NIPPON STEEL TECHNICAL REPORT No. 86 JULY 2002

UDC 669 . 054 . 83

Dust Recycling Technology by the Rotary Hearth Furnace

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Abstract

With the purpose of recycling of surplus dust, Nippon Steel has installed a de-zinc plant which is applied thereto with a rotary hearth furnace (RHF) at Kimitsu Works. Regular operations were started in May, 2000. It reached the amount of treatment of the plan in a half year by attempting various technological improvements. Reduction pellets produced by this plant have been used directly by blast furnace from the beginning of its regular operation, making it the first technology of its kind in the world. Fuel rate of the blast furnace has effectively been reduced by using the pellets. Thus, it effectly saves energy and costs, and efficiently uses resources.

1. Introduction

Nippon Steel has been trying long and hard to recycle most of the iron-containing dust produced at Kimitsu Works as sintering raw material in the Works. The limitation of charging zinc into a blast furnace, however, has rendered it particularly difficult to recycle the total quantity of zinc-rich dust as a resource, making it inevitable to dispose of the surplus dust for land filling.

The dust is composed mostly of iron and carbon. It therefore becomes an important task for us to actively promote the recycling of those resources in terms of the reduction of the amount of dust to be dumped, the effective use of resources, and energy saving to answer to social needs and to global environmental protection. Since the Works has succeeded in the development and commercialization of the process for resource recovery and de-zinc of dust, this paper deals with this dust recycling technology[1].

2. Conventional dust flowchart in the Works

It is customary with Kimitsu Works to recycle most of the iron-containing dust produced in the Works as the raw material for sintering or cold bond pellets so that the resources for a blast furnace can be recovered. The use of zinc as the raw material for a blast furnace, however, is limited in terms of the prevention of slagging in the blast furnace. This makes it difficult to recycle all the zinc-rich dust for resource recovery. The surplus dust is therefore dumped for land filling.

The total quantity of dust dumped is some 300 thousand tons per year, in which about 150 thousand tons of iron and about 30 thousand tons of carbon are dumped as waste resources (**Fig. 1**). Accordingly, the removal of zinc in the dust for reuse as raw material will undoubtedly lead not only to the reduction in the imports of coal and iron ores, but also to large-scale resource and energy conservation. This has prompted us to tackle the development and commercialization of the process of removing zinc from the dust for resource recovery.

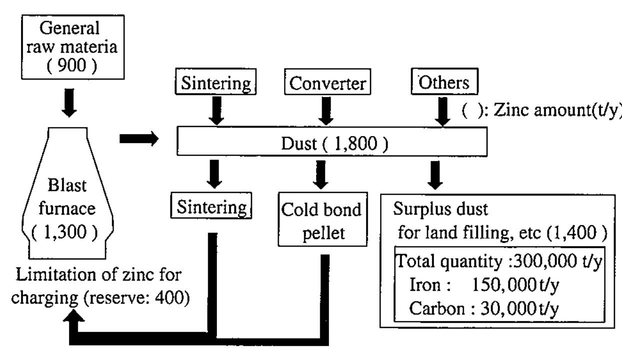

Fig. 1 Conventional dust flowchart at Kimitsu Works, Nippon Steel

*1 Kimitsu Works

Table 1 Selection of de-zinc processes

	Rotary hearth furnace(RHF)	Waelz kiln	Smelting type kiln	Electric furnace	Shaft furnace
De-zinc ratio	90 - 97%	75 - 90%	99%	99%	99%
Designed maximum treatment capacity	400,000 - 500,000 t/y	80,000 t/y	60,000 t/y	30,000 - 50,000 t/y	50,000 - 80,000 t/y
Equipment cost per ton *	1	3	3 - 4	4 - 6	3 - 4
Running cost *	1	1.5 - 2	1.5 - 2	2 - 3	2 - 3
Overall evaluation	○	△	△	△	△

* Relative value when the rotary hearth furnace is 1.

3. Selection of de-zinc processes

From several de-zinc processes now available, we selected the basic process considered optimal for dust treatment conditions. Although a high de-zinc ratio is desirable, we aimed at a de-zinc ratio of 90 to 95% in consideration of the quantity required of zinc to be removed from the subject dust. Based on the overall evaluation of treatment capacity and profitability, we decided to employ a method of using the rotary hearth furnace (**Table 1**).

4. Study of the applications of the products reduced with the rotary hearth furnace method

A general de-zinc process should be followed by a de-sulfur process for removal of sulfur remaining in the product. The applications of recycled material to the manufacture of both pig iron and steel can be considered. In case of the use as the raw material for pig iron, a sulfur-related problem lessens because of the function of a blast furnace to remove sulfur. What is more, in case of pig iron manufacture, the product in question, when reused as a sintering raw material, can be processed into sintered ores for charging into a blast furnace. However, oxidization of the product, once reduced, for re-sintering can hardly be considered as an effective energy-saving means due to a loss of reducing energy. It is therefore ideal to charge the product, reduced by reducing de-zinc treatment, directly into a blast furnace (**Fig. 2**).

On the other hand, the raw material for charging into a blast furnace should be strong enough to allow a gas permeability in a blast furnace so that temperature rise, reduction, and pig iron formation can be carried out smoothly with the reducing gas in the blast furnace. Accordingly, the development of technology for the manufacture of a high-quality reduced product as above-described becomes vital for the technology of dust recycling, a very important task on which the success of development depends.

Prior study was deliberately made as to whether dust-treated pellets can be rendered strong enough as described above. Tests were carried out for this study after adjusting dust blending conditions and reduction conditions to find out that reduced pellets can be made with a considerably high strength. This has prompted us to launch into the recycling of resources as a blast furnace raw material. The use of a material reduced with the rotary hearth furnace directly for a blast furnace is the first accomplishment in the world.

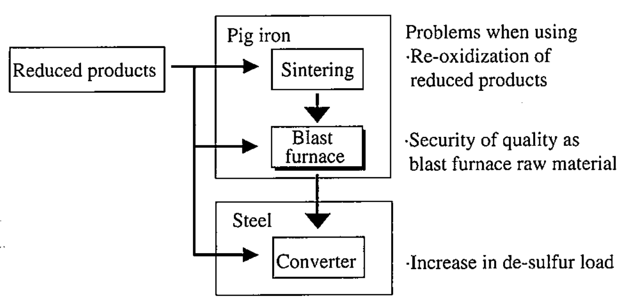

Fig. 2 Applications of reduced products

5. Outline of dust recycling equipment

Figs. 3 and **4** and **Table 2**, respectively, show the appearance, process flowchart, and main specifications of the dust recycling equipment constructed. As raw-material dusts, wet dust from a blast furnace and a converter, and bag-house dust from a blast furnace, a converter, and a sintering system are mixed in a given ratio, pelletized into green pellets with the disk type pelletizer, dried, and then charged into the rotary hearth furnace, where the pellets are reduced at about 1300°C for 10 to 20 minutes per revolution, discharged, cooled with the pellet cooler, and transferred to the product pellet bin. The reduced products are sent on the belt conveyor from the product pellet bin directly to the blast furnace raw material tank for direct use for the blast furnace.

The dust-pelletized pellets on the hearth are reduced with the carbon included as temperature rises, and the zinc reduced along with the formation of metal iron is gasified to be discharged out of the system. Zinc in the exhaust gas is concentrated with the exhaust gas dust collector to be recovered as secondary dust (**Fig. 5**).

6. Performance after the start-up of the dust recycling equipment

The dust recycling equipment started operation from May, 2000, gradually increasing its capacity of treating dust by the application of various technologies to about 15,000 tons monthly, a planned target level, half a year after its start-up (**Fig. 6**).

The most important technical point in the stable treatment of dust is to supply green pellets in a stable manner. Since the dust itself naturally changes its properties depending on how it was produced

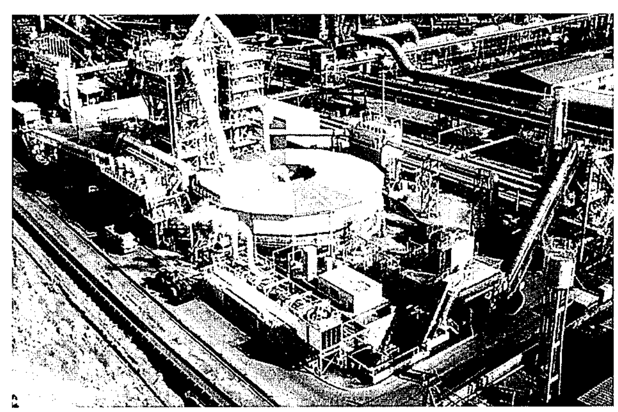

Fig. 3 Appearance of dust recycling equipment

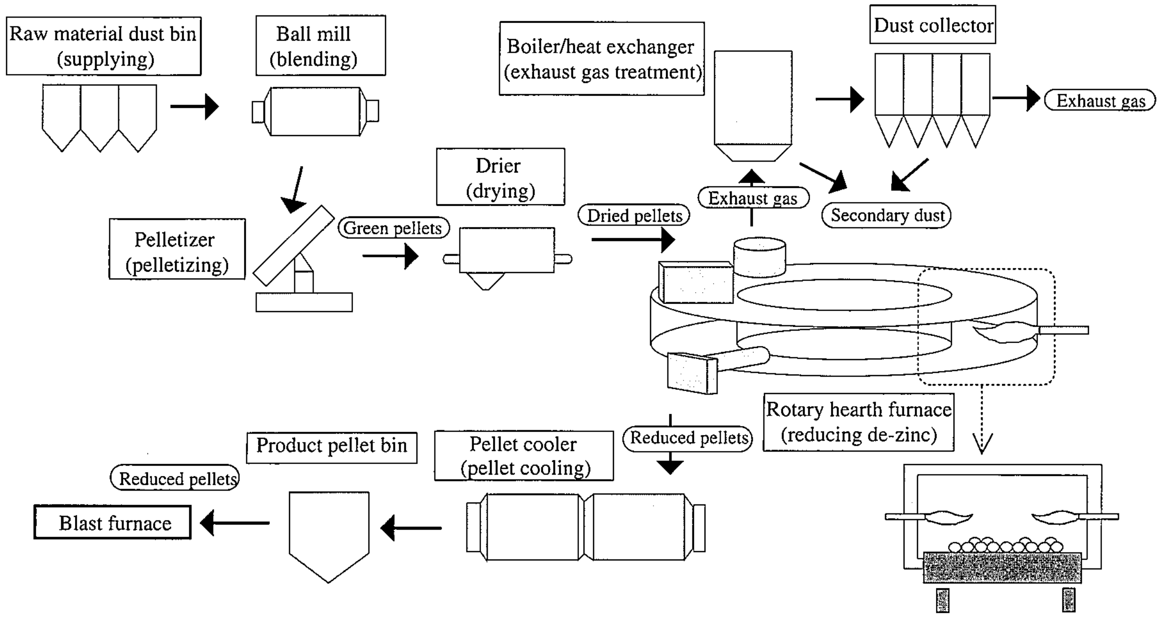

Fig. 4 Dust recycling equipment flowchart

Table 2 Main equipment specifications

	Equipment specifications
Dust treatment capacity	180,000 t -dry dust/y , (22 t/h)
Raw material	Blast furnace dust , converter dust , sintered dust
Pelletizing	Disk pelletizer (6-m dia.)
Rotary hearth furnace	Hearth outside diameter : 24 m, Width: 4 m Reaction temperature : About 1,300 °C Reaction time : 10 - 20 min.
	Product pellet cooling : Pellet cooler (Drum type external water spray method) Exhaust gas system : Boiler, heat exchanger, bag filter
Product pellet transfer	Belt conveyor, product pellet bin

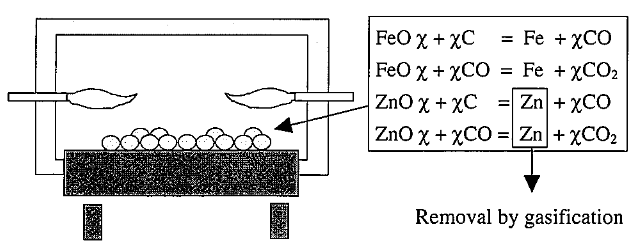

Fig. 5 Reducing de-zinc reaction in rotary hearth furnace Removal by gasification

during operation, the supply of green pellets as raw material, stable in both quantity and quality, has been the most important task from the beginning of the study. Particularly, with the recognition of the importance of the stable supply of green pellets at the start of operating the equipment, development was focused on how to stabilize the amount of supply of green pellets and how to increase their strength.

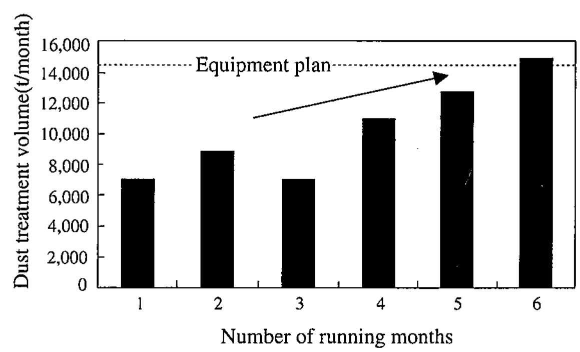

Fig. 6 Monthly changes in dust treatment volume

This resulted in establishing a basic blending pattern, closest to the average blending of the subject dust and excellent in pelletizabilty. At the same time, the optimal point of adjusting the blending was structured by keeping pace with the daily changes in properties of dust after grasping to what extent each dust changes its properties.

A comparison of the changes over time in the amount of supply of green pellets to the rotary hearth furnace at the start and after the improvement shows a significant decrease in the range of fluctuations, indicating the improvement of the overall stability of dust treatment (**Fig. 7**).

7. Improvement in quality of reduced pellets

The quality of reduced pellets was improved as expected in the initial stage of planning in crushing strength, de-zinc ratio, and metallization ratio (**Table 3**). **Figs. 8** and **9** show respectively the comparison in properties with sintered ores, generally used as raw material for a blast furnace. Particularly excellent in abrasion resistance, reduced pellets have proven their high quality with a fine ratio much lower than that of sintered ores. **Fig. 10** shows the appearance and section-photograph of reduced pellets. It is evident that reduced pellets are made stronger by metallization.

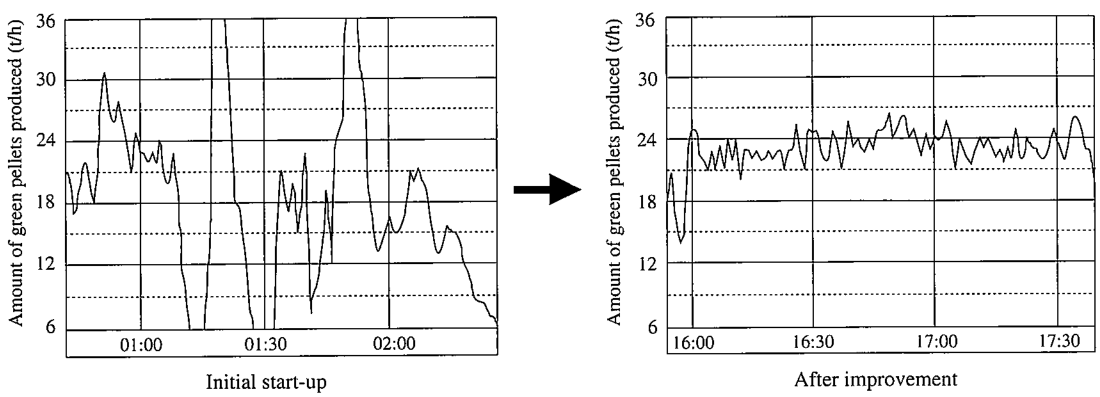

Fig. 7 Stabilization of green pellet production

Table 3 Results of improved properties of reduced pellets

	Results	Initial plan
Amount of dust treated	14,900 t/month	14,500 t/month
Crushing strength	≒100kgf/cm²	>50kgf/cm²
De-zinc ratio	90 - 97%	95%
Metallization ratio	70 - 85%	70%

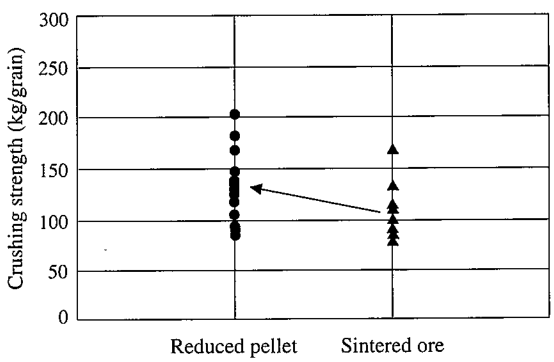

Fig. 8 Crushing strength

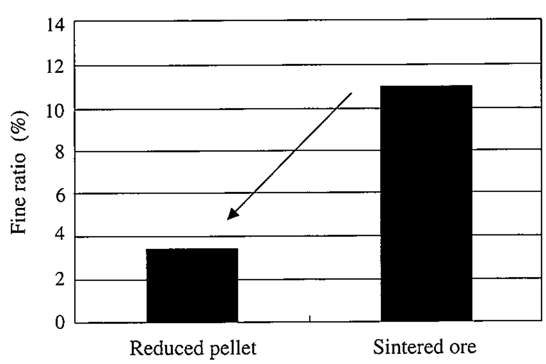

Fig. 9 – 5mm fine ratio in rotary strength test

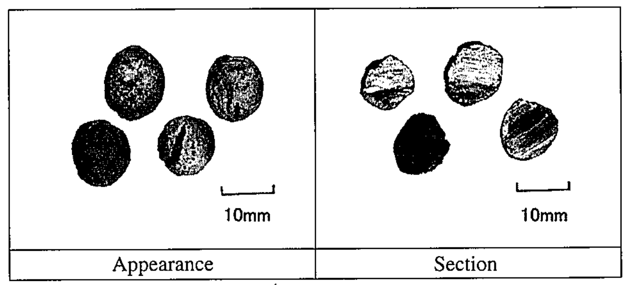

Fig. 10 Properties of reduced pellets

8. Effects of recycling reduced products on a blast furnace

The use of high-quality reduced pellets as above-described leads us to expect the following effects on a blast furnace.

· Reduction in blast furnace fuel rate.

· Reduction in general basic raw material unit of sintered ores in a blast furnace when dust-derived iron is used.

Accompanying effects:

· Decrease in fineness ratio, stable permeability, and operation improvement in a blast furnace by the use of high-strength pellets.

Kimitsu Works has started using the reduced pellets in question directly for No. 4 blast furnace immediately after the start of operation of the dust recycling equipment. Particularly worth noting is that the use for the blast furnace is showing a significant effect as

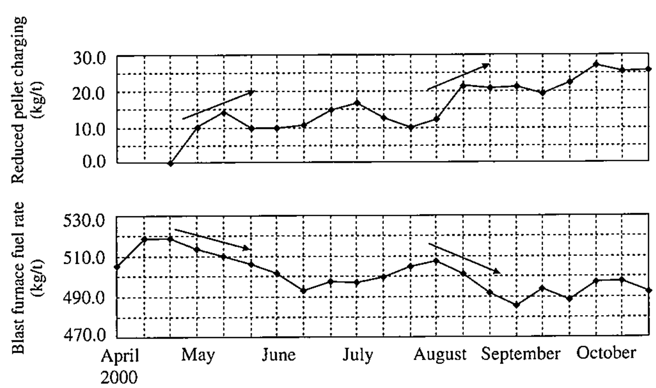

Fig. 11 Transition of the amounts of reduced pellets used for the blast furnace

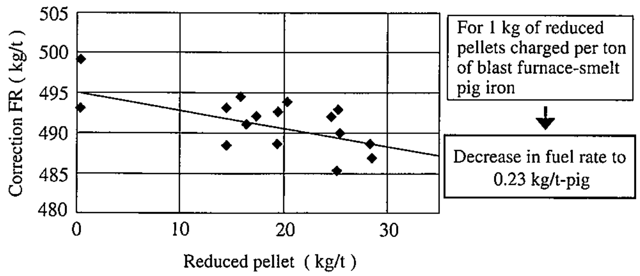

Fig. 12 Relationship between basic unit of reduced pellets used for the blast furnace and fuel rate

seen in a decrease in blast furnace fuel ratio when used in larger quantity (**Fig. 11**). The analysis of the between the basic unit of the use of reduced products for the blast furnace and a blast furnace fuel ratio under the given operating conditions has shown that the effect of reducing a fuel ratio is more marked than that equivalent to reduced energy (**Fig. 12**).

The effects of energy reduction, when carbon and iron, recycled from the dumped dust, was effectively used, including the effect of fuel ratio reduction in the blast furnace, amounted to a total of 783 TJ annually, equivalent to about 20,000 kl when converted to oil. One word more. This energy-saving figure corresponds to 0.4% of the total energy consumed at Kimitsu Works.

9. Conclusion

Kimitsu Works introduced the dust recycling process using the rotary hearth furnace, and accomplished a smooth start-up. The points of this technology are listed below.

· The method of using the rotary hearth furnace for treating dust in the Works is an excellent process.
· The technology of manufacturing high-quality reduced products was established that can satisfactorily be used directly as the raw material for the blast furnace.
· Stable operation was achieved of the actual equipment, for example, by establishing the technology of supplying green pellets stably.
· A significant effect of resource and energy conservation was produced by recycling carbon and iron from dumped dust.
· A great cost-saving effect was produced by the reduction in both of raw material buying cost and surplus dust disposal.

Based on the above results, Kimitsu Works is in the process of promoting the plan of developing further zero-emission and resource and energy conservation by enlarging a range of subjects to raw materials relatively difficult to recycle.

Reference

1) Takahashi, M., Oda, H., Ibaraki, T., Ootsuka, H., Takashima, S., Nonoyama, S.: CAMP-ISIJ. 14, 149 (2001)