A Study on Furnace Heat Dissipation in Terms of Structure and Optimization of Electrical Calciner

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Abstract **– We study the structure of electric calcines based on the calcine furnace heat balance calculation process. We examine the temperature of the furnace wall surface and its production based on practical experience to optimize the structure of the furnace. We study the rear wall surface to measure the actual temperature, the ratio is obtained by theoretical calculations of heat loss through the walls. By calculating the noted increasing insulation inside the furnace, the furnace heat and temperature can be improved effectively. The raw materials is treated in a similar way, the results yield improved production quality, the equipment is improved, resulting in a greatly reduced cost of the product.**

Keywords: Electrical calciner, thermal equilibrium, furnace structure, optimization

I. INTRODUCTION

Calcination is one of the most important processes in the industrial production of carbon graphite products, whether the calcining quality of raw materials is good or bad can have a great influence on the physical index and quality of the final product. At present, as for the production of carbon, it is mainly about the petroleum coke and anthracite calcined [1,2]. So far, both the international and domestic factories use the calcination process of the furnace equipment, there are mainly three kinds, namely, pot type calcined furnace, rotary kiln and electric furnace (electric calcined furnace or resistance furnace). According to the different raw materials as well as different requirements on quality, it can choose different types of equipment [3,4]. The pot type calcined furnace and rotary kiln are mainly used in the calcination of petroleum coke, and the temperature is: the maximum temperature of the pot type calcined furnace is 1200℃, the maximum temperature of rotary kiln is 1300℃.The general temperature of electric calcined furnace is generally at 1700℃-2000℃, which is mainly used in the production of anthracite calcination. With the development of modern production, the requirement on product quality is higher and higher, as well as the development of new products, such as: the emergence of high density warming reducing agent (using anthracite as raw material), the requirement on the highest temperature of calcination should be to 2000℃-2500℃, therefore, the emergence of high temperature electric calcined furnace is for granted [5,6]. At present, there are some problems for high temperature calcined furnace, such as the separation between the upper and lower electrode fracture, flue blockage and so on[7]. Therefore, it should calculate the thermal equilibrium and optimize its mechanism based on understanding its structure.

II. THE PRINCIPLE AND STRUCTURE OF ELECTRIC CALCINED FURNACE

The electric calcined furnace is a kind of thermal equipment which can use the electric heating calcined anthracite coal, which is calcined without air in theory. After adding anthracite coal to the furnace, it can go through by gravity through the electrodes, so that power can be changed into heat energy by using the resistance of raw material itself, heating to a high temperature by the resistance of the material itself, adding to the high temperature, so as to remove the material moisture, impurities and volatile points, so that the high quality, stable thermal properties of calcined anthracite can be got.

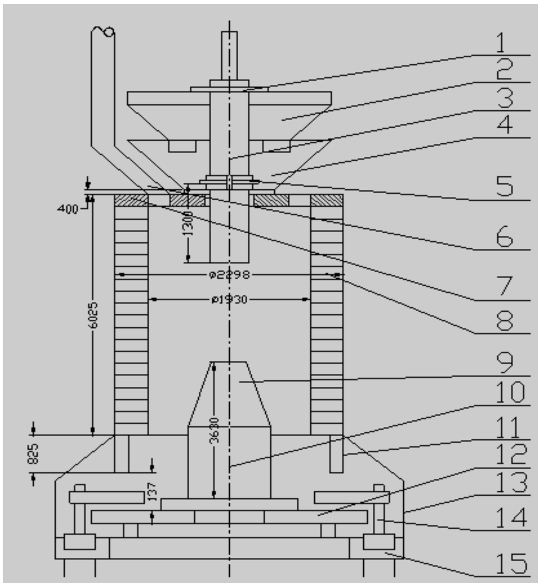

Fig. 1-A. The Existing Electric Calcined Furnace and Structure of Furnace Body

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Fig.1 (a) is the current structure of commonly used electric calcined furnace: furnace body is a vertical cylindrical shell, lined with refractory material, from top to bottom, it can respectively act as the calcined furnace preheating zone, high temperature calcination zone, mixed calcination belt. While refractory lining is surrounded by water-cooled furnace wall plus the bottom of electrode water jacket can form a space, which can be acted as the cooling zone of the furnace.

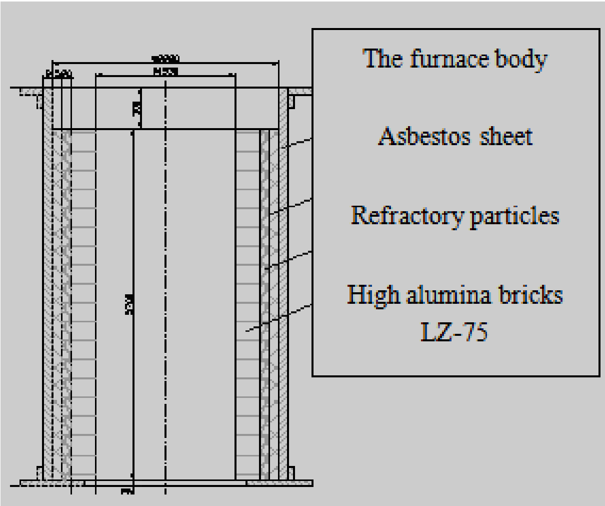

Fig. 1-B. The Existing Electric Calcined Furnace and Structure of Furnace Body

The structure in the figure are as follows: (1) friction ring, (2) raw material warehouse, (3) upper electrode, (4) top of silos, (5) electrode holder, (6) flue, (7) furnace cover, (8) furnace body, (9) lower electrode, (10) water jacket of lower electrode, (11)water jacket of side part, (12) cooling discs, (13) seal enclosures for dust protection (14) mechanical exhausting system, (15) discharging chute. While Fig. 1 (b) is the internal structure of the furnace body. The outside diameter of furnace body is φ2298mm, while the inside diameter is φ1930mm, the lining of furnace body can use the first class high alumina bricks, whose thickness is about 150 mm, with the height is about 100mm, in the middle, there are filled with refractory particles, whose thickness is 20mm (the particle is 3-7mm) which can be acted as the expansion space. The outer layer is asbestos board, which is 5mm, on one hand, it can play the role of insulation, on the other hand, it can play a role of keeping warm. The height of furnace body is 6025mm.

III. THERMAL EQUILIBRIUM OF ELECTRIC CALCINED FURNACE ND OPTIMIZATION

A. Thermal Equilibrium Calculation of Electric Calcined Furnace

The working principle of electrical calcined furnace is based on the principle of Joule Pendulum law: $Q=I^2Rt$. Electric energy can be transferred into heat power, which has close contact with the resistance, since the electrical calcined furnace takes the calcined anthracite as the conducting medium, when the current is obtained by calcined anthracite, the resistance of the anthracite itself can have electrical energy consumption, which can transfer the electric energy into heat energy, making the calcination furnace temperature increased, thus the calcined anthracite coal can be heated and calcined.

Before the calculation of thermal equilibrium, it should understand the thermal equilibrium of material in the electric calcined furnace, the material balance equation of the electric calcined furnace is as follows:

$$M_{before} + M_{after} = M_{volatile} \quad (1)$$

In the formula:

M before, the flow of calcined anthracite before calcination, kg/s:

M after, the flow of calcined anthracite after calcination, kg/s;

M volatile, the flow of the volatile matter of calcination production flow kg/s;

The experimental results are as follows: the real yield after calcination by using anthracite is 74.5%,

M after=16t/d=0.1852kg/s,

M before -M before×(1-74.5%) = M after

M before=0.2486 kg/s

M volatile = M before x (1-74.5%) =0.0472 kg/s.

The Calculation of Thermal Equilibrium of Electric Calcined Furnace:

As for the electrical calcined furnace itself, the basic equation of thermal equilibrium is as follows:

$$Q_{electricity} = Q_{diameter} + Q_{volatile} + Q_{anthracite} + Q_{waste} \quad (2)$$

In the formula :

Q electricity, refers to electrical heat (input power), KW;

Q diameter, radial heat dissipation of electrical calcined furnace, KW;

Q volatile, the heat that volatile matter takes away , KW;

Q anthracite, the heat that anthracite takes away after calcination, KW;

Q waste, namely, the heat that the electrical loss, clamping device, cooling water jacket and the heat absorbed reaction takes away, KW.

In the formula:

Q electricity refers to the normal operation of power transformer when the electric calcined furnace produced high-temperature calcined anthracite, which is 680KW, so the electrical heat Q electricity =680KW, it takes the calcined anthracite as the benchmark and electricity can converse the thermal unit, then Q' electricity =680/ (0.1852 ×3600/100)=1019.99 KW.h/t (calcined coal).

According to the statistics of production, the electric calcined furnace can actually produce calcined coal per ton: 1050 KW.h/t (high temperature calcined anthracite, the resistance of grinding is 650±μΩm/m2), which is basically the sane with the calculated value.

Q diameter refers to the radial heat of electrical calcined furnace (Q diameter, KW), the following table is a carbon factory 1#, 2#, 3# that have electric calcined furnace overhaul repaired, taking the temperature on the calcined cylinder body (1 meter distance away from the cylinder body, it can use the infrared thermometer), the average value can be obtained, which can be shown in Table 1.

TABLE 1 ACTUAL VALUE OF MEASURED TEMPERATURE OF CALCINED CYLINDER ZONE

Temperature /℃ \ Electrical calcined furnace	The measured average value of the first time	The measured average value of the second time	The measured average value of the third times	The measured average value of the fourth times	Average value
1#(2001.5)	255.6 ℃	257.2 ℃	256.3 ℃	257.1 ℃	256.55 ℃
2#(2003.11)	263.6 ℃	261.3 ℃	262.1 ℃	264.6 ℃	262.9 ℃
3#(2002.7)	270.5 ℃	271.3 ℃	272.6 ℃	270.3 ℃	271.18 ℃

According to the actual measured temperature of the three electric calcined furnace walls, it can get the average temperature of the furnace wall, namely, the temperature of the electric calcined furnace is: tdiameter=256.55 ℃ +262.9℃+271.18℃=263.54℃

The temperature of the surroundings is as follows: t surrounding =15℃

The height of the calcined furnace body, H=6025mm, a furnace body the outside diameter of the calcined furnace body, D=φ2298mm

So the qualitative temperature is as follows: t=(263.54+15)/2=139.27℃2=139.27

At this time, the expansion coefficient of air is: β=1/(139.27+273)=2.4255×10-3K-1

While the coefficient of thermal conductivity coefficient is:

λ=0.033W/m.k

And the specific heat is: Cp=1.009×103J/kg.K

Viscosity is μ=22.6×10-6Pa.s,

Kinematic viscosity is:

γ=μ/ρ=22.6×10-6/0.9124=24.77×10-6m2/s,

Prandtl number is:

Pr= Cpμ/λ=1.009×103×22.6×10-6/0.033=0.691,

Grashof number: (indicating the ratio of buoyancy and viscous force caused by temperature difference).

Gr= β g△tH3/ γ 2=2.4255×10-3×9.81×(263.54-15)×6.0253/(24.77×10-6)2=2.108×1012,

Natural convection heat transferring coefficient:

aconvection=0.135×λ/H×(PrGr)1/3 =
0.135×0.033/6.025×(0.691×2.108×1012)1/3 =
8.382W/m2.k,

The blackness of the steer plate: ε=0.8, the radiation constant is: CO=5.669 W/m2.k4, while the radiation heat transferring coefficient is:

aradiation = =εCO{[(tdiameter+273)/100]4-[(tsurrounding+273)/100]4}/

(tdiameter-tsurrounding)=0.8×5.669×{[(263.54+273)/100]4-
[(15+273)/100]4}/(263.54-15)=13.8666W/m2.k

Total heat transferring coefficient is: a=aconvection+aradiation=8.382+13.8666=22.2486 W/m2.k

The diameter of electric calcined furnace is: D=Φ 2298mm=2.298m, thus, the radial fins can: Qdiameter=π×D×H×a×△t=3.14×2.298×6.025×23.483×(263.54-15)=253738w=240.4kw, taking calcined anthracite as reference: Q’diameter=240.4/(0.1676×3600/1000)=398.43kwh/t(calcined anthracite).

B. The Optimization Structure of Electric Calcined Furnace Body

According to the electric calcined furnace thermal equilibrium calculation and long-term working experience, under the circumstance that the electrical calcined furnace is certain with the electrical heat(input power, kW), and the other condition of the electric calcined furnace body are unchanged, changing the lining structure of the electrical calcined furnace, do ad to improve the lining insulation and reduce the heat dissipation of furnace wall, as to improve the heat in the furnace, as well as to improve the temperature of the inside furnace. If under the circumstance that quality of the raw material is the same, when it produced the same quality products, due to the increase of

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the temperature of the furnace, the production capacity can be increased. According to this principle, when the transformation of Carbon Factory 4# electrical calcined furnace is carried on, it can redesign in accordance with this principle, the capacity can be increased from the original 16 tons to 21 tons (taking anthracite as the raw material) , its structure can be shown in Fig.2. In ensuring the internal diameter of the electrical calcined furnace is constant(φ1930mm),between the high alumina brick and expansion joint, it can add a layer of high aluminum light weight heat insulation bricks, at the same time, changing the asbestos board that the original thickness is 5mm into ceramic fiber board LYGX-164B whose thickness is 50mm.

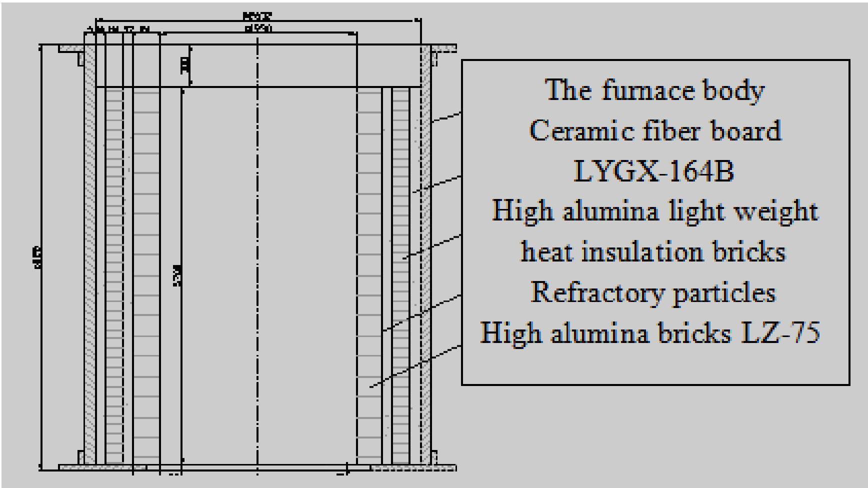

Fig. 2 The Structure of Furnace Body after Optimization

After the transformation is completed, the surface temperature of the furnace wall can be measured(calcined zone) taking the average value.

TABLE 2 ACTUAL VALUE OF MEASURED TEMPERATURE IN CALCINED CYLINDER ZONE AFTER TRANSFORMATION

Temperature /℃ — Electrical calcined furnace	The measured average value of the first time	The measured average value of the second time	The measured average value of the third times	The measured average value of the fourth times	Average value
4# electric calcined furnace	86.6℃	87.6℃	87.3℃	87.18℃	87.17℃

Based on the measured furnace wall temperature, the thermal equilibrium of the furnace wall ($Q_{diameter}$) of the electric furnace can be calculated: $t_{diameter}$=87.17℃

The temperature of surroundings can be defined as follows: $t_{surrounding}$=15℃

The height of the furnace body, H=6025mm, the outside diameter of furnace body is: D=φ2632mm

So the qualitative temperature is as follows： t=(87.17+15)/2=51.085℃

At this time, the expansion coefficient of air is:β=1/(51.085+273)=3.0856×10-3K-1

While the coefficient of thermal conductivity coefficient is: λ=0.033W/m.k,

And the specific heat is:

C_p =1.009×103J/kg.K,

Viscosity is μ=22.6×10-6Pa.s,

Kinematic viscosity is:

γ=μ/ρ=22.6×10-6/0.9124=24.77×10-6m2/s,

Prandtl number is:

P_r= Cpμ/λ=1.009×103×22.6×10-6/0.033=0.691,

Grashof number: (indicating the ratio of buoyancy and viscous force caused by temperature difference).

Natural convection heat transferring coefficient:

$A_{convection}$ = 0.135×λ/H×(PrGr)1/3 = 0.135 ×0.033/ 6.025 × (0.691×2.108×1012)1/3 = 8.382W/m2.k,

The blackness of the steer plate:

ε=0.8, the radiation constant is:

CO=5.669 W/m2.k4,

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while the radiation heat transferring coefficient is:

$a_{radiation}$ = =εCO{[(t diameter+273)/100]4 - [($t_{surrounding}$+273)/100]4}/($t_{diameter}$-$t_{surrounding}$) =0.8×5.669×{[(87.17+273)/100]4-[(15+273)/100]4} /(87.17-15)=6.251W/m2.k

Total heat transferring coefficient is:

$a=a_{convection} + a_{radiation}$ = 6.035+6.251=12.286 W/m2.k

The diameter of electric calcined furnace is:

D=φ2632mm2.632m, thus, the radial fins can:

$Q_{diameter}=\pi\times$D×H×a×△t=3.14×2.632×6.025× 12.286×(87.17-15)=44151w=44.151kw,

taking calcined anthracite as reference:

$Q'_{diameter}$ = 44.151/(0.1676×3600/1000) =73.175kwh/t(calcined anthracite).

From the comparison of the heat contrast of the furnace surface body before transformation before and after transformation, the surface temperature is decreased obviously, the radiating heat of the furnace body surface is greatly reduced, according to the law of balance of energy, the heat inside the furnace will be increased, thus the temperature will be increased, therefore, we can improve the quality of products as well as the equipment capacity, so ad to reduce the production cost of the products.

IV. CONCLUSION

(1) By using the thermal equilibrium calculation of the electric calcined furnace body before and after the transformation, it can get the reference time of anthracite , which can be decreased from 398.43kwh/t to 73.175kwh/t, therefore, the energy consumption is decreased significantly;

(2) The optimization of the furnace body structure is mainly to strengthen the heat insulation of furnace body, which can effectively enhance the furnace temperature, so as to improve product quality as well as productivity.

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