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Energy Saving Technologies for Anode Manufacturing

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Abstract

The energy saving technologies for anode manufacturing have been developed and applied in the anode production processes in Jinan Aohai Carbon Products Corporation Ltd. The surplus heat from shaft calciners is recovered for heating pitch and mixer and power generation as well. The baking furnace structure and the lining materials have been improved so as to get reasonable anode occupation efficiency and less heat loss. The heating curves for anode baking are finely adjusted and controlled for completely burning of the volatiles in the green anodes for less energy input into the baking furnace. Based on the technology application mentioned above a great energy saving and benefit to the plant environment have been achieved in Aohai anode plants.

Introduction

Carbon anode manufacturing consists of a series of processes including petroleum coke calcining, crush and grinding of calcined coke, paste mixing, green anode forming and cooling and anode baking etc. The coke calcining and anode baking are the key energy intensive processes in the anode manufacturing. And development and applications of energy saving technologies in these processes will be of great importance to reducing the energy consumption in the whole anode production.

Aohai Carbon Products Corporation Limited, as a leading anode manufacturer in China with a capacity of 400 k t of anodes, produces high quality of anodes mainly for export and supplying the large scale domestic smelters. Aohai Carbon has made great efforts in energy saving and emission reduction in anode manufacturing for reducing production cost and improving its competition capability, especially with focus on the energy saving and surplus heat recovery technology development in the coke calcining, anode baking and technology applications in all the carbon plants in Aohai Carbon.

Energy saving in coke vertical shaft calciners

Structure and operation description of Aohai Carbon's vertical shaft calciners

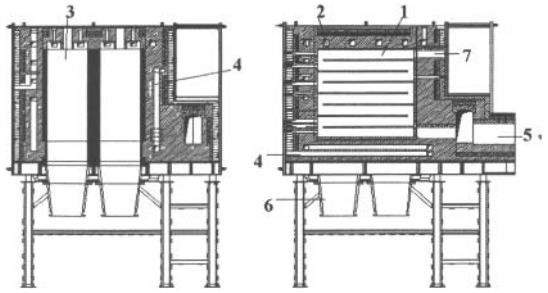

Fig.1 Structure of multistage vertical shaft calciner
1-flues, 2-volatile exit, 3-calciner, 4-preheat air, 5-exit flue, 6- water cooling, 7-air inlet

Fig.1 shows the general structure of the shaft calciners. The calciner is vertically installed. The green coke crushed to <70 mm is fed continuously into calciner through the feeding facility on top of the calciner and heated indirectly by the flues on both sides of the calciner.

The green coke firstly passes through the preheating zone of the calciner to remove moisture and some part of the volatile matter. Devolatilization occurs mostly between 500 to 1000 °C. Some of the volatile matters are condensing on the fine coke grains and glue them together to larger compact cokes.

In the calcination zone where the highest temperature in the flue reaches up to about 1300°C the coke shrinkage takes place. After about 30 hrs the coke enters into the cooling zone at the calciner bottom for quick cooling by the cooling water sleeve. The cooled calcined coke is discharged continuously through a sealed discharger.

The energy needed for calcining is only from combustion of the volatile in green coke so that the shaft calciners are self sufficient in energy for coke calcining without any other fuel addition.

Based on the heat balance evaluation of the shaft calciners about 33.5% of heat energy from the volatile burning is for heating green coke and up to 47.9% of the energy is carried by the waste gas emission into air, which provides the possibility to recover the surplus energy and reduce emission.

Approaches of energy saving in Aohai's vertical shaft calciners

The approaches to save energy in shaft calciners and the technology development directions in the calcining plants of Aohai Carbon can be considered as follows:

1. To improve the shaft calciner structure to achieve the better utilization of the energy from volatile burning and to enhance the heat exchange efficiency inside the multi-stage flues of the shaft calciners. The heat preservation lining materials are used for better heat insulation and less heat loss in the shaft calcining.
2. To fully recover the waste heat in the emitted gas from the shaft calciners for enhancing the medium temperature during pitch melting and paste mixing and generating vapor and power as well.

Energy saving technology development for Aohai's vertical shaft calciners

1. The technologies to improve the shaft calciner structure

The energy simulation study for vertical shaft calciner has been carried out. As a result of the study the number of flue stages in the shaft calciners is increased to 8 for the better heat recovery in the waste gas. With the flue stage number increase the heat exchange, the burning zone and the calcined coke quality will be improved.

The dimensions and profile of the flues are modified for the better heat exchange between flues and cokes. And the better heat insulation materials are used for reducing heat loss from the calciners.

In order to fully burn the volatiles in coke for saving energy a combustion air control system allows adjusting air injection to ensure full combustion of the volatiles.

2. The technologies to recover the heat in the waste gas from shaft calciners

The waste gas from the shaft calciners at the high temperature up to 850°C is rich in energy, which can be recuperated and reused for the carbon plants. The capacity of calcined coke production in Aohai Carbon is up to 500 kt, which is a great driving force for Aohai Carbon to develop and apply the heat recovery technologies to save energy in the anode manufacturing.

First technology is to recover surplus heat from the high temperature calcining waste gas in a heat exchanger to heat the heating oil.

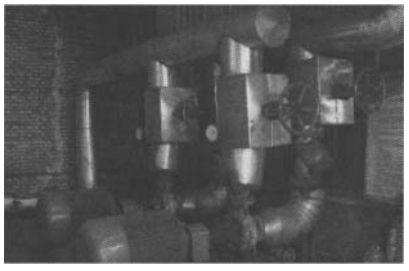

Fig. 2 Oil heating system

The hot waste gases flow through a recuperation unit to recover the heat and raise the temperature of the heating oil indirectly for melting pitch and preheating the dry aggregate in the batch mixer. The energy of heating systems for pitch and paste mixing is thus totally from the surplus gas heat recovery and a great amount of energy is saved in the green anode plants.

Second technology applied in Aohai Carbon is to generate power by the vapor from the waste gas surplus heat boilers shown in Fig.3. Four sets of waste-heat boilers besides the shaft calciners are installed, each has a vapor generation capacity of 30 t/h.

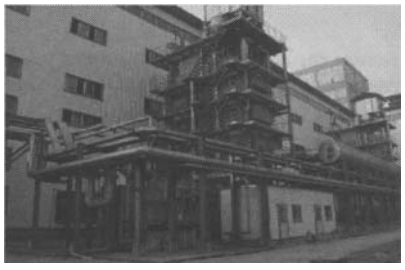

Fig. 3 Aohai Carbon's waste gas surplus heat boiler

The power generator driven by steam from the surplus heat boilers is shown in Fig.4. Three sets of generators with a capacity of 12 MW for each are set up, in which two sets are in operation and one set is for spare, so that total power generation capacity can reach 24 MW. The annual electricity output is 207 GWh, in which about 3% is used for coke calcining process and 12% is for power station and gas desulfurization process.

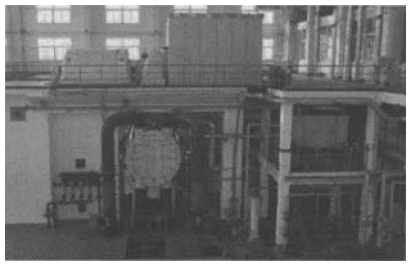

Fig.4 Aohai Carbon's power generator

The control room of Aohai Carbon's power station by surplus heat recovery is shown in Fig. 5.

Fig.5 Control room of Aohai Carbon's power station

Energy saving in the anode baking process

Anode baking process scheme

Anode baking is a heat treatment process of green anodes needed for evaporating the lighter components of the pitch binder in the green anodes and binding the coke grains tightly together. Fig.6 shows Aohai Carbon's baking furnace retrofitted by energy saving technology.

Fig.6 Aohai Carbon's energy saving baking furnace

A well-designed baking furnace is a prerequisite for energy saving and optimum anode quality. Achieving optimum heat transfer conditions in the baking furnaces will result in reducing fuel consumption and improving the qualified product rate. The target baking curve can then be designed for achieving the goals.

The baking process can be divided into four stages as preheating stage, binder coking stage, high temperature baking stage and cooling stage as shown in Fig.7.

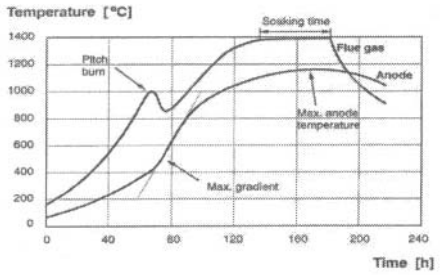

Fig.7 Anode baking process scheme

In the preheating stage the anodes are heated by the waste gas and the temperature is below 200°C. In the temperature range between 200°C to 800°C the pitch vapors are volatilized to provide optimal conditions for maximum binder coke yield and energy utilization efficiency. At the beginning of the third stage the baking temperature is further rising and the heat-up rate (gradient) can be raised. After the temperature reaches above 1100°C the soaking begins and is kept for some time. The final stage is to cool the prebaked anodes for unloading from the furnace.

Energy saving approaches in the anode baking

The energy is mainly consumed in the third baking stage for keeping high furnace temperatures, while in the second stage the energy is provided by combustion of the volatiles in green anodes. So it is most important to focus on how to fully utilize the volatile burning energy and how to reduce the energy consumption in the energy intensive stages in the baking process.

The technical solutions for energy saving are considered by Aohai Carbon as follows:

1. To optimize the structure of the chambers, pits and flues in the baking furnaces for larger capacity, higher loading rate, more homogeneous temperature distribution and better heat transfer so as to save energy.

2. To develop the advanced baking control systems for more accurate temperature control and the proper baking temperature curves for efficient burning of the volatiles in the green anodes and better energy utilization.

3. To develop the new packing technology including modifying the packing material recipe and packing process for better heat transfer and less heat loss.

Structure modifications for the open type baking furnaces

Aohai Carbon has undertaken this project as one of the key innovation projects of Shandong Province, which includes optimization of the open type baking furnace structure and its design, engineering and construction.

Based on the heat balance and temperature distribution study by computer simulation and considering the properties and supply of the domestic refractory materials, Aohai Carbon has developed a modified structure of the open anode baking furnace with the larger size chambers of 5.5 x 5.5 x 0.8 m, with 8 pits in each chamber with a capacity of 190-220 tons of anodes. The annual anode production yield for each firing system is as large as 55-63 k t of prebaked anodes.

By application of the modified structure baking furnaces the anode occupation efficiency in the furnaces and land utilization rate are much improved. The large loading amount will bring about higher capacity, less unit energy consumption and less refractory cost. The anode capacity is increased from the original 4.6 t to 7.2 t per ton of the refractory materials. A great energy saving is achieved by the furnace structure modifications.

The new baking furnaces not only have higher capacity chambers but also have the W type flues, in which the burning gas flow is distributed suitably for stable and homogeneous temperature distribution. The adjustment ranges of temperature raise in the flues are enlarged by the advanced furnace structure design for the large enough flue flow profiles and reasonable configuration of flue walls to reduce the resistance to the gas flow.

The low creep refractory bricks are applied in the new baking furnaces and a kind of casting refractory material premade blocks are used for the flue covers to greatly reduce the furnace structure deformation and prolong the furnace life. Furthermore, it results in enhancing the heat transfer effect between the flues and pits, which will certainly reduce energy consumption.

The operation technology development of the new baking furnaces

1. Optimization of baking temperature curve

Based on the raw materials recipe in the green anodes, especially the pitch addition, the optimized baking temperature curve is accurately predetermined. The temperature raising stages and heat up rate are finely adjusted and correctly controlled by the computer systems so that the volatiles in the green anodes will be released and completely burned at the proper temperatures during some heating stages in the baking furnaces. The coking and high temperature soaking time are thus adjusted and controlled for energy saving and high quality anodes. The cooling process after baking will be kept long enough for minimization of cracks and fractures in the prebaked anodes.

2. Development of the advanced firing control systems

The advanced control systems are installed to separately control the firing systems for all the individual flues to improve the gas temperature accuracy during the heating stages for the stable and better quality of the prebaked anodes. Fig. 8 shows the firing system in Aohai Carbon's anode baking process.

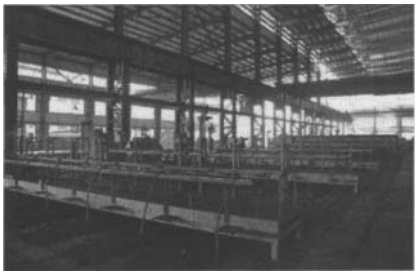

Fig.8 Firing systems in Aohai Carbon's baking process

3. Development of the new packing process

The packing materials between green anodes and the flue walls play a very important role in both oxidation protection of the anodes and heat transfer. A proper packing granule size distribution and a homogeneous impacting process are required to achieve the expected results. The better conditions in the

unpacking and unloading processes of the prebaked anodes from the furnaces will be provided by less powder content in the packing materials.

The advantages of the new energy saving baking technology

1) The capital cost of the new baking furnaces is greatly reduced owing to the higher capacity and yield for unit weight of the refractory materials.

2) The service life of the new baking furnaces will last longer with reduced maintenance cost.

3) The energy consumption of the new baking furnaces is reduced to 2.0 GJ per ton of prebaked anodes and reaches the advanced energy saving level in the world.

4) The waste gas amount and the various pollutants in the gas are greatly reduced.

Achievement of energy saving for the new baking furnaces

Significant energy saving and emission reduction have been achieved for the new baking technology.

The high quality prebaked anodes have excellent and consistent properties even better than the quality parameters of the first grade of China national standard YS/T 285-2007. The volatiles in the green anodes are burnt almost completely in the baking furnaces with a combustion rate of more than 99% and the heat energy utilization efficiency is obviously improved.

The energy saving technology applications result in that the natural gas consumption is reduced by 40% and achieves the advanced level of 49-52 m^3 per ton of prebaked anodes.

Furthermore, the green anode loading in the baking furnaces is increased by 28.6% and the amount of packing material added is reduced by 0.643 tons in each pit. The working life of the baking furnaces will last as long as 11 years due to less deformation of the flue walls and furnace body.

As a result of energy saving both the waste gas emission and the harmful components in the gas are greatly reduced by about 50%, which is of great importance to environment protection and human health.

Conclusions

1. The major energy saving technologies for Aohai Carbon's shaft calciners are shown as follows:

- The shaft calciner structure is improved to achieve the better utilization of the energy from volatile burning and to enhance the multi-stage heat exchange inside the shaft calciners.
- The better heat preservation materials are used for heat insulation and less heat loss during the shaft calcining.
- The operation stability and calcined coke quality are improved for higher qualified product rate and saving energy as well.
- The waste heat in the emitted gas from the shaft calciners is fully recovered for enhancing the medium temperature in the pitch melting and paste mixing and for generating steam and power as well.

2. The major energy saving technologies for the Aohai Carbon's baking process are shown as follows:

- The structure of the chambers in the new baking furnaces is optimized for larger capacity, higher loading rate and less energy consumption.
- The flue structure in the baking furnaces is modified for more homogeneous baking temperature distribution and better heat transfer.
- The baking control system is developed for more accurate temperature control, finely adjusted heating up rate and higher qualified anode rate.
- The proper baking temperature curves are set up for efficient burning of the volatiles in the green anodes and better energy utilization.
- The new packing technology is developed including the packing material size recipe and packing process for better heat transfer and less heat loss.

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