Ironmaking Technologies Contributing to the Steel Industry in the 21st Century

Akira Maki* and Tatsuro Ariyama**

* General Manager, Ironmaking Technology Development Dept., Steel Technical Center
** General Manager, Dr., Ironmaking Research Dept., Materials & Processing Research Center

In the 20th century, NKK's ironmaking sector sharpened its competitive edge by taking the initiative in developing innovative technologies and fulfilling social requirements. Noteworthy achievements included: extended utilization of various raw materials for ironmaking, improved productivity, and decreased energy consumption. These innovations are now being applied successfully to the expansion of NKK's environmental businesses. In the 21st century, technological breakthroughs will continue to be pursued, diversifying the areas of R&D in accordance with social needs.

1. Introduction

bining blast furnace operation technology with that used in high quality sintered ore production as well as equipment that allowed high load blast furnace operation. The ironmaking division contributed to the development of the revolutionary Zero Slag Process

[1] in the steelmaking sector by establishing low-silicon blast furnace operations through optimizing raw material properties. These achievements are now fully utilized in NKK's expanding environmental businesses, opening up new horizons in the interaction between the steel industry and society centering on resource recycling.

In order to respond to the diversifying need for developing new ironmaking technologies in the 21st century, NKK's ironmaking sector will merge its technologies with

Works. It was installed at each blast furnace in order to strengthen heat level control, and as a result, stable production of low-Si hot metal became possible. In October 1997, the Fukuyama Works achieved a world record in terms of Si content (less than 0.2%) averaged across the entire hot metal produced over a month by a steelworks.

In terms of prolonging blast furnace life, refractory properties and cooling systems have steadily improved. These improvements were successively applied when blast furnaces were relined. Technical improvements have also been made in terms of repairing the shaft and bosh sections while blast furnaces are in operation. As a result, the Fukuyama No.5 blast furnace, which began operations in 1986, is still working after 17 years. This is remarkable when contrasted with those blast furnaces that began operations in the 1970's whose working life was a mere five to seven years (**Fig.2**). Some of the old blast furnaces achieved productivity levels of 1.9 t/d-m^3 and PCR (Pulverized Coal Rates) of 170 kg/t, making large contributions to productivity increase.

Fig.2 Transition of NKK's blast furnaces life

The furnace life prolongation technologies developed in the 1990's include the new technology for replacing the bosh cooling staves and the newly developed, long lasting copper cooling staves[5)]. The latter will be described later. In 1999, all 60 cooling staves were replaced by cast copper cooling staves at the Fukuyama No.4 blast furnace. The deal with the problem that using large amounts of ore with high combined water content tends to lower the sintering yield. **Fig.4** shows the transition of the mixing ratio of pellet feed and ore with high combined water content as well

Fig.7 Transition of COG and steam recovery (Keihin)

In order to increase the amount of COG recovery, increased use of coal with a high volatile content was promoted. At the same time countermeasures were taken against carbon adhesion to the carbonization chamber walls. In CDQ steam recovery, air injection into the CDQ system was optimized by performing 3-D numerical analysis and introducing real-time models[13].

Constructing a new coke oven battery entails a huge capital investment, so it is important to prolong the life of a coke oven. This aspect has been attacked on two fronts: developing techniques for repairing coke ovens and for diagnosing oven life. Typical new technologies developed for the former are as follows:

(1) Hot repair technique for oven walls. Parts of the refractories that make up the oven wall are replaced while the oven is still hot.

(2) Large-scale thermal spray technique for smoothing refractory surfaces that have become uneven due to degradation, and for plugging small penetrating holes. (This technology was jointly developed with other companies.)

In order to diagnose oven life, various sensors have been developed and a database constructed (**Fig.8**). Based on these, it is planned to develop an optimal repair method.

Fig.8 Sensors installed for facilitating efficient oven repair

3. Massive injection of pulveriz new technoiaN0 Tc(.2(937

furnace in April 1994. Subsequently, all NKK's blast furnaces were equipped with it, making a large contribution to a massive PCI operation.

3.2 Sinter properties optimized to massive PCI operation

Reduction degradation of sintered ore tends to be caused in the blast furnace's upper zone due to low temperatures in this zone. As the massive PCI operation lowers the heat flux ratio, this low-temperature zone is narrowed, suggesting that the reduction degradation of sinter could be weakened by a massive PCI operation. In order to obtain sinter properties optimized to a massive PCI operation, attempts were made at the Fukuyama Works to lower the SiO_2 content of HPS ore and increase the RI of sintered

4. Low-Si hot metal production technology

In recent years, further reduction of the consumption of flux materials and ferroalloys in the steelmaking process has been required, as well as the reduction of slag generation, and zero slag operation of converters is increasingly desired. In response, NKK's ironmaking division has tried to reduce the Si content in hot metal being sent on to the steelmaking process. Two approaches were tried: the first was to reduce the Si content in hot metal before tapping; the second to reduce Si content after hot metal has been tapped from the blast furnaces.

4.1 Developing FIMPIT[4)] and reducing Si content in hot metal

It is important to determine the heat level in a blast furnace accurately and in real-time in order to reduce Si content in hot metal before it is tapped. For doing so, it is necessary to be able to measure the hot metal temperature directly immediately after it has been tapped from a tap hole. However, the tap hole surroundings is a severe environment with high-temperature hot metal spouting from the blast furnace, and it has been extremely difficult to directly measure the temperature.

A new technology using optical fibers has been developed by NKK for directly measuring the temperature of hot metal immediately after it has been tapped. This new FIMPIT technology allows the direct measurement of hot metal temperatures with minimal external disturbance(on has t)4(r)-0.7(i)4([FIMP5.h1mf1aus[oped)6(usi4hw37 TmhD0)-4l

In this process, the anti-foaming flux is directly charged into the hot metal ladle and reacts efficiently in the ladle, suppressing the generation of CO gas that causes foaming. This process also allows for the steady injection of large amounts of desiliconization flux, making desiliconization more efficient. With this process, the hot metal already has a fairly low Si content when it is sent to the steelmaking process, and contributes to the achievement of a 100% zero slag steelmaking operation.

5. Recycling businesses applying ironmaking technologies

Since the second half of the 1990's, efforts have been concentrated on applying ironmaking technologies to the development of new environmental businesses. Recycling businesses currently being carried out by the ironmaking division are introduced below.

5.1 Waste plastics injection into blast furnace feeding

Before starting up the waste plastics feeding system for the Keihin No.1 blast furnace, the effects on the blast furnace were investigated using the operating furnace[18). **Fig.16** shows the results of photographing the interior of the tuyere using a high-speed camera (13500 frames/sec) during waste plastics injection. Two types of waste plastics, with different grain sizes, were injected. For comparison, the state during pulverized coal injection is shown as well. When pulverized coal was injected, the combustion flame was observed immediately after injection. In contrast, plastics with a large grain size did not start combusting immediately.

As shown in **Fig.17**, the H_2 concentration in the furnace top gas was higher when plastics were injected as compared to that during conventional operations. Moreover, the difference in the two measurements with or without plastics injection became larger, nearer to the furnace center. These observations suggested that injected plastics remain swirling in the raceway for a certain period of time, and then are gasified near the far end of the raceway. Thus, it was found that the combustion gasifying rate could be increased by controlling the grain sizes of waste plastics within an appropriate range.

It was also verified that the amount of tar contained in the dust discharged along with the furnace top gas was at the same level as that in conventional operations thus posing no problems in furnace operations. Based on these results, Japan's first waste plastics injection operation began in 1996 at the Keih

6. Conclusion

The development of NKK's ironmaking technologies since the 1990's has been outlined. As stated in the beginning, recent technological developments in the ironmaking field are diversifying, centering on recycling businesses. NKK's ironmaking sector met the needs of society in the 20th century through developing highly efficient energy-saving technologies, and will continue to fulfill its social responsibility by leading the industry in responding to the needs of society in the 21st century.

References

1) Tanaka, S. et al. "Establishment of a Zero Slag New Steel Manufacturing Process". NKK Giho. No.169, pp.6-10(2000).
2) Ogaki, Y. et al. "Blast Furnace Feeding of Container and Packaging Plastics". NKK Giho. No.169, pp.1-5(2000).
3) Wakimoto, K. et al. "New Blast Furnace Operation using a Hot Blast Control Valve". NKK Giho. No.153, pp.1-5(1996).
4) Wakai, W. et al. "Development of a Rapid Measurement Method of Blast Furnace Heating by Consumption-type Optical Fiber Radiation Temperature Meter". CAMP-ISIJ. Vol.8, p.1093(1995).
5) Gocho, M. et al. "Development of Bosh Copper Staves". Free Theme Material for 90th Iron Manufacturing Subcommittee, p.15(2000).
6) Osada, K. et al. "Low-stock Level Shutdown at Fukuyama No.4 BF for Bosh CS Change". CAMP-ISIJ. Vol.12, p.707(1999).
7) Niwa, Y. et al. "Commercial Production of BF Agglomerate Using Large Amounts of Low-gauge Fine Iron Ore Powder". Tetsu-To-Hagane. Vol.78, p.1029(1992).
8) Takai, T. et al. "Feeding Zone Modification of Fukuyama No.4 Sintering Machine". CAMP-ISIJ. Vol.6, p.916(1993).
9) Watanabe, T. et al. Automatic Operation at Fukuyama No.4 Sintering Machine, CAMP-ISIJ. Vol.6, p.916(1993).
10) Sugioka, S. et al. Development of Coke Quality Forecasting System, CAMP-ISIJ. Vol.9, p.138(1996).
11) Miyake, T. et al. Automatic Operation of Coke Oven Transfer Machine, CAMP-ISIJ. Vol.9, p.650(1996).
12) Ogawa, M. et al. Development of Chemical Plant Expert System, CAMP-ISIJ. Vol.8, p.966(1995).
13) Ishiguro, H. et al. Development of Optimum Model for CDQ Steam Recovery, CAMP-ISIJ. Vol.8, p.969(1995).
14) Sato, M. et al. Development of Massive PCI Lance at Fukuyama No.4 BF, CAMP-ISIJ. Vol.8, p.318(1995).
15) Ichikawa, K. et al. Production Technology of Low-SiO_2 Sintered Ore Optimized for Massive PCI BF Operation, CAMP-ISIJ. Vol.13, p.702(2000).