High-productivity Operation of Commercial Sintering Machine by Stand-support Sintering

Abstract

The sinter cake load on the combustion-melting zone causes gas channel plugging during the formation of pore structure of sinter cake, resulting in low productivity and inferior quality of the sinter product in the sintering process. The influence of gravity was focused on to develop a new sintering technique, called ‘stand-support sintering’, for obtaining high permeability at the lower layer as a result of reducing shrinkage due to gravity and suction by supporting the sinter cake load with plates attached to pallets. This technique has been applied to four sintering machines at Kimitsu and Oita Works, Nippon Steel Corp. since 1996 and contributed to their high productivity operation without lowering quality of the sinter product. This paper provides the principle of stand-support sintering and the influence of productivity and quality of the sinter product in commercial sintering machines.

1. Introduction

Iron ore resources are degrading as their mining proceeds; the degradation shows itself in such as the decrease in the ratio of lump ore and increase in that of particulates in fine ore. An important task of sintering, a principal method of ore pretreatment, to cope with these problems is to increase productivity. For the first time in the world, Nippon Steel Corporation developed a technique to analyze the structure of sinter cake using X-ray CT\textsuperscript{1}, clarified by the technique that the forming process of a permeation network in the ore bed had a significant influence over the productivity of a sintering machine\textsuperscript{2}, and pointed out that to control the process it was effective to reduce the loads of the sinter cake on the combustion-melting zone\textsuperscript{3}. Based on the finding, the company developed the stand-support sintering method\textsuperscript{4}, applied it to the commercial operation of its sintering machines, and achieved significant improvement in productivity. The method makes it possible to remarkably enhance the productivity of a downward-suction type sintering machine by decreasing the adverse effect of gravity, which constitutes a constraint on the operation of this type of machine. This paper outlines the principle of the method and its effects of improving the commercial operation of sintering machines.

2. Principle of Stand-support Sintering Method

In a typical sintering machine, blended fine iron ore mixed with coke breeze, which serves as the fuel, is loaded onto grate pallets to form a thick bed, ignited at the upper surface of the bed, and the combustion of the fuel proceeds downwards under the downward suction of the air to melt and sinter the fine ore and preheat the ore bed portion below the combustion-melting zone. Since the permeation resistance of the ore bed determines the propagation speed of the combustion, a decrease in the permeation resistance increases the productivity of the machine. Because the combustion proceeds downwards and the combustion-melting zone is just below the layer of sintered ore (sinter cake), the sintering process (melting and so-
Fig. 1 Schematic diagram showing the principle of stand-support sintering

Fig. 2 Supporting behavior of load on combustion-melting zone by stand during sintering

Fig. 3 Improvement of productivity by stand-support sintering
Fig. 4 An appearance of stands attached to a pallet in Kimitsu No. 3 sintering machine

height is too large, the durability is deteriorated, and in addition, the tops of the stands break through the fragile surface of the sinter cake, and the support effect is lost9). As a result of these studies, support stands having a service life of two years or more under the normal commercial operation conditions were developed.

With respect to the arrangement of the stands, while it was desirable cost-wise to minimize the number of the support stands, when the distance between two stands was too large, the sinter cake tended to sag because of its porous structure. Eventually, based on the results of measurement of the ore bed shrinkage and the distribution of gas flow rate through the bed surface layer, the longitudinal and transversal distances between the stands were determined to realize homogeneous distribution of the support effect, and the difference in the shrinkage of the ore bed was controlled to less than 10 mm4). Fig. 4 shows the support stands installed on a pallet of No. 3 Sintering Machine of Nippon Steel’s Kimitsu Works.

3.2 Production increasing effect of stand-support sintering

The stand-support sintering method was introduced to the following sintering machines of Nippon Steel: Kimitsu No. 1 (grate area 183 m²) in June 1996, Kimitsu No. 3 (500 m²) in March 1997, Kimitsu No. 2 (280 m²) in December 1997, and Oita No. 2 (660 m²) in November 2004.

Fig. 5 and Table 1 show the change in the operation data of Kimitsu No. 3 Sintering Machine before and after the application of the method10). The support stands were installed on three occasions of scheduled shutdown for maintenance. After the completion of the installation work, the permeation of the ore bed was improved in spite of a high bulk density of the bed and a low mixing ratio of quicklime at that time, and the flame front speed (FFS) increased. What is more, in spite of the increased FFS, the product yield increased, maintaining a high strength of the product. This is presum-

Table 1 Operation results at Kimitsu No. 3 sintering machine

<table>
<thead>
<tr>
<th>Period</th>
<th>Base 1997/12/30</th>
<th>With stand 1998/3/22</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-1998/1/27</td>
<td>-1998/7/31</td>
</tr>
<tr>
<td>Productivity</td>
<td>t/d/m²</td>
<td>37.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40.8</td>
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<tr>
<td>Bulk density of bed</td>
<td>t/m³</td>
<td>1.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.66</td>
</tr>
<tr>
<td>FFS</td>
<td>mm/min</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.9</td>
</tr>
<tr>
<td>Product yield</td>
<td>%</td>
<td>78.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>79.4</td>
</tr>
<tr>
<td>Shatter index</td>
<td>%</td>
<td>89.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>89.5</td>
</tr>
<tr>
<td>Burnt-lime</td>
<td>kg/t-sinter</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15.8</td>
</tr>
<tr>
<td>JPU</td>
<td>–</td>
<td>24.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26.3</td>
</tr>
<tr>
<td>Bed height</td>
<td>mm</td>
<td>562</td>
</tr>
<tr>
<td></td>
<td></td>
<td>608</td>
</tr>
</tbody>
</table>

Fig. 5 Changes in operation by installing stand-support sintering at Kimitsu No. 3 sintering machine
ably because (1) the advantage of the permeability improvement by
the support stands was made the most of by increasing the height
and bulk density of the ore bed instead of increasing the pallet trav-
elling speed, and (2) the sintering process of the lower portion of
the ore bed was homogenized. As a result of these improvements, the
production rate (t/d/m²) increased by 9%.

Fig. 6 shows the change in the shrinkage behavior of the ore bed
and that of the gas flow rate through the surface layer of the ore bed.
The graphs confirm that the support stands effectively suppress the
shrinkage of the ore bed at the later stages of the sintering process
and improve the permeation of the ore bed.
The factors of the production increase (+9.4%) were analyzed
using equation (1), and it was found that the most significant factor
was the increase in the FFS (+6.9%) due to the improvement in permeability. In addition, while the pallet inner volume decreased by
0.9%, the bulk density of the bed increased by 3.2%. In spite of the
higher FFS, the product yield increased by 1.3% thanks to the homo-
genous sintering process in the lower bed portion. As a result, the
production rate increased by 9% in total.

Prod. = 60 • 24 / 1000 • FFS • ρ • η₁ • η₂ (1)

where, Prod. is the production rate (t/d/m²),
FFS is the flame front speed (mm/min),
ρ is the bulk density of the ore bed (t/m³),
η₁ is sintering yield (sinter cake / feedstock ore, %), and
η₂ is product yield (%).

Since the introduction of the stand-support sintering method, the
sintering machines of Kimitsu Works have been producing high-qual-
ity sinter at a high productivity with high blending ratios of pisolite ores
11,12). Fig. 7 shows the relationship between the bed height and
suction pressure before and after the introduction of the new method.
Thanks to the improvement in permeability, it became possible to
increase the bed height to 700 mm or more, and as a result, produc-
tion efficiency increased, keeping the shatter strength (SI) at 92.5%
or higher12.

Table 2 shows the operation data of Oita No. 2 Sintering Ma-
chine (with a VVVF blower motor) before and after the introduction
of the stand-support sintering method13). The support stands were
installed at the time of the width expansion of the machine, and as a
result, the production increased by as much as 18%; of this, the stand-
support sintering method was responsible for 7%. In addition, as a
result of the improvement in permeability, the unit power consump-
tion of the main blower (MB) decreased. Fig. 8 shows the relation-
ship between the tumbler strength (TI) of product sinter and FFS of
the sintering machine before and after the introduction of the new
method. The bed height was increased after the installation of the
support stands, and the TI improved in spite of an increase in the FFS.

3.3 Change in sinter cake structure

Fig. 9 compares the X-ray CT images of the sinter cakes of

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Table 2 Operation results at Oita No. 2 sintering machine

<table>
<thead>
<tr>
<th>Period</th>
<th>Sintering area</th>
<th>Productivity</th>
<th>FFS</th>
<th>Product yield</th>
<th>Burnt-lime</th>
<th>Bed height</th>
<th>MB</th>
<th>O₂ in exhaust gas</th>
<th>Air consumption</th>
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<tr>
<td></td>
<td>m²</td>
<td>t/h</td>
<td>mm/min</td>
<td>%</td>
<td>kg/t-sinter</td>
<td>mm</td>
<td>kWh/t-sinter</td>
<td>%</td>
<td>Nm³/t-sinter</td>
</tr>
<tr>
<td>2004/10/1</td>
<td>600</td>
<td>713</td>
<td>21.4</td>
<td>77.4</td>
<td>7.1</td>
<td>578</td>
<td>18.4</td>
<td>14.9</td>
<td>1721</td>
</tr>
<tr>
<td>2004/12/31</td>
<td>660</td>
<td>840*</td>
<td>22.0</td>
<td>78.6</td>
<td>8.4</td>
<td>670</td>
<td>16.7</td>
<td>13.5</td>
<td>1323</td>
</tr>
<tr>
<td>2005/11/17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005/11/30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

* Inclusive of effect of width extension
confirmed that, under the operating condition of a commercial sintering machine where the heat capacity is large, the adverse effect of the heat removal from the ore bed by the support stands was insignificant.

4. Summary

To cope with the degradation of iron ore resources, Nippon Steel developed the stand-support sintering method, whereby the load of sinter cake in the upper portion of the ore bed is supported by steel stands during the sintering process, and applied the method to the sintering machines of Kimitsu and Oita Works. The following findings were obtained through the tests and commercial application of the method:

(1) The load of the sinter cake on the combustion-melting zone below it makes the ore bed shrink (ore bed compaction), and thus significantly deteriorates the permeability of the bed.

(2) The support stands installed inside the sintering pallets begin to support the load of the sinter cake above at the time when the ore bed portion around the tops of the stands begins to solidify after heating and melting. The sintering process of the lower portion of the bed proceeds thereafter under a reduced load, and a permeation network develops well in the portion to improve permeability.

(3) As a result of the commercial application of the method to the sintering machines of Kimitsu and Oita Works, productivity increased significantly.

The machines continue to operate stably after the application of the method, contributing to the high productivity of the sintering operation of the company.

References
5) Kasai, E., Rankin, W. J., Lovel, R. R., Omori, Y.: ISIJ Int. 29 (8), 635 (1989)