction variations between pellets as shown in **Fig. 3 (right)**. In contrast to this, the DRyIron™ Process with the use of dry briquettes results in pellets of a fixed size and a density without causing reduction variations between pellets as shown in **Fig. 3 (left)**. Compared to the conventional pellet method, a higher metallization rate in a shorter time is possible by the DRyIron™ Process.**Fig. 4** shows the iron-metallization rate and zinc, lead, and chlorine removal rates of briquettes of electric furnace dust of ordinary steel by way of example.

(2) Even charging of briquettes by means of a special vibration feeder type material charger

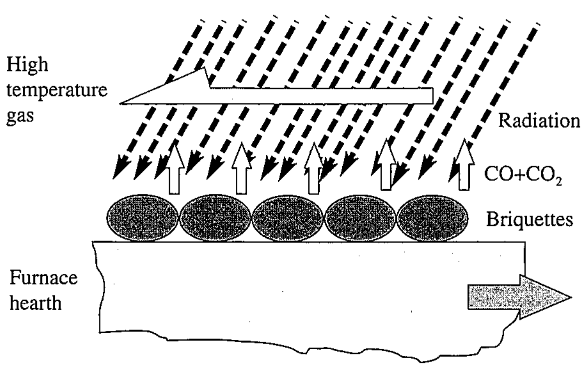

Fig. 1 Reduction in rotary hearth furnace

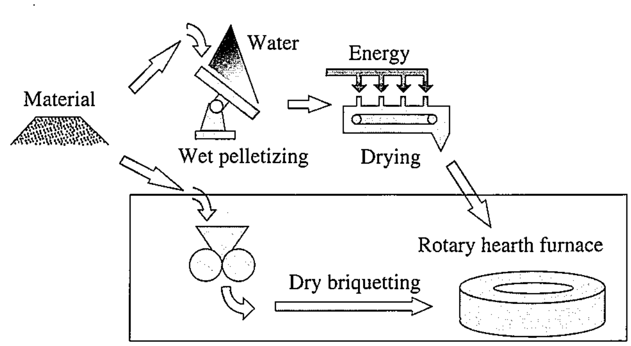

Fig. 2 Comparison between pelletizing and dry briquetting

The briquettes charged into a furnace are heated by radiant heat from the upper space in the furnace. If the briquettes are placed in layers inside the furnace, the upper layers of briquettes are overheated while the lower layers are underheated as shown in **Fig. 5 (right)**, which results in undesirable reduction variations between briquettes. It is very important to place briquettes preferably in a single layer as evenly in the furnace as possible. With the DRyIron™ Process, which uses a special vibration feeder type material charger, it is possible to place briquettes almost in a single layer evenly in the furnace as shown in **Fig. 5 (left)**. This special material charger is also effective in preventing briquettes from powdering, as it does not apply any external force to the briquettes upon charging.

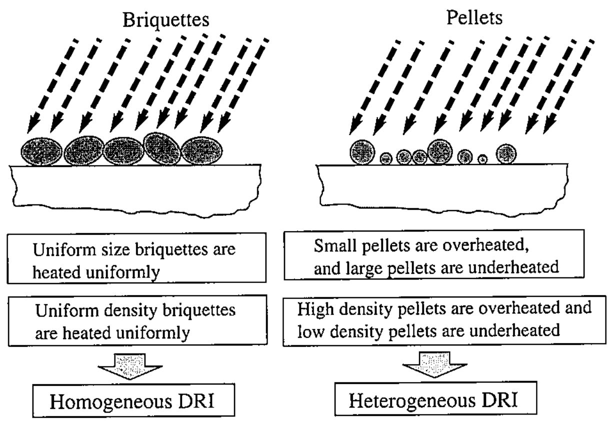

Fig. 3 Comparison of size and density

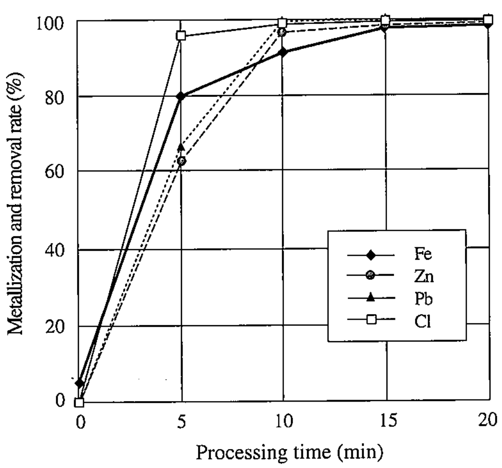

Fig. 4 Example of iron-metallization rate and zinc, lead, chlorine removal rates

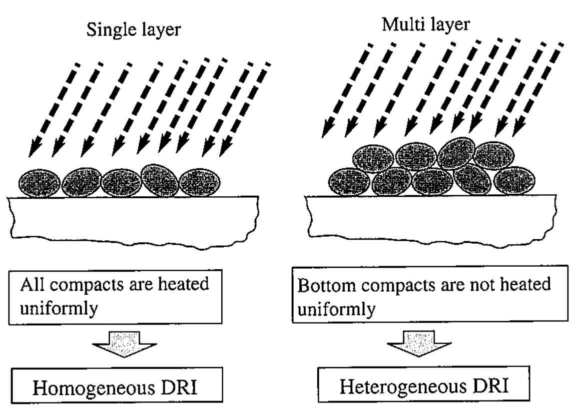

Fig. 5 Comparison between single layer and multi layer

4. Facilities installed at Nippon Steel's Hikari Works

4.1 Outline of facilities

The facilities are characterized in that they can process not only the dust collected from electric furnaces but also the wet sludge generated from a pickling line (a water content of 54%) and scale with high water content (a water content of 90%) as shown in **Fig. 6. Table 2** shows examples of processed material elements after the mixing process.

Fig. 7 shows a simplified layout of the facilities. The capacity is 60,000 wet-t/y (25,200 dry-t/y). The outer diameter of the rotary hearth furnace is about 15 m. The time required for processing inside the furnace is about 15 minutes.

The wet sludge and scale with high water content are charged

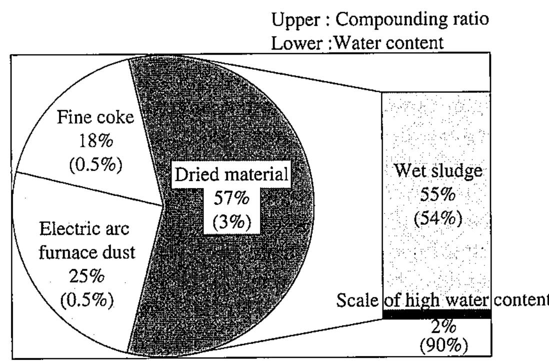

Fig. 6 Example of material compounding ratio in Hikari Works

Table 2 Examples of processed material elements after the mixing process

Fe	Ni	Cr	Zn	Ca	S
19.7%	1.7%	4.6%	1.5%	15.7%	0.6%

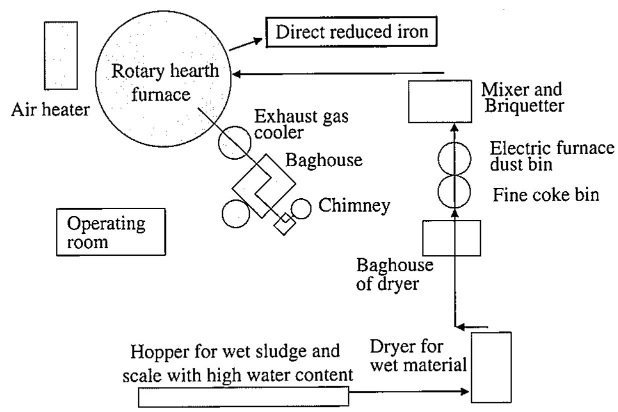

Fig. 7 Simplified layout of facilities at Hikari Works

into the dryer via the conveyer from the hopper for wet sludge and scale with high water content. Then, electric furnace dust and reductant (fine coke) are added to the dried sludge and scale. These are mixed in a mixer and agglomerated into briquettes. The water content of the briquettes is only 3%. So the briquettes are charged into the rotary hearth furnace without a drying process.

The briquettes are heated by radiant heat in the doughnut-shaped furnace. As a result, iron oxide in the briquettes is reduced to metallic iron and the reduced zinc is gasified to be discharged from the system. The zinc contained in the exhaust gas is collected at baghouse as secondary dust. After a rotation of the rotary hearth furnace, reduced briquettes are taken out of the furnace by the discharging screw into the heat-insulating container, and then high temperature briquettes are charged into an electric furnace. Since a cooling equipment for the reduced briquettes is also available, the briquettes may be recycled into an electric furnace and AOD (Argon Oxygen Decarburization) system after a cooling process.

4.2 Present operating condition of the facilities

Full operation of the facilities started in June 2001. As shown in **Fig. 8**, ever since the start-up of full operation, the facilities have served in a good condition at an operating ratio on the order of 80%.

The most important technical factor to support stabilized processing performance is stabilized mixing of material elements. The facilities can process wet sludge and scale of a high water content as shown in Fig.6. However, at the initial stage of the facilities commercial operation, the compounding ratio of material elements was unstable due to fluctuations of the water content rate which resulted in variations in the weight of materials after the drying process. Consequently, the strength and yield of briquettes decreased. However, with the control logic changed from fixed volume control to fixed compounding ratio control, the variations of the compounding ratio were lowered as shown in **Fig. 9**. In addition, the strength and yield of briquettes improved without using any binder.

The iron-metallization rate of direct reduced iron is at 70-80%, and the Ni-metallization rate stands at 92-100%. The recovery of valuable metals is realized by recycling the materials into electric furnaces or AOD system.

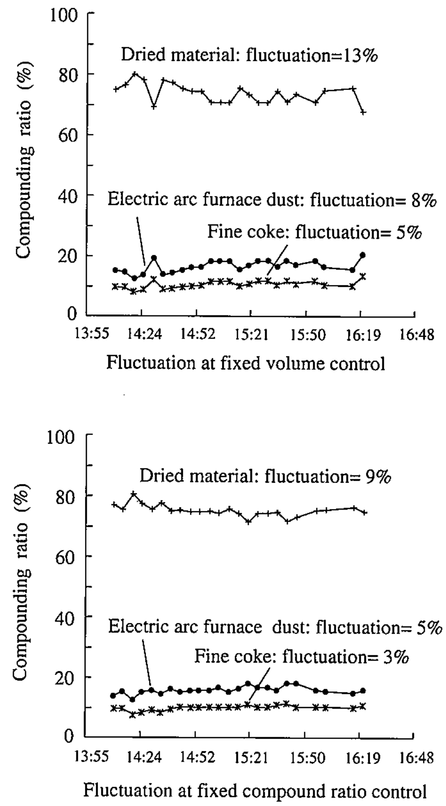

Fig. 9 Comparison of material compounding ratio fluctuation

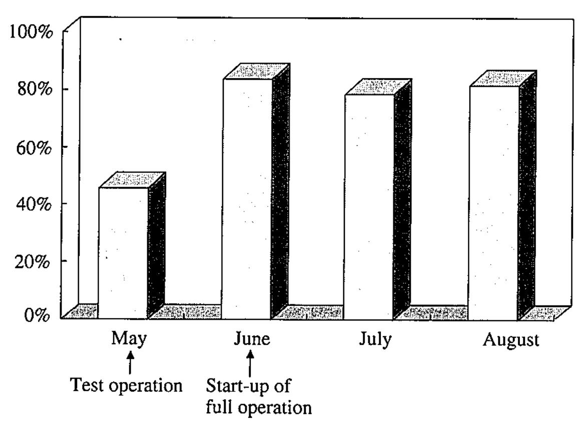

Fig. 8 Operating ratio after start-up

5. Conclusion

In the paragraph above, the characteristics of the DRyIron™ Process and the outline of the actual facilities at Hikari Works for processing stainless dust and sludge were introduced. In keeping with the trend toward much more promoted recovery of valuable metals and zero-emission plant operation, there will be a growing demand for recycling of steelmaking dust and sludge.

Nippon Steel Corporation is going to put strenuous efforts into the development and implementation of steelmaking dust and sludge treatment facilities and iron-source material production facilities which meet the needs in the 21st century, by utilizing the advantageous aspects of the DRyIron™ Process introduced, and combining the company's accumulated facility technologies and operation technologies related with iron and steel making with the state-of-the-art technologies in the future.

References

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