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PRACTICAL TECHNICAL REVIEWS IN ENERGY SAVING AND CO_2 EMISSION REDUCING FOR THE BLAST FURNACE[1]

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Abstract

It's systematic and detailed presented the subsequent entry point about the energy saving and CO_2 emission reducing for the blast furnace. It indicates great potential and practical value in the area of hot charging of the material and fuel, hydrogen-matter injection, process optimizing for hopper pressure modulation, sensible heat reuse of slag, pure oxygen injection.

Key words: Blast furnace; CO2 emission reduction; New developments.

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1 INTRODUCTION

In recent years, the new processing—Non coking ironmaking which receive extensive concern by expert of metallurgy development quickly in the world, as if the predominated BF process which we depended on was neglected. For future development, as the shortage of raw material, quality descending and strict requirements of environmental protection rules, energy saving and environment protection would become the key problem of all industry. A long time is needed for the development of non coking ironmaking process in the prospective of the process maturity, its scale and the predominated position of BF cannot be changed with the steel industrial development recently.

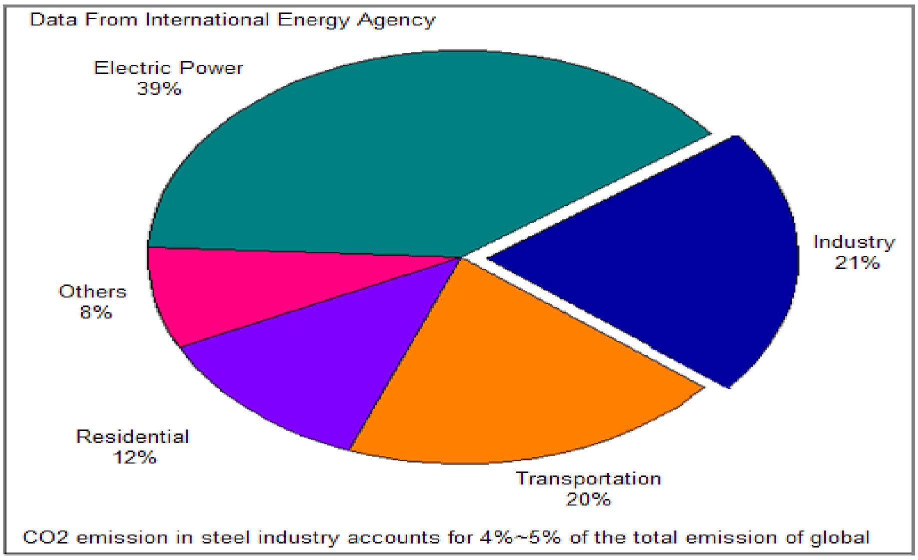

Fig.1 proportion of CO2 emission in different industry in the world.

With the global warming, CO_2 emission reduction plan was put forward by all country, advocating and promoting the development of low carbon industry. Steel industry is the main source of greenhouse gas emission, the emission amount per year of CO_2 is around 4 percent of total emission amount in the world, even ironmaking process accounting for 74 percent of total emission amount in the steel industry. So the key point for emission reduction in steel industry is ironmaking process. Is there any potential of CO_2 emission reduction can be developed? Can it face to the challenge of the warmer global weather? Of course much work could be done. Although BF process is mature compared with non coking ironmaking process, it still have a lot work to do such as reducing fuel consume, decreasing CO_2 emission and promoting environment protecting. For optimizing the ironmaking technology, long-term research on non coking ironmaking process need to be done in long period. on the other hand, regard as current BF process we should find a good way to optimize and promote the process to fix current shortage.

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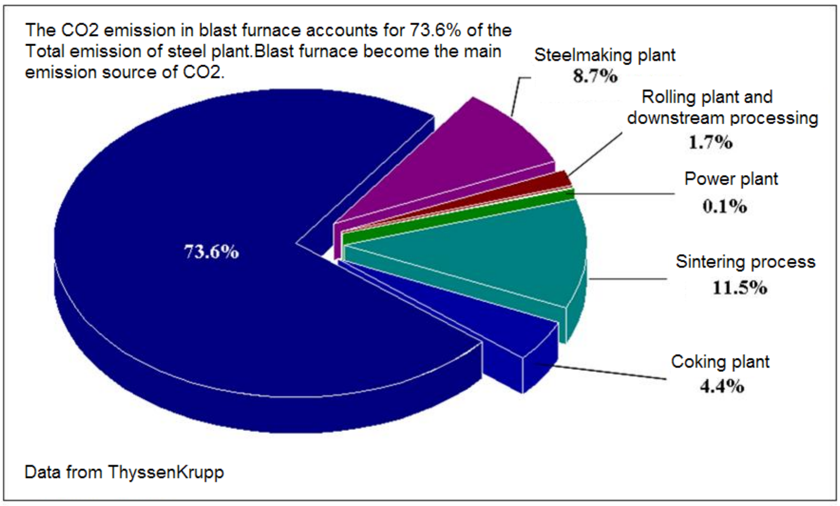

Fig.2 The proportion of CO_2 emission in different process in steel industry.

In conclusion, importantly aiming at the BF process in this article, the found entry point were discussed practicability from the perspective of ironmaking main process, expecting to illumine the industry insider.

2 CHARGE THE FURNACE WITH HOT RAW MATERIAL

At present the raw material for BF such as sinter, pellets and coke were fed into furnace in cold state. One side the raw materials produced by sinter plant, pellet plant and coke plant need to be cooled to room temperature for deposited and transported, on the other hand much quantity of heat is needed to preheat the raw materials in the upper part of blast furnace, so a large great deal of heat is wasted.
The energy consumption per ton pig iron is 559.6kgce (71.96 kgce for sinter, 51.79 kgce for coking, 7.69 kgce for pellet, 428.16 kgce for ironmaking). The 500-600°C sponge iron which was produced in HYL shaft furnace in Mexico are hot charged into electric furnace directly, compared to charging with cold state the energy saving is around 60~80kwh/t steel, that is 28kgce/t steel(calculated according to 360kgce/t electricity). Just think that if hot raw materials were charged into BF, only in BF process the energy consumption can be reduced 22~28kgce, approximately six percent of total energy consumption in BF process, 44~56kgce/t iron can be saved if heat loss added during cooling to room temperature for raw materials before BF, accounting for 10% energy consumption of whole ironmaking system.
It is worth to notice that hot compaction process was adopted after fluidized bed reduction process in POSCO's Finex process in Korea. Sponge iron in hot state around 850°C was charged into latter melter-gasifier process, through high temperature pneumatic conveying, high temperature chain grate machine and hot temperature tank for hot charge. This process was successfully implemented in two Finex plant with the scale of 80 and 150 million ton per year and worked well, the correlative facility endure practical test. So it can be seen that raw materials hot charge process can be also applied to BF process.

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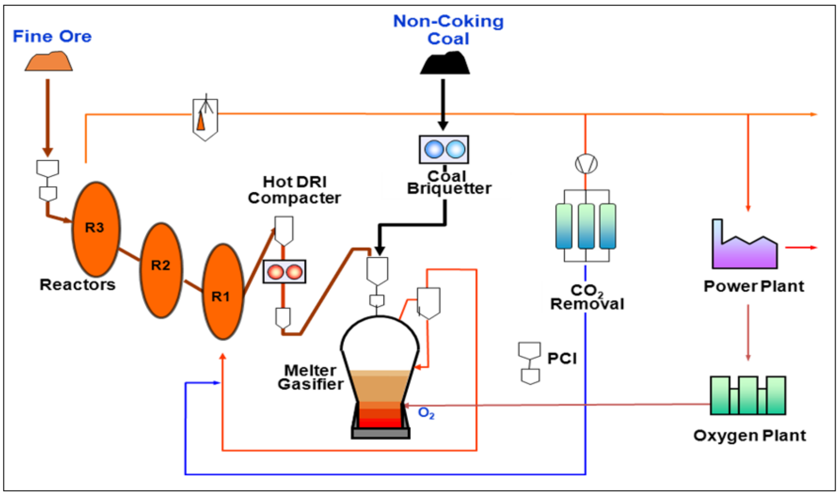

Fig.3 Hot charge schematic flow sheet of Finex process.

3 BLOWING MATERIALS CONTAINING HYDROGEN

Blowing materials containing hydrogen and strengthen hydrogen reduction have become the research hotspot nowadays. The main reasons for blowing materials contained hydrogen in BF are that: firstly whether from thermodynamics or dynamics, H_2 act as reducing agent of iron oxide is more preponderant than CO, with good reaction condition and high productivity, it also can reduce the quantity of heat the reduction reaction need, only one fifth of C reduction but the reduction rate faster an order of magnitude than C, secondly gaseous product of hydrogen reduction is vapor instead of CO_2, so blowing materials containing hydrogen can reduce the amount of CO_2 produced by BF, effectively settle the problem of green house gas CO_2 emission. The research results and productive practice show that as blowing materials containing hydrogen, hydrogen atmosphere in BF can be strengthen, hydrogen reduction proportion of iron oxide in the whole indirect reduction can be obviously increased as shown in Tab.1, the indirect reduction in stack was accelerated, thus improving the metallurgical properties in BF, achieving to the target of increase production and conserve energy.

Table 1. The change of indirect reduction after blowing materials containing hydrogen

BF operation	The proportion of hydrogen indirect reduction /%		
	$Fe_2O_3 \rightarrow Fe_3O_4$	$Fe_3O_4 \rightarrow FeO$	$FeO \rightarrow Fe$
whole coke operation	0.4	11.2	28.6
blowing nature gas (140 kg/tHM)	10.9	79.8	74.4
blowing wasted plastics (40 kg/tHM)	1.2	27.0	49.3

Considering the economic cost and security and so on, it is inadvisable for BF to blow hydrogen directly, but it's possible for the material rich in hydrogen, such as the top gas in BF, coke oven gas, waste plastics, natural gas and so on.

3.1 Circulation Use of Top Gas

Top gas in BF is used as low heat value fuel generally, causing a lot of CO_2 discharged to the atmosphere. If CO_2 in BF gas was removed, thermal value of top

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gas can be increased to 6500~7000kJ/Nm^3, based on traditional thermal value 3500kJ/Nm^3, and if circularly top gas was blown into BF from the upper part of the furnace body, thirty percent of fuel ratio can be reduced. (Fig.4)

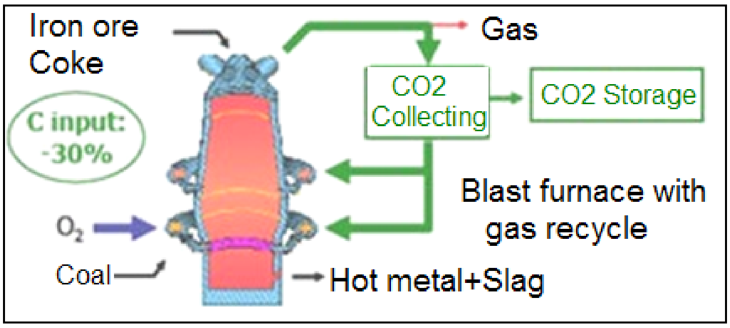

Fig.4 Top gas blown into BF.

Top gas after remove CO_2 containing a lot of CO and H_2 was blown into the lower part of BF after heated to 900°C. Adopting top gas circulation technology in BF, iron ore is totally deoxidized by gas lower than 900°C from exchange facility at the top of BF. During this process the coke consumption is 204kg/t, CO_2 emission is 1177kg/t, 24 percent decreased compared to traditional BF (total amount of CO_2 emission is 1557kg/t).
Top gas is also largely used circularly in Finex process, pressure swing adsorption was introduced to blow gas into fluidized bed after gas enriching, reduced the flue ratio from ~900kg originally to ~700kg currently.

3.2 Blowing Coke Oven Gas

Coke oven gas is the product after recovery of chemical products and refining from waste gas generated by coke oven. (as shown in fig.5). Because of the difference of coking coal ratio and coking process parameters, the components of coke oven gas are different slightly. According to volume percentage, in general coke oven gas contain 54.0%~59.0% H_2, 5.5%~7.0% CO, 24.0%~28.0% CH_4.
The function blowing mixed coke oven gas is that coke saving 0.4~0.8kg/Nm^3 and reducing CO_2 emission 120kg/100Nm^3. After coke oven gas was blown into BF, coke ratio can be reduced to 200 kg/tHM. In some steel plant in Germany and Ukraine, coke oven gas is excess and become free resource, so coke oven gas was blown in some BF, blowing quantity varied from 100 m^3/tHM to 250~300 m^3/tHM.

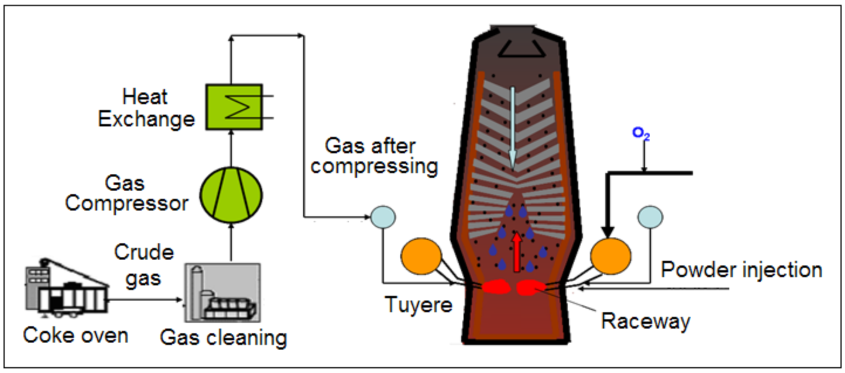

Fig.5 Coke oven gas blown in BF.

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3.3 Waste Plastics Blowing

Plastic is the petrochemical products, replacement ratio to coke is 1:1. Along with the intensification of industrialization degree, the amount of waste plastics produced by industry and society is increasing year by year. Blowing waste plastics in BF can not only achieve to control white pollution, but also can utilize resource synthetically, reducing the consumption of BF fuel, and creating greater economic benefits (Fig.6).

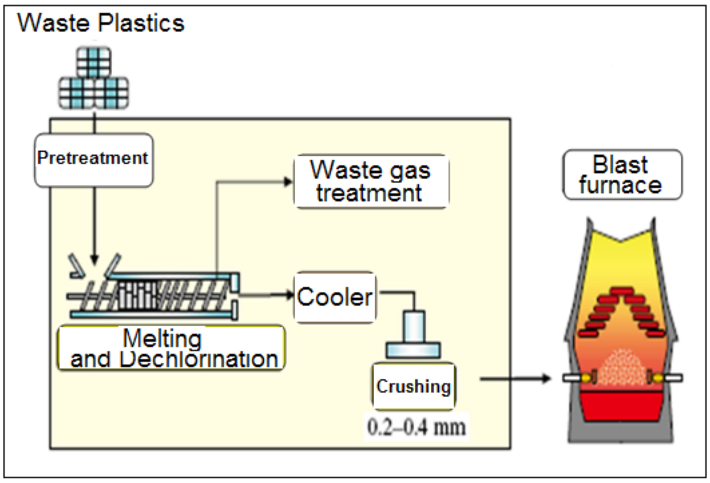

Fig.6 Flow sheet of blowing waste plastics in BF.

Waste plastics blowing technology in BF have been successfully applied in practical production in Bremen Steel Corporation in Germany and in JFE Corporation in Japan, with the maximum amount of spray 60kg/t HM. The theoretical analysis shows that the maximum amount of blowing should be around 200kg/t HM. In the sight of combustibility and practical application of waste plastics, it is feasible to use waste plastics instead of coal blown into BF in technical point, with promising application prospect. Processes such as machine pellet and chlorine removal treatment for waste plastics containing PVC still should be improved in future to decrease economic cost and promote the technology popularize.

4 PROCESS OPTIMIZATION FOR BF TOP EVEN PRESSURE DISCHARGING

For traditional ironmaking process currently, during charging and discharging of BF top equipment weighing hopper is working on charging pressure and discharging by turns. Raw gas, semi purified gas or Nitrogen is needed to spray into hopper for gas adjust pressure, then the same pressure with BF internal can be obtained through this after charging in order to discharge to BF internal, Raw gas emission to the atmosphere is needed to reach the atmospheric pressure during discharging, meeting to the charging ofhopper. Quantity of gas and dust are discharged during dispersing, dust can be recovered into furnace by cyclonic collector but the gas is discharged to atmosphere, the calculated dispersing gas volume is 6~8Nm^3 per ton iron. The annual output of hot metal in China is 600 million tons, the dispersing gas volume is more than 40,000 million m^3 by pressure balancing dispersing equipment in top of BF (about 70 million dollars when the unit price of BF gas is calculated according to 0.017$/Nm^3). Much resource are wasted, causing serious pollution to air, meanwhile gas itself have good economic value so it is needed to optimize the process.

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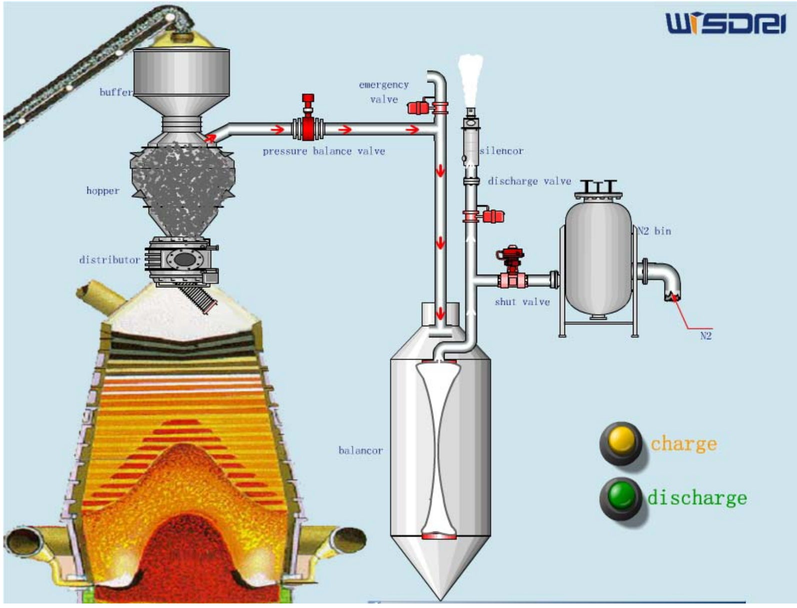

Fig.7 New-style ballonet pressure balancing dispersing process in top of BF.

Ballonet pressure balancing and dispersing process was put forward by the author (shown in Fig. 7 and that have been applied patent), in order to change traditional pressure balancing and dispersing process currently for BF, make sure no gas emission and internal circulation use without pollution. Ballonet pressure balancing adjustment device is connected as the terminal in series in pressure regulation outlet of charging equipment. The pressure balancing dispersing process is carried on through adjusting the volume of gasbag, and concrete operation process was introduced as below: when blast furnace is just put into production, the hopper with full materials is on atmospheric pressure. Open pressure regulation valve in pressure regulation outlet and high pressure cut-off valve for Nitrogen connected to ballonet balancing equipment, blow Nitrogen with high pressure into ballonet so that air volume in ballonet is compressed, increasing pressure of tank. When pressure in tank equals to the pressure in BF, shut off the high pressure cut-off valve for Nitrogen and pressure regulation valve, and open the discharge gate in the bottom of tank to charge to BF, when pressure discharging was carried on, open pressure regulation valve in pressure regulation outlet, and then open Nitrogen dispersing valve, disperses Nitrogen in ballonet to increase air volume in the side of tank. When the pressure reduced to atmospheric pressure, shut off Nitrogen dispersing valve and cut-off valve, then open charging gate of tank to charge to tank, thus circularly complete the pressure adjusting process. The characteristic of this process are clear process, simple structure, easy to implement and work stable and reliable.

5 SENSIBLE HEAT RECOVERY FROM BLAST FURNACE SLAG

Sensible heat recovery of blast furnace slag can effectively increase the energy utilization rate. The tapping temperature of blast furnace slag is between 1400 and 1550°C, sensible heat per ton slag equal to heat value of 60Kg standard coal, accounting for about 14 percent of energy consumption in BF process. Sensible heat recovery can make well up for energy consumption of BF.

Currently physical and chemical heat recovery have been developed in the light of sensible heat recovery at home and abroad, in which the former can be divided into rotary cylinder method, air quenching method, continuous casting waste heat boiler

ISSN 2176-3135

and rotary method according to different method of slag pretreatment. These technologies are in the test now and cannot achieve good application effect. More time is needed for their application.
Over 90 percent of BF slag in our country is treated in water quenching method to make water dregs as raw material for cement. The common water treatment include INBA, RASA, TYNA and so on, with no heat recovery function and loss of all slag heat. Domestic waste heat recovery of BF slag is confined to supply heat by using waste heat of slag washing water. It is reported that heat supply or hot water supplying for bathrooms is partially solved by using waste heat of slag washing water. But it is accounting for few parts of all sensible heat of BF slag, waste heat recovery rate is very low, only about 10 percent. Moreover restricted by time and region, such this part energy can only be wasted in summer or southern region with no heating equipment, so its popularization and application are restricted.

6 PURE OXYGEN BF

Blowing hot air contain plentiful of nitrogen in traditional oxygen-enriched and high temperature blast, resulting in ~49 percent of Nitrogen in BF gas, reducing the gas quality, taking out a lot of heat and producing NOx. Only a half of C were transformed to CO and about 37 percent of energy was not made use (function 1), causing great deal of waste.

$$Fe_2O_3 + 3.3C + O_2 + 3.2N_2 = 2Fe + 1.7CO + 1.65CO_2 + 3.2N_2 \qquad \text{function 1}$$

Now it is feasible for pure oxygen blast and was testified sufficiently by the practice of Corex and Finex process. Based on BF process, traditional blast with high temperature and oxygen-enriched process may be replaced by the process of full oxygen blast, accordingly increasing coal ratio and setting gas outlet in blast furnace shaft to improve direct reduction degree and cause decreasing of coke ratio. Only the application of this technology can save energy over 25%, reducing CO_2 emission 25%, directly decreasing the coke ratio lower than 200kg. So it has good prospect in future application.

7 SUMMARY

From detailed analysis on all above practical technology, it can be easily seen that a lot of work need to be done for BF energy-saving and emission reduction, 30-50% reduction of energy consumption can be realized validly on the basis of energy consumption currently.
Much successful experience was accumulated for BF ironmaking including design, construction, production and operation. Based on these experiences for the development and implementation of new technology, it can be expected soon for the successful technology breakthrough mentioned above, and it is believable that BF can coruscate vigor ahead of other new technology for ironmaking. For engineering company providing technical service, through finding a good and feasible respect, forming technical monopoly advantage based on the effective breakthrough of technical research, sound self-development can be ensured, remaining invincible in the fierce market competition.