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RECENT DEVELOPMENT OF FINEX® PROCESS[1]

Hoo-Guen Lee[2]
Sang-Ho Yi[3]
Sanghoon Joo[4]
Chang-Oh Kang[5]

Abstract

FINEX® is an alternative ironmaking process based on the direct use of ore fines and sub-bituminous coal. The key technologies are the fluidized-bed reduction of iron ore, the hot fine DRI(direct reduced iron) compaction to HCI(hot-compacted iron), the briquetting of coal fines, and melting of HCI into hot metal. The technologies upgraded by plenty of experience at the pilot and demo plants make it possible to commercialize the process. The first commercial FINEX process,.5 Mt/year FINEX® plant has been operating at Posco's Pohang Works since April 2007. Recently, the plant is carrying out coke-free operation. Furthermore, the second commercial FINEX® plant which is scaled-up to 2.0 Mt/year, is being constructed at Posco's Pohang Works.

Key words: FINEX®; Ironmaking; Coke-free.

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[2] *FINEX R&D Project Department, POSCO, Pohang, 790-300, Republic of Korea*
[3] *Technical Research Laboratories, POSCO, Pohang, 790-785, Republic of Korea*
[4] *Synergy Group, POSCO, Seoul, 135-777, Republic of Korea*
[5] *Graduate Institute of Ferrous Technology, Pohang University of Science and Technology, Pohang, 790-784, Republic of Korea*

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1. Introduction

Since initiation of the FINEX® development program in 1992 in cooperation with Siemens VAI in order to create an alternative ironmaking process : 1) removing coking and sintering processes, 2) operating on low-grade, low-cost raw materials, and 3) competing with the blast furnace process on cost, POSCO have been successful in commercialization of the process through the sequence of tests at a 15 t/day model plant starting in 1996, a 150 t/day pilot plant in 1999 and a 600 kt/year FINEX® demonstration plant in 2003. Based on the successful results from the demonstration plant, the first commercial FINEX® plant with a capacity of 1.5 Mt/year constructed at the Pohang Works and commenced operations in April 2007 at Pohang Works of Posco. Up to now, 1.5 Mt/year FINEX® plant has shown several noticeable operational results in the aspect of performance, raw material, environment and energy. They indicate that the process is not completed but can evolve continuously to be suited to various local conditions.

Currently, the scaled-up FINEX® plant to 2.0 Mt/year is under construction at Pohang Works. Posco is poised to make a significant contribution to the global steel industry with an innovative ironmaking technology, FINEX®

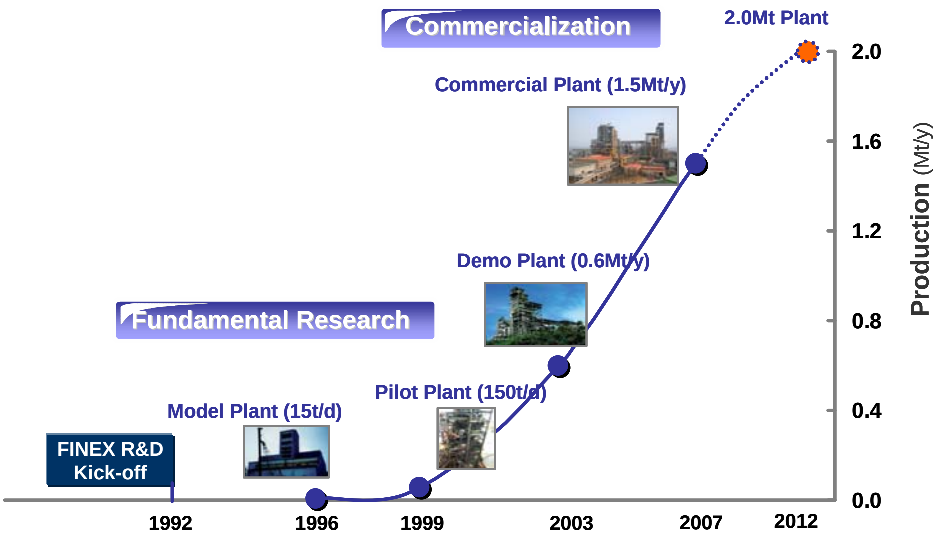

Figure 1 Chronological diagram of FINEX® scale-up

2. Process overview

The FINEX® process consists of a cascade of fluidized-bed reactors, a coal briquetter, a hot DRI compactor, and a melter-gasifier. Iron ore fines are charged and reduced in the fluidized-bed reactors. The pre-reduced iron ores are agglomerated into lumps by the hot DRI compactor and then charged into the melter-gasifier for iron melting. It is possible to make operational control uncomplicated by the separation of zones of iron ore reduction and melting. In the case of coal, non-coking coal fines are briquetted by the coal briquetter and then charged into the melter-gasifier.

Figure 2 is the schematic for the process flow of FINEX®. Ore fines are

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charged into the fluidized-bed reactors together with a flux such as limestone or dolomite. As it passes through the four reactors, it is preheated and reduced. The reduced iron ore or hot DRI is transformed into lump by the hot DRI compactor, and then charged into the melter-gasifier. Coal fines are processed by either the briquetter or the pulverized coal injection (PCI) facilities. Coal briquets are put into the dome of the melter-gasifier, while pulverized coal is injected through the tuyeres. The reducing gas generated by coal combustion with pure oxygen in the melter-gasifier is transported to the fluidized-bed reactors to reduce the iron ore. A portion of outlet gas of the reactors goes through CO_2 removal utilities for recycling. It leads to higher gas utilization efficiency.

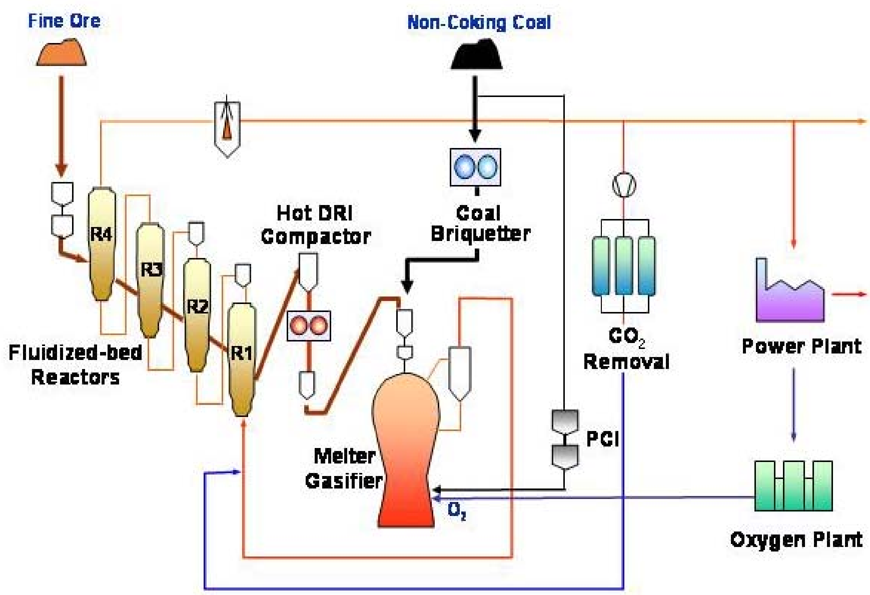

Figure 2 FINEX® Process Flow

3. FINEX® Plant Operation

3.1. Operation results of the first commercial FINEX® plant

Figure 3 shows the 1.5 Mt/year FINEX® plant at the Pohang Works.

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Figure 3 FINEX® 1.5 Mt/year Plant

The start-up of the1.5 Mt/year FINEX® at Pohang Works was successfully performed. The productivity reached the target value of daily 4,300 ton in May of 2008. With the operation optimization and facility stabilization, the coal consumption rate was decreased to 720 kg/t_{HM} and high plant availability was achieved as shown in Table 1.

Indices			Target (designed)	Operation (May~Oct,2008)
Production		Mt/y	1.5	1.5
		t/d	≥ 4,200	4,300
Coal Rate		kg/ t-HM	≤ 730	720
	Coke		≤ 70	60
	PCR		≥ 140	150
Hot Metal	[S]	%	≤ 0.030	0.027
	[Si]	%	≤ 0.80	0.81

Table 1. Operational achievements of 1.5 Mt/year FINEX®

It is critical to obtain the operational stability of the fluidized-bed reactors for the high plant-availability of the FINEX® process. A great deal of experience from demonstration plant operations provides with solutions to frequent sticking and blocking problems curtailing performance of the fluidized-bed reactor system. Furthermore, the reactor maintenance interval has gradually been extended by improvements in equipment and operational skills. The availability of the 1.5Mt/year FINEX® plant is on a par with that of conventional blast furnaces.

Significant efforts have been paid to reduction of the coal rate, the primary indicator of process heat efficiency. Coal-rate could be declined to 720 kg/t_{HM} by the main contribution of carbon dioxide removal and pulverized coal

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injection. Half of off-gas from the fluidized bed reactors is recycled to the reactors through the carbon dioxide removal process. This removal process provides 30 % of the total reducing gas needed by the fluidized-bed reactors, filling for the coal consumption for the reducing gas generation. PCI increases the burden retention time and the volume of hot gas in contact with the burden in the melter-gasifier bed. Those consequently improve the efficiency of the heat exchange in the melter-gasifier bed.

After the targets in Table 1 were reached, the various operation modes have been executed following the R&D program aimed at the further enhancement of competitiveness of the process. One of them is so called '*Zero Coke*' operation.

3.2. 'Zero Coke' Campaign

'Zero Coke' operation means only the pulverized coal and coal briquettes are used as carbonaceous charging materials in the melter-gasifier. Namely, it is coke-free operation. The stable operation could be achieved by the improvement of strength of coal briquettes. Otherwise, the internal condition of the melter-gasifier would be deteriorated. In this campaign, it was found that the gas and liquid permeability in the char bed got worsen slightly by the inferior strength of coal briquettes to that of coke and thus the production rate was decreased but 'Zero Coke' operation generated following benefits: (1) increase in the gas volume, (2) decrease in the high-price coke consumption, (3) decrease in [Si] of hot metal and (4) increase in reduction degree of hot DRI. It was estimated that losses from decline in productivity could be offset by those benefits. The constant technical exertions will be made to increase the productivity afterward. When FINEX® advances to the green field where there is no coke, the competitiveness of the process can be distinguished from any others.

4. Raw Materials

FINEX® can handle various types of iron ore fines in terms of composition and size distribution. High alumina bearing low grade iron ores restricted in the blast furnace are available. For the test period of application of Australian iron ore with 2.5% alumina and Indian iron ore with 3% alumina to FINEX® process, any serious operational problems have never been reported in the melter-gasifier. The commercial plant is stably running with Australian iron ore.

Although the process initially targeted for the usage of the sinter feed, it showed the possibility of usage of the pellet feed up to 30% of total charging fine ore without drastic modification of the facilities of the process. It was analyzed that the extremely fine particles, pellet feed interacted with relatively large particles, sinter feed or flux materials, in the fluidized bed reactors so as to reduce elutriation losses. Besides, while magnetite pellet feed was being used in the process, the reduction degree of HCI and coal rate could be maintained by technical and technological development. Fig. 4 depicts the direction of diversification of types of iron ore. Intensive R&D programs for using iron ore

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and coal known not to be suitable for the conventional ironmaking process are progressing.

Coal briquetting technology enables FINEX® to use various kinds of coal. The technology is to control the composition and quality of the briquettes by coal blending. Their superior quality over lump coal leads to the stable operation of the melter-gasifier. The role of coal briquettes is similar to that of cokes in the blast furnace. For the pulverized coal injection, semi-anthracite is mainly use. Lately, non-metallurgical coal is being used up to 30% in the process.

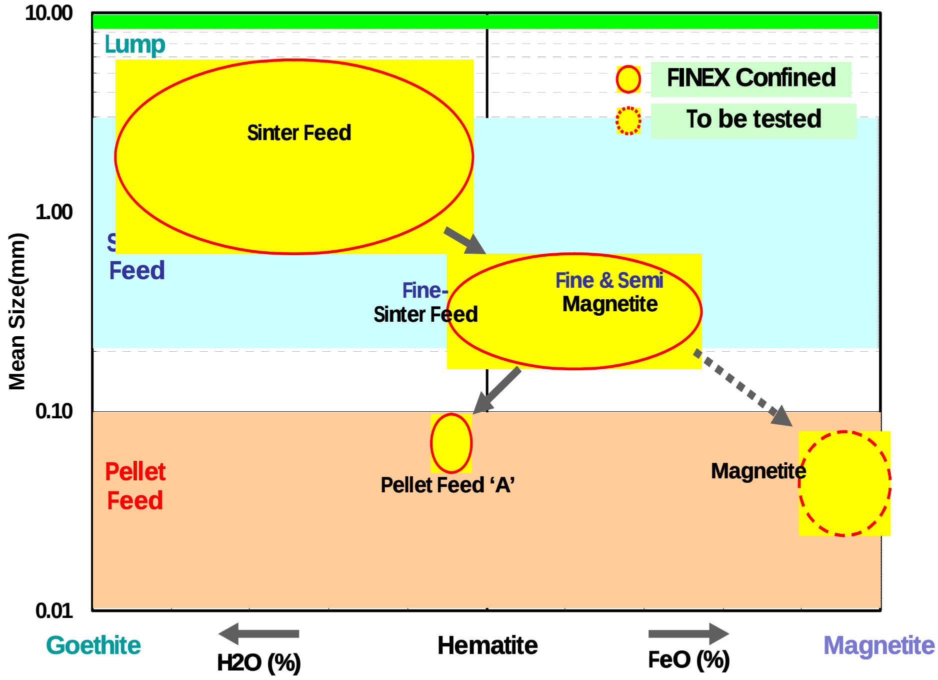

Figure 4 Diversification direction of ore in FINEX®

Operational tests to use magnetite ore fines and non-metallurgical coal were successfully demonstrated in the FINEX® plant, which will lead to the expansion of FINEX feed. The broadening of the type of the resources shows this process is able to efficiently meet the local resources condition.

5. Environment

The environment-friendly ironmaking process, the FINEX® will get more competitive in the future. The emission level for SO_x, NO_x, and dust emissions are a mere 3%, 1%, and 28%, respectively, of those generated by the blast furnace process. Even comparing to the BF route with environmental best available technology, FINEX® still shows much lower emissions. This enables FINEX® to easily comply with strict environmental standards and legal regulations.

Due to the elimination of coke oven and sinter plants, the FINEX® process inherently prevents pollution from being generated. Most of sulfur contained in coal and ore reacts with limestone added as flux to form CaS in the reactors, and then captured into slag. NO_x emissions are naturally very limited because of

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combustion with pure oxygen in the melter-gasifier. Dust emissions are lowered by simplified processing rout. And it has been verified that no dioxins are generated in the FINEX® process.

Due to the lower coal consumption rate, the current CO_2 emission of FINEX® is 96% of the world's averaged blast furnace emissions, and it is expected down to 94% by process optimization soon. Besides, because FINEX uses pure oxygen for coal gasification and employ an in-situ CO_2 removal system, the concentration of CO_2 in off-gas is higher. It can be helpful to separate CO_2 for the storage. Subsequently, FINEX® is highly feasible to apply CO_2 sequestration, and the CO_2 emission can be even reduced to 56% of the world's averaged blast furnace emissions.

6. ENERGY

In FINEX®, with parallel to the reduction of oxygen and electricity consumption rate, the high energy efficient route for producing oxygen and electricity is important. For the energy and operational cost savings, the 1.5 Mt/year FINEX® at Pohang Works is combined with an energy efficient oxygen pant and a cycle power plant using FINEX® export gas. The oxygen and power plant are under the stable operation with satisfactory efficiency and performance. For the further energy saving, the integrated configuration of oxygen, power, and a FINEX® plant is under investigation. This integration is critical in enhancement of the energy efficiency of FINEX® process to surpass the blast furnace process.

The recovery of waste energy in FINEX® process is also important for energy savings. R&D program has been progressed to develop the recovery of waste energy customized for the FINEX® process. One of the outcomes of R&D program was the waste heat recovery system installed at the off-gas line of fluidized-bed reactors in 1.5 Mt/year FINEX® plant. This system is operating under the high dusty and tar-contained gas, therefore the customized design factors has been studied and verified by the hot simulation test. The system is supplying steam to the steam network at Posco's Pohang Works. Approximately 150 Mcal/t_{HM} of energy and corresponding operational cost are being saved.

7. Capex and Opex

POSCO will strengthen the competitive power of FINEX in both capital and operating costs.

Comparing a 3Mt/year blast furnace with two 1.5Mt/year FINEX units, there is presently a saving of 15% in Capex costs in favour of FINEX.

The operating costs of the 1.5Mt/year FINEX are currently 95% of those of a 2.0Mt/year blast furnace but this is expected to fall to 85% as optimization is achieved. The 2.0Mt/year FINEX Plant is anticipated to reduce this to 80% of the operating cost of a blast furnace due to the scale-up effect.

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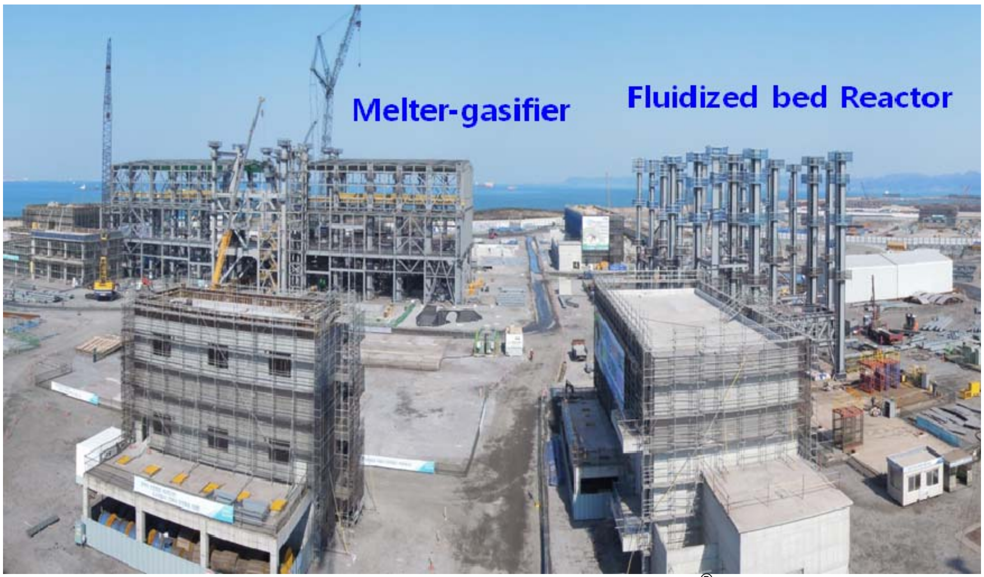

Fiure 5 Picture of 2.0Mt/year FINEX®

8. The Second Commercial Plant, 2.0Mt/year FINEX

POSCO is constructing a second commercial 2.0Mt/year FINEX plant at the Pohang Works. The scaled-up FINEX design incorporates the operating experience at the 1.5Mt/year plant and the results of the R&D programs so far. It has three larger fluidized bed reactors in cascade rather than the four of the 1.5Mt/year plant and the hearth diameter of the melter gasifier will be increased from 8.9m to 11.5m. The overall height, however, will be reduced.

POSCO started construction of the 2.0Mt/year plant in Q2 2011 and expects plant start-up to be within the Q2 2013. Fig. 5 shows the degree of the construction progress of 2.0Mt/year FINEX plant.

9. Conclusions

Posco completed the commercial FINEX process 1.5Mt/y which could compete with the blast furnace. But Posco still keeps not only developing the FINEX process technology to possess the flexibility to various types of resources but also improving its facilities and operation technique to optimize the process. In the second half of 2013, the second commercial plant 2.0Mt/y will be completed. The plant can achieve economies of scale in production, and all of the technologies and known-how accumulated until now will be dissolved into the plant. We are sure that the 2.0Mt/y FINEX plant can be the world's most competitive ironmaking process.