Development of Technology for Producing Ultra Low Sulphur Steel by RH Powder Top Blowing Method

by

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Synopsis

In order to obtain ultra low sulphur and nitrogen steel for producing high grade electromagnetic steel, the RH -PB (Powder Top Blowing) method was developed for use in a 160t RH.

In this method, the pulverized desulphurizer is blown into molten steel from a top-blowing lance with an argon gas carrier under reduced pressure in RH treatment.

Since 1996, this method has been under commercial operation in a 160t RH at the Wakayama Steel Works and S and N as low as 5 and 15 ppm have been obtained.

Further, the total refining time, from the end of tapping to the start of casting, was reduced by 40%.

1. Introduction

In recent years, there has been an increasing demand for high purity steel.

So far, in order to obtain ultra low sulphur steel, a gas injection method has been applied in the ladle treatment.

However, in the conventional method, the process is very complicated because some secondary refining facilities are used.

High cost, low productivity and an increase of nitrogen concentration are the results.

In order to solve such problems, the RH-PB (Powder Top Blowing) method[1)~5)] has been developed for use in a 160t RH degasser at the Wakayama Steel Works.

2. Features of Electromagnetic Steel

With electromagnetic steel used for transformers and motors, it is required to reduce sulphur, carbon, and nitrogen levels in order to enhance the most important characteristics, such as core loss or induction.

To improve these characteristics, the RH-PB method was introduced on an industrial 160t RH.

The chemical composition of electromagnetic steel is shown in **Table 1**.

3. Features of RH-PB

The RH-PB method is a new refining process in which a pulverized desulphurizer is blown into the

Table 1 Chemical composition of electromagnetic steel (wt%)

C	Si	S	N	Sol.Al	S+N
≦.0024	2.6 ~2.9	≦.0010	≦.0025	1.05 ~1.20	≦.0030

molten steel under reduced pressure through a water-cooled lance at the top of RH furnace.

The features of RH-PB method are summarized below.

(1) Prevents air contamination (O, N, H) because desulphurization is performed under vacuum conditions.

(2) Pressure reduction is handled entirely by the desulphurizer, so the previously used vacuuming process can be omitted.

4. Concept of Reaction Mechanism

The concept of the reaction mechanism is shown in **Fig. 1**.

The blown pulverized materials, which greatly increase the reaction interfacial area between the particles and the molten steel, penetrate the surface of the molten steel.

As a result, the desulphurization reaction is extremely accelerated.

Further,the great increase in reaction interfacial area between the argon gas bubbles and the molten steel significantly accelerates the removal rate of nitrogen.

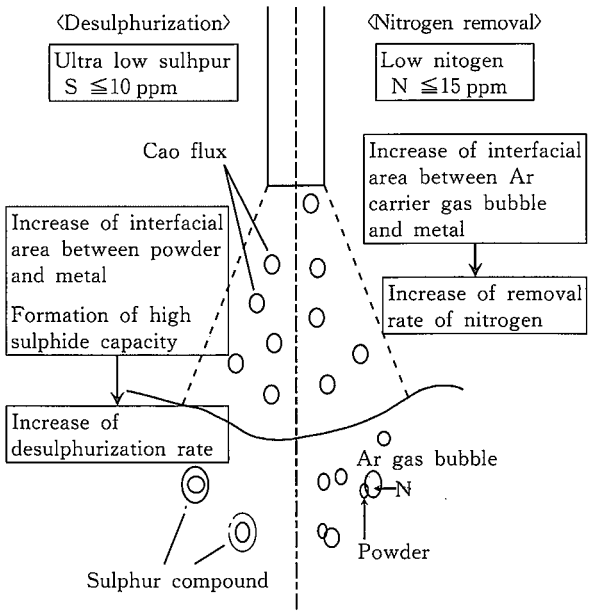


Fig. 1 Concept of reaction mechanism

5. Operational Conditions

5.1 RH-PB Equipment

As shown in **Fig. 2**, the RH-PB equipment was installed on the 160t RH degasser at the Wakayama Steel Works already in commercial operation.

The specifications of the RH degasser are shown in **Table 2**.

This equipment consists of the powder feeding system and the water-cooled lance through which the pulverized material is blown into the molten steel.

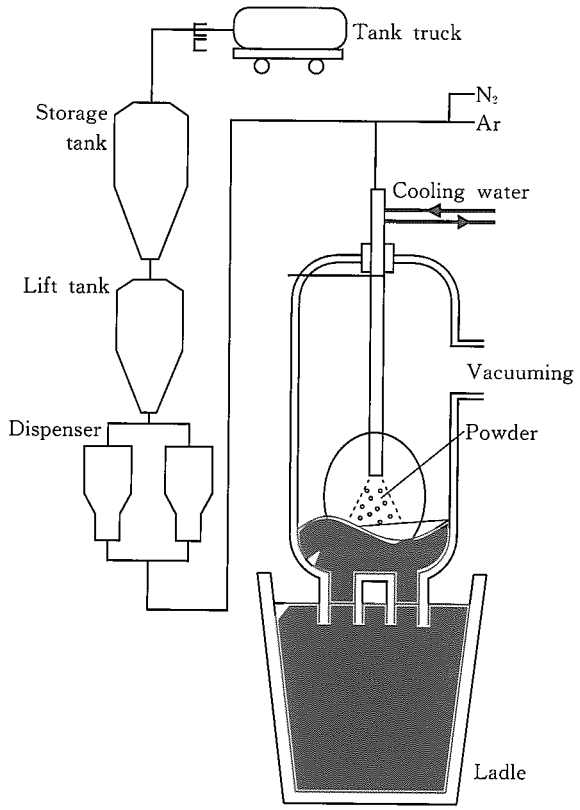


Fig. 2 Schematic view of RH powder top blowing (RH-PB)

Table 2 Specification of RH degasser

Heat size	160 t
Exhaust capacity	1 000 kg/h(at 0.6 torr)
Snorkel diameter	450 mm
Circulation gas	Max 2 500 Nl/min

5.2 Powder Blowing Conditions

The powder blowing conditions are shown in **Table 3**.

The lance height and ambient pressure are optimumly set so that the penetration efficiency of the pulverized materials is high enough and no operational trouble occurs.

Table 3 Condition of powder blowing

Material	CaO-CaF_2
Size	− 100 mesh
Blowing rate	100 ~ 130 kg/min
Lance height	2 ~ 3 m
Ambient pressure	1 ~ 2 torr

5.3 Process Flow

Table 4 shows the refining process of high grade electromagnetic steel.

In the conventional process, after tapping, desulpurization treatment was first done using the ladle injection method.

After removing slag, carbon and nitrogen were removed in by the RH degasser.

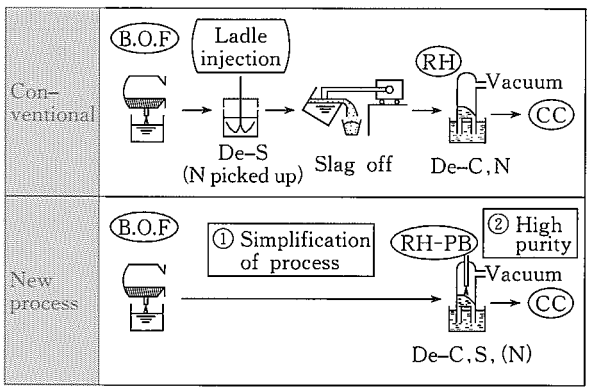
This complicated process results in high cost, low productivity and an increase of nitrogen concentration.

But in the RH-PB method, installing the new desulphurizing system in the RH treatment offers the following benefits.

(1) Simplified refining process

(2) Higher quality and purity by treatment under reduced pressure only

Table 4 Producing process



6.Results and Discussion

6.1 Sulphur and Nitrogen Levels

Figure 3 shows the typical behavior of sulphur and nitrogen concentration during powder blowing.

In the commercial operation, ultra low sulphur concentration under 5 ppm, can be obtained with low nitrogen under 15 ppm.

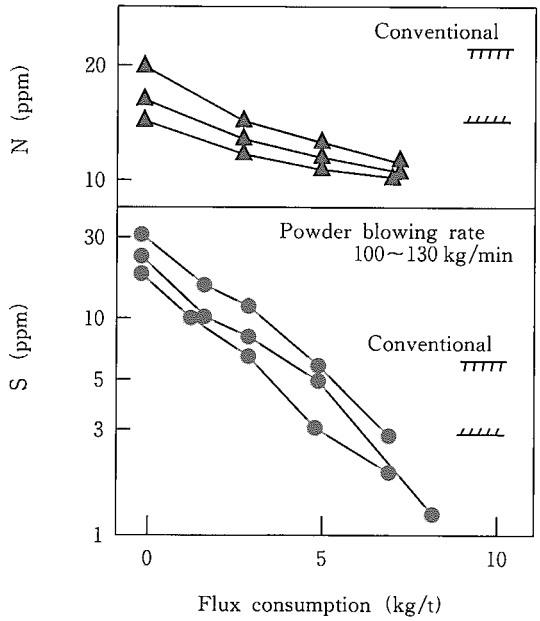


Fig. 3 Change of S and N during powder top blowing

6.2 Sulphur Removal

Figure 4 shows the relationship between desulphurization ratio and flux consumption.

A high desulphurization ratio can be obtained in commercial operation with the same results as in experiments.

Further, a high desulphurization ratio can be obtained by the RH-PB method with less flux consumption than the conventional method.

This is because the following.

In the RH-PB process, the transitory reaction

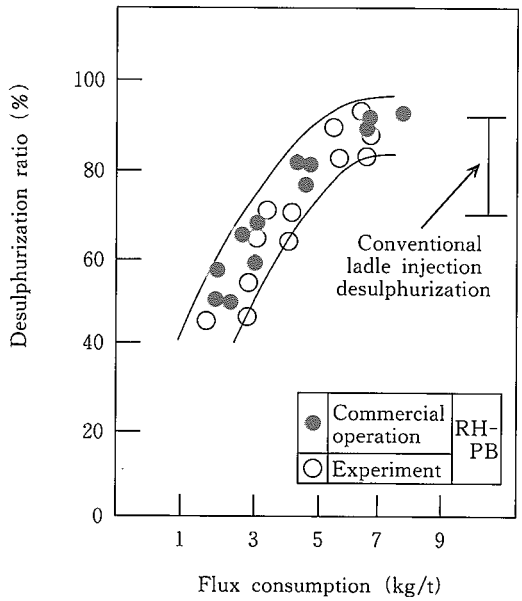


Fig. 4 Relationship between the flux consumption and the desulphurization ratio

between the penetrating particles and the molten metals is the dominant reaction, although the permanent reaction between the top slag and the molten metal is the dominant reaction in the conventional ladle injection process.

Thus, in the RH-PB process, the slag particles with high sulphide content, formed from blown flux and distributed in the metal, increase the desulphurization efficiency.

6.3 Nitrogen Removal Rate

The nitrogen removal reaction occurs during powder blowing.

In general, the nitrogen removal rate can be represented by equation (1) or (1)'.

$$-d[\%N]/dt = K_N[\%N]^2 \quad (1)$$

$$1/[\%N] = K_N t + 1/[\%N]_0 \quad (1)'$$

where, [%N] : Nitrogen content in steel (%)

$[\%N]_0$: Initial nitrogen content (%)

K_N : Apparent rate coefficient ($\%^{-1}$ $min.^{-1}$)

In equation (1), it is assumed that the rate-determining step is the chemical reaction on the gas-metal interface. **Figure 5** shows the relationship between the inverse of nitrogen concentration and powder blowing time. From the inclination of the line, the apparent rate coefficient of nitrogen removal, K_N, is calculated.

In the RH-PB method, the apparent rate coefficient of nitrogen removal was estimated to be about 3.5 times larger than in the conventional method. This seems to depend on the increase in reaction interfacial area between argon gas bubbles and the molten steel.

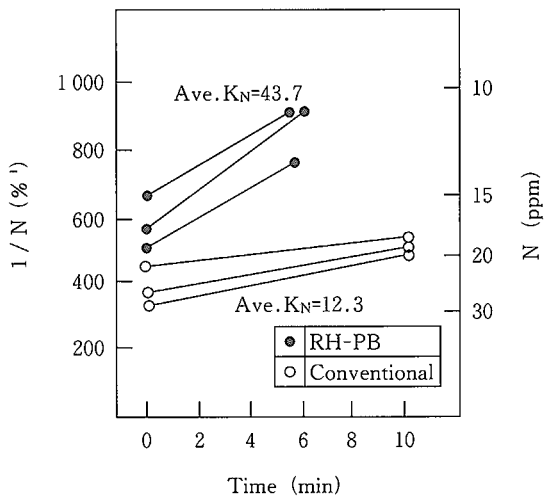


Fig. 5 Relationship between blowing time and 1/ [N]

6.4 Process Simplification

Figure 6 shows the process flow and the behavior of sulphur and nitrogen in the conventional method and RH-PB method. In the RH-PB method, ladle injection treatment and slag removal have been omitted. Therefore, the total refining time is reduced by 40%.

Figure 7 shows RH treatment time is the same as in the conventional method because of the simultaneous removal reaction of sulphur and nitrogen. That is to say, the nitrogen removal process in the conventional method can be omitted.

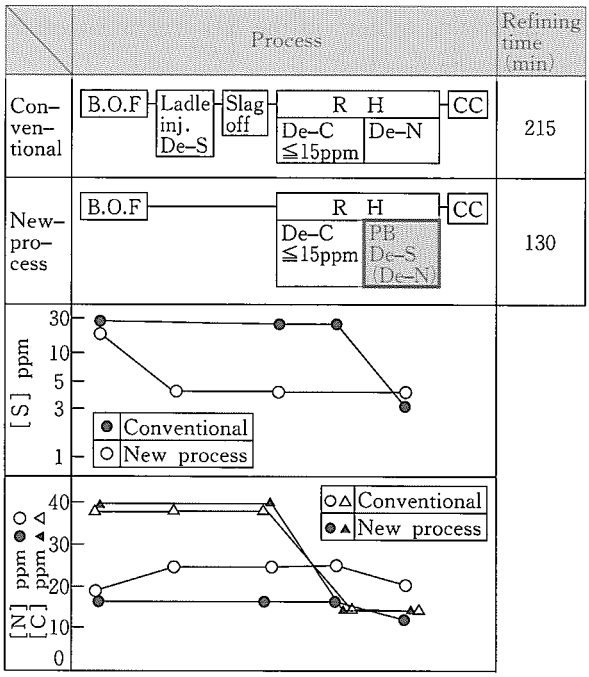


Fig. 6 Refining process and composition behavior

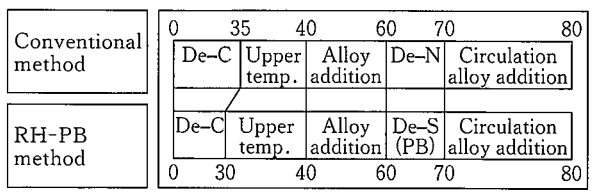


Fig. 7 RH treatment time (min)

7. Conclusion

In order to obtain ultra low sulphur and nitrogen steel for producing high grade electromagnetic steel, the RH-PB(Powder Top Blowing) method was developed for use in a 160t RH.

In this method, the pulverized desulphurizer is blown into the molten steel from a top-blowing lance with an argon gas carrier under reduced pressure in RH treatment.

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