MgO control for reduction of refractory erosion on stainless refining furnace.

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ABSTRACT

A new refining process for stainless steel has been developed at NKK Fukuyama Works. The new process features the use of nickel and chromium ore as raw materials of nickel and chromium. The operating time for nickel ore reduction and chromium ore reduction are long, and slag volume are extremely large. One important difficulty for this new process was refractory life. Dissolution rates of MgO sources were investigated in order to deduct dissolution from refractory. An MgO clinker was found to be most dissoluble and most suitable for preventing refractory erosion. The MgO control methods of nickel ore reduction slag and chromium`ore reduction slag were introduced. Refractory life of the stainless steel refining furnace was improved.

1. INTRODUCTION

A new refining process for stainless steel has been developed at NKK Fukuyama Works[1-3]. The new process has been operating since September 1990. Fig. 1 shows the schematic diagram of the process. The new process features followings;

1. A top and bottom blowing converter (Stainless Refining Furnace, SRF in short) is used.
2. Nickel ore, chromium ore and scrap are used as raw materials of nickel and chromium.
3. Coke and oxygen are used as energy source.
4. Conventional secondary refining facilities and a continuous casting machine are used.

Using nickel and chromium ore as raw materials of nickel and chromium, the consumption of refractories is one of the main determinants of production costs. The operating time for nickel ore reduction and chromium ore reduction are long, and the refractory of the furnace is exposed long time to large amount of slag in high temperature.

An MgO control of slag is very important to reduce refractory erosion of the furnace on the SRF operation. The MgO dissolution rates of MgO sources were investigated by laboratory crucible tests. The differences of MgO dissolution rate between MgO sources and dissolution mechanism are discussed.

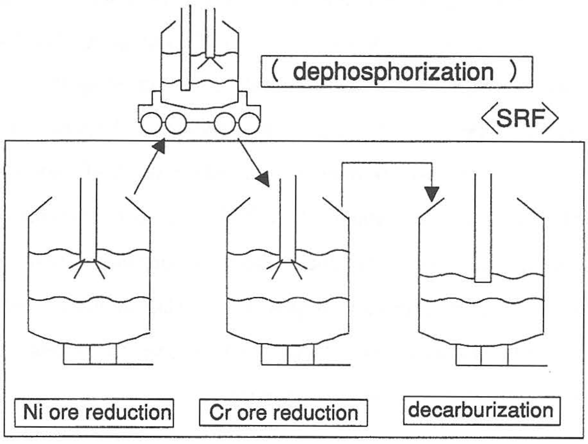

Fig.1 Process flow of new Stainless Steel Refining Process. (SRF)

2. EXPERIMENTS

The furnace used for experiments is a high frequency induction furnace. Graphite crucible was used to hold slag and to work as heating element. The furnace was rotated roundly to agitate slag. Experimental conditions are shown in Table 1. A 2.0kg of 54%CaO-36%SiO_2-10%MgO slag was smelted. An MgO brick, an MgO-C brick and an MgO clinker were examined as MgO sources. The compositions of MgO sources are shown in Table 2.

Table 1 Experimental conditions.

Furnace	High Frequency induction furnace
Temperature	1400～1700℃
Crucible	Carbon, φ100mm
Slag	2.0kg , C/S=1.5
MgO Source	150～250g
Particle size of MgO Source	1～20mm

Table 2 MgO Sources.

mass%

	MgO	CaO	SiO2	Al2O3	C
MgO clinker	92.4	1.6	3.1		
MgO brick	98				
MgO-C brick	74				20

After the slag smelted and temperature came set value, an MgO source was added into the crucible and agitated by the rotation. Samples of slag were taken by suctioning through copper tube every 5 minutes and quenched. Experimental time were 10 to 20 minutes depending on MgO source. Slag samples were analyzed by XMA and compositions of molten part were obtained. Because ordinary chemical analysis gives average composition of slag including both molten phase and solid phase, XMA analysis was applied to know the composition of molten phase.

3. RESULTS

Fig. 2 shows the changes of MgO in slag. Experimental conditions are; temperature is 1600°C, MgO particle size is 5-10mm, rotation is 45rpm. Dotted line on the figure indicate the saturation MgO concentration taken from phase diagram of CaO-SiO_2-MgO ternary system at 1600 ° C. MgO clinker dissolved quickly and slag was saturated in 10 minutes, while MgO brick and MgO-C brick dissolved slowly and slag were still not saturated in 20 minutes.

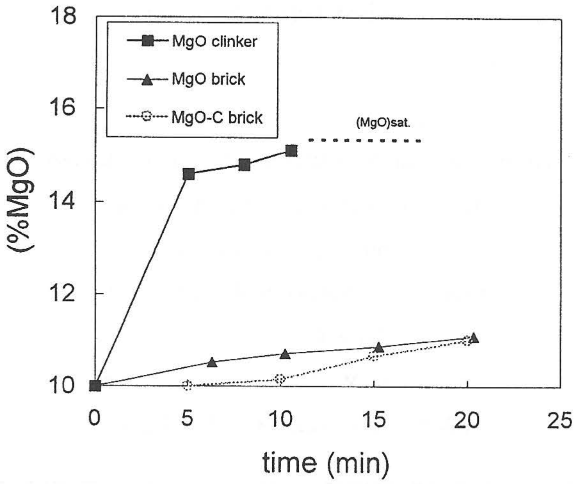

Fig. 2 Changes of MgO in slag.

4. DISCUSSION

MgO dissolution rate equation is described as equation (1), assuming mass transfer of MgO in liquid phase is rate limiting step.[4]

$$\frac{d(MgO)}{dt} = \frac{kA}{V}((MgO)_{sat.} - (MgO)) \qquad (1)$$

where (MgO) : MgO concentration in slag (%)
$(MgO)_{sat.}$: saturated MgO concentration in slag (%)
k : mass transfer coefficient (cm/sec)
A : surface area (cm^2)
V : slag volume (cm^3)

Integrating equation (1) gives equation (2).

$$-\ln\frac{(MgO)-(MgO)_{sat.}}{(MgO)_0-(MgO)_{sat.}} = \frac{kA}{V}t \qquad (2)$$

where $(MgO)_0$: initial(t=0) MgO concentration(%)
t : time (sec)

Yadomaru et al.[5] reported mass transfer coefficient, k, of MgO in liquid phase on similar slag system. Kienow et al.[6] and Oeters et al.[7] studied dissolution kinetics on MgO and discussed mass transfer in slag liquid.

Iiyama[8] showed the relationship between mass transfer coefficient and kinetic viscosity, diffusion coefficient. Referring their work and estimating the surface area from MgO source's size, MgO behavior was calculated. Dissolution of MgO brick and MgO-C brick agree well with calculation, but MgO clinker does not agree. The volumetric coefficient, $\frac{kA}{V}$, of MgO clinker is estimated 15 times larger than that of calculated. The reason of the difference is discussed next.

The microscopic analysis of slag sample after experiments was done. There are many small MgO particles(<100μm) scattered in the molten slag when MgO clinker was added, while there are no small particle and slag/brick interface is clear when MgO-C brick was added. There is an evident difference on the dissolution mechanism of these MgO sources. MgO clinker crumbles easily to fine particles when added into liquid slag. This means surface area was increased remarkably. On the other hand bricks kept their shape as original, dissolution agrees well with calculation.

5. APPLICATION TO SRF OPERATION

An MgO control by adding MgO clinker was introduced to SRF operation in order to reduce the refractory erosion. Good improvement was obtained. Wear rate was reduced by 20% as shown in Fig. 3, and refractory life was extended by 25%.

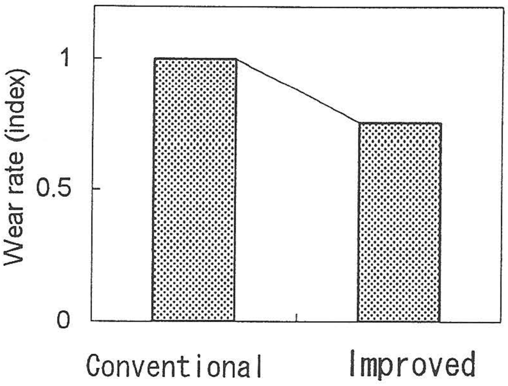

Fig. 3 Comparison of wear rate before and after MgO control applied.

6. CONCLUSION

Dissolution rates of MgO sources were investigated. An MgO clinker is most dissoluble among tested MgO sources, because dissolution mechanism is different. The MgO control by using an MgO clinker was introduced to stainless steelmaking process to reduce refractory erosion, and good improvement was obtained.

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