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# TECHNOLOGICAL PROGRESS OF BLAST FURNACE IRONMAKING IN BENGANG[1]

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**Abstract**

The paper concludes the main experience of technological progress for blast furnace ironmaking in Bengang since 1990. By means of optimizing burden structure, improving the qualities of the raw and fuel materials, innovating and upgrading ironmaking equipments, optimizing the blast furnace operation etc. intensified smelting is realized with good techno-economic index in Bengang.

**Key words**: Blast furnace; Burden structure; Operation; Technological progress.

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## 1 INTRODUCTION

Benxi Iron and Steel Co. Ltd (shortened as Bengang), which lies in Benxi city, the east of Liaoning province, P.R of China, established in 1905.Bengang ironmaking plant owned by Bengang group is a 10 millions tons of pig iron producer through the continuous development since establishing in 1943. Now, the ironmaking system includes one 2600 $m^3$ blast furnace, two 2850 $m^3$ blast furnaces, one biggest 4747 $m^3$ blast furnace, five 75$m^2$ sinter machines, two 265$m^2$ sinter machines and one 360$m^2$ sinter machine. Table1 shows Bengang Ironmaking plant main technical and economic indexes in recent years.

**Table 1.** Bengang Ironmaking Plant Blast Furnace main technic and economy indexes in recent 10 years

| year | Average production (t/d) | Productivity ($tm^3/d$) | Coke rate (kg/t) | Coal rate (kg/t) | Blast temperature (℃) | Smelting intensity ($tm^3/d$) | Tfe (%) | 【Si】 (%) | 【S】 (%) |
|---|---|---|---|---|---|---|---|---|---|
| 2001 | 6410 | 1.743 | 494 | 88 | 951 | 1.015 | 57.33 | 0.6278 | 0.0321 |
| 2002 | 9137 | 1.93 | 468 | 91 | 1024 | 1.099 | 57.33 | 0.5558 | 0.0289 |
| 2003 | 9673 | 2.044 | 454 | 97 | 994 | 1.122 | 57.59 | 0.5137 | 0.0324 |
| 2004 | 11274 | 2.141 | 453 | 85 | 1003 | 1.125 | 57.71 | 0.5030 | 0.0323 |
| 2005 | 16012 | 1.966 | 448 | 73 | 1010 | 0.992 | 58.25 | 0.4562 | 0.0462 |
| 2006 | 17963 | 2.027 | 418 | 96 | 1071 | 1.112 | 58.27 | 0.4465 | 0.033 |
| 2007 | 17302 | 1.96 | 457 | 79 | 1025 | 1.145 | 57.48 | 0.5179 | 0.0339 |
| 2008 | 18281 | 1.994 | 419 | 93 | 1030 | 1.117 | 58.55 | 0.6194 | 0.0288 |
| 2009 | 25124 | 2.105 | 370 | 130 | 1109 | 1.127 | 59.2 | 0.5457 | 0.0257 |
| 2010 | 26906 | 2.214 | 381 | 112 | 1160 | 1.162 | 59.43 | 0.5544 | 0.0307 |
| 2011 | 26989 | 2.286 | 368 | 120 | 1149 | 1.194 | 59.52 | 0.5277 | 0.0288 |

## 2 USING BENEFICIATED BURDEN MATERIAL

Beneficiated raw and fuel materials can lead to high yield, low consumption and longevity for blast furnace. Hot sinter ore had to be charged into blast furnaces because of the shortage of circuit cooling system in sinter machines in Bengang before 2000. Low quality problems of hot sinter such as high powder rate, lower strength and more powder coke lead to lower intensity smelting, utilization coefficient of blast furnace only 1.8t/$m^3$.d before 2000. From 2001, a serial of methods of beneficiation materials have been adopt in order to improve ability of blast furnace in Bengang.

### 2.1 Cold Sinter Utilization

Five 75$m^2$ sinter machines had provided hot sinter to blast furnaces about 50 years in Bengang, Powder rate of sinter over 20%. Operation institution of blast

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furnace had to be marginal gas flow of blast furnace development, resulting in serious staves damage. Blast furnaces had to be shut down for revamping. In order to improve quality of sinter, realize hot sinter charging, two 265 $m^2$ and one 360 $m^2$ sintering machines equipped with circular cooling technology were constructed in 2000 and 2004 respectively. Starting of these two sintering machines entirely ended the history of using hot sinter and realized total cooling ore charging. Higher strength and screen rate of sinter bring about powder rate of sinter is lower than 5% in Bengang from 2001. TFe content in sintered ore increased to 59.4% from 57.33% after 3 years.

## 2.2 Improvement of Coke Quality

### 2.2.1 Revamping coke oven and using dry quenching coke

Since 2000, Bengang has regarded large-scale and high efficiency as the construction direction of coke oven to replace backward and high consumption small coke oven. Up to the end of 2010, four coke ovens of 6 m and four coke ovens of 7m carbonizing chamber were constructed. Auxiliary with four coke dry quenching production lines were utilized to significantly improve coke quality, now the dry quenching coke rate is about 93%~94%. Dry quenching coke was first applied in blast furnace No.6 on Sep.15.2007.

### 2.2.2 The coke passivation technology

The passivation agent can decrease coke gasification reactivity, improve the reaction of the strength and reduce coke rate.

In order to increasing the strength of coke, improving CRI and CSR index of coke, passivation agent about concentration ratio for six percent was sprinkled on charging coke belt for blast furnace No.6 and 7 from May.2008.Industrial experiment carried out about 6 months, shows the coke passivation technology can decrease coke ratio 2.5kg/t.

Based on the improvement of coke oven and coke coal quality. Bengang`s coke quality got huge improvement (shown in table 2), moisture of coke is controlled effectively, and the cold strength and hot property of coke are improved.

**Table 2**.Quality index of coke in Bengang

| year | Ash Content % | Sulfur % | Moisture % | $M_{40}$ % | $M_{10}$ % | CRI % | CSR % |
|---|---|---|---|---|---|---|---|
| 2006 | 12.92 | 0.73 | 6.44 | 83.7 | 6.7 | 28.14 | 60.3 |
| 2007 | 12.68 | 0.78 | 5.62 | 80.6 | 6.6 | 27.49 | 61.42 |
| 2008 | 12.69 | 0.8 | 4.01 | 83.0 | 6.8 | 26.36 | 62.61 |
| 2009 | 12.32 | 0.72 | 3.86 | 84.49 | 6.69 | 25.64 | 63.39 |
| 2010 | 12.34 | 0.69 | 2.39 | 84.6 | 6.6 | 23.31 | 65.82 |
| 2011 | 12.17 | 0.69 | 2.13 | 84.75 | 6.6 | 22.19 | 67.11 |

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## 2.3 Optimizing Material Structure

### 2.3.1 Increasing the percentage of pellets

In order to balance the shortage of acid ore, Bengang imported more pellets from Brazil, India and Australia and other domestic areas. This lead to very difficult to control the blast furnace slag basicity because of unsteady composition in pellets from different places before 2000. So in May.2006, newly Bengang pellet plant was constructed, the annual output capacity of acid pellet has reached to four million tons. Pellet component stability has risen steadily. Bengang`s charging ore realized reasonable burden structure with approximate proportion of sinter, pellet, imported lump ore are 75%, 20%, 5% respectively.

### 2.3.2 Increasing the basicity of sinter, avoiding limestone charging

In order to increase the TFe content in charging material, Bengang increased sinter basicity to 1.8~2.0 %from 1.6% from 2008. At the same time, limestone ore is prohibited charging into blast furnaces, available for decreasing the coke ratio.

## 3 BLAST FURNACE EQUIPMENT UPDATING

With the development of steelmaking, more and more pig iron was demand, Bengang began to modify existing blast furnace, Modern equipments have been widely employed during implementing reconstruction or new-construction projects from 1990.Table3 show the main revamping items at Bengang.

**Table 3.** Reconstruction of Bengang`s blast furnace since 2001

| Year | Newly constructed or reconstructed blast furnace |
|---|---|
| Oct.31.2001 | No.5 blast furnace blowing-in after enlarging volume to 2600m$^3$ from 2000m$^3$. equipped with PW BLT top, soft closed cooling water, 4 external combustion hot stove, INBA process, UCAR carbon brick with ceramic cup. PW copper stave. expert system |
| Aug.17.2004 | No.6 blast furnace whose capacity 2850m$^3$ with PW BLT top, UCAR brick, domestic copper stave, INBA process, 3 Hoogoven internal combustion hot stove, TRT Bischoff gas cleaning system was blown-in. |
| Sep .5.2005 | No.7 blast furnace with working volume 2850m$^3$ was blown-in. PW BLT top, UCAR brick, domestic copper stave, INBA process, 3 Hoogoven internal combustion hot stove, TRT Bischoff gas cleaning system. |
| Oct.9.2008 | Biggest blast furnace New No.1 with working volume 4747m$^3$ was blown-in. PW serial hopper BLT top, UCAR brick, domestic copper stave, INBA process,4 Hoogoven internal combustion stove, full hydraulic drills and guns. Hearth monitoring system |

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### 3.1 Top System Equipment Installation

#### 3.1.1 PW bell - less top

In 200, PW central feed type with rotating hopper top was applied on blast furnace No.5 in Bengang to replace existing two bell type. The main advantages of a bell-less top are increased flexibility in charging different raw materials and optimal control of gas flow even at high PCI injection rates. Charging type for blast furnace No.5 was transformed to conveyer belt from scale car in 2001. Blast furnace No.6,7 and new No.1 were equipped with PW bell-less top in 2004,2005 and 2008 respectively.

#### 3.1.2 Top gas pressure recovery Turbine

Blast furnace No.5 was equipped with latest state of the art a top gas recovery turbine for the first time at Bengang in 2001. TRT`s electricity generating index has gradually improved. Up to now, all blast furnace at Bengang equipped TRT devices and accumulative power generation 800 million KW at the end of 2010.amount to 280 thousands standard coal.

### 3.2 Blast Furnace Body

#### 3.2.1 Enlargement of blast furnace volume

In order to facilitate construction of converter of Bengang steelmaking plant, Bengang began to enlarge blast furnace volume during construction new blast furnaces to replace backward blast furnaces. Blast furnace No.5 was enlarged to 2600 $m^3$ from 2000 $m^3$ in 2001, blast furnace No.6,7 and new 1 were enlarged to 2850 $m^3$ and 4747 $m^3$ from 1070 $m^3$ and 380 $m^3$ blast furnace respectively.

#### 3.2.2 The application of UCAR carbon bricks at hearth area

Bengang had decided to apply UCAR hot-pressed bricks on the hearth area of blast furnace No.5 after discussing on the erosion solution carefully in order to prolong the lifetime of blast furnace in JUN 1990 campaign 4. Taphole area and sidewall other area of hearth was constructed with NMD and NMA bricks respectively. UCAR hot-pressed carbon bricks possess higher thermal conductivity, low permeability and minimizes water and iron penetration characteristic as compared with domestic carbon blocks, blast furnace No.5 equipped with UCAR bricks produced 6754.2 tons iron in the past campaign 4(over11 years), and blast furnace No.4 produced 9088.78 tons iron for campaign 8 in the period of 13.2 years.

#### 3.2.3 Copper stave utilization

In 2001，four rows of copper staves from PW to provide efficient blast furnace shell cooling in the area of belly and lower stack of blast furnace No.5.Copper staves had been installed in Bengang to achieve a better control of the heat load. Blast furnace No.6, 7 and New1 were equipped with domestic copper plates in the belly and

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stack areas respectively. Up to 2011, copper staves provided stable skull protection for belly and stack areas. The highest temperature of copper staves bellow 280℃ after 6years normal operation for blast furnace No.6 since 2004.

### 3.2.4 Application of closed loop of soft water cooling

Before 1992, cooling water for blast furnace in Bengang was industrial open circuit water, bad quality water, more fur inside the cooling pipes, decreasing cooling intension of the stave, resulting in more stave damaged rapidly after blowing-in. Blast furnace No.4 applied closed loop soft water for cooling staves and hot blast valves at Bengang for the first time in 1992.soft water solve the quality and decrease the consumption of cooling water , circular cooling water reused rate was over 99%. soft cooling system for blast furnace No.4 runs over 14 years until shut-down in 2006. Now, all existing blast furnace at Bengang applied closed loop of soft water.

## 3.3 Blasting and Pulverized Coal Injection

### 3.3.1 Utilization of high blast temperature stove

Blast furnace No.6, 7 and New 1 adopted Hoogovens internal combustion stoves because of limited site in Bengang, Mushroom dome, silica refractories were applied in the upper part of the stove construction, inverted catenary, the chainline shape would eliminate internal bending moments in the dome walls. Ceramic burners, designed service life for stoves 30 years. Designed hot blast temperature 1250˚C.Now, the actual temperature of stove at Bengang 1170˚C.

### 3.3.2 The development of pulverized coal injection(PCI)

Bengang started the trial of PCI in 1978, and PCI rate of 30kg/thm at that time. Blast furnace No.5 applied two middle speed mills used for anthracite in 2001, coal rate 100kg/thm. Blast furnace No.6, 7 equipped with two middle speed mills designed capacity 36t/h with mix bituminous coal. Now bituminous coal account for 55%.In recent years, the yearly average PCI rate has exceeded 120 kg/thm in Bengang, the monthly highest PCI rate was 145 kg/thm reached by blast furnace No.6 in March.2007.

## 3.4 Automatic Instrument and Monitoring System

From1991, blast furnace No5 began to adopt automatic instrument and monitoring system to monitor blast furnace lining status.

### 3.4.1 Expert system

Blast furnace expert system developed by RAUTARUUKKI in Finland was adopted at blast furnace No.5 in 2002 to make the operation of furnace as steady as possible. No.6,7 applied domestic monitoring system to detect and diagnose lining temperature. After analyzing the factual data, the failing was summarized and some reasonable advices were given.

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### 3.4.2 Top gas automatic analyzing system

Blast furnace No.5 applied top gas automatic analyzing system in 2001.Blast furnace top gas distribution and surface of charging material were monitored at any moment and reflected back to the screen located in the control room. Operator control the gas distribution through the data from the computer screen.

### 3.4.3 Blast furnace material prewarning management system

Due to increasing the grade of burden into blast furnace is a effective measure for intensified smelting, but the grade of ore concentrate was only 57% before 10 years in Bengang, meanwhile composition fluctuation is huge for powder of sinter. It is difficult for operator to control blast furnace. Bengang monitored the raw material charged blast furnace by using online supervision of burden from 2008.

Online supervision for raw material and coke content is the important device to supervise the stable operation of blast furnace. The change of static charge for coke and row material will reflect the screen in the control rooms. If there are any changes for the coke and materials, controller will inform the change value measured to the blast furnace operator at the first time.

### 3.5 Cast House System

### 3.5.1 Using higher power hydraulic mud gun and driller in cast house.

Blast furnace No.6 and 7 adopted TMT(Tapping-Measuring-Technology) full hydraulic drills and guns to increase tapping rate timely of blast furnace. At the same time, adjusting chemical compositions of mud and increasing its strength for avoiding the appearance of dispersed spraying, keeping daily times of opening taphole to 4.

### 3.5.2 Environmental protection

Taphole and trough cover were used for collecting dust in cast house from 2000 to protect environment in blast furnace No.5. Stockhouse, bell less top and transfer stations dust collecting system were installed in blast furnace No.6 and 7 in 2004,2005 respectively.

## 4 OPTIMIZING BLASTFURNACE SMELTING OPERATION

The optimizing blast furnace smelting operation includes oxygen enrichment blasting, election of suitable blasting and slagging regulation, high top pressure and charging regulation improvement etc.

### 4.1 Oxygen Enrichment Blasting

Oxygen enrichment was commenced in Bengang in 1989. Before 2003, the average oxygen enrichment was kept below 1 %,and then increased step by step, the oxygen enrichment reach 3.2 % now.

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### 4.2 Election of Suitable Blasting System

In order to increase the combustion intensity, the blasting kinetic energy should keep to higher to activate the hearth, so blasting kinetic of blast furnace No.7 reached 11696kgm/s from 8476kgm/s since 2009. Blasting speed 242m/s, blasting volume 5000m$^3$/min. Total tuyere areas is 0.3441m$^2$.

### 4.3 High Top Pressure

High top pressure enables enhanced burden descent and increases furnace productivity. Top pressure of Blast furnaces in Bengang only 0.18MPa for the reasons of hot sinter charging before 2001, now 4747m$^3$ blast furnaces has been designed for top pressure of 0.28MPa in Bengang.

### 4.4 Charging Regulation Improvement

The charging distribution regulations of two bell type furnaces seldom change before 2000.To make use of the advantage of bell-less top equipments, multiple rings was adopted since 2009 in Bengang. For further optimizing smelting operation, the technology loading coke to center of the top of blast furnace was used from 2010 in blast furnace No.7.

Blast furnace No.7 adopts "big α angle, big ore angle "(angle 41.5˚C between the center line of blast furnace and chute)charging regulation in 2009.From then on the angles of loading ore and coke were increased further, ore batch weights were increased from 56t to 78t per batch, coke batch weights keeps 15.8t, center gas flow was intensified while peripheral gals flow was prohibited.

### 4.5 Selection of Suitable Slagging System

Blast furnace operators should try to maintain a relative stable slag crust thickness in front of staves, neither too thick nor thin, otherwise affect gas flow of blast furnace. According to years` smelting practice, for blast furnace No.7 in Bengang, the slagging basicity is 1.10±0.02, physics temperature 1520±30˚C

## 5 CONCLUSIONS

Although backward facilities have to be eliminated, the main equipments of blast furnace of Bengang have reached the domestic advanced level by large-scale technological innovation, but there is long way to go for Bengang as compared with advanced domestic technic and economy indexes of blast furnace. Ironmaking production cost for Bengang facing great pressure because of the market crisis and challenge. Next steps of our work are as follows: realize the intensified smelting by intensified measures such as high blast temperature, higher enrichment oxygen and

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PCI to improve the conditions of hearth, controlling reasonable blast furnace lining profile, pay a great attention to energy-saving and environment protection, adhere to the base of first-class equipment, scientific management and technological innovation to make Bengang ironmaking technology continuously improve. Build Bengang into international first class energy saving making plant.

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