Production and Development of Large Blast Furnaces from 2011 to 2014 in China

Dong-dong ZHOU,^{1)*} Shu-sen CHENG,¹⁾ Ying-sheng WANG²⁾ and Xi JIANG²⁾

1) School of Metallurgical and Ecological Engineering, University of Science and Technology Beijing, 30 Xueyuan Road, Haidian District, Beijing, 100083 P. R. China.

2) China Iron and Steel Association, 46 East Fourth Street West Road, Dongcheng District, Beijing, 100711 P. R. China.

(Received on June 16, 2015; accepted on August 18, 2015)

This article reviews the production and technical characteristics of the large blast furnaces in China. The reasons for low level development of large blast furnace in past decades were analyzed. It introduces the production, raw materials and operation indexes of large blast furnaces from 2011 to 2014. On this basis, some thoughts on operations of large blast furnace were proposed. The affected factors on the development of large blast furnace were analyzed, the conclusion that the number of large blast furnace in China will increase in future was obtained.

KEY WORDS: large blast furnace; China; production; development.

1. Introduction

With the rapid increasing of China's economy in recent years, the demand for steel products is changing constantly, leading to that the productions of crude steel, hot metal and steel products have been at the top of the world for many years.¹⁾ According to the data²⁾ published by WSA (World Steel Association), the crude steel productions of China increased continuously from 355 million tons in 2005 to 823 million tons in 2014 (**Fig. 1(a)**). The global sluggish growth caused by the world financial crisis in 2008 and the Europe debt crisis in 2010 results in a slow growth of globe crude steel production. However, compared to the rapid growth tendency in China, the crude steel productions in major steel-production countries remain stable all these years except for 2009, in which the production of Japan and USA decreased temporarily because of the world financial crisis.

After decades of rapid development, the Chinese economy has entered into a stage of medium-speed growth since 2007.^{3,4)} The annual growth rate slowed down from a double-digit growth to a single-digit one (**Fig. 1(b)**). When the annual growth rate of GDP was larger than 10%, the annual growth rate of crude steel production was also greater than 10%, as seen in 2005 to 2007 and 2010. Specifically, steel production increased only about 0.9% in 2014,¹⁾ which was the lowest over the past decade, indicating that the crude steel production of China has reached the peak in 2014.

Currently, there are more than 260 blast furnaces with an effective volume of larger than 1 000 m³ in China.⁵⁾ According to China's experience and industry standards, the blast furnace with effective volume greater than or equal to 4 000 m³ is called large blast furnace. There are 19 blast furnaces

that are larger than 4 000 m³, accounting for only 9.21% in the nationwide hot metal productions. Most of large blast furnaces were built since 2008⁶⁾ (**Table 1**). However, there are 13 of all 27 blast furnaces in Japan whose effective volume are larger than 5 000 m³, and most of the others are larger than 4 000 m³.⁷⁾

The development of large blast furnace in China was in a low level in past decades, the reasons are as follows. Firstly, the large blast furnace technology in both design and operation was immature. Secondly, the main resources used in large blast furnace were limited because of the lacks of high grade iron ore. Thirdly, the equipment and control system couldn't meet the requirements of large blast furnace. Fourthly, the capital investment was too high for the ordinary iron and steel company.

In order to understand the production and technical characteristics of large blast furnace in recent years, the productions, raw materials and operation parameters of 19 large blast furnaces were analyzed from 2011 to 2014.⁸⁾ Furthermore, the affected factors on the development of large blast furnace in future were analyzed.

2. The Indexes of Large Blast Furnace in China

2.1. Production Indexes

2.1.1. Productivity

The average effective volume of the 19 large blast furnaces and productivity were 4 539.15 m³ and 2.15 t/(m³·d), respectively (**Fig. 2**). Compared to other blast furnaces in China,⁹⁾ the productivity of the large blast furnaces was small, which was the same as the Japan blast furnace at the same period.⁷⁾ This is mainly caused by the changes of the operation idea during those years. For a longtime, Chinese operators focused only on the productivity and economic benefits, ignoring the different conditions of raw materials,

* Corresponding author: E-mail: dongdongzhou@live.com
DOI: <http://dx.doi.org/10.2355/isijinternational.ISIJINT-2015-353>

Fig. 1. The production of crude steel in China and other major steel-production countries and the variation of the growth rate of crude steel and GDP in China during the past decade. (Online version in color.)

Table 1. The volume and commissioning date of large BF in China.

NO	Blast furnace	Effective volume, m ³	Commissioning date
1	Baosteel No.1	4 966	2009.02.15 (3rd)
2	Baosteel No.2	4 706	2006.12.07 (2nd)
3	Baosteel No.3	4 350	1994.9.20*
4	Baosteel No.4	4 747	2005.4.27
5	Wuhan Steel No.8	4 096	2009.08.01
6	Maanshan Steel No.1	4 000	2007.02.08
7	Maanshan Steel No.2	4 000	2007.05.24
8	Shagang Group	5 800	2009.10.20
9	Taiyuan Steel No.5	4 350	2006.10.13
10	Qian'an Steel No.3	4 000	2010.01.08
11	Shougang Jingtang Steel No.1	5 500	2009.5.21
12	Shougang Jingtang Steel No.2	5 500	2010.6.26
13	Bayuquan Ansteel No.1	4 038	2008.09.6
14	Bayuquan Ansteel No.2	4 038	2009.04.26
15	Benxi Steel new No.1	4 747	2008.10.10
16	Meishan Steel No.5	4 070	2012.6.2
17	Anyang Steel No.5	4 836	2013.03.19
18	Taiyuan Steel No.6	4 350	2013.11.07
19	Baotou Steel No.7	4 150	2014.5.27

Notes: (1) If there is no particular note, it means this blast furnace is on the first generation; 2nd means the second generation; 3rd means the third generation.

(2) * The Baosteel No.3 blast furnace was shutdown in Aug. 29 in 2013, and the first generation was from Sept. 20 in 1994 to Aug. 29 in 2013. It started the second generation in Nov. 16 in 2013.

operate conditions and other particular factors for blast furnaces. Currently, a stable operation state, a high quality of hot metal and a long-term campaign of large blast furnace have become the key points during the daily operations.

2.1.2. Reducing Agent Rate and Energy Consumption

Reducing agent rate (RAR) and energy consumption are important indexes to judge the energy utilization efficiency of a blast furnace. The average RAR of the large blast furnaces was 510.97 kg/t, which was smaller than the average

Fig. 2. The production indexes of the large blast furnace in China. (Online version in color.)

of the nationwide blast furnaces. It was almost the same as that of Japan at the same period.⁷⁾ Coke rates of four blast furnaces in Baosteel (No. 1 to 4) were the lowest, and their pulverized coal (PC) rate were also high (Fig. 2). The average of coke rate, PC rate and energy consumption were 339.88 kg/t, 155.51 kg/t and 393.46 kgce/t, respectively.

2.1.3. Blast Parameters

Blast parameters affect the thermal state and the energy consumption of blast furnace. The average blast volume of one ton hot metal, oxygen enrichment rate, blast temperature and the top gas temperature were 1 039.14 m³, 3.56%, 1 212.27°C and 176.11°C, respectively (Fig. 2). The oxygen enrichment rate of Sha Steel (No. 8) reached about 10%, which was the highest in the 19 large blast furnaces and its

blast consumption was also the lowest. The blast pressure of large blast furnace was between 366 000 and 458 000 Pa, and the average blast and top pressure were 407 090 and 171 860 Pa, respectively.

2.2. Raw Material Indexes

2.2.1. Coke and Pulverized Coal Quality

Coke strength is an important parameter to determine the permeability of blast furnace. The sulfur content in coke could affect the quality of hot metal, and the pulverized coal quality impacts the thermal state of blast furnace. The carbon content, volatile and ash in PC of various blast furnaces have larger differences (Table 2). Low carbon content and high volatile content could affect the calorific value during the PC combustion process in raceway, leading to a decreased theoretical combustion temperature and a high RAR value. It indicates that the worse coal quality is not beneficial to the stability and energy saving of blast furnace. In order to improve the PC combustion rate, low volatile content PC should be injected into blast furnace, which means the quality of pulverized coal used for large blast furnaces should have a higher standard than the others.

Coke used in large blast furnaces also should have a higher quality, the greater the blast volume, the higher the coke standard, including low ash, high strength and large particle size. Increasing sulfur content in coke increases the sulfur content in hot metal. Small M40 and particle size of coke, high CRI and small CSR, which may decrease coke size in hearth and the permeability of blast furnace, eventually decrease the activity of hearth and gas utilization rate.

2.2.2. Burden Parameters

Most of the iron ores produced in China are low in grade, so a large amount of iron ores used by iron and steel industry need to be imported from abroad, resulting in a high percent basicity sinters and pellets and a small percent of lump ores for burden structure. The average rate of sinters, pellets and lump ores were 70.43%, 19.87% and 9.57%, respectively (Fig. 3(a)). And the average burden size and iron content in burden were 20.18 mm and 59.01%, respectively (Fig. 3(b)). The iron content in burden of large blast furnaces in China was lower than that of other countries.⁷⁾

2.3. Operation Indexes

2.3.1. Hot Metal Compositions

The silicon content in hot metal is one of the most important indexes to reflect the heat state and RAR in blast furnace. It will affect the smelting cost and hot metal productivity. Furthermore, it has relationship with limestone consumption and smelting time during steelmaking. The average silicon content in hot metal was 0.44%, the pig iron temperature was between 1 490 and 1 515°C, and the average pig temperature was 1 504.47°C (Fig. 4). According to the Chinese standard and experience, first-grade products (FGP) rate of hot metal is defined as hot metal with sulfur content less than 0.035%. The average sulfur content in hot metal and FGP rate were 0.029% and 78.84%, respectively.

2.3.2. Slag Compositions

Slag rate and CaO/SiO₂ (C/S) rate affect the energy consumption and sulfur content in hot metal. The slag rate of

Table 2. Parameters of the coal and coke used in large blast furnaces.

No.	Coal, %			Coke, %							
	Carbon	Ash	Volatile	Carbon	Ash	Sulfur	M40	M10	CRI	CSR	Size, mm
1	72.49	9.34	16.61	86.88	12.06	0.63	88.31	5.93	25.72	67.11	51.85
2	72.76	9.45	16.55	86.91	12.02	0.63	88.39	5.92	25.52	67.22	51.78
3	73.02	8.99	17.71	86.90	12.03	0.66	88.43	5.87	25.49	67.27	51.70
4	73.37	9.80	16.77	86.83	12.12	0.64	88.72	5.85	25.53	67.26	52.14
5	76.52	11.18	12.65	86.09	12.47	0.73	88.85	5.63	23.65	66.72	53.63
6	67.02	9.10	21.02	85.69	12.58	0.70	89.68	5.48	23.12	69.83	48.84
7	66.64	9.10	21.02	85.69	12.58	0.70	89.68	5.48	23.12	69.83	49.03
8	70.9	9.26	19.09	86.68	12.26	0.76	88.96	5.83	24.16	67.24	48.62
9	70.61	10.23	18.84	86.94	11.96	0.65	89.93	5.26	23.12	70.03	55.89
10	70.01	10.13	19.74	86.01	11.92	0.75	88.55	6.05	22.02	67.73	50.13
11	71.56	9.69	20.00	85.81	11.99	0.76	91.03	5.59	20.72	71.20	52.92
12	71.45	9.71	20.03	85.78	12.00	0.75	91.02	5.60	20.73	71.19	53.01
13	70.13	9.90	19.54	86.49	11.35	1.16	83.15	6.73	26.08	63.82	49.86
14	68.69	9.69	19.35	86.46	11.36	1.17	83.15	6.73	25.53	63.12	51.53
15	71.07	9.66	15.58	86.36	11.95	0.67	88.42	5.83	20.36	69.32	51.69
16	73.75	8.99	17.25	86.72	12.19	0.66	88.61	6.05	25.01	66.92	48.89
17	69.07	9.26	20.09	85.80	12.22	0.80	89.88	5.18	22.91	67.82	54.81
18	70.45	10.34	19.19	87.24	11.71	0.63	90.37	4.81	21.58	70.65	55.47
19	80.66	10.01	9.66	86.31	11.83	0.63	89.69	6.70	22.88	69.54	50.28

Fig. 3. Burden composition, iron content and average particle size of large blast furnaces.

Fig. 4. The operation parameters of large blast furnaces. (Online version in color.)

large blast furnace was larger compared with other major steel produced countries because the iron content of burden was lower. The nationwide average slag rate and C/S were 302.79 kg/t and 1.19, respectively. There is an inverse correlation between the slag rate and C/S, as seen from the blast furnaces of No. 6, 19 and No. 1 to 4.

2.3.3. Gas Utilization Rate

There has a direct relationship between gas utilization

(GU) rate and RAR in blast furnace, when the GU rate is high, the RAR will decrease, as shown in Fig. 4 for Baosteel, and the nationwide GU rate was 48.72%. The CO₂ content in top gas could reflect the reduction reaction between gas and iron-bearing burden, the average CO₂ was 22.53% (Fig. 4). The top gas temperature could reflect the gas heat utilization degree, and its average value was 176.11°C (Fig. 2).

3. Thoughts on Large Blast Furnace Operations

3.1. The Stability State Should be Maintained

The stability state of blast furnaces has extremely important influence on the production, gas utilization efficiency, RAR and other indexes. It also is the basis of the high efficiency, high quality, low consumption and long campaign of blast furnace, especially for large blast furnace. Therefore, the stability of the blast furnace is the foundation of all other technical parameters and the composition and physical properties of raw materials should keep stable. Moreover, the operation parameters in blast furnace such as heating, blast, tapping and charging systems also should be kept in a reasonable range.

3.2. The Quality of Raw Material Should be Improved

Blast furnace ironmaking is a resource consumption process. Although lacking the coking coal resources and the high grade iron ore, China is one of the most coal-abundant countries and the largest coal producer and user in the world.⁹⁾ However, China has become a net coal importer country since 2009. The produced in domestic and imported iron ore increased dramatically from 2005 to 2014 (Fig. 5(a)). The CIF price of one ton of imported iron ore containing 62% Fe declined from \$ 133.1 to \$ 68.7,¹⁾ leading to a sharp increase of foreign iron ore in 2014. And the top three iron ore production countries in the world are Australia, Brazil, China, accounting for 74.68% of the global iron ore production (Fig. 5(b)). In order to decrease the slag rate and energy consumption, the quality of iron ore, sinter and pellet used in large blast furnace should be improved. The lump ore percent in burden was about 20% in Japan and Korea,¹⁰⁾ but the average value of large blast furnace in China was only 9.58%, which should be improved. Coke quality of some blast furnaces should be improved because the indexes were lower than the nationwide average values.

Fig. 5. The iron ore production, imports in China and the production of iron ore in major countries.

3.3. Energy Consumption and Production Cost Should be Reduced

The steel industry is a high energy and resource consumption field, accounting about 15% for the nationwide energy consumption or 23% for the nationwide industries, in which the ironmaking processes takes about 70%.¹⁾ In recent years, the main pollutant emissions and energy consumptions in Chinese steel industry has been declined, and some environmentally-friendly technologies such as sintering desulfurization and energy management technologies have been widely used. The energy saving effect was obvious, the comprehensive energy consumption, total water consumption and fresh water consumption of one ton steel fell 1.2%, 0.6% and 0.5% in 2014,¹⁾ respectively. And the total amount of wastewater, sulfur dioxide and dust emissions decreased 5%, 16% and 9.1%, respectively. However, compared with developed countries,⁷⁾ the energy consumptions and emissions should be reduced greatly in China. One of the most effective ways is to optimize operation parameters of large blast furnaces during daily process.

Using nut coke to replace the metallurgical coke used in blast furnace by mixing nut coke with iron-bearing burden, which could not only increase the permeability of lumpy zone and cohesive zone of blast furnace, but also improve the reduction of sinter, pellet and ore. Moreover, using nut coke in blast furnace could also improve the utilization efficiency of resources, and indirectly save the energy consumption during coking process. The coke rate of large blast furnace has already contained nut coke (Fig. 2), the average nut coke rate (NCR) was 36.61 kg/t, accounting for 10.84% in coke rate. Although the largest NCR was nearly 20%, but most of large blast furnaces under a low level. The restriction factors to increase NCR were the shaft permeability and sinter reducibility, which should be improved by mix nut coke in the iron-bearing burden bed, as mentioned by Mousa.¹¹⁾

The high blast temperature would bring benefits to fuel combustion and hearth activity.¹²⁾ However, the blast temperatures of some large blast furnaces were still low than the average of nationwide, which should be improved by optimizing operation parameters of hot stove and adjusting its structures when the large blast furnace is shut down for repairing. Firstly, in order to increase the blast temperature, the blasting time of hot stove should be reduced and the gas preheating temperature should be increased before

it enter into the hot stove. Secondary, when the large blast furnace is shut down for repairing, the temperature of hot stove dome should be increased by optimizing its structures, and the heat-transfer capacity of hot stove should be improved by optimizing the structures of checker bricks. Meanwhile, the charging parameters should be adjusted to decrease the top gas temperature.

In order to improve the resource utilization efficiency and environment protection efficiency, the dust injected¹³⁾ and low silicon operation technology⁷⁾ should be used in large blast furnace.

4. The Development of Large Blast Furnace in Future

Since the amount of steel scrap which are used as the main material in electric furnace smelting process is small,²⁾ the main route of steel smelting are the blast furnace and oxygen steelmaking in China. Enlarging the effective volume of blast furnace will be the main tendency in future, the reasons are as follows. Firstly, large blast furnace has the technology advantage in energy saving and emission reducing. Secondly, it has a high labor productivity and low production cost. Thirdly, it has advantage in controlling CO₂ emission because the low carbon smelting and resources recycling system will be easily achieved for large blast furnace. Fourthly, it has a higher return to investment ratio than that of small one.

The development of large blast furnace will be affected by economic conditions, national industry policies, environmental pressures and market requirements in future.

4.1. Economic Conditions

The economic growth in China was mainly guided by investments in fixed assets and foreign-trade export over the past decades, which was easily affected by the globe economy state. After the 2008 financial crisis, the Chinese government conducted a large-scale construction and economic stimulus plan with a large amount of capital,¹⁴⁾ most of which was flowed into the real estate because of its high return rate, leading to a sharp increase in demands for construction steel materials. Besides, the debt crisis in Europe makes the world economic recovery process slower,⁶⁾ causing the reduced outputs of manufacturers and shipping companies in China. Moreover, with the rapid promotion of the urban construction scales in the past few years, the growth

of the construction industry had sharply reduced since last year. Consequently, the demands for steel products were decreased, resulting in a serious surplus of capacities, an oversupply of steel, an intensified competition among steel companies, and a declined price in the market.

According to calculations and researches,⁴⁾ the strength of steel consumption per 10 000 Yuan GDP dropped from 174 kg in 2007 to 100 kg last year, which will be further reduced to 70 kg for the slow growth of Chinese economy in next few years. In conclusion, the steel prices will be kept in a lower range, causing a small profit period of iron and steel industry. The large blast furnace has advantage in energy saving and cost-cutting, which will enhance the cost control and competitiveness of the iron and steel enterprises.

4.2. National Industry Policies

The steel industrial concentration in China was low for many years.¹⁾ In 2014, crude steel production of top ten companies in China accounted for 36.6% of the nationwide output, decreasing 2.8% compared to 2013. However, the top four companies in Japan produced about 80%,¹⁶⁾ which was much higher than China. The same situations also occurred in Germany, USA and South Korea.¹⁷⁾ According to the official steel policies, the production of top ten companies will be increased to 70% in 2020.¹⁸⁾

Moreover, the national industry policies in China are industrial transformation and upgrading. The high-tech and new industries which produce high added-value products will be further developed and strengthened. The large blast furnace has high mechanization degree, technical content, automation level, which are conforming to national industrial policies.

4.3. Environmental Pressures

With the rapid development of industry without strict environmental protection system for many years, the continuous hazy weather formed by the industrial and automobile exhaust emissions has affected many people in China. People pay more attention to poor air quality caused by industrial pollutions, and appeal to reduce the pollutants enormously from pollution industries, especially the iron and steel industry. The new published environmental protection law also puts forward higher standards to pollutant discharges.¹⁷⁾ The iron and steel industry are facing great environmental pressures. Compared with the small effective volume one, large blast furnace have the advantage to reduce the emissions.

4.4. Market Requirements

With the reformation of China's economic structure, the market demands will also be changed, which should be met by the developing of new steel grades and producing of high quality steel products. It means that the production of long steels will be decreased, and the plates used in the automobiles, household appliances, shipbuilding and machinery manufacturing industry will increase. Large blast furnace has advantage in producing stable and high quality hot metal, which should be supplied to the steelmaking process to produce high quality steel products.

In conclusion, with the requirements on hot metal quality, energy saving and cost-cutting, industrial transformation and upgrading, pollution emissions and steel industrial concentration, the number of large blast furnace in China will increase in the future.

5. Summary

This article analyses the main reasons for that the number of large blast furnace is less than the other major steel-production countries. The productivity, reducing agent rate and energy consumption, coke and pulverized coal quality, hot metal and slag compositions, blast parameters and gas utilization rate of large blast furnaces in China from 2011 to 2014 were introduced. On this basis, maintaining the stability state, improving the quality of raw material and reducing energy consumption and production cost during large blast furnace operation were suggested. The large blast furnace has advantage when it faces the economic conditions, national industry policies, environmental pressures and market requirements challenges in future. The conclusion that large blast furnace has advantage on the hot metal quality, energy saving and cost-cutting, mechanization degree, technical content and automation level was drawn.

Acknowledgements

The authors would gratefully acknowledge the financial support from the National Natural Science Foundation of China (61071303, 61333002). And also express their gratitude to the operation indexes of blast furnace from China Iron and Steel Association.

REFERENCES

- 1) National Development and Reform Commission of the People's Republic of China: Operation of the Iron and Steel Industry in 2014, (online), http://www.ndrc.gov.cn/fzgggz/jjyx/gjyx/cyyxd/201502/t20150205_663401.html, (accessed 2015-05-05).
- 2) World Steel Association: Website of WSA, <http://www.worldsteel.org/>, (accessed 2015-05-05).
- 3) National Bureau of Statistics of the People's Republic of China: The National Economic and social development statistical bulletins in 2014, http://www.stats.gov.cn/tjsj/zxfb/201502/t20150226_685799.html, (accessed 2015-05-05).
- 4) National Bureau of Statistics of the People's Republic of China: China Statistics Yearbook of 2014, <http://www.stats.gov.cn/tjsj/ndsj/2014/indexce.htm>, (accessed 2015-05-05).
- 5) Z. J. Liu, J. L. Zhang, H. Zuo and T. Yang: *ISIJ Int.*, **52** (2012), 1713.
- 6) Y. S. Wang, X. Jiang and D. D. Zhou: Proc. 2014 Natl. Iron Production & Technology and Annual Ironmaking Conf., CSM, Beijing, (2014), 305.
- 7) M. Naito, K. Takeda and Y. Matsui: *ISIJ Int.*, **55** (2015), 7.
- 8) The indexes of blast furnaces in 2011 to 2014, CISA, Beijing, (2015), 1.
- 9) S. R. Zhang and Z. J. Yu: *Iron Steel*, **49** (2014), 8.
- 10) F. M. Zhang: *Ironmaking*, **31** (2012), 1.
- 11) E. A. Mousa, A. Babich and D. Senk: *ISIJ Int.*, **51** (2011), 350.
- 12) S. Nomura and T. G. Callcott: *ISIJ Int.*, **51** (2011), 1033.
- 13) D. Senk, H. W. Gudenau, S. Geimer and E. Gorbunova: *ISIJ Int.*, **46** (2006), 1745.
- 14) J. He: *ISIJ Int.*, **51** (2011), 696.
- 15) The Technical Society, ISIJ: *ISIJ Int.*, **54** (2014), 1177.
- 16) H. Guang: Doctoral Thesis, Jilin University, (2012), 211.
- 17) Y. J. Li and J. P. Han: *Yejin Jingji yu Guanli*, **3** (2014), 4.
- 18) National Development and Reform Commission of the People's Republic of China: Iron and Steel Industry Development Policies in China, (online), http://www.gov.cn/gongbao/content/2006/content_320630.htm, (accessed 2015-05-05).