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STUDY ON BAG FILTER CLEANING TECHNOLOGY OF BF GAS AT SHOUGANG JINGTANG[1]

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Abstract

BF gas bag filter cleaning technology is an important technical innovation for energy saving, emission reducing and clean production for modern blast furnace. It can reduce significantly the fresh water consumption during iron making process and reduce environmental pollution. It has become the development direction of modern BF iron making technology. This paper explain the process flow and technical principle of BF gas dry bag filter cleaning, Introduce the research and application on dry bag filter cleaning technology of BF gas for 5500m^3 blast furnace at Shougang Jingtang. The totally dry type low pressure pulse bag filter cleaning technology of gas self-developed has been applied successfully in 5500m^3 blast furnace, and standby wet type gas cleaning system has been cancelled. Several key technologies have been developed including gas temperature control, anti-corrosion of pipe, measuring of dust content in gas, dense phase pneumatic transportation of collected dust etc. The totally dry gas bag cleaning technology has reached internationally advanced level.

Key words: Blast furnace; Iron making; Gas bag filter cleaning; Top gas recovery turbine.

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1 INTRODUCTION

Blast furnace gas (BFG) dry bag cleaning technology is an important technical innovation in 21st century to realize the energy saving, reduction of emission and clean production for BF. Compared with traditional BFG wet cleaning technology, it has increased gas cleanness, gas temperature and heat value, obviously reduced fresh water and power consumption during iron making process and also can increase efficiency of secondary energy source, reduce environment pollution, it is an important technical solution for cycling economy and sustainable development of iron and steel industry and become the developing direction of BF iron making technology.[1]

The project of Shougang Jingtang iron and steel plant is a key project for restructuring of Chinese iron and steel industry and promotion of overall technical equipment level for iron and steel enterprises. The annual capacity of the iron and steel plant is 9.7Mt, two 5500m^3 BFs has been built up with capacity of 8.9815 Mt/a of hot metal. It is the first in China to build super large BF above 5000m^3. The characteristics of design and technical equipment of super large BF above 5000m^3 in the world was studied and analysed during design. All round independent innovation was performed. A series of innovative advanced technologies and process equipment were designed and developed independently such as bell-less top, top combustion hot blast stove, gas fully dry bag filter cleaning and screw-slag granulation process.[2]

2 TECHNOLOGICAL PRINCIPLE OF BF GAS DRY CLEANING TECHNOLOGY

2.1 Process Flow of BF Gas Dry Bag Cleaning

At the beginning the bag cleaning technology was adopted in environment cleaning field. BFG is a flammable, explosive and toxic gas, and the throughput is large, temperature fluctuation is great, system pressure is high and dust content is high so it has high technical difficulty and risk to adopt bag cleaning technology. Bag cleaning technology is based on fibre filtering theory, the application in BFG cleaning system changed the wet cleaning technology of BFG cleaning with water and developed BFG fully dry low pressure pulse injection bag cleaning process.

BFG generated during BF operating will enter cyclone catcher through eduction pipe, ascension pipe and down comer, the crude gas after cyclone cleaning will enter into each bag filter catcher through crude gas main and branch. The clean gas purified by bag filter shall enter clean gas main through clean gas branch and enter gas pipe network through top gas recovery turbine (TRT) or pressure reducing valves block and then is supplied to iron and steel plant as secondary energy resource. Figure 1 shows the process flow diagram for gas dry bag cleaning of Shougang Jingtang No.1 BF.

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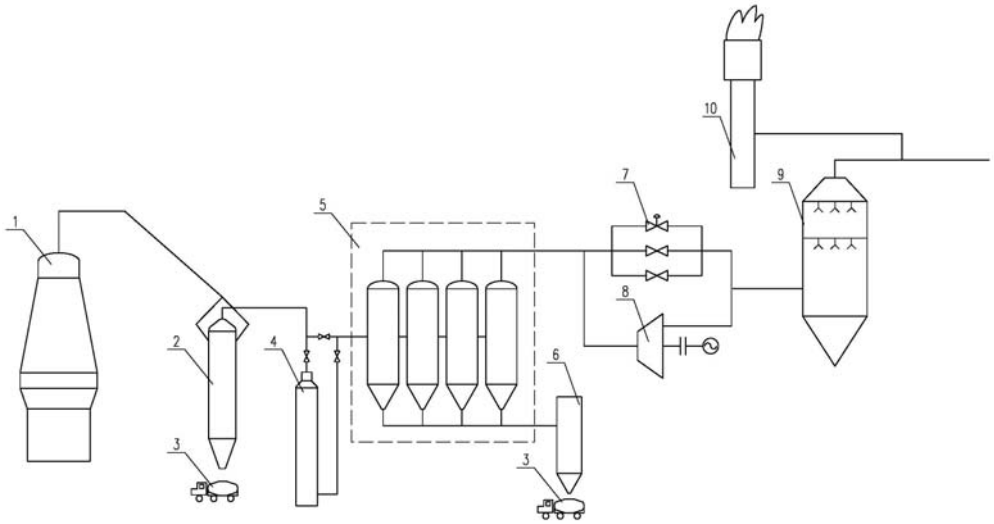

Figure 1. Process flow diagram of BF gas dry bag filter cleaning. 1-BF, 2-cyclone catcher, 3-tank car, 4-heat exchanger, 5- bag filter dust catcher, 6-centralized dust bin, 7-pressure reducing valve block, 8-TRT, 9-chloride remover, 10-gas bleeding tower.

2.2 Technical Principle of Pulse Injection Bag Cleaning

After primary cleaning by cyclone catcher, large particles in BFG shall be collected, dust content in gas is generally reduced to about 10g/m^3. Gas has to be purified after primary cleaning to reduce the dust content to below 10mg/m^3. Superfine powder particles suspend in the BFG not purified which is a typical aerosol system. The filtering mechanism of BFG bag cleaning is based on fibre filtering theory, its filtering process can be divided into two stages: under the joint function of dispersing effect, direct intercept, gravity deposition and screening effect when the gas go through clean bag, first the bag fibre shall arrest the dust, it is the fibre who plays main function, and then the dust arrested in bag fibre together with the fibre join the filtering, this process is called "internal filtering"; when the dust in bag fibre layer is up to certain volume, the dust will deposit on the surface of bag fibre layer and form a dust layer with certain thickness, dust layer on bag surface will play main function on filtering of gas dust, this process is called "surface filtering". In actual operation of bag cleaning, surface filtering is the main filtering method, having an important significance on BFG bag cleaning technology.

In bag filter operation, the resistance will be increased with thickness increase of dust layer on bag surface, when the resistance had reached the set value; the dust on bag surface has to be removed in time. The basic requirement on dust removing is to rapidly and evenly remove the dust deposited on bag surface while a certain thickness of dust on bag surface has to be maintained. Dust removing is an important factor in normal operation of bag filter, dust removing method commonly used are mechanical dust removing, back blown dust removing and pulse dust removing, back blown and pulse dust removing are mainly used in BFG bag cleaning.

Reverse blown dust removing is one method to remove dust in which the gas flow counter to filtering gas flow will be applied to deform the bag and make the dust layer fall down; all Japanese BFG dry bag cleaning processes adopted bag reverse blown dust removing method. Pulse dust removing technology was applied to BFG bag cleaning process in 1980's in China and has been rapidly promoted. Pulse injection dust removing is to inject pressurized nitrogen or gas (pressure is 0.15 to 0.6MPa) in a very short time ($\leqslant$0.2s) with high velocity into bag, and at the same

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time induce huge amount of gas to form an gas wave inside the bag, generate a rapid expansion and impacting shock from the bag opening to bag bottom, having a strong dust removing effect. The impacting strength of pulse injection dust removing is strong, and its strength and frequency can be adjusted, dust removing effect is increased, system resistance loss is low, power consumption is less and on-line dust removing during bag filtering process can be realized, bag filtering surface is lower than that of reverse blown dust removing with same throughput of gas.

3 RESEARCH AND DEVELOPMENT OF KEY TECHNOLOGY

BFG fully dry bag cleaning technology is an integrated technology, relating to many engineering technology fields such as metallurgy, machinery, chemical fibre and textile, automatic detection and control. In order to increase the reliability of system operation and optimize process equipment, research and development were conducted on key technologies, a series of problems arose in engineering design, equipment manufacture, construction and operation were resolved, overall technical equipment level and control level were increased and technical breakthrough were made in application on large BF.[3],[4]

3.1 Optimization of Process Flow and Determination of Technical Parameters

Rational design of BFG dry bag cleaning process is the foundation for stable operation of the system. Deduster and gas pipeline are rationally arranged following the basic principle of fluid design. The layout and design of gas pipeline will directly influence the gas flow distribution inside the deduster and uniformity of resistance loss, gas volume and dust amount that enter into each deduster should be evenly distributed. Shougang Jingtang No.1 BF bag filter deduster adopts double row in parallel arrangement, dust containing gas and clean gas main are arranged between two rows of deduster and connected with deuster through branch. Gas pipeline is designed according to equal velocity principle and evenly distributes gas volume that enters into each deduster, the process layout of whole system is compact, process flow is short and smooth and equipment maintenance is convenient. The deduster adopts low filtering velocity design concept, flow filed distribution inside the deduster is researched and analysed by calculation of fluid dynamic（CFD）, rational gas flow velocity and gas flow direction are determined based on mathematical simulation calculation results, deflector is provided in deduster, deduster structure is optimized, and the gas flow field is evenly distributed inside deduster to ensure that the bag inside the deduster work under even and stable gas flow, this is the key technology in the design of large BF gas bag deduster. The technical parameters of deduster filtering surface, filtering velocity, gas flow ascending speed, resistance loss and dust removing cycle should be rationally determined, for super large BF with top pressure up to 0.28～0.3MPa, the rational design of gas flow, pressure, temperature and filtering velocity under working condition is the key factor to ensure reliable operation of the system. Table 1 shows the technical parameters of Shougang Jingtang No.1 BF gas dry cleaning process, Figure 2 shows the result of flow field simulation calculation inside the bag filter, Figure 3 shows the 3-D simulation design drawing for Shougang Jingtang No.1 BF gas dry bag cleaning process.

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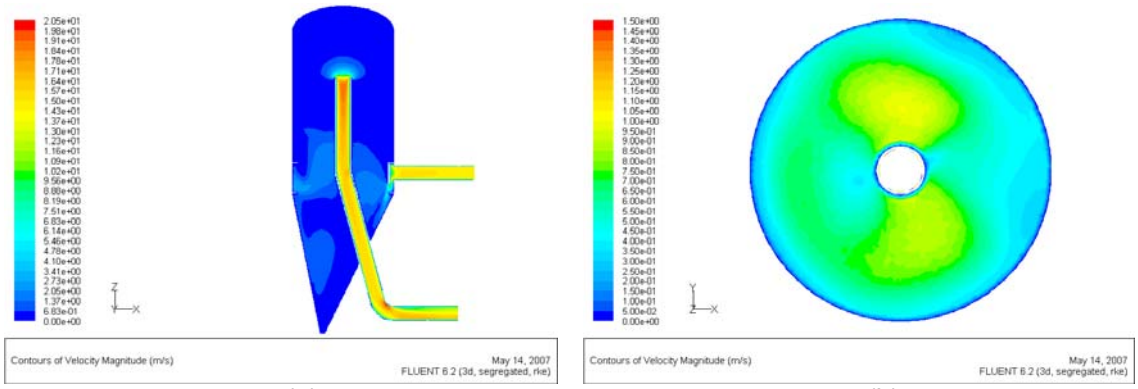
Table 1. Technical parameters of Shougang Jingtang No.1 BF gas dry cleaning process

Item	Parameters
BF volume m^3	5500
Diameter of the hearth mm	15500
Production ($thm \cdot d^{-1}$)	12650
Gas volume ($Nm^3 \cdot h^{-1}$)	760000 (maxiume 870000)
Top pressure MPa	0.28-0.30
Gas temperature ℃	100-250
Number of deduster	15
Diameter of the deduster mm	6200
Number of bag per single deduster	409
Specification of bag $\Phi \times L$ mm	160×7000
Total filtering surface m^2	21586
Filtering area of single deduster m^2	1439
Filtering velocity under standard condition ($m \cdot min^{-1}$)	0.59
Filtering velocity under working condition ($m \cdot min^{-1}$)	0.23
Dust content in crude gas ($mg \cdot m^{-3}$)	≤10000
Dust content in purified gas ($mg \cdot m^{-3}$)	≤5



(a) (b)

Figure 2. Result of flow field simulation calculation inside the bag filter. (a) Comprehensive velocity distribution at vertical section inside, (b) Comprehensive velocity distribution at horizontal section inside the deduster.

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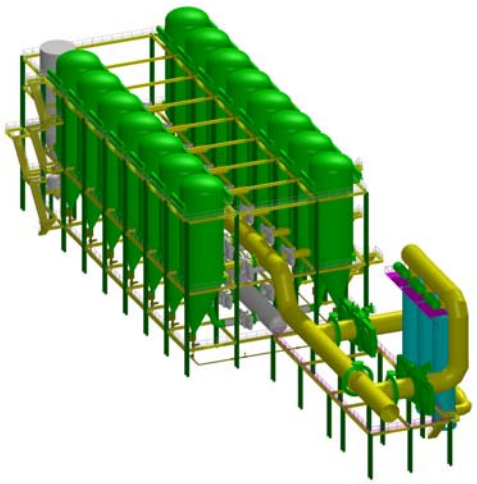

Figure 3. 3-D simulation design for Shougang Jingtang No.1 BF gas dry bag cleaning system.

3.2 Gas Temperature Control Technology

Gas temperature control is the critical factor for stable and reliable operating of bag filter system. At normal status, gas temperature shall be controlled in 80-220℃. Normal running of this system can be impacted by too high and too low gas temperature. When gas temperature reaches to 250℃, and this exceeds applicable safety temperature of ordinary bags, abnormal damage, even burnt bags can be happened in case of long term high temperature working condition of bags. Due to water in gas, and when gas temperature is lower than the dew-point temperature, phase transition can happen to water steam so as to appear condensation phenomenon and bag sticking. Therefore, bag filter cleaning technology for gas is applied, and regulating and control of top temperature should be paid more attention during BF operation.

When top temperature rises, mist water spraying at the top is used as temperature lowering measure. 3 groups of water spraying device for temperature lowering are provided at the top of BF with 5 nozzles each group. On/off of the 3 groups of water spraying device are controlled automatically as per the top temperature. 3 grade control is considered for spraying water according to the top temperature. When the top temperature reaches to 255℃, the system gives alarm and the 1st water spraying device is turned on automatically; When the temperature rising is keeping on to 270℃, the 2nd water spraying device is turned on automatically for temperature lowering purpose; When the top temperature reaches to 290℃, the 3rd water spraying device is turned on automatically for water spraying and temperature lowering; When the top temperature is lowered to 220℃, the top water spraying devices for temperature lowering are closed.

High-efficient hot tube heat exchanger is a kind of gas temperature lowering device developed based on principle of hot tube heat exchange for efficient control of BFG temperature. Hot tube heat exchanger is provided at the BF crude gas pipeline, and soft water is used as cooling medium. BFG heat is exchanged via the hot tube to make soft water evaporate and absorb gas heat so as to lower gas temperature efficiently. Under normal condition of gas temperature less than 220℃, the crude gas after the cyclone dust catcher enters to the bag dust catcher directly for purification treatment; When temperature of the crude gas through the cyclone dust catcher is higher than 220℃, the system opens the valve of the hot tube heat exchanger automatically. The high temperature gas enters to the hot tube heat exchanger to

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lower the gas temperature around 200℃, and then it comes to the bag dust catcher. When gas temperature lowers to 180℃, temperature lowering system is closed automatically. At beginning of No.1BF blow in, temperature of the crude gas reaches to 260℃ for times, even to 300℃. 3 sets of high efficient hot tube heat exchanger provided at the crude gas pipeline is used to lower gas temperature above approximate 70℃ to meet requirement of safe and reliable running of the bag cleaning system. It is proven from practice that this technical measure can solve technical problem on high temperature control of gas.Comprehensive measures should be taken to control too low gas temperature, for instance, technical measures of improvement of input quality of raw material and fuel, decrease of moisture of input raw material and fuel, intensification of monitor of furnace proper cooling device, rational control of top pressure, temperature insulation of the crude gas pipeline, etc. to achieve high efficiency. Especially during BF blow-in and BF re-blow, control of gas temperature should be drawn to attention in order to reduce moisture in gas, and control gas temperature 20-30℃ above the dew-point.

3.3 Anticorrosion Technology Applied to Gas Pipeline System

Due to application of BFG dry dust catcher technology, chloride ion in condensate of the purified gas is obvious high. Main reason for this is that chloride exists in BF raw material and fuel. Gaseous HCl is formed during BF smelting process. When gas temperature reaches to the dew point, gaseous HCl is combined with condensate so as to generate acid watery solution, which leads to acid corrosion. At damp neutral environment, chloride ion in gas also produces dot corrosion, stress corrosion and local corrosion to the gas pipeline and stainless steel bellow compensator. Test and analysis is taken to condensate of the purified gas after dry bag deduster, it is found that chloride ion in the condensate reaches to 1000mg/L, PH in the gas condensate is lower than 7, sometimes even to 2-3. Heavy corrosion is happened to the gas pipeline and bellow compensator and abnormal corrosion is occurred to the gas pipeline.

In order to suppress abnormal corrosion of the gas pipeline system, analysis and study on corrosion mechanism of bellow compensator of gas pipeline is carried out to improve material and structure of stainless steel bellow compensator. Material of bellow compensator is improved to stainless steel Incoloy825, which can prevent corrosion due to chloride ion, instead of austenite stainless steel 316L (00Cr17Ni14Mo2); polyethylene resin anti-corrosion paint is sprayed at the inner wall of the gas pipeline to separate metal pipeline and acid corrosion medium in order to suppress abnormal corrosion; For elimination of chloride in BFG, the chloride removing device is developed with application of chemical and Physical adsorption principle to remove chloride in BFG efficiently. Lye sprinkler is provided at the purified gas pipeline to make lye contact with BFG sufficiently in order to reduce chloride content in gas. Since the blast furnace was put into production, pH of condensate in gas is stabilized at around 6, with chloride content 400mg/L, and there is no abnormal corrosion happened to the gas pipeline and bellow compensator.

3.4 On-line Monitor Technology of Dust Content in BFG

On-line monitor device of dust content in BFG is the critical detection device for stable operation of monitor of BFG bag cleaning system, TRT. BFG dust content on-line monitor system researched and developed adopts charge induction principle.

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In running BFG, dust particles produce static charge due to friction and collision so that static field is formed. Change of its static field reflects change of BFG dust. BFG dust on-line monitor system deduces BFG dust figure via measurement of change on static charge. This is used to judge whether the bag dust catcher runs normally. When the bag has damaged, dust in the purified gas pipeline increases, and strength of static charge increases, too. Charge sensor can monitor charge volume timely and sent it to the transformer so as to realize automatic monitor of BFG dust.

3.5 Dense-phase Pneumatic Transportation Technology for Collected Dust

Collecting and transportation of dust from the BFG bag dust catcher is the critical factor, which impacts normal operation of the system. There are many technical defectives on conventional mechanical dust conveying process. Dust pneumatic conveying technology has be developed with nitrogen or purified gas as carrying gas for dust conveying. Dust from every bag of the dust catcher is collected and transferred to the dust bin via pipeline, and then they are centrally taken to the tank car to the sintering plant for recovery and utilization. Airtight conveying in the whole course is realized, technical detectives on conventional mechanical dust conveying process is solved, the process flow is optimized, energy consumption is reduced, secondary pollution is decreased and technical difficulties like wear-off of dust conveying pipeline and so on are overcome.

4 APPLICATION IN PRODUCTION

Shougang Jingtang No.1 BF adopts self-developed BFG fully dry bag filter cleaning system with complete elimination of wet dust catcher system as standby. Technical breakthrough of gas fully dry bag cleaning system is realized in super large blast furnace firstly all over the world. The blast furnace was blown in and put into production on May 21 of 2009. After two years' uninterrupted production, BFG dry cleaning system has been proven by various operating conditions. It runs stably and reliably, and various parameters have fully achieved or exceeded the design level. From June of 2009 till now, dust in the purified gas is stabilized in 2-4mg/m^3, minimum dust in the purified gas only about 1mg/m^3, annual average 3.74mg/m^3, which is better than the design figure 5mg/m^3; Average gas temperature is 140℃, and approximate 100℃ gas temperature is improved in comparison with that from wet cleaning system, with high gas cleanness and low moisture. Gas calorific value and hot blast stove flame temperature are improved accordingly. Under condition of full application of BFG for BF hot blast stove, hot blast temperature can be stabilized in range of 1250℃-1300℃ in long term. BFG fully dry cleaning process is applied to realize "zero consumption of fresh water, zero discharge of waste water", eliminate large quantity of poison sewage and slurry produced from wet cleaning process. Issues on fresh water consumption, secondary water pollution and slurry treatment are resolved from the springhead.

Shougang Jingtang No.1 BF adopts fully dry TRT system which is matched with BFG fully dry cleaning system. Fully dry axial type adjustable static blade turbine is applied with generator power 36.5MW, and TRT power generation is promoted greatly. TRT power generation is stably and continuously improved since the BF commissioning. Average monthly power generating capacity achieved more than 52 kWh/thm in 2010, maximum average power generating capacity reached 64.9kWh/thm. Annual average power generating capacity which is improved by

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approximate 45% in comparison with the gas wet cleaning process. Service life of the bag can reach to 18 months. There is no abnormal corrosion appeared at gas pipeline, bellow compensator, etc. Preliminary result on anti-corrosion measure of the gas pipeline has been achieved. Table 2 shows main operating parameters of BFG dry cleaning system. Figure 4 shows TRT power generating capacity achievements of No.1 BF in 2010.

Table 2. Main operating parameters of BFG dry cleaning system

Date	Crude gas temperature (℃)	Purified gas temperature (℃)	Dust in crude gas ($mg \cdot m^{-3}$)	Dust in purified gas ($mg \cdot m^{-3}$)
2010-1	319	109	7320	4.07
2010-2	191	112	7320	4.44
2010-3	228	120	10930	4.73
2010-4	127	122	9170	1.47
2010-5	138	135	7130	4.97
2010-6	141	137	8470	4.67
2010-7	154	150	8060	4.86
2010-8	174	167	7730	4.73
2010-9	156	152	9000	4.96
2010-10	172	166	8840	4.65
2010-11	177	170	7800	4.83
2010-12	169	163	7950	4.78

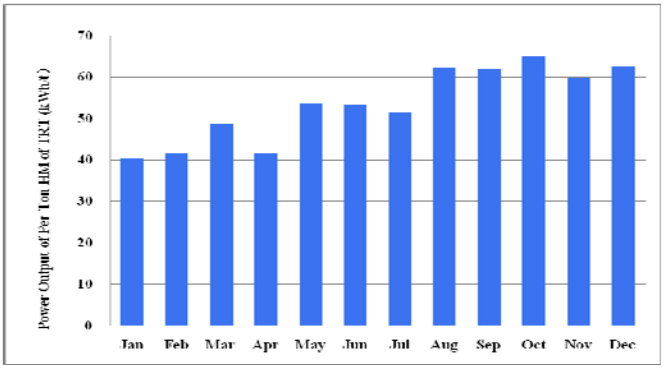

Figure 4. TRT power generating capacity performance of No.1 BF in 2010.

5 CONCLUSIONS

Gas dry bag dust catcher technology applied on large scale blast furnace is the development trend of iron making technology, and is an important support technology for realization of high efficiency and low consumption, energy saving and emission control, reduction of water source consumption, improvement of energy utilization efficiency, development of recycle economy for iron making industry.

By system research and technical integration, the important breakthrough is realized on gas fully dry dust catcher technology of Shougang Jingtang No.1 BF, with complete elimination of wet cleaning system as standby. The system has been run

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stably for 2 years with major technical parameters of dust content in purified gas, gas temperature, TRT power generating capacity, etc. has achieved or exceeded the design level, and huge technical and economic efficiency has been obtained. China has already been mastered the core and key technology on BFG dry bag filter cleaning in super large scale blast furnace, and it has been successfully applied in the Shougang Jingtang 5500m^3 super large blast furnace.

Breakthrough progress has been made in aspects of design, study, technical innovation, engineering integration, production, application of BFG dry bag cleaning technology, which is self researched and developed in China. A series of key and core technologies have been researched and developed to make the gas fully dry bag cleaning technology on super large sized blast furnace be perfect day by day, such as the low pressure impulse injection and dust cleaning technology of BFG dry bag cleaning, gas temperature control technology, gas dust online detection and digital control system, dense-phase pneumatic conveying of collected dust, anti-corrosion of pipeline system, etc.

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