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DESIGN, CONSTRUCTION AND COMMISSIONING OF 5500m^3 BLAST FURNACE AT SHOUGANG JINGTANG[1]

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Abstract

Shougang Jingtang iron and steel plant engineering is an important project of China iron and steel industry structure adjustment and improvement of general technology and equipment level. Its annual output is 9.7 Mt/a, including two sets of 5,500 m^3 blast furnace with annual hot metal output of 8.98 Mt/a. A number of innovative advanced technologies including bell-less top, dome combustion hot blast stove, blast furnace gas dry bag filter cleaning process and environmental protection screw slag granulation facility etc. are developed. In this paper description is given to the technical features and advanced technologies of the extra large sized blast furnace in Shougang Jingtang. Also introduction is made to blast furnace sinter charging by different fraction sizes, bell-less top equipment and control technology of burden distribution, high efficiency and long campaign life technology of blast furnace, high blast temperature with long campaign life technology of dome combustion hot blast stove, environment-friendly slag treatment technology, oxygen-enrichment pulverized coal injection technology and blast furnace gas dry type bag filter cleaning technology that are applied to the 5,500 m^3 blast furnace at Shougang Jingtang.

Key words: Blast furnace; Bell-less top; Dome combustion hot stove; Bag filter dedusting.

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1 INTRODUCTION

Shougang Jingtang iron and steel plant engineering is an important project of China iron and steel industry structure adjustment and improvement of general technology and furnishment level. Its annual output is 9.7 Mt, including 2 sets of 5,500 m^3 blast furnace with total annual hot metal production of 8.98 Mt. They are the first two huge BF above 5,000 m^3 in China.[1] In the engineering, the design and technical specifications of large sized BF above 5000m^3 around the world are researched and studied. Self innovation is implemented completely. A great number of innovative advanced technologies including bell-less top, dome combustion hot blast stove, gas dry bag filter dedusting system and new type screw slag granulation facility etc. are developed and applied.

2 DESIGN AND MAIN TECHNICAL SPECIFICATIONS

In the designing, the design philosophy of “high efficiency, low consumption, high quality, long campaign life and clean” is followed, advanced, practicable, mature, reliable, energy saving, environmental friendly, high efficiency and long campaign life technologies, equipments and materials are adopted. The design and operation experience of huge BFs above 5,000 m^3 in Japan and Europe and large BFs over 4,000 m^3 in China which were completed in recent years are researched and studied.[2,3] The advanced technology and equipment are adopted according to general planning of Shougang Jingtang iron and steel plant.

The BF iron making process flow is optimized, general arrangement is compact and reasonable, process flow is short and smooth. The systematicness and completeness for each process sequence is considered thoroughly to achieve harmony of the operation. Complete automation control system is adopted to achieve the full automation of BF operation.

The operation parameters of internationally advanced large BF are analyzed. Considering BF raw material and fuel conditions and technological furnishment level, the design parameters of 5,500 m^3 huge BF are advanced. Table 1 shows main technical-economic specifications of the BF.

Table 1. Main Technical-economic specifications of BF

Item	Data
Effective volume m^3	5500
Working volume m^3	4670
Diameter of hearh m	15.5
Output per day t	12650
Annual productivity t/(m^3·d)	2.3
Coke rate kg/thm	270
PCI rate kg/thm	220
Agglomeration ratio %	90
Total Fe in burden %	≥61
Oxygen enrichment ratio %	3.5
Hot blast temperature ℃	1300
Top pressure MPa	0.28
Slag volume kg/thm	250
Campaign life year	≥25

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3 ENGINEERING HIGHLIGHTS

3.1 Beneficiated Material Technology and Stock House

Reasonable burden composition, 61% Fe content in charging material, 90% agglomeration ratio are considered. The burden composition includes 70% sinter, 20% pellet ore and 10% lump ore. Improving the mechanical strength of coke (M40≥89%，M10≤6.0%), especially the coke strength after reaction (CSR≥68%) and coke thermal reaction performance (CRI≤23%) are the key conditions to ensure stable operation of huge BF.
The raw material and fuel are transported by belt conveyors from sintering plant, pellet plant, coking plant and raw material yard to BF bins. One integrated bin is adopted for two sets of BF. Coke bins and ore bins are arranged in parallel. Sinter ore, pellet, lump ore and coke are screened under the bins. Individual screening and weighing system is adopted. There is no central weighing station and the material is transported directly by belt conveyor. In this process, the material transferring route is shortened, material crushing and fines are reduced which creates beneficial conditions for improving BF permeability and smooth operation of BF.

3.2 Bell-less Top and Burden Distribution Control

Bell-less top charging device is the key equipment for contemporary BF. The top charging equipment for 5,500 m^3 huge BF shall meet not only the charging capacity, but also the requirements of burden distribution control in order to achieve burden classification and charging and central coke charging.
The bell-less top with parallel hoppers can charge five different grades and kinds of material into BF within one charging cycle to achieve the burden classification charging and central coke charging. The advantages of bell-less top with parallel hoppers includes matured technology, sufficient charging capacity, simple equipment structure and operation, small equipment maintenance work and low operational cost. Bell-less top with parallel hoppers is the reliable technology self-developed and grasped by Shougang with sufficient operation and maintenance experience. The application of Shougang type bell-less top with parallel hoppers can achieve complete localization of equipment and reduce significantly the equipment investment. Table 2 shows the main performances of bell-less top.

Table 2. Main performances of bell-less top

Item	Data
Hopper effective volume m^3	2×80
Design pressure of hopper MPa	0.30
Upper sealing valve diameter mm	Φ1100
Lower sealing valve diameter mm	Φ1100
Material flow regulating gate valve diameter mm	Φ1000
Discharging speed of regulating gate valve m^3/s	0.7
Central throat tube diameter mm	Φ760
Length of distribution chute mm	4500

3.3 Blast Furnace Proper and Cooling System

The design campaign of BF is 25 years, and the hot metal output during one campaign reaches more than 20,000 t/m^3. In the design, advanced BF long campaign

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concept is introduced, internationally advanced BF high efficiency and long campaign life integrated technology is applied, proper BF profile is adopted, non-overheat cooler and demineralized water closed loop circulating technology is adopted, BF proper lining is optimized, complete BF automation measuring and control system is provided in order to achieve stable operation and long campaign life of BF.
Reasonable BF profile is designed. Based upon heat transfer, mass transfer, momentum transfer and chemical reaction principle during BF operation, combining the raw material and fuel conditions of BF, and in order to improve burden permeability and gas energy utilization and achieve BF stable operation, the design is optimized. The effective volume of BF is 5,500 $m^{3,}$ hearth diameter is 15.5 m, belly diameter is 17.0 m, well death depth is 3.2 m, hearth height is 5.4 m, effective height is 32.8 m, effective height to belly diameter ratio is 1.93. Four tap holes and 42 tuyeres are arranged.
BF long campaign life technology with high quality refractory and high efficiency non-overheat cooling system is adopted. The BF hearth and bottom lining is provided with combined structure of carbon brick and ceramic pad. The BF bottom uses combined structure of high conductivity graphite block, micropore carbon block, super micropore carbon block and ceramic pad. At the hearth side wall and interface of hearth and bottom, hot pressed carbon brick is used. At the position of tuyeres and tap holes, combined brick structure is applied. In order to achieve BF campaign over 25 years, copper stave is used at hearth 'elephant foot' wear zone and tap hole position. Full cooling stave structure is used for the BF proper. 4 rows of high efficiency copper cooling staves are used for BF bosh, belly and lower stack. 7 rows of brick cast iron cooling staves are used for the middle and upper stack. 1 row of C shape cooling stave is used below the throat armor. From BF bosh to stack, there is stave and brick lining integrated thin lining structure. At the hot surface of lining, gunning material is used. At BF bottom cooling pipes, cooling staves and tuyeres, demineralized water closed loop circulating cooling system is used.

3.4 Cast House

Two symmetrically arranged flat rectangular cast houses are provided. Two tap holes are arranged in each cast house. Each tap hole is provided with independent clay gun, driller, cover removing device and tilting chute etc. Clay gun and driller are arranged under tuyere platform at same side of tap hole. At another side of tap hole, cover removing device is configured. Under each cast house, there are 4 ladle car railways. The hot metal is transported directly to the steelmaking plant by ladle instead torpedo car. There are two platforms in the cast house. Slag runner and iron runner is arranged at lower floor. The flexible cover of slag runner and iron runner is connected with upper floor in order to achieve flat operating platform of cast house. The maintenance equipment can work on the operating platform. The tuyere platform is overhead type steel structure which can achieve mechanization of equipment maintenance.
In order to optimize the interface technology between BF and BOF, achieve short hot metal transportation, reduce heat loss and environmental pollution during hot metal ladle changing, hot metal direct transportation technology is developed. 300t hot metal ladle is used to replace conventional torpedo car, which can optimize hot metal transportation, delete the ladle changing work, reduce hot metal temperature drop and environmental pollution and expedite the production cycle.

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At one side of tap hole, a dedusting suction hole is provided. One top hood is arranged over the tap hole to prevent the secondary dust pollution during tap hole opening and blocking. Movable flat cover is arranged over the slag iron separator, slag runner and iron runner. Dedusting duct is arranged between two platforms of cast house to collect the dust during tapping. Suction holes are provided at both sides of two tilting chutes and over the hot metal ladle in each cast house. There are three dedusting systems in the cast houses. One set of bag filter dedusting system is provided for each cast house, and one set of secondary dust bag filter dedusting system is provided for 4 tap holes.

3.5 Slag Granulation

The slag is completely water granulated. Dry slag pit is used as standby slag treatment unit. After super fine grinding, the granulated slag is used to produce addition of cement. Melted BF slag flows to slag nozzle through slag runner. The high speed water flow from slag nozzle makes the melt slag cool down and forms granulated slag. The mixture of slag and water goes through tunnel to condensing tower to water granulation pond. In the pond, the mixture is separated by screw separator. The granulated slag is transported by belt conveyor to slag yard. The fine particle slag is separated by rotary drum filter. The water in the pond is filtered and circulated. The steam generated during granulation and water slag pond is discharged to condensing tower. In condensing tower, there are two layers of spraying units. The spraying water and condensed water returns to water tank for circulation.

3.6 Dome Combustion Hot Blast Stove

High blast temperature is an important technical characteristic of contemporary BF iron making technology. High blast temperature can reduce effectively fuel consumption and improve BF energy utilization efficiency.[4] Upon the basis of Shougang type dome combustion hot blast stove (DCHBS) technology and Russian Kalugin type DCHBS technology, BSK (Beijing Shougang Kalugin) type DCHBS technology is developed by combining the advantages of these two technologies, and the DCHBS is applied in first time in 5000m^3 class super large BF.

The main technical features of DCHBS are as follows: Ceramic burner for DCHBS is arranged at dome position, which has wide applicability. It can be operated under several operating conditions including gas and combustion air. It has big combustion capacity, high combustion efficiency and long service life. The ceramic burners are provided with special circulating flow technology to ensure the complete mixing and combustion of air and gas and improve the flame temperature and dome temperature. Dome space is used as combustion chamber, and separate combustion chamber structure is canceled, which can improve the thermal stability of hot stove structure. Burner is configured at dome space; high temperature fume is evenly distributed under circulating flow condition, which can improve effectively the evenness and thermal conductivity of high temperature fume on checker bricks surfaces of checker chamber. The checker chamber is provided with high efficiency checker bricks with reduced channel diameter and increased heating area.

The BF is provided with 4 sets of dome combustion hot blast stoves with high blast temperature and long service life. The design blast temperature is 1,300°C, and the maximum dome temperature is 1,420°C. The high temperature zone of hot blast

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stove is provided with silica bricks whose design service life is over 25 years. The fuel for hot stove is BF gas only. Fume waste heat reclaim unit is used to preheat gas and combustion air. Two sets of small dome combustion hot stove are used to preheat combustion air in order to achieve combustion air temperature over 520°C. The high temperature valve for hot blast stove is cooled by soften water closed loop circulating system. The combustion, blasting and stove changing of hot stove system is controlled automatically. Figure 1 shows the photograph of dome combustion hot blast stoves.

Figure 1. Photograph shows the dome combustion hot blast stoves.

3.7 BF Gas Dry Bag Filter Dedusting and Top Pressure Recovery Turbine

BF gas dry type bag filter dedusting technology is an important technical innovation for energy saving, emission reducing and clean manufacture in 21st century. It can reduce significantly the fresh water consumption during iron making process and reduce environmental pollution. It has become the development direction of contemporary BF iron making technology. The self-developed BF gas dry type low pressure pulse bag filter technology is adopted, and standby gas wet type dedusting system is cancelled.[5]
Several key technologies including gas temperature control, gas dust content online supervision, collected dust pneumatic transportation, corrosion proof of duct and digital control etc. are developed, which makes the huge BF gas dry bag filter technology to internationally advanced level.
This system uses 15 dedusting vessels with diameter of 6.2 m. The vessels are arranged in two lines in parallel. Between these two lines of vessels, crude gas and purified gas ducts are arranged. The gas pipe is designed based upon equal velocity principle to ensure the even distribution of gas volume to each vessel. This system is compact arranged, short and smooth flow with convenient maintenance.
Low filtering velocity principle is adopted to ensure the safe and stable system operation. Each vessel has 409 bag filters. The bag filter size is Φ160×7,000 mm. Filtering area for each box is 1,439 m^2 and total filtering area is 21,586 m^2. In the design, the diameter and length of bag filters are increased, and the bag structure and dimensions are more reasonable. The vessel diameter is increased to improve the treatment capacity of dedusting unit, reduce vessel quantity, investment and occupied area. table 3 shows the main technical performances of BF gas bag filter dedusting technology, figure 2 shows the BF gas dry bag filter dedusting system already built.

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Table 3. Dry bag filter dedusting technical performances for BF gas

Item	Data
BF gas flow volume m^3/h	760,000（Max 870,000）
Top pressure MPa	0.28(Max 0.30)
Operating temperature °C	100-220
Vessel number set	15
Vessel diameter mm	6,200
Bag sizes mm	Φ160×7,000
Total filtering surface m^2	21,586
Filtering surface per vessel m^2	1,439
Filtering velocity under standard conditions m/min	0.59
Filtering velocity under operating conditions m/min	0.23
Dust content in cleaned gas mg/m^3	≤5

After bag filter dedusting system, BF gas goes into top pressure recovery turbine (TRT) system, the top gas pressure is recovered and transformed to electrical power. The top pressure regulating valve block as TRT alternate device with a parallel arrangement, as an aid to adjust the BF top pressure. A new generation of dry type TRT is introduced to matche the BF gas dry dedusting system, and the BF gas heat energy and kinetic energy can be recovered and utilized fully to realize energy conversion with high efficiency. The dry type fully static vane adjustable axial-flow turbine is adopted in TRT system with the generator capacity is 36.5 MW, the generating capacity of 45 kW·h/thm is designed.

Figure 2. Photograph shows the BF gas dry bag filter dedusting system.

3.8 Pulverized Coal Injection System

The design pulverized coal injection rate of the BF is 220 kg/thm (max. design capacity is 250 kg/thm) and normal PCI capacity is 116 t/h. The coal injection and pulverization facilities are constructed together for two BFs. Medium speed mill is used to pulverization. Bag filter catcher and direct injection process is adopted. The capacity of medium speed mill is 2×75 t/h. The PCI system uses high density phase direct injection technology with three hoppers in parallel and main pipe-distributor process.[6]

Each BF has three injection hoppers working in sequence, two injection main pipes and two distributors. High density phase pneumatic transportation technology is adopted with density is above 40 kg/kg. The velocity of coal flow in injection pipe is 2-4m/s. In each main pipe coal flow meter and regulating valve is provided. The effective volume of pulverized coal bin is 1,200 m^3. Below the pulverized coal bin,

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there are three coal discharging hoppers. The effective volume of injection vessel is 90m^3 with normal injection cycle of 30 min. Below the injection hopper, there are fluidizing vessel. Fluidizing PCI technology is adopted. Two injection branch pipes are provided for each fluidizing vessel. The pulverized coal is injected through injection main pipe to two distributors, and through 42 injection branch pipes to each tuyere. Nitrogen is used for the pressurizing of injection hopper, transportation of pulverized coal, fluidization and anti-explosion. Injection supervision units are provided for each injection branch pipe. In case of blocking, the branch pipe will be shut off and injecting automatically.

4 ENGINEERING CONSTRUCTION

The No.1 BF of Shougang Jingtang from March 12, 2007 construction started, on October 18, 2008 blast furnace heated up, the whole project took a period with 19 months. The total weight of steel structure was about 80000 ton, the total of 25 bands furnace shell, and the total height was about 126m. The BF foundation structure was completed on April 2, 2007, this work took a period of 84.5 hours, poured concrete volume was 10,500 m^3. On October 2007, the BF proper mian structure engineering has been finished, the hot blast circle pipe has been installed, the hot blast stove and cyclone structure have been accomplished, the structure frame of cast house was erected, started to assemble the cooling stave, the hot blast stove proper shell has been ercted, started to assemble the grid.
On September 5, 2007, hot blast stove shell installation was completed, in March, 2008, furnace brick laying was started, on August 15, furnace brick laying work was completed. On January 23, 2008, the blast furnace cooling staves were installed completely. Since March 2008, the blast furnace hearth and bottom lining laying work were started, which lasted 100 days was completed on June 23. On May 27, 2008, “five-way ball” connection joint was assembled, and on June 6, 2008, down comer for blast furnace has been successfully installed. On July 13, 2008, main belt conveyor corridor installation was competed. The blast furnace bleeding valve was completed on August 20, 2008. No.1 and No.3 hot blast stoves baking work was started on September 8, 2008, No.2 and No.4 hot blast stoves heating up wrok was started on September 9. The blower installation and debugging were comleted on September 12, 2008, and the blower motor commissioning was started. The BF gas dedusting system debugging was finished on October 16, 2008.
The No.1 blast furnace heating up work started on October 18, 2008, that proved the BF engineering has fully completed, as well as that have been provided with the BF commissioning conditions. Foundation construction of No.1 blast furnace began on March 12, 2007, the engineering take a period of 19 months to complete construction. Due to the market and business reasons, No.1 blast furnace blew-in on May 21, 2009.

5 COMMISSIONING AND OPERATION

Shougang Jingtang’s No.1 BF blew-in on May 21, 2009, after commissioning, BF operated stably and smoothly, the main production technical performances promoted constantly. The highest per day production reached 14,290 t/d, monthly productivity reached 2.37 t/(m^3·d), fuel ratio reduced to 480 kg/thm, coke rate lower to 269 kg/thm, PCR reached 175 kg/thm, hot blast temperature reached 1,300°C, the international advanced performance of 5,000 m^3 grade BF production has been achieved. Table 4

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shows the main operating technical specifications of No.1 BF at Shougang Jingtang after it blew-in for 11 monthes.

Table 4. Main operating parameters of No.1 BF at Shougang Jingtang

Date	Production thm/d	Productivity t/(m^3·d)	Coke rate kg/thm	PCR kg/thm	Fuel ratio kg/thm	Hot blast Temp. ° C
2009-5	4840	0.88	551	83	634	914
2009-6	7425	1.35	503	62	565	998
2009-7	8525	1.55	483	49	532	1063
2009-8	11000	2.01	372	94	481	1166
2009-9	11660	2.12	354	101	483	1212
2009-10	12210	2.22	340	117	488	1262
2009-11	12500	2.27	299	145	484	1276
2009-12	12694	2.31	288	149	479	1281
2010-1	12657	2.30	307	137	482	1259
2010-2	12847	2.34	287	161	482	1277
2010-3	13035	2.37	269	175	480	1300

6 CONCLUSIONS

Shougang Jingtang 5,500 m^3 BF is a new generation huge BF following circulating economy principle and dynamic accurate design system. More than 60 advanced technologies of current international iron making industry are adopted and integrated in the design. The general technology and equipment achieves internationally advanced level. Reasonable burden composition and burden distribution control technology ensure the BF stable operation. The self-designed and manufactured bell-less top is applied in huge BF for the first time.
BF long campaign life technologies including suitable BF profile, demineralized water closed loop circulating cooling technology, copper stave, thin wall lining structure lay foundation for the 25 years of campaign life. High blast temperature technologies including combustion air high temperature pre-heating technology and dome combustion hot stove ensure the blast temperature 1,300°C. BF gas dry type dedusting technology, slag treatment technology, environmental protection technology and complete automation control system can achieve the clean and automatic BF operation.
After blew-in, No.1 BF operated stably and smoothly, the main operation technical performances promoted constantly. The main technical-ecnomic specifications have been achieved the design goal since commissioning 6 monthes.

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