

# Dust Recycling System by the Rotary Hearth Furnace

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## Abstract

*Dust recycling technology by the rotary hearth furnace has been applied at Nippon Steel's Kimitsu Works since 2000. The dust and sludge with iron oxide and carbon are agglomerated into shaped articles and the iron oxide is reduced in a high temperature atmosphere. Zinc and other impurities in the dust and sludge are expelled and exhausted into off gas. The DRI pellets made from the dust and sludge have 70% metallization and are strong enough for being recycled to the blast furnaces. No. 1 plant, which was constructed in May 2000 and has an agglomeration method of pelletizing, recycles mainly dry dusts. No. 2 plant, which was constructed in December 2002 and has an agglomeration method of extrusion, does mainly sludge. The combination of the two plants is a solution for recycling variety kinds of dusts and sludge emitted in an large scale steel works as Kimitsu Works.*

## 1. Introduction

At Nippon Steel Kimitsu Works, much of the iron-containing dust that arises from its routine operation has been reused as a raw material for sinter, etc. However, it was difficult to reuse the entire volume of surplus dust because of various factors, including limits on the permissible amount of zinc contained in the blast furnace burden. Therefore, a considerable amount of the surplus dust has been simply discarded.

The principal components of the dust are iron and carbon. Recycling such resources has become an extremely important issue from the standpoint of reducing waste, utilizing resources effectively and saving energy – prerequisites for the promotion of a recycling-based society. Under these conditions, positive efforts were made toward the development and application of a process that makes it possible to recycle dust using a zinc removal treatment. As a result, the world's first a technology for recycling dust as a high-grade raw material was developed for blast furnace using a dust reduction process that employs a rotary hearth furnace (RHF). As a first step, equipment for treating low-moisture dust was developed. This method makes

it comparatively easy to pretreat<sup>1,2)</sup>.

After that, the world's first pretreatment technology was developed that employs an RHF for the direct treatment of high-moisture sludge which was formerly difficult to treat for technical and economical reasons, a dust treatment plant was also built that also utilizes an RHF<sup>3)</sup>. These have made it possible to recycle almost all the iron-containing dust and sludge generated within the works as raw materials for blast furnace<sup>4)</sup>. This paper describes an optimum dust and sludge treatment system that combines dry and wet processes using an RHF.

## 2. Conventional Dust Flow at Kimitsu Works

The iron-containing dust generated within the works has been recycled as a raw material for sinter or cold pellets to be used in the blast furnaces as much as possible. On the other hand, if material that contains an excessive amount of zinc is fed into the blast furnace, the surplus zinc builds up within the furnace, thereby impeding the operation of the blast furnace. Because of this, limits have been set on the permissible amount of zinc contained in the blast furnace burden.

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In the sinter or cold pellet process, almost all the zinc contained in the raw material is directly transferred to the product. Because of the above limits on the permissible amount of zinc that can be contained in the blast furnace burden, dust containing a large amount of zinc could not be used as a raw material and hence was simply discarded (Fig. 1). The total amount of surplus dust thus discarded was 300,000 tons per year. This means that about 150,000 tons of iron and 30,000 tons of carbon contained in that surplus dust were wasted annually. Since the No. 1 and No. 2 dust recycling plants, each employing an RHF, were put into operation, it has become possible to

remove zinc from the dust and hence recycle almost all the dust and sludge generated within the works (Fig. 2).

### 3. Requirements of Dust Recycling Plant

The most basic function required of the dust recycling plant is the removal of zinc from the dust. The total dust balance at Kimitsu Works called for a zinc removal rate of 90% or so. From various existing processes capable of removing zinc by reduction, RHF was selected as the optimum dust treatment process after making a comparative study of treatment capacity, zinc removal rate, equipment

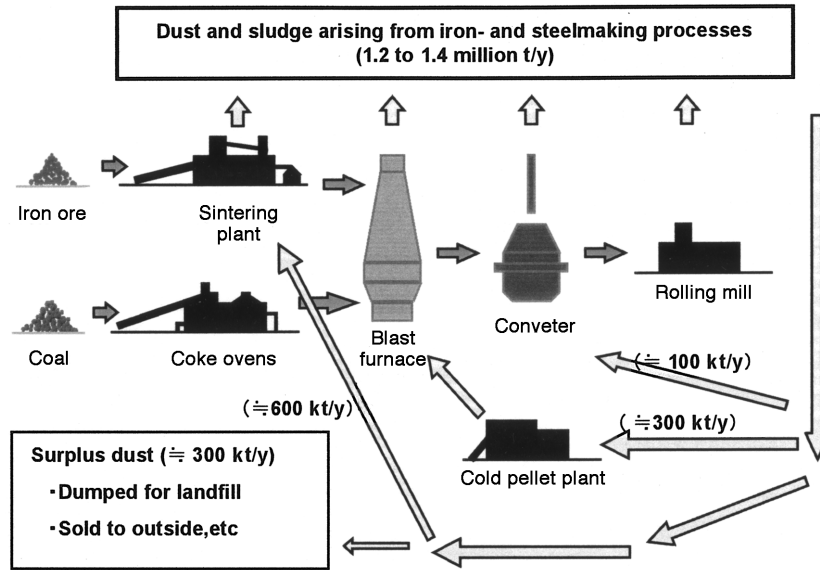


Fig. 1 Dust balance before construction of dust recycling plants

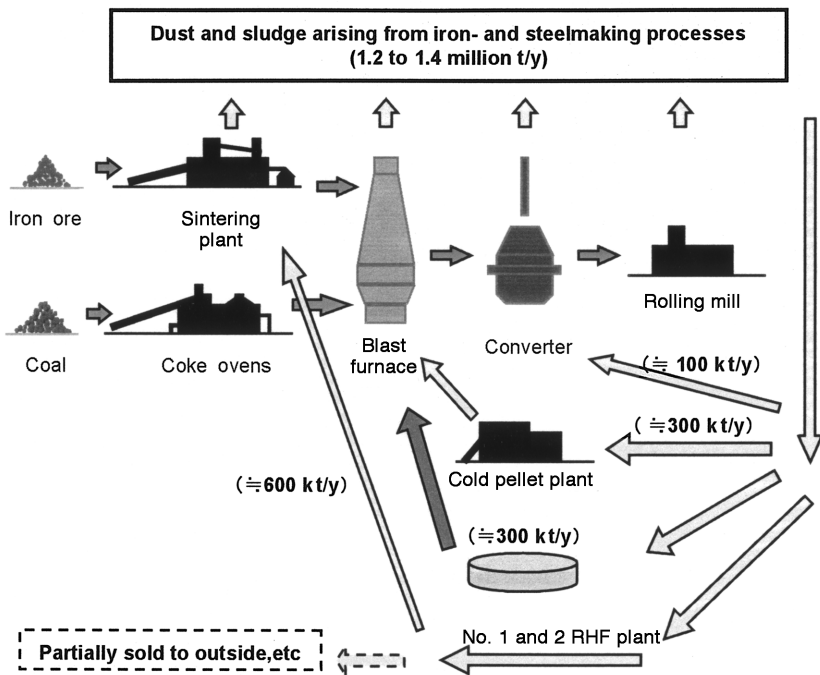


Fig. 2 Dust balance after construction of dust recycling plants

cost, running cost, etc.

When it comes to recycling the dust as a raw material for steel, consideration must be given to the limitations set by the individual processes (blast furnace, converter, electric furnace, etc.) that are likely to use the product made from recycled dust. When the product is used in a blast furnace, low zinc concentration and high strength matter most. When it is used in a converter or electric furnace, sulfur concentration and metallization ratio are especially important. Thus, it is necessary to determine the process that can reuse the dust most efficiently (Fig. 3). At Kimitsu Works, the development of a technology for manufacturing low-zinc, high-strength reduced pellets by using an RHF has made it possible to recycle dust for the blast furnace process. As a result, it has become possible to recycle dust economically without having to remove sulfur and or increase its metallization ratio.

One important technology in the production of high-quality reduced product using RHF dust treatment is the optimization of the agglomerate to be used in the RHF using dust pretreatment. The particle size of dust and sludge to be pretreated ranges from less than a micrometer to several millimeters and the moisture content, from 0 to 98%. Therefore, it is necessary to properly treat the dust and sludge according to their specific physical properties. The first dust recycling plant was built for dry dust and low-moisture dust, which are considered relatively easy to pretreat. The accumulation of technology to supply raw pellets of the required quality on a stable basis in order to optimize the reactivity within the RHF and product properties has made major contributions to the stable RHF treatment of dust (Fig. 4).

Compared with low-moisture dust, high-moisture sludge was far more difficult to recycle because of technical and economical problems involved. The following are the two major problems:

- Efficient and sufficient moisture removal
- Formation of agglomerates that seldom disintegrate, that are mostly free of deformations, deposition, etc., and that are suitable for the reaction in RHF

Therefore, a new dehydrator for high-moisture sludge was introduced. A new technique was also developed to manufacture agglomerates appropriate for the new dehydrator. Since those agglomerates

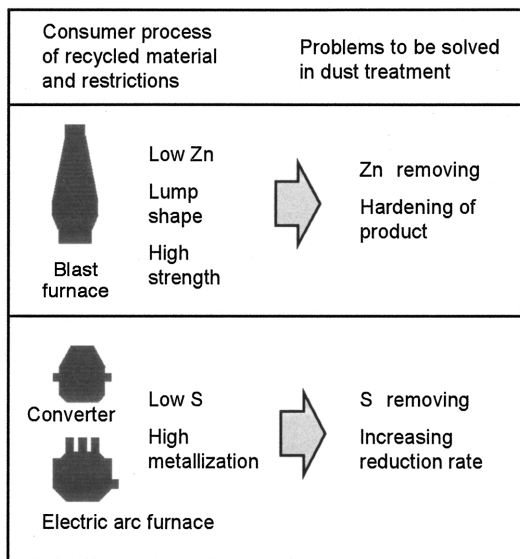


Fig. 3 Problems to be solved in dust treatment

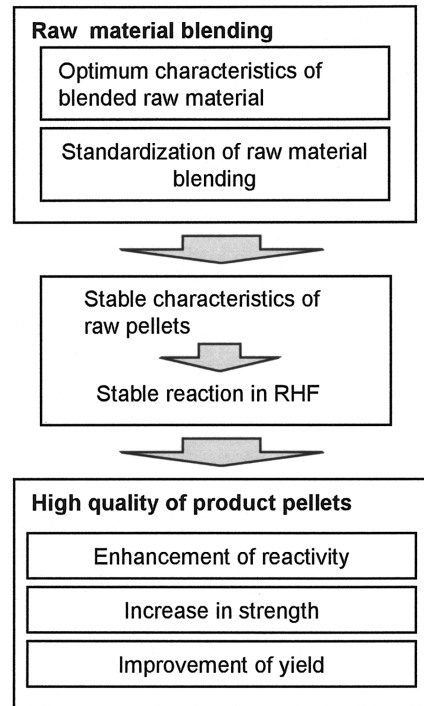


Fig. 4 Raw material pretreatment and quality of reduced pellets

seldom explode at high temperatures, they can be fed into the RHF directly without having to use equipment such as dryers to pre-dry the agglomerates. Since the newly developed dehydration agglomeration process can reduce the moisture of sludge to the required level regardless of the sludge properties and produce agglomerates relatively easily, it has become possible to treat and recycle sludge of varying properties. The following are the salient characteristics of the newly developed pretreatment technology:

- Production of agglomerates that can be put into the RHF directly without requiring pre-drying.
- The process is hardly influenced by sludge properties and hence can be applied to a wide variety of sludge materials.
- The process is capable of removing alkalis and other water-soluble substances from raw material sludge, making it possible to improve the sludge properties.
- Simple equipment design is possible.

#### 4. Outline of Processing in RHF

Fig. 5 is a diagram of the doughnut-shaped rotary hearth furnace (RHF) from the feeding zone to the discharging zone. The raw material pellets that are feed from the feeder are carried by the moving floor to the heating zone, where they are heated to 1,000°C or higher. Then, in the reduction zone, the pellets reach the reaction temperature, which is greater than 1,100°C, and the reduction of zinc oxide and iron oxide by carbon takes place. Here, as the zinc evaporates from the pellets, the zinc removal reaction proceeds. The surplus carbon monoxide is utilized as thermal energy through secondary combustion. The combustion gas and reaction gas flow in the direction opposite to the floor motion and are removed through the off-gas duct. The reduced pellets are expelled from the furnace by the discharger and cooled by the cooler before they are transported to the blast furnace.

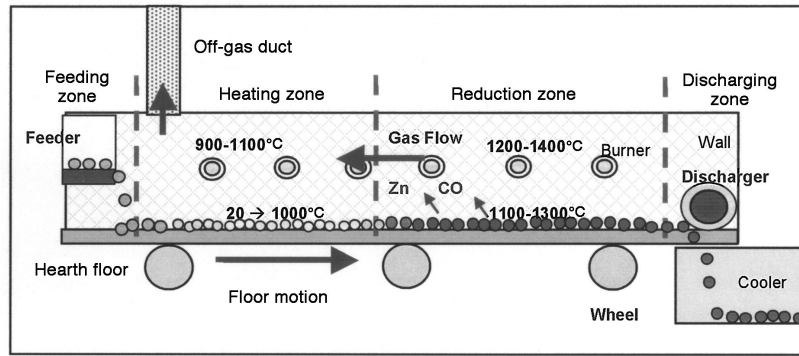


Fig. 5 Structure of the RHF along the rotating direction

### 5. Outline of Dust Recycling Plant

The process configuration of each of the two dust recycling plants employing RHF is shown in Figs. 6 and 7, and the principal specifications of the plants are shown in Table 1.

The No. 1 plant uses a disk-type pelletizer for pretreatment. Based

on a prescribed mixing ratio, amounts of different grades of dust are removed from their respective hoppers and added to the ball mill, where they are mixed and made into pellets by the disk-type pelletizer. These green pellets are dried before they are put into the RHF.

In the No. 2 plant, various types of sludge that are directly trans-

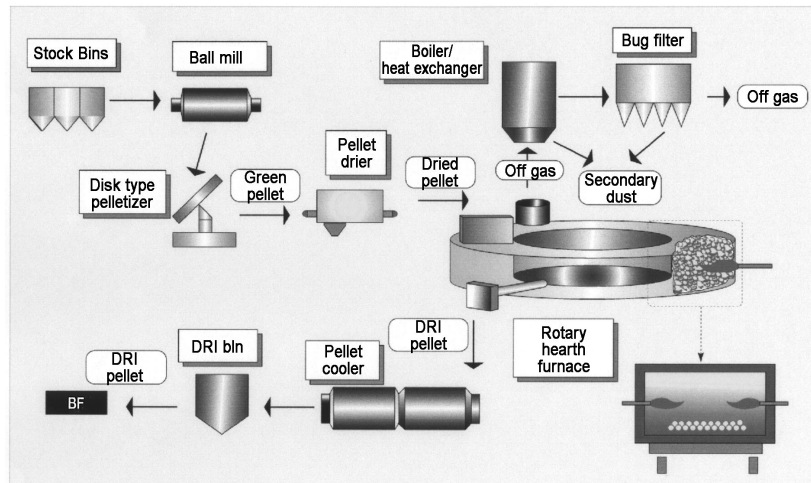


Fig. 6 Process configuration of No. 1 dust recycling plant (1DRP)

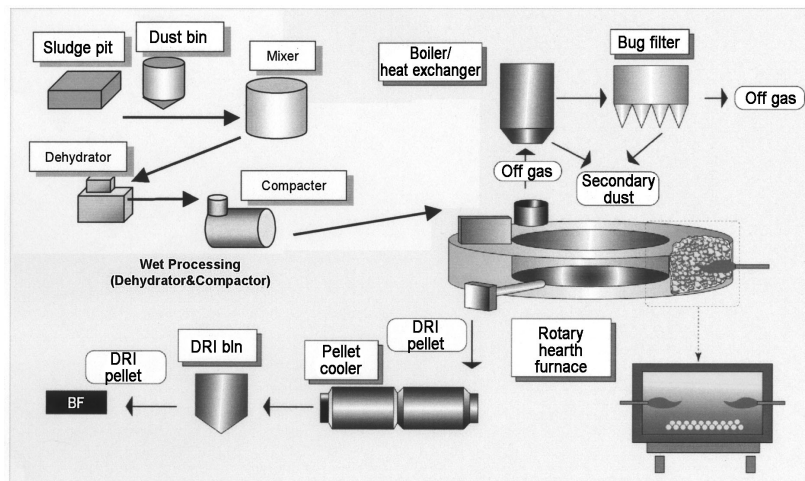


Fig. 7 Process configuration of No. 2 dust recycling plant (2DRP)

Table 1 Specifications of dust recycling plants

	No. 1 DRP	No. 2 DRP
Agglomerate	Pellet (disc pelletizer)	Wet processing (compactor)
Hearth diameter	20 m (at hearth center)	20 m (at hearth center)
Hearth area	230 m <sup>2</sup>	230 m <sup>2</sup>
Processing capacity	22 t/h	17 t/h
(green pellet base (dry))	15,000 t/month	10,000 t/month
Green pellet diameter	5 - 20 mm	5 - 30 mm
Processing temp.	1,250 - 1,300 °C	1,250 - 1,300 °C
Retain time	10 - 20 min	15 - 30 min
Off-gas system	Boiler, air heater, bag house	Boiler, air heater, bag house

ported to the plant by a pipeline or carried in by tank truck, etc. are stored temporarily in sludge pits. They are mixed in a mixing tank according to a prescribed mixing ratio, dehydrated by a dehydrator, made into green pellets by an extruder, and fed in the RHF.

After the zinc has been removed from the pellets through reduction in the RHF, the pellets are cooled and stored in product hoppers till they are used in the blast furnace. The exhaust gas containing zinc is cooled using a boiler and recuperator and then, the secondary dust containing condensed zinc is collected in a precipitator.

### 6. Comparison of Strength between Reduced Products

Figs. 8 and 9 compare the strengths of fired pellets and sinter ore produced from ordinary raw material for blast furnace. According to the results of a shatter test and tumbler test, the pellets produced by the two plants have low fine ratios and very high strength.

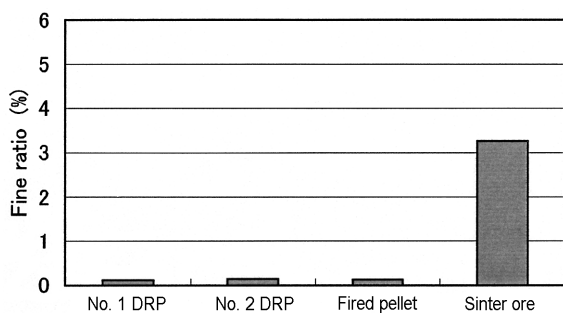


Fig. 8 Fine ratio after shatter test

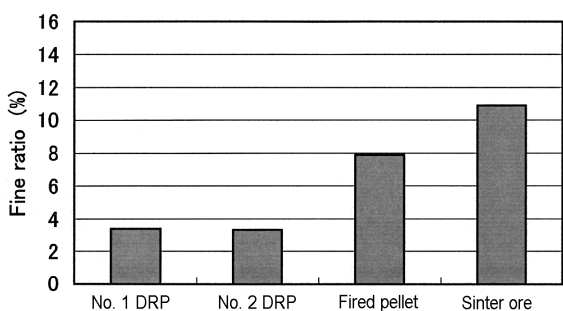


Fig. 9 Fine ratio after tumbler test

### 7. Effects of Using Reduced Pellets in Blast Furnace

The reduced pellets have been directly used in the blast furnace ever since the No. 1 dust recycling system was put into operation. During the period when the amount of reduced pellets used in the blast furnace was increased, the blast furnace reducing agent ratio decreased, indicating that the initially expected effect had been realized.

Fig. 10 shows the results of analysis of the relationship between the consumption of reduced product in the blast furnace and the blast furnace fuel ratio. It can be seen that about 7 kg of reducing agent can be saved for every 30 kg of reduced pellets used in the blast furnace.

### 8. Total Dust Recycling System Employing RHF

Fig. 11 shows the distribution of dust in the total dust recycling system. Types of dust that contain small amounts of moisture, zinc, chlorine and alkalis include scale, sinter dust, dust collected from blast furnace air, and blast furnace flue dust containing a comparatively large amount of zinc. These types of dust are used for sinter. Sinter dust collected by a precipitator has small amounts of moisture and zinc but has comparatively large amounts of chlorine and alkalis. Since this dust cannot be used in the sintering process, it is used in the form of cold pellets in the blast furnace. Dust collected from the converter air, converter sludge, and dehydrated blast furnace thickener ash are dry or low-moisture types of dust that contain a large proportion of zinc. These dusts are used in the RHF of the No. 1 dust recycling plant that is able to remove the zinc. High-moisture blast furnace thickener ash and dredged sludge in the converter and roll-

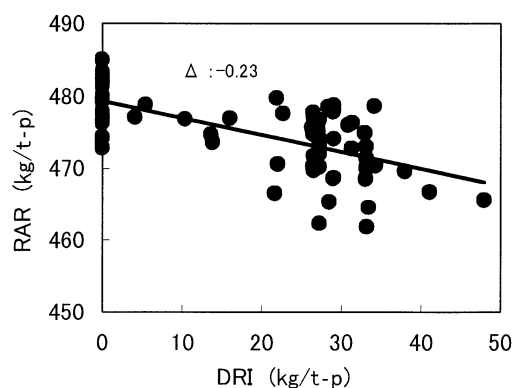


Fig. 10 Effect to decrease reducing agent rate (RAR) of blast furnace

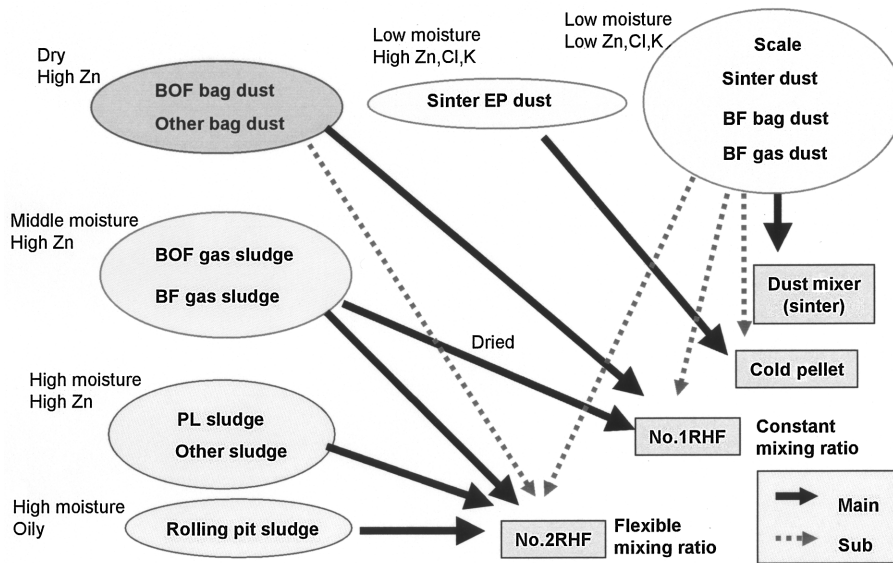


Fig. 11 Material flow of dust and sludge

ing processes are treated using the RHF of the No. 2 dust recycling plant.

By optimizing the allocation of various types of dust to suitable treatment processes based on the dust properties and using individual dusts for specific purposes as required, it has become possible to recycle many different types of dust and sludge.

### 9. Conclusion

The two RHF plants that were installed at Kimitsu Works are in good operating condition. Use of the RHF plants enabled the authors to create technologies for stabilizing plant operations (dust pelletization, agglomeration, reaction condition control, exhaust gas treatment, etc.) and a technology for manufacturing high-strength reduced pellets for blast furnace. This is the first time to use RHF for recycling

of raw materials at the blast furnace. Combining items such as RHF, cold pellets, enabled the authors to build a new dust recycling system that permits the recycling of all types of dust and sludge that are generated at steelworks.

### References

- 1) Takahashi, M., Oda, H., Ibaraki, T., Otsuka, H., Takashima, S., Nonoyama, S.: Equipment and Operation of Dust Recycling Process of Kimitsu Works. CAMP-ISIJ. 14, 149(2001)
- 2) Oda, H., Ibaraki, T., Takahashi, M.: Dust Recycling Technology by the Rotary Hearth Furnace. Shinnittetsu Giho. (376), 28(2004)
- 3) Oda, H., Ibaraki, T., Abe, Y., Takahashi, S.: Recycling plant of high water content sludge by RHF. CAMP-ISIJ. 17, 857(2004)
- 4) Oda, H., Ibaraki, T.: A New Dust Recycling System at Kimitsu Works. CAMP-ISIJ. 17, 856(2004)