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RECENT DEVELOPMENT OF IRONMAKING TECHNOLOGY IN KOREA "RESOURCES ARE LIMITED, CREATIVITY IS UNLIMITED"[1]

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

Abstract
Steelmakers in Korea are expected to face challenges as followings: The upsurge in prices of raw materials, the oversupply and saturation of steel market, the lowered inflexibility to raw material quality by increased number of large-scale blast furnaces and the pressure to mitigate CO_2 emission. To solve the challenges, steelmakers in Korea have made the technological innovation based on creativity, including the development of FINEX® process. In addition, they have been developing the hydrogen reduction technology to enhance the reduction of non-reducible iron ores and to mitigate CO_2 emitted from the steel plants. The current efforts in Korea will give a great opportunity to leap over the next advanced stage.
Key words: Challenges; Hyundai-steel; Raw material; FINEX® ; Synergy; CO_2.

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[2] *Senior Vice-President, Division of FINEX R&D Project, POSCO, Pohang, 790-300, Republic of Korea*
[3] *Director, Technical Research Laboratories, POSCO, Pohang, 790-785, Republic of Korea*
[4] *Chair Professor, Graduate Institute of Ferrous Technology (GIFT), POSTECH, Pohang, 790-784, Republic of Korea*

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1. Introduction

"Resources are limited and Creativity is unlimited" is the motto written at the main entrance of POSCO Pohang works. This shows the strong will of POSCO to create 'something' out of 'nothing' by the technical development of resources.

Since 1990s, there have been massive demands for resources and high production of crude steel in China. Moreover, as shown in figure 1, the concentration of the production in three countries: Korea, Japan and China, resulted in the radical change in price structure of raw materials and steel-market saturation. Korean steelworks were located in the seaside to facilitate transportation of raw materials in bulk. Therefore the productivity of the blast furnace has been increased with its capacity to obtain cheap raw materials and to meet the abundant demands of markets till lately. However, as the situation changes, the steel industry is experiencing not only both upsurge in the price of raw materials and saturation in the market but also pressure to reduce CO_2 emission. The present situation is considered unprecedentedly so critical that the competitiveness of Korean steel industry is challenged.

The current challenges, however, can be defined as the knowledge-limited problems. The facility-limited problems as experienced in the past were easy to be solved by the investment on appropriate facilities: Financial means. But the means is not effective any longer to the knowledge-limited problems which Korean steelmakers are undergoing recently. It can be solved by creativity and innovation so that Korean steelmakers have made efforts to secure creative human resources and to develop innovative ironmaking technology.

2. Brief Review of Korean Ironmaking

In ancient Korea, countries were founded based on advanced ironmaking technique. But the wide spread of advanced ironmaking technique caused the depletion of the domestic iron ores and charcoal followed by declining of the technique.

While getting modernized after Korean War, Korean steel industry got the technical assistant from Japanese major steel companies and chose Japanese proven model, so called "Seaside Integrated Steel Works", importing massive low-cost raw materials so that they could have been developed for 40 years.

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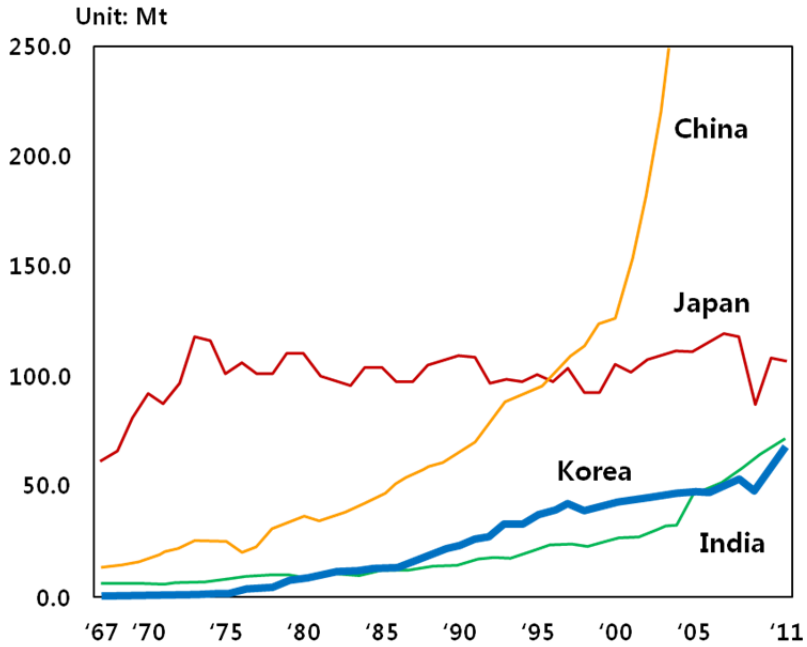

Figure 1. Trend of annual production of crude steel in Northeast Asia

The first Blast Furnace with capacity of 1.0MTPA (1660m^3) got operated at POSCO Pohang Works in 1973. Figure 2 shows the trend of crude metal production in Korea after POSCO foundation. Starting from 1982 to 1992, the Gwangyang Works was built. POSCO completed a commercial FINEX® plant in 2007. Another integrated steel mill was also launched in Dangjin in 2006 by Hyundai Steel for the vertical integration of their parent company, that is, steel-to-complete products. Hyundai Steel added another big blast furnace in 2010 and the third one is under construction now. The specification of BF and FINEX® in POSCO Pohang and Gwangyang Works, and Hyundai-Steel Dangjin Works is briefed in Table 1. Now, POSCO Pohang and Gwangyang Works, and Hyundai Steel Dangjin have four blast furnaces and two FINEX®s, five blast furnaces, and two blast furnaces, respectively, as shown in figure 3.

3. Challenges of Korean Steel Industry

The challenges Korean steel industry are faced with are categorized into four types as shown in figure 4. The first challenge is the upsurge in prices of raw materials. Most of the large-scale seaside integrated steel works are located in East Asia and use iron ore sourced from Australia and Brazil, which resulted in radical change in the price of raw materials.

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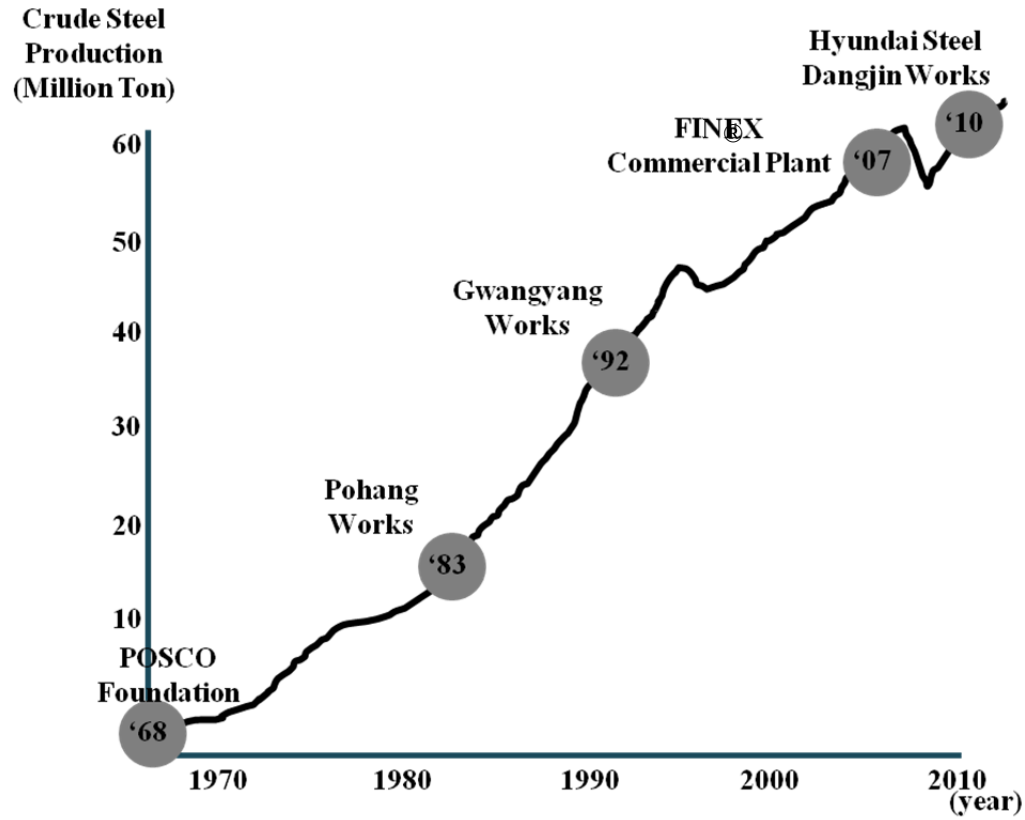

Figure 2. Trend of crude metal production in Korea

	POSCO Pohang Works						POSCO Gwangyang Works					Hyundai
	BF1	BF2	BF3	BF4	FNX1	FNX2	BF1	BF2	BF3	BF4	BF5	BF 1&2
Inner volume(m^3)	1,660	2,550	4,350	5,600	0.6Mt	1.5Mt	3,950	4,350	4,600	5,500	3,950	5,250
Hearth Diameter(m)	9.2	12.3	14	15.6	7.3	8.9	13.2	14	14.3	15.6	13.2	14.8
Number of Tuyeres	24	28	38	42	26	28	36	38	40	42	36	42
Number of Tapholes	2	2	4	4	2	2	4	4	4	4	4	4
Top Pressure (bar.g)	1.3	1.5	2.8	2.8	4.0	4.5	2.5	2.5	3.1	2.8	2.5	3.0
PCI(kg/tHM)	150	150	250	200	250	220	200	200	200	250	200	180 (normal)

Table 1. Specifications of BF and FINEX® in POSCO and Hyundai Steel, Korea.

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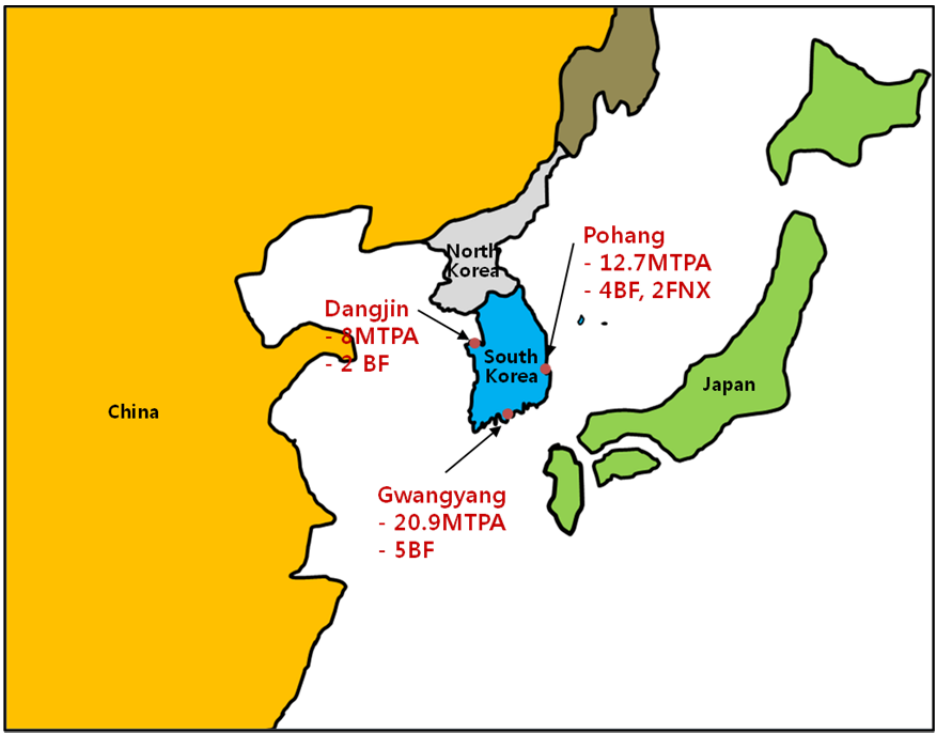

Figure 3. Locations of POSCO Pohang & Gwangyang Works and Hyundai Steel Dangjin Works.

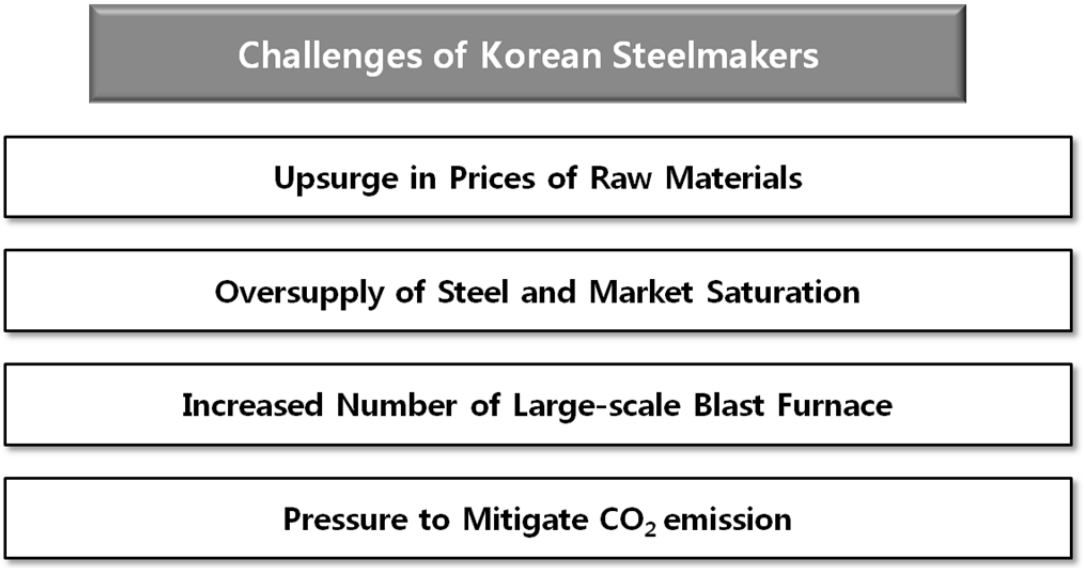

Figure 4. Four typical Challenges of Korean steel industry

The price of iron ore which was about $20/t-ore in 1975 has shot up to $160/t-ore in 2011 and that of Australian hard coking coal has risen sharply from $60/t-coal to $300/t-coal which is higher uptrend compared with the rise of crude oil price after going through two times of oil shock. Consequently, Korean seaside integrated steel mills which were appropriate to transportation of massive cheap resources have made high reliance on Australian and Brazilian major resource-companies, and the raw material has occupied most of production cost of pig iron.

The second one is the dependency of Korean steelmakers on the foreign market. Because Korean economy is export-oriented, the large amount of steel is actually

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consumed out of the country through making ships, vehicles, plants etc. Table 2 shows that the apparent steel uses per capita in some countries. In the case of Korea, it is approximately twice more than that of Japan. On the other hand, the saturated Northeast Asia steel market and the worldwide economic downturn as well as the current recession of Korean domestic market are intensifying the competitions among steelmakers. Besides, the price of steel product which is widely used material in the society cannot be index-linked with that of raw materials.

The third one is that most ironmaking process consists of large-scale BFs, which have many advantages such as high efficiency, high productivity and long life span. Figure 5 depicted the increase in the average capacity of the blast furnace in Korea. However, the larger is the blast furnace, the less flexibility to both quality variation of raw materials and market volatility. Therefore it is not easy to make direct application of low grade raw materials to the large-scale furnace by maintaining sound operation.

The fourth one is related to the worldwide trend 'Green Economy' applying pressure on Korean steelmakers to mitigate the emission of carbon dioxide as well as hazard gases such as SO_X and NO_X, etc.. Therefore they are struggling to develop the eco-friendly ironmaking and steelmaking technologies.

It is necessary to have very creative directions to get over the challenges we are facing, which is to be discussed with the directions in the following section.

2011 (Kg/Capita)					
1	South Korea	1,157	**6**	Austria	473
2	Taiwan, China	784	**7**	China	460
3	Czech Republic	596	**8**	Italy	460
4	Japan	507	**9**	Sweden	425
5	Germany	480	**10**	Belgium-Luxembourg	423

Table 2. Countries with the highest apprarent steel use per capita

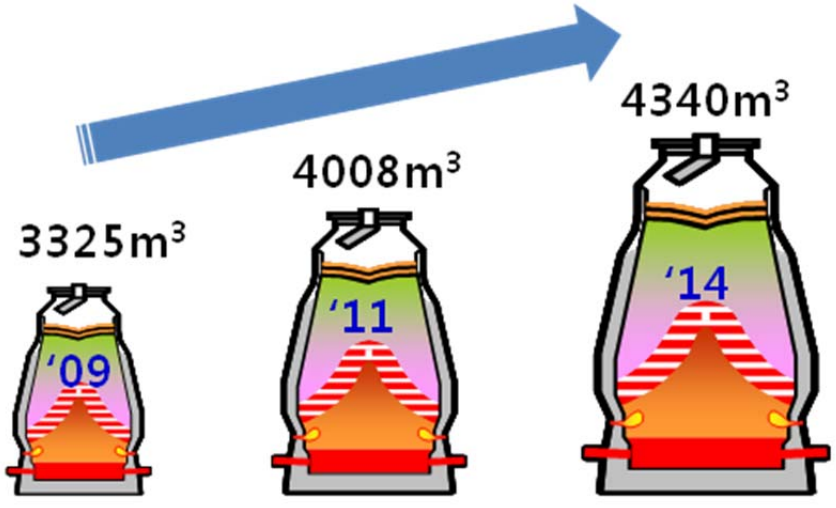

Figure 5. Increase in the average working volume of BFs in Korea

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4. Responses to the Challenges

4.1 Technical Innovation with Creativity

It is expected that companies who don't own any resources will face the difficulties over the next 10 years and Korean steelmakers cannot be an exception. However, challenges such as resource depletion are not a new thing for us. There was no natural resource in Korea from the beginning and we were always searching for the way to use the resources effectively. Fortunately, Korea is rich in high competency human power. The man power has been a cornerstone in overcoming the obstacles and the present challenges confronting Korean steel industry can be solved by aid of only the human creativity without substantial investment.

Korean steelmakers have been exerting efforts on constructing techmology developing system. For example, POSCO completed the platform for the technical development of iron and steel technology which is connected from basic research to commercialization by research network for Industry-University-Institute. The cooperation in the network made a critical contribution to development of FINEX®, CEM® (Compact Endless cast rolling Mill) and poStrip® (POSCO STRIP casting process).

4.2. FINEX® Process to Use Low Grade Raw Materials

Since the steelmakers of the form of the seaside steelworks possessing no captive mines are being challenged by instability of raw material supply, they have considered the development of various types of alternative ironmaking processes with a keen interest to overcome the situation. However, although the processes have been developed over the past 30 years, they did not reach the commercial state to compete with the blast furnace. Most of the processes still have limitation in usage of raw materials.

In Korea, the investment in the development of the alternative ironmaking technology to use low grade raw materials has been maintained. As a result, POSCO developed FINEX® process. It took only 15 years to start to operate the first commercial FINEX® plant, 1.5MPTA, since the lab-scale test was initiated in 1992 as shown in figure 6. Executive's commitment and technical development workforce made it possible to achieve such a rapid development. The plant has been operated successfully for 5 years. Currently, the second commercial plant, 2.0MPTA FINEX®, is under construction in Pohang works with a goal of its start-up to run by 2013.

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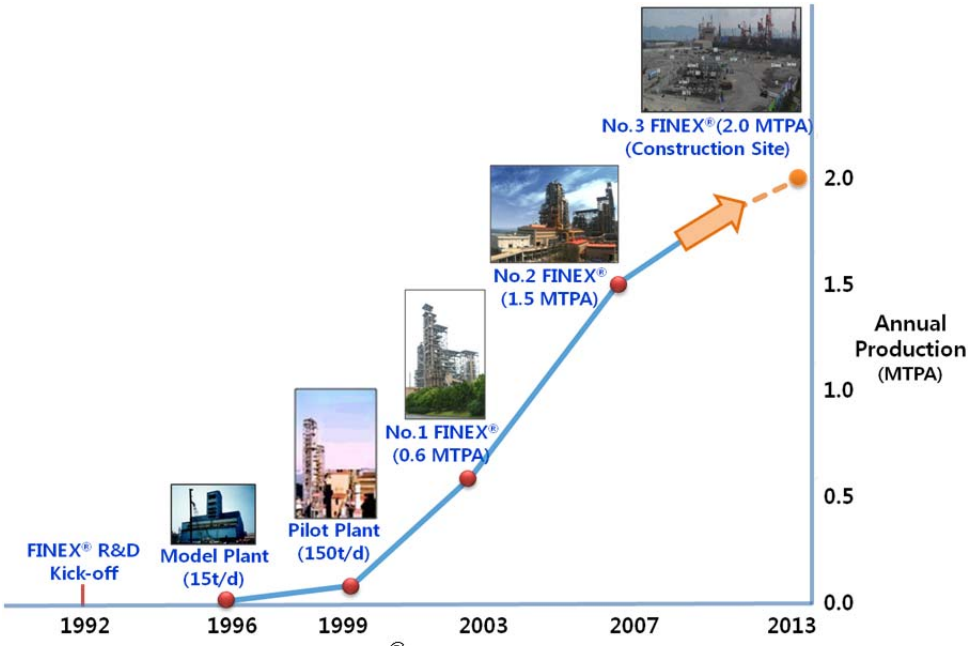

Figure 6. Scale-up history of FINEX® process

FINEX® can handle various types of iron ore fines in terms of composition and size distribution. High alumina bearing iron ores limited to use in the blast furnace are available in FINEX® process. In addition, the process shows the possibility of usage of the pellet feed up to 30% of total charging fine ores. Many-times operational tests prove various kinds of iron ores and thermal coals can be used in the process.

Recently, FINEX® is on 'Coke-free Operation', which means only the pulverized coal and coal briquettes are used as carbonaceous charging materials in the melter-gasifier. 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 'Coke-free' operation showed meaningful results providing FINEX® with flexibility to various circumstances. The parameters of 1.5MTPA FINEX® plant in table 3 are the achieved operation results after its blowing-in.

FINEX® can create synergy effect with BF. A large-scale blast furnace has low flexibility to the qualities of the coal and iron ores, which requires high grade iron ore and coking coal. The furnace condition is very sensitive to the size of charging materials. Combining the blast furnace with FINEX® with high flexibility to the qualities of the raw material, powerful synergetic effect is expected in the brown field works. The schematics for the combinations are shown in figure 7.

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Indices			Target (designed)	Operation I (2008)	Operation II (2010)	Coke-free operation
Production		Mt/y	1.5	1.5	1.6	1.2
		t/d	≥ 4,200	4,300	4,500	3,400 ~ 3,600
Coal Rate		kg/t-HM	≤ 730	720	700~720	780~820
	Coke		≤ 70	60	170	0
	PCR		≥ 140	150	150~160	200 ~ 230
Hot Metal	[S]	%	≤ 0.030	0.027	0.018	0.036
	[Si]	%	≤ 0.80	0.81	0.69	0.26

Table 3. Operating parameters of 1.5MPTA FINEX® plant since blowing-in, 2007

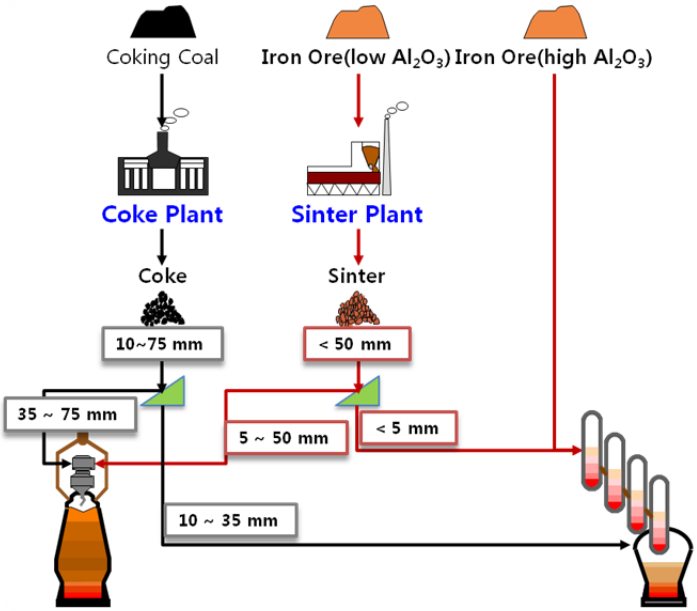

Figure 7. Schematics for synergy effects between BF and FINEX®

4.3. Technology to Use Hydrogen for Less-reducible Iron Ore

The problem of ironmaking and steelmaking process is to inevitably emit large amount of carbon dioxide because of the use of carbon-based such as coal and natural gas for the reduction process. Worldwide tighten regulation of carbon dioxide emission leads the steel industry to pay attentions to the research related to clean ironmaking technology instead of the existing carbon-based ironmaking in the viewpoint of the environment, energy and cost-competitiveness. Since it uses hydrogen as a reducing agent to replace the carbon, the emission of carbon dioxide is somewhat reduced.

Hydrogen-based ironmaking technology can be divided into hydrogen amplification-manufacturing and its reduction. In the technology, it is very critical to procure the hydrogen source economically. The former is to produce large amount of hydrogen by reforming of byproduct gases from ironmaking-steelmaking process. It is expected that the hydrogen technology can resolve the bottleneck of FINEX® and BF process by enrichment of H_2 in reducing gases as shown in figure 8. The technology makes it possible to use reducibility-inferior iron ores. As a result, the span of usable iron ore can be extended.

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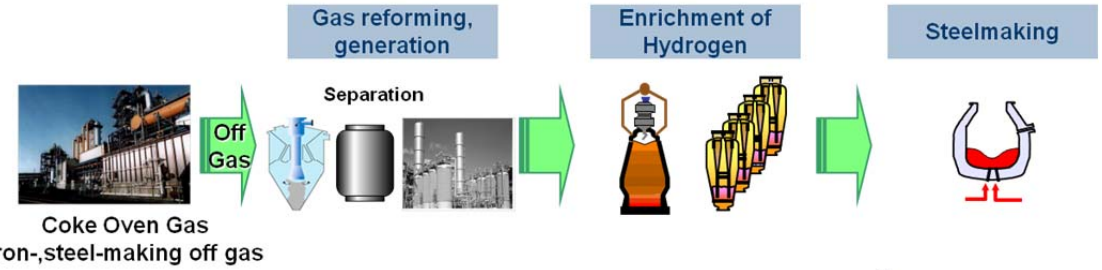

Figure 8. Schematics for Hydrogen enrichment in BF and FINEX®

4. Concluding Remarks

Steelmakers in Korea are expected to face the challenges caused by current global economic recession and oversupply of steel products in Northeast Asia. Those challenges are, however, able to provide a great opportunity to the steelmakers in Korea so as to leap-over the next advanced stage through fostering creative steel-related professionals as well as investing in technological innovation. Following the motto: “Resources are limited, Creativity is unlimited”, not frustrated by limited resources but innovating steel by unlimited creativity, we will design the future.