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NEW GENERATION OF VERTICAL SHAFT CALCINER TECHNOLOGY

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Abstract

The vertical shaft calciner has been widely applied in China for CPC calcination. Its application, however, is restricted by its lower capacity, less automation and no waste heat recuperation. A new generation of energy saving shaft calciner technology with higher capacity and power generation system has been developed recently and illustrated in this paper. 75 kt of CPC annual production can be achieved by only one new shaft calciner, the waste heat from which can be recuperated to generate electricity of about 28 million kWh. The major invention is calciner structure optimization by computer simulation for better volatile combustion and calciner heat balance, which brings about better CPC quality, higher capacity and provides more energy for power generation. The new shaft calciner technology is flexible to the size distribution and volatile content in the green coke and applicable for the pulverous coke and the coke with high volatile content.

Introduction

China is the largest production country of calcined petroleum coke (CPC) in the world with about 100 CPC producers. The total CPC capacity reached more than 10 million tons in 2009, of which about 80% was used for anode manufacturing in aluminum reduction industry and about one million tons of CPC was exported abroad. Only a small part of high quality CPC was applied for the production of graphitized electrodes and acieration agent.

The green coke produced in crude oil refineries that meets quality requirements for size, impurities, and coke structure is calcined before production of anodes for the aluminum industry in order to remove the volatiles and to form the coke grain structure [1].

The calcination technology has a significant impact on CPC quality, especially such properties as its bulk density, grain size distribution and hardgrove index. To produce high quality CPC it is essential to keep the optimized control of calcination parameters including calcination temperatures, duration and volatile burning

The calciner operation cost for CPC is closely related to coke recovery and energy consumption during the process and to requirements for green coke quality, for which the extra coke burning control and waste heat recuperation play a very important role.

Both the calcination process control and waste heat recovery mainly depend on the calciner itself and the affiliated facilities.

Most of CPC is produced by either vertical shaft calciners or rotary kilns in China. The rotary calciners are usually applied in the anode manufacturers belonging to the large scale integrated smelters, while the shaft calciners are commonly used by the specialized and independent anode manufacturers and all the graphitized electrode producers in China.

A characteristic comparison between shaft calciners and rotary calciners will be made and the development of the new generation of shaft calciner technology will be outlined in this paper. In addition, its application and great achievements obtained in Chinese anode industry will be introduced.

Comparison between the shaft calciner and rotary calciner technology [2]

Figure1 and Figure2 show briefly the technology scheme of rotary calcining and vertical shaft calcining technologies respectively.

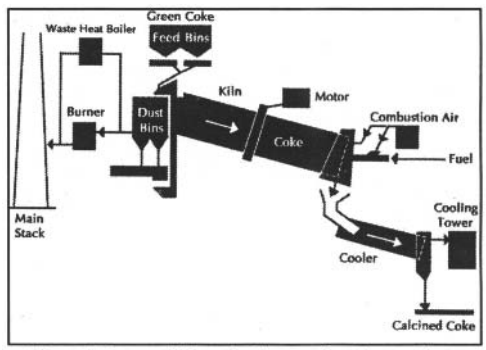

Figure1 Rotary kiln calcining technology scheme

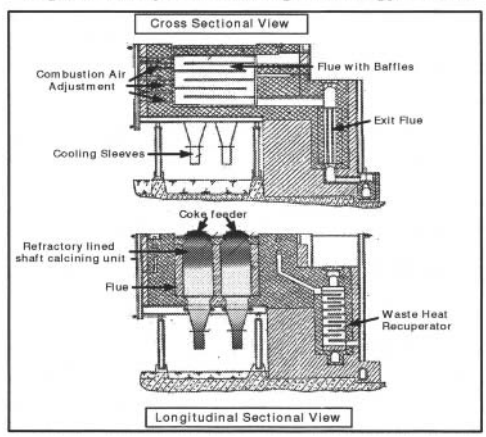

Figure.2 Vertical shaft calcining technology scheme

Table 1 The technical and economical comparisons of both calcining technologies

Calciner types	Rotary calciner	Old vertical shaft calciner
capacity	larger	middle or smaller
control	higher automation level	more manual operation
operation cycle	shorter, less than 85% operation	much longer
heat loss	more heat loss	less heat loss
environment	better waste gas treatment	waste gas emission issue
working conditions	better	worse
heat recovery	waste heat boiler	heat recovery for oil heating
coke recovery	lower, about 75-78%	higher, more than 82%
ash content in CPC	more ash from calciner lining	less ash content
CPC bulk density	lower	higher
CPC reaction resistance	lower	higher
requirements for GPC*	strict for green coke size	wider tolerance for GPC size

GPC*--green petroleum coke

Rotary kiln calciners are widely used for CPC production in the world, while the vertical shaft calciners are used in most Chinese CPC plants. Vertical calciners are stationary calcining furnaces.

The technical and economical comparisons between the rotary calcining and the old vertical shaft calcining technologies are illustrated in the Table 1.

There are many advantages for rotary calciners: larger capacity, higher automation level and better working conditions. But in the major aspects on CPC properties and coke recovery, which related more closely to the CPC application and its production cost, the advantages come up for vertical shaft calcining technology.

The adaptability of the calciner to handle dusty coke becomes more and more important since the green coke grain size distribution has deteriorated. The vertical shaft calciner will be more suitable to the calcining process for this kind of GPC.

Major considerations for developing new shaft calciner technology are that the old shaft calciner technology should be modified and improved in the following aspects:

(1) Extend its capacity by new design concept and simulation;

(2) Set up a modern inspection and control system;

(3) Install sets of operational machines instead of original manual operation;

(4) Install a waste heat boiler and power generation system to recover surplus heat from the waste gas;

(5) Remove sulphur from the waste gas by the advanced environment technology.

A new generation of vertical shaft calciner with 14 shafts and 56 units has been successfully developed and applied in Jinan Aohai Carbon Corporation, Ltd., China. to replace the original old shaft calciner. The calcine, which has increased capacity and improved energy efficiency based on the above mentioned considerations. A set of the relevant design, construction and operation technologies has been developed and optimized.

Technology development of the new generation vertical shaft calciner

There are two aspects for extending the shaft calciner capacity: increasing the unit number and changing the calciner structure. A new structure design concept has been developed and an optimized calciner layout completed by using computer simulation.

For the structure design a better heat transfer, insulation and the flue dimensions should be considered carefully and the refractory expansion during furnace baking and long term operation is of great importance.

The high temperature waste gas can be used for a surplus boiler, which supplies steam for power generation. The pyrology simulation is applied for higher heat transfer efficiency.

The different technical solutions have been compared for sulfur removal from the waste gas. A technical solution has been selected for the higher efficiency and the best economical results.

1. Green coke blending system [3]

The green coke feed stock usually comes from various suppliers with quite different chemical and physical properties in large scale CPC plants. Coke blending should be implemented for CPC quality stability and uniformity.

The coke blending facility is installed in the calcination plant. Cokes are blended based on the property analysis of the different sources.

The Chinese GPC produced in the refineries in different areas in China has quite different content of the elements, such as S, Na, Ca, V and Ni, greatly impacting on the coke reactivity. Some

elements will also catalyze coke oxidation, while some elements like sulphur will inhibit the oxidation. Based on the regulation mentioned above a blending technology is developed for improving the coke reactivity.

Some high sulphur content coke is blended with low sulphur content and high calcium and vanadium cokes. The blended coke mixture will have better properties than the original cokes.

2. Green coke feeding system

There are many more calcination units and feeding entrances for the new generation shaft calciners. An automatic green coke distribution facility has been developed and installed above the calciner for more homogeneous feeding and less manual operation. Every unit is fed with an equal amount of green coke during calcination, which keeps a constant operation for all the calciner units.

Distribution facilities are specially designed and installed over the calciner units with multiple outlets that can be moved forward and backward. A crane is installed to charge the GPC into the distribution facility.

3. CPC discharge and dust recovery during discharge

The discharge of CPC for the old shaft calciners was labor intensive and generated high levels of dust.. Based on our research, a new CPC discharge system and a dust collection system have been developed. No manual intervention is required for CPC discharge and the dust emission issue is solved. The coke dust collected can be used for dry aggregates in anode production. Figure 3 shows the CPC discharge system of the new shaft calciner.

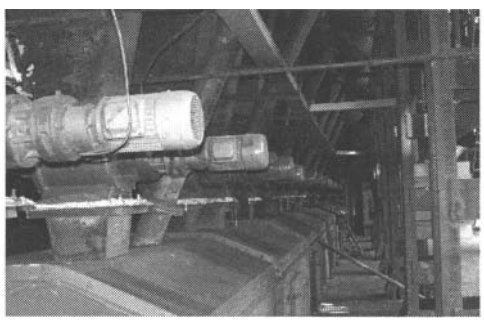

Figure 3 CPC discharge system

4. Online inspection and display system

An online inspection and display system has been developed in the new generation shaft calciner.

The temperature and pressure at the key points in the calciners are monitored. The system also includes an alarm system which highlights any out of range parameters. Figure 4 shows the display in the online parameter inspection system.

The online inspection system shows the temperatures in various calciner units. The color of the digits shows the deviation from the target temperature.

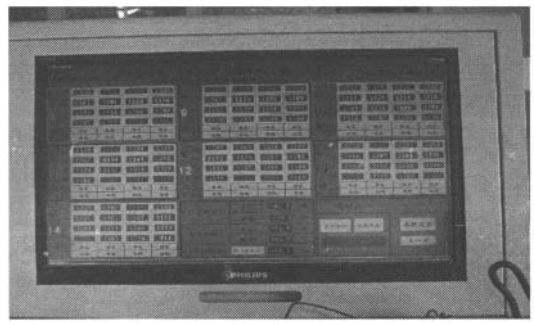

Figure 4 Display of the online inspection system

5. Power generation by the waste heat recovery [4]

Considering the process parameters of the new shaft calciner for heat recovery the technical and engineering scheme for the power system is determined as follows:

A surplus heat boiler is installed at the outlet of the waste gas from the calciner for generation of the superheat vapor with 3.82Mpa and 450°C. The superheat vapor is used for electricity generation in the power generator.

The exhaust vapor from the generator is condensed and pumped into a deoxidizing facility for oxygen removal, from which the water is recovered and recycled for the surplus heat boiler.

The facility configuration of the surplus heat recovery and electricity generation will provide a reliable and flexible operation platform to combine the shaft calcination system and electricity generation system for maximum surplus heat recovery and utilization.

6. Sulfur removal from the waste gas

A sulfur removal technology from the new calciner waste gas has been applied in the new shaft calciner plant.

The key technology is to absorb sulfur oxides from the waste gas by ammonia to form ammonia sulfates as a fertilizer. With this process, the achievable sulfur recovery can be greater than 90%. The waste gases meet all local sulfur emission limits.

Technology characteristics of the new generation shaft calciner

This new generation shaft calciner technology has the following characteristics:

- Greater height and length of the units for a longer calcination stage;
- More and larger exit shutes for more efficient volatile emission;
- Optimized flue design for larger flue profile squares;
- Larger refractory expansion slots to effectively prevent calciner deformation;
- Improved heat insulation design for the upper and side areas

of the calciner to maintain the flue temperatures;

- Utilization of automatic green coke feeding and calcined coke discharging facilities;
- Fully airtight and automatic conveying of the materials to and from the calciner;
- Application of the integrated temperature inspection and display by computer.

Applications and achievements of the new generation shaft calciner

The new generation shaft calciner technology has been applied in Jinan Aohai Carbon Corp. Ltd. An installed capacity of 150 kg/hr per unit and 73.6 kt of annual yield for one calciner with 56 units is achieved.

The operation has been kept stable and highly efficient. A reduction in manpower is required and the working conditions are much improved. There has also been a reduction in the coking and blockages observed in the calciner flues, further reducing manual interventions..

Most waste gas heat is recovered and the power generation goal is achieved. The environment in the plant is much improved and the sulfur emissions are greatly reduced.

The CPC quality has been improved. Compared with the rotary calciners the vertical shaft calciners are able to produce better quality CPC as follows:

①The CPC real density from shaft calciner can reaches to 2.08-2.10 g/cm^3 and is increased by 0.04 g/cm^3 as shown in Figure 5.

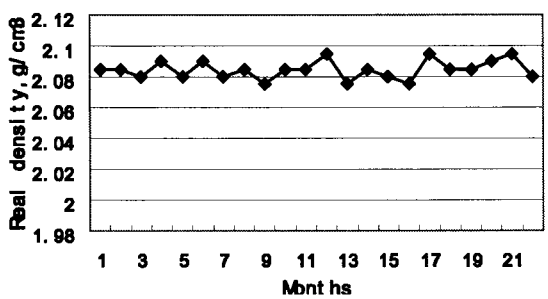

Figure 5 Real density of CPC from the new shaft calciner

② The CPC from shaft calciner has lower powder electrical resistance and is reduced by 30-50μ Ω .m .

③The CPC from shaft calciner has better CO_2 reactivity of 8-12% compared with rotary calciner of about 15% due to its higher bulk density as shown in Figure 6.

④ About 3% higher recovery rate of coke can be reached.

⑤There is no need of extra fuels for shaft calciner technology.

The CO_2 reactivities of CPC can also be much improved by use of green coke blending technology.

Owing to the stable feeding and operation in the new calciner CPC quality becomes more stable and more homogeneous.

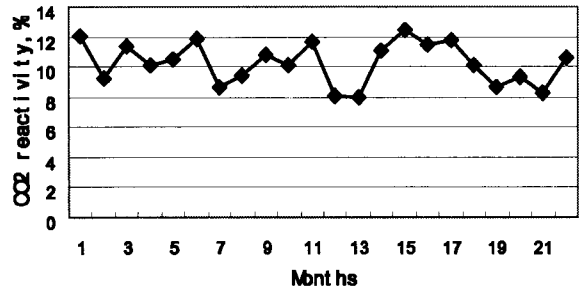

Figure 6 CO_2 reactivity of CPC from the new shaft calciner

It is predicted that the calciner life will be much prolonged due to the structure design and stable operation.

The new shaft calciner technology can be applied for the new calcination systems or to retrofit engineering projects with lower investment, higher capacity, more energy saving, less emission and higher productivity. This will lead to lower calcined coke production costs.

The higher CPC quality from the new shaft calciner will benefit anode manufacturing and anode quality improvement.

Conclusion

1. A new generation of vertical shaft calciner technology has been developed and applied in China instead of the old shaft calciner.
2. The key technology for the new generation shaft calciner includes a new shaft calciner structure design, new feeding and discharge systems, heat recovery and power generation technology from waste gas and sulfur removal technology from exhausted gas.
3. The major technical achievements are: much larger scale; great energy saving; mechanized feeding and discharge systems; better environment and working conditions; power generation from the waste gas; much lower sulfur emission.
4. The CPC quality is much improved by using the new shaft calciner, especially the CPC bulk density, air and CO_2 reactivities etc., which greatly benefit anode quality improvement.

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