Dust generation control during BOF operation

Ryo Kawabata*, Ikuhiro Sumi*, Yoshiteru Kikuchi*
Shuei Tanaka**, Satoshi Kohira**, Atsushi Watanabe**
* Materials and Processing Research Center
** Fukuyama Works
NKK Corporation
1 Kokan-cho, Fukuyama, Hiroshima 721-8510, Japan
Fax: +81-849-45-3465
Tel: +81-849-45-3458

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ABSTRACT

The dust generation behavior in the combined blowing converter was investigated to obtain the high iron yields with the 300T scale commercial BOF at #3 steelmaking shop in NKK Fukuyama works. Dust generation model was introduced and the operational parameters of that model were discussed by analysis of measured dust generation rate. Using this model, dust generation rate during the operation were controlled and 10% increase of oxygen blowing rate was obtained for high productivity with the same level of dust generation rate. As a result, the total amount of dust was decreased by 10%.

1. INTRODUCTION

NKK has succeeded in developing a new steelmaking process-ZSP (Zero Slag Process) in which the volume of slag formed during the steelmaking operation is greatly reduced.[1] Figure 1 shows the process flow of ZSP. After tapping from blast furnace, hot metal is desiliconized at a new desiliconization station followed by the dephosphorization process. This hot metal pretreatment enables the operation of the combined blowing converter with a minimal slag. In such a minimal slag operation, the dust generation behavior has created considerable interest in recent years for obtaining high iron yield, because the dust generation rate is higher than that with the conventional operation.

Various investigations have been carried out to decrease the dust generation rate. The origin of dust generation has been studied as follows [2-8];

1) Small iron droplet made by spitting with the oxygen top blowing

2) Bursting of iron droplet by the decarburization.

3) Vaporization of iron at the fire spot.

Though the dust generation behavior of the real converter is considered to be these combination forms, these mechanisms are not fully understood.

In this study, the dust generation behavior at minimal slag operation was investigated to obtain the high iron yield with a commercial combined blowing converter. Dust generation model was introduced and the operational parameters of that model were discussed by the analysis of measured dust generation rate. Using this model, dust generation behavior during an operation was estimated. This model was used to improve the operational conditions for decreasing a total amount of dust.

2. EXPERIMENTS

Experiments of minimal slag operation were performed to investigate dust generation behavior during oxygen top blowing with the 300T scale commercial combined converter (NK-CB) at #3 steelmaking shop in NKK Fukuyama works. Experimental conditions are shown in Table 1. Dust samples were obtained by filtration of dust contained water which was taken from the coarse dust particles separator in the OG dust collectors. Sampling was made every one to two minutes during the operation. The dust composition, metallic Fe, FeO, Fe2O3, MnO, C, CaO, were determined by chemical analysis.

3. RESULTS

Figure 2 shows a typical trend of generation rate and major components of dust during the operation. Dust generation rate is kept to the high level for 10 minutes from blowing start. Then it decreases with blowing time, because oxygen top blowing rate is decreased at the final stage of an operation. The total amount of dust was calculated by integral for trend of dust generation rate. The total amount of dust of each charge was between 9.5 and 11.1 kg/t and the average was 10.1 kg/t. From a measurement of the dust particle size, particle size distribution of each charge was almost same and diameter of all particles was almost 10ƒÊm or less. Dust generation behavior was discussed using this data.

4.DISCUSSION

In this study, mechanism of dust generation at the minimal slag operation is assumed as follows;

1) Generation of primary iron particles made by oxygen blowing jet at the fire spot.

2) Generation of secondary minute particles made by bursting or evaporating of primary particles with the decarburization.

3) Discharge to the outside of the converter.

That is to say, primary iron particle made by the oxygen blowing jet is an origin of all dust particles. Figure 3 shows dust generation mechanism we supposed schematically.

In the previous study, it has been proven that there is the positive correlation between the amount of iron particles made by top blowing jet and the dynamic pressure of oxygen blowing at the metal surface.[3] Therefore, regarding the dust generation, it is considered that the dynamic pressure plays an important role.

It is well known that there is a following relationship between initial flow velocity and total back pressure of a nozzle.[9]

$$U_0 = 740 \times \sqrt{1 - \left(\frac{P_a}{P_{00}} \right)^{2/7}} \quad \text{---(1)}$$

Flow velocity at metal surface is obtained by Eq. (2) and (3) submitted Imai et al.[10]

$$\frac{U_{max}}{U_0} = \frac{d_0}{2 \times C \times L_H} \quad \text{----(2)}$$

$$C = \frac{0.202}{\left(\frac{P_{00} - P_a}{98067}\right)} \quad \text{-----(3)}$$

Then, dynamic pressure at metal surface, P, is expressed by Eq. (4)

$$P = \left(\frac{r_g}{2g}\right) \times U_{max}{}^2 \quad \text{--} \quad 4$$

Where

P : Dynamic pressure at metal surface[Pa] U_0 : Velocity at nozzle exit [m/sec]

U_{max} : Flow velocity at center [m/sec] P_a : Atmospheric pressure in BOF [Pa]

P_{00} : Back pressure in nozzle [Pa] L_H : Lance height [m]

d_0 : Diameter of nozzle exit [mm] r_g : Gas density [kg/m^3]

g : Gravity constant [m/sec^2]

Figure 4 shows the relationship between dust generation rate and dynamic pressure at metal surface. Because slag forming and cavity condition were not stable, the data obtained within 3 minutes after blowing start were omitted.

In this figure, dust generation rate is in proportion to dynamic pressure at metal surface even if oxygen flow rate or lance height is different. Also, this figure supports the assumption that spitting by top blowing generates the dust. Dust generation rate is expressed by Eq. (5).

$$Wd = K \cdot P \quad \dots\dots\dots\dots\dots\dots \quad (5)$$

Where W_d : Dust generation rate (kg/min) K :Constant

We suppose additional mechanism of dust generation to include an influence of carbon content in metal, as follows:

1. Generation rate of primary droplets by spitting is in proportion to dynamic pressure at metal surface.
2. Generation rate of secondary minute particles from primary droplets by bubble bursting or vaporizing depends on carbon content in metal.

Figure 5 shows the relationship between estimated carbon content at sampling time and the value of K in Eq. (5). Finally, dust generation rate (W_d) is expressed by Eq. (6)

$$W_d = K([C]) \cdot P \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

W_d : Dust generation rate (kg/min)

$K([C])$: Function of carbon content in metal

Figure 6 shows the comparison between observed and calculated dust generation rate. This model can explain the dust generation behavior of commercial scale BOF.

4. APPLICATION

This model was used to improve the operational conditions for decreasing a total amount of dust. Experimental conditions are shown in Table 2. With this model, the same dust generation rate is obtained with the same level of dynamic pressure even though oxygen-blowing rate is increased for high productivity. In the tested condition, in comparison with the conventional condition, following changes were conducted in the experimental conditions;

1) Oxygen blowing rate was increased by 10%.

2) The lance height was controlled to keep the same level of dynamic pressure on the metal surface as the conventional conditions.

As a result of the experiment, the same dust generation rate was obtained in both conditions. Since oxygen-blowing rate in the tested condition was increased by 10%, the blowing time was decreased by 10% with the same dust generation rate. Comparison of the total amount of dust is shown in Figure 7. As a final result, the total amount of dust was decreased by 10%.

5.CONCLUSIONS

The dust generation rate of the combined blowing converter with minimal slag operation was measured and discussed to obtain the high iron yields with the 300T scale commercial BOF at #3 steelmaking shop in NKK Fukuyama works. Dust generation model was constructed and this model was applied to decrease the dust generation rate during the operation. Dust generation rate was controlled with this model and 10% increase of oxygen blowing rate was obtained for high productivity with the same level of dust generation rate. As a result, the total amount of dust was decreased by 10%. A further application of the model introduced in this study is being attempted.

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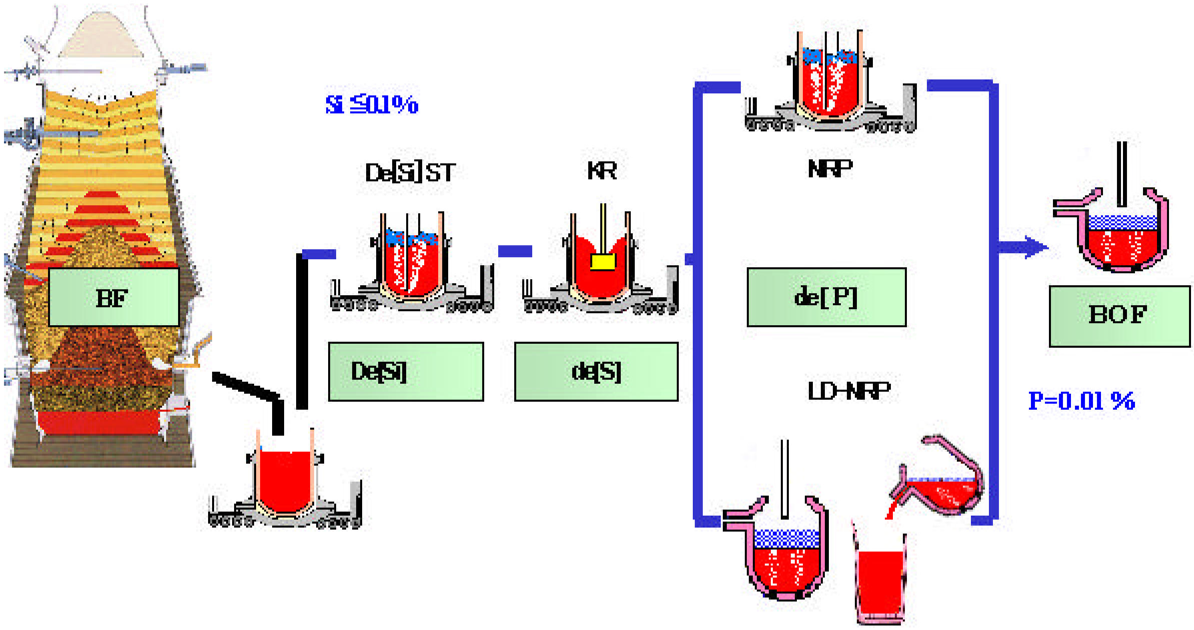

Figure 1: Process flow at NKK Fukuyama works [1)]

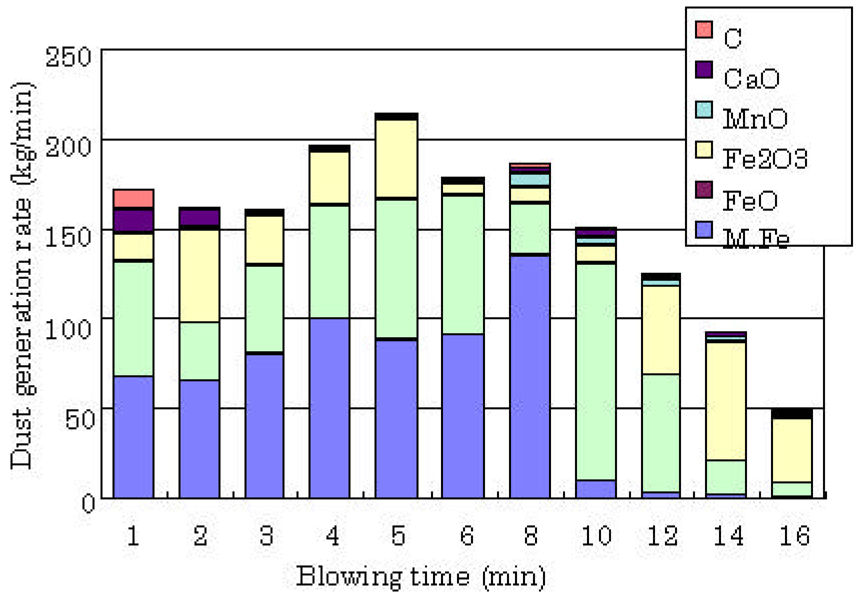

Figure 2: Typical trend of dust generation rate and dust composition

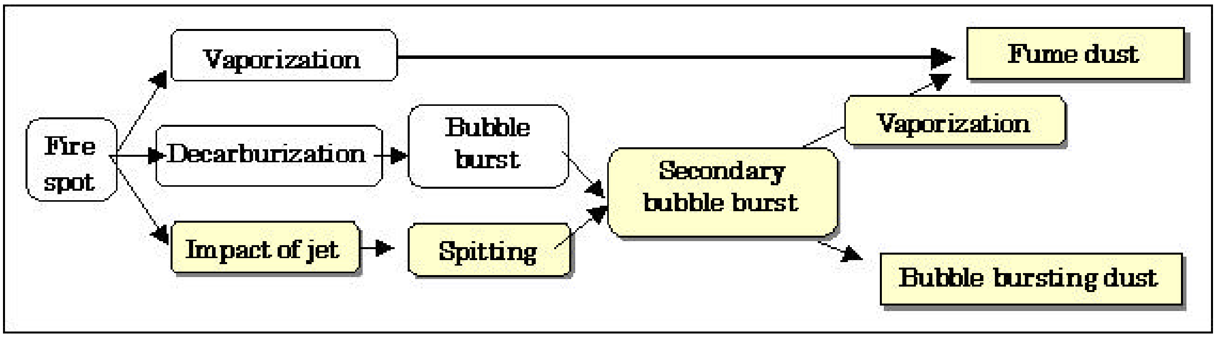

Figure 3: Mechanism of dust generation

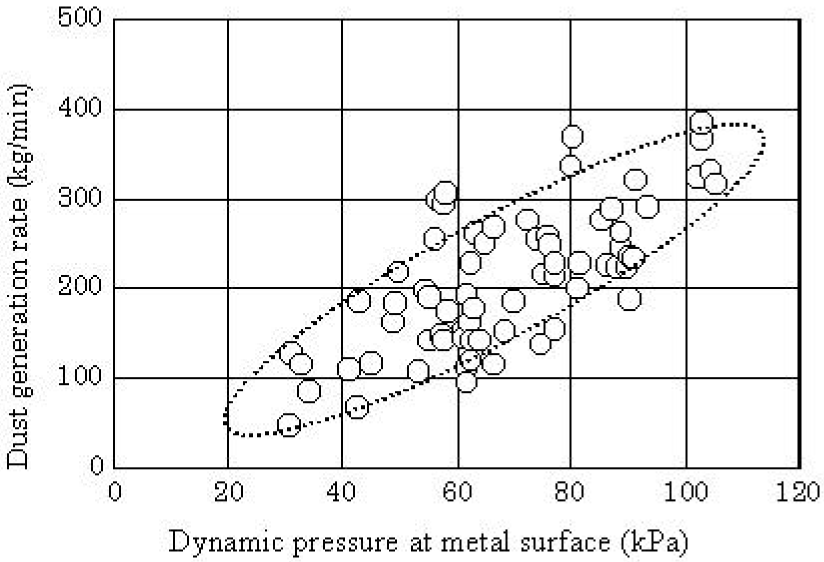

Figure 4: Relationship between dust generation rate and dynamic pressure at metal surface

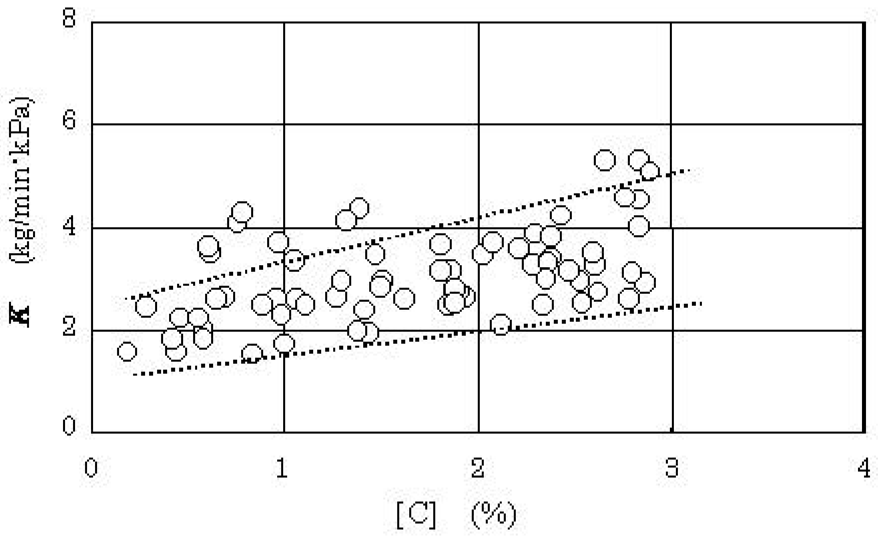

Figure 5: Dust generation factor, K, as a function of carbon content (estimated) in Metal

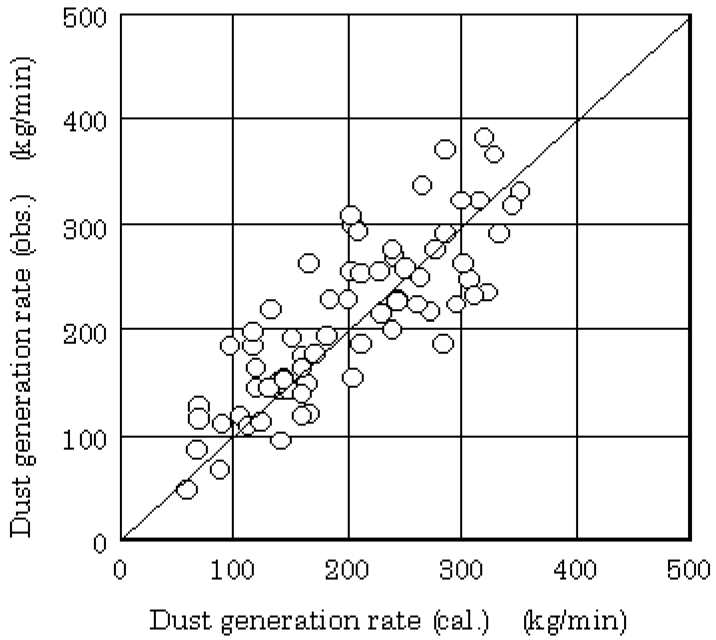

Figure 6: Comparison between calculated and observed dust generation rate

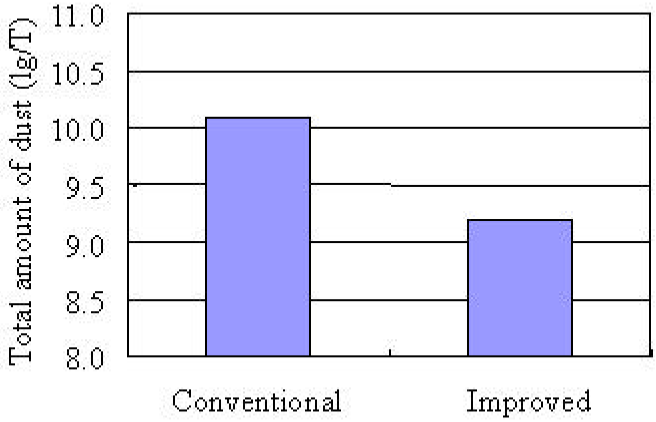

Figure 7: Comparison of the total amount of dust

Table 1: Experimental Conditions

Capacity / type	300T NK-CB
Oxygen blow rate	50000-56000 Nm^3/hr
Number of nozzle hole	5
Bottom gas	Ar, N_2
Slag volume	5 - 10kg / T

Table 2: Experimental Conditions of Application

	conventional	experiment
Oxygen flow rate	55000 Nm^3/hr	62000 Nm^3/hr
Lance height	2.4 m	2.8 m