Large blast furnace technologies by NIPPON STEEL ENGINEERING

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Summary
The large blast furnace can lead to reduce initial cost and higher labor productivity. Therefore blast furnaces in Japan have been enlarged. And blast furnaces in world are also enlarged in general, stable operation is difficult for large blast furnace, productivity and gas utilization as inner volume becomes larger.
The large blast furnace has following issue.
1) Circumferential distribution in the furnace is easy to become non-uniform.
2) When the profiles in the furnace changed by some factors, it has a profound effect on operation.
3) Easy to become inertness because Deadman is large.
4) Operation trouble and equipment trouble have a profound effect on production and difficult to recover operation.
NIPPON STEEL ENGINEERING (here in after called “NSE”) has newly installing and relining 80 or more blast furnaces. Since delivering a large blast furnace exceeding 5,000 m^3 for the first time in the world in 1976, we have continued to provide solutions to the aforementioned issue.
Our large blast furnace keeps the stable operation and high production, low reduction agent ratio due to our technology. This paper introduces equipment technology for stable operation of large blast furnace which NSE has accumulated in many years of experience.

Key Words
Large blast furnace technologies; Top charging system; Furnace cooling system; Cast house machine; Cast-in steel pipe copper stave

1. Introduction
1.1 The records of Large Blast Furnace construction of NSE
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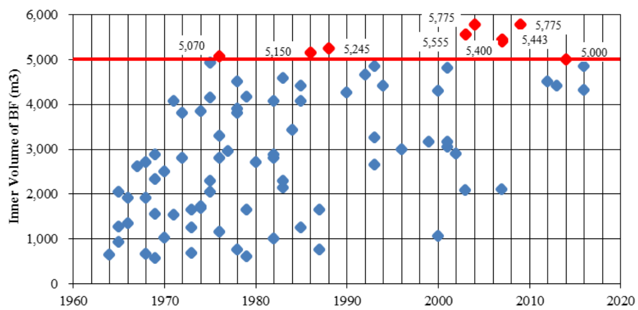


Figure 1: NSE’s the record of Blast furnace construction

Figure 2 shows the comparison of the gas utilization and productivity between NSE construed blast furnaces and other blast furnaces. High gas utilization means efficient reduction in the furnace, which result in decrease in the Reduction Agent Ratio (here in after called “RAR”). As shown Figure 2, NSE constructed blast furnaces have achieved high gas utilization and been operated under low RAR, resulting in a high productivity. Particularly, low RAR and high productivity are also maintained in large blast furnaces whose Inner Volume exceeds 5,000m^3.

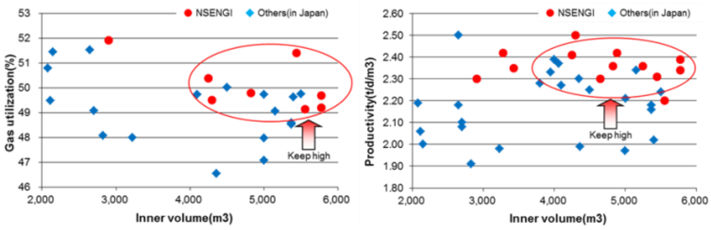


Figure 2: Comparison of fuel rate and productivity between Blast furnaces of NSE’s and others

1.2 Features of large blast furnace and proposed technology
In general, stable operation is difficult for large blast furnace, productivity and gas utilization falls as inner volume becomes larger.
The large blast furnace has following issue.

1) Circumferential distribution in the furnace is easy to become non-uniform.
   The large blast furnace has a large diameter, and the distribution of burden tends to be distribution is easy to become non-uniform in the radial direction compared to small blast furnace, so uneven gas flow tends to occur.
   → CIRCUMFERENTIALLY UNIFORM BURDEN DISTRIBUTION IN THE FURNACE
2) When the profiles in the furnace changed by some factors, it has a profound effect on operation.
   Changes in the furnace profile cause operational fluctuations. Large blast furnaces have a greater impact on operation than small blast furnaces.
   → MAINTAIN SHAPE OF THE FURNACE PROFILE
3) Easy to become inertness because the Deadman is large.
   Large blast furnaces tend to be inertness because the Deadman is larger than small blast furnaces. Therefore the operation is easy to become out of condition.
   → DEADMAN INERTNESS PREVENTION TECHNOLOGY
4) Operation trouble and equipment trouble have a profound effect on production and difficult to recover operation.
   The large blast furnaces have a big impact on production due to operation problems and equipment problems, and it takes time to recover from operational trouble, so stable operation and reliable equipment are required.
   → OPERATION AND EQUIPMENT TROUBLE PREVENTION TECHNOLOGY

The following describe our technologies for the problem of large blast furnace.

2. Large blast furnace technology

2.1 Circumferentially uniform burden distribution in the furnace

In a large blast furnace, a more stable furnace operation is required as compared with a small blast furnace. In order to operate a large blast furnace stably, it is important to make gas flow uniform in the furnace.
Fig. 3 shows an ideal furnace inner condition. The burden is distributed uniformly circumferentially and a center gas flow is provided. As a result, gas flow becomes uniform and an in-furnace reaction progresses efficiently, achieves a stable furnace operation. In contrast, in Fig. 5 the burden is not uniform distribution and no center gas flow. Thus, gas flow is non-uniform, causing unstable operation.

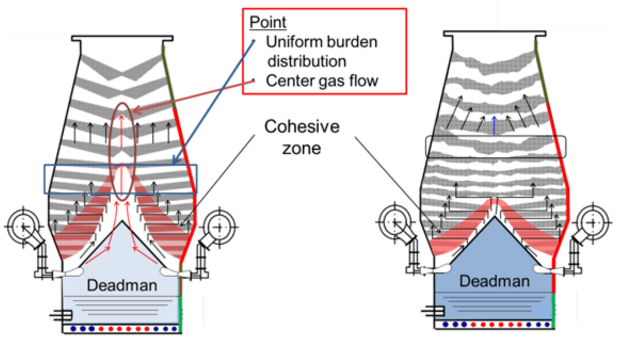


Figure 3: Ideal gas flow Figure 4: Non-ideal gas flow

Since 1974, NSE has been delivered more than 80 units of top charging equipment and has also been continuously making improvements to make in-furnace gas flow uniform circumferentially and provide a center gas flow.
As shown in Figure 6-(A), materials are charged into the furnace lopsidedly because there is generally the horizontal component of the velocity in parallel hoppers. However, NSE has the technology of preventing inertia-caused uneven flows from being created and of charging materials into the furnace uniformly circumferentially as shown in Figure 6-(B). In addition, for the particle sizes of the materials to be discharged from the hoppers, fine particles are discharged first and coarse particles are fed later. As shown in Fig. 6-(A), an occurrence of time-series size segregation of the material causes finer particles to be apt to be concentrated at the furnace center, making a center gas flow weaker. NSE has the technology of controlling material flows so that the distribution of the particle size is constant in time series at the hopper outlets as shown in Fig.6-(B). Therefore, size segregation in the radial direction in the furnace is eliminated, enabling the gas flow to be distributed as shown in Figure 4 and achieves a stable furnace operation.

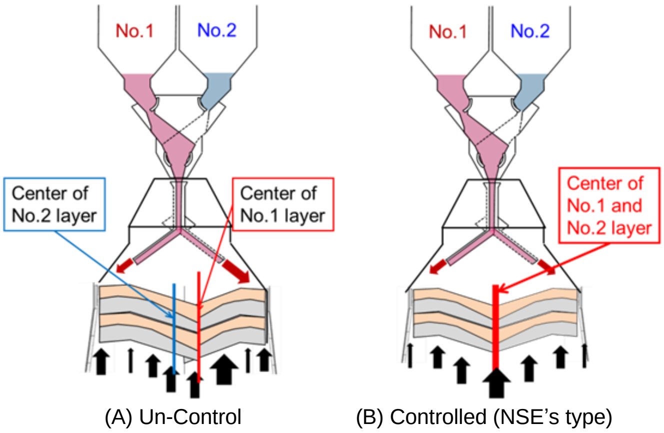
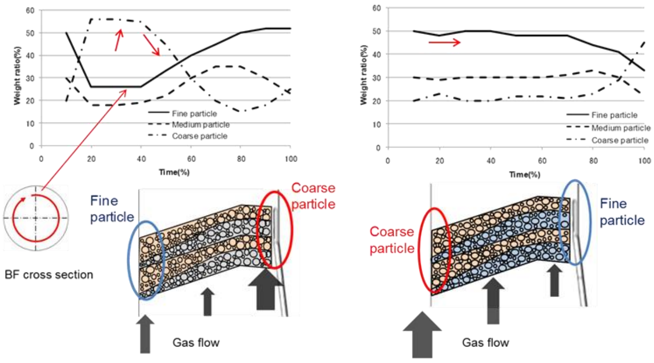


Figure 5: Change in in-furnace material distribution by improvement of top charging equipment



(A) Un-Control (B) Controlled (NSE's type)

Figure 6: Time-series change in the particle size of Raw material discharged into the furnaces

2.2 Maintain shape of the furnace profile

Maintain shape of the furnace profile is mast-have technology for stable furnace operation. Have example Here.

The conventional fixed throat armor (non-water cooled) is subjected deformation caused by heat received from the furnace inside, which not only causes changes in the blast furnace profile but also induces early wear of abrasion-resistant materials on the surface. As a result, the furnace operation changes due to burden descending of raw materials. The solution for this is water-cooled fixed throat armor. The water-cooled fixed throat armor water cools the abrasion resistant materials on the hot face from the rear. As result, the fixed throat armor can be prevented from being deformed, increasing the life of the abrasion resistant materials. Furthermore, stable furnace operation can be continued because changes in the profile in the furnace are reduced.

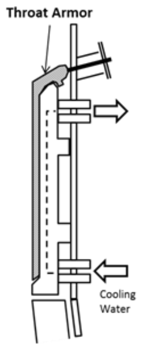


Figure 7: Cooling type Throat armor

2.3 Deadman inertness prevention technology

The raceway length is the same for the small blast furnace and the large blast furnace. Therefore, the large blast furnace has a large proportion of Deadman located inside the raceway and tends to be inertness

When the temperature in bottom is low, cooling capacity should be weakened in order to prevent the flow of pig-iron from getting worse in Deadman. If the flow of pig-iron in the inside of Deadman worsens, as shown in Figure 9 , pig-iron will flow in annular, and ring carbon brick will be worn out unusually. Furthermore, tapping and slag discharging become unstable. Therefore, we adopt the water flow control system at bottom like Figure 9.

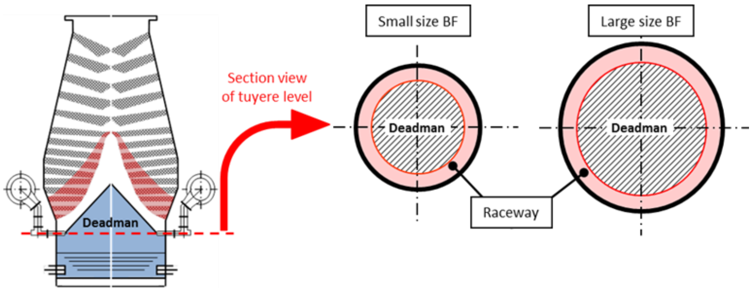


Figure 8: Comparison of raceway

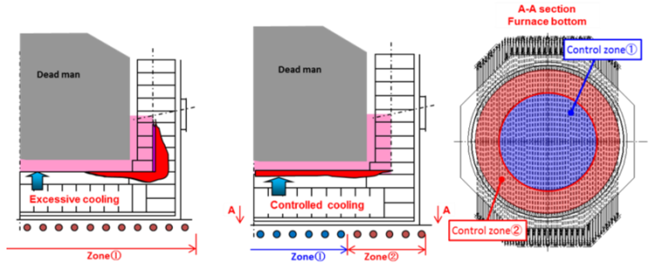


Figure 9: Blast furnace bottom cooling system

2.4 Operation and equipment trouble prevention technology

2.4.1 Zone cooling

For furnace-body cooling, the furnace body is divided into zones as shown in Figure 10 and appropriate cooling is provided on each zone basis.

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We propose optimal furnace-body cooling for each zone based on such concept.

Optimal cooling enables stable operation without the problem of delay in temperature rise of raw materials.

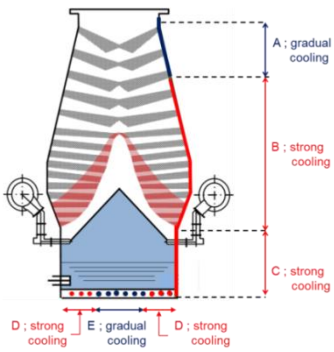

Figure 10: Blast furnace body cooling system

2.4.2 Cast House Machines

NSE has designed, manufactured, and delivered machines such as the taphole openers, mud guns, rod changers, cover traversers, and mud filling

machines. This paper introduces the Hydraulic Taphole Opener and Mud Gun essential for stable iron tapping from a blast furnace.
During iron tapping, the taphole mud is corroded by hot metal and the size of the taphole becomes greater with tapping time. To achieve consistent tapping from the blast furnace taphole for a long time, it is important to limit the widening of the taphole to make the tapping time constant. As countermeasures for this, ①use of high-strength mud and ②control over the development of cracks in the hole internal surface during opening are effective. The taphole can be constructed to be resistant to crumbling by improving the mud' s resistance to hot metal as to item ① and limiting entry of hot metal into cracks as for ②. To use high-strength mud, a high-power mud gun and hydraulic taphole opener are required. NSE has delivered more than 100 high-powered mud guns and over 60 units of hydraulic taphole openers. Furthermore, to suppress the development of cracks during opening a taphole, we have developed automatic operation control based on appropriate power to enable a constant quality hole to be opened with a few cracks on the surface irrespective of operator skill. An example of hydraulic control is shown in Figure 11.

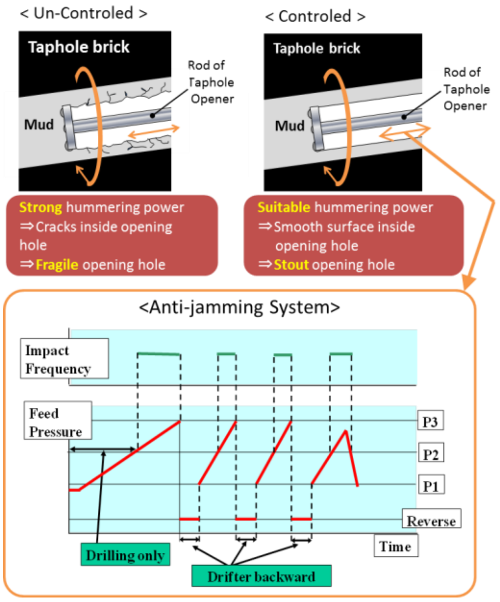

Figure 11: Hydraulic tap-hole opener

2.4.3 Cast-in steel pipe copper stave

A cast-in steel pipe copper stave forms channels using steel pipes, eliminating the need for plug welding or pipe welding, inevitable for the conventional rolled copper stave.
Elimination of welds remove the risk by omitting the welds those are weak in structure.
Different from rolled copper staves whose grooves are cut by machining, the ribs of a cast-in steel pipe copper stave can freely be formed into any shape because ribs are formed integrally with stave body by casting. Making use of this advantage, NSE developed an upward-rib which can reduce the contact force and descending speed of burden. (Refer to Figure 12.)

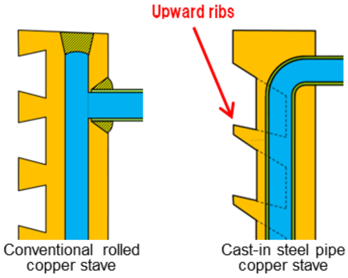

Figure 12: Copper stave

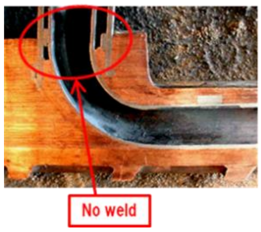

Figure 13: Cross section of Cast-in steel pipe copper stave

Because the rib of a conventional rolled copper stave is small, the burden once entered between ribs almost does not move. As a result, the burden descends on the front face of stave without interruption of ribs as shown in Figure 14. To the contrary, because the rib of a cast-in steel pipe copper stave is large and upward, it produces a flow of burden once entered between ribs to go out toward the furnace inside. At this time, the burden is swept upward from the upper surface of ribs. By this upward flow, the burden on the front face of stave is pushed back to the furnace inside. Through this mechanism, the contact force and descending speed of burden on the front face of stave can be reduced.

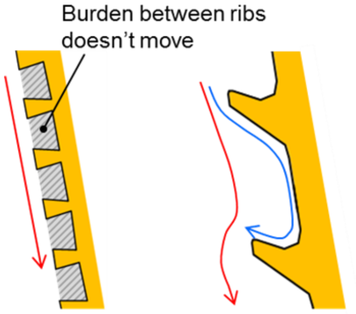

Figure 14: Difference in burden flow on conventional ribs and upward ribs

Figure 15 shows the result of Discrete Element Method (here in after called "DEM") analysis to simulate the behavior of descending burden by modeling the burden as particles. It can be seen that a layer of smaller descending speed is formed on the front face of stave by the effect of upward ribs.

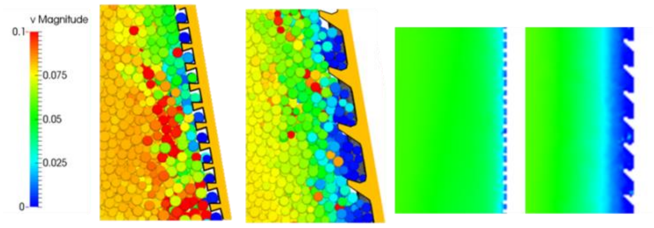

Figure 15: Simulation of burden descending behavior by DEM analysis

By above mechanism, the abrasion resistance improves and the change in the furnace profile becomes small and achieves a stable furnace operation.

3. Conclusion

The adoption of the technology and equipment described in this paper make a contribution to stable operation by constructing and revamping many the large blast furnaces.
If future, NIPPON STEEL ENGINEERING will continue to make technological improvements and development in blast furnace in response to changing as user.

Abbreviations

NSE : NIPPON STEEL ENGINEERING CO., LTD.
RAR : Reduction Agent Ratio
DEM : Discrete Element Method