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Study on New Thermal Insulation Construction of Thermal Recovery Boiler

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Abstract

This paper analyzed existing problems of thermal insulation construction of thermal recovery boiler, and studied and designed a new thermal insulation construction of thermal recovery boiler. We carried out thermal insulation transformation for transition section of boiler, and tested the thermal insulation effect of it. According to the test data, we obtain thermal conductivity of thermal insulation construction of transition section of boiler with and without transformation. Contrast analysis shows that thermal insulation effect of new thermal insulation construction of thermal recovery boiler using fibre spray technology is better than common thermal insulation construction.It can be applied widely.

Keywords: thermal recovery boiler;thermal insulation; new construction

1. Foreword

In recent years, there were many studies on thermal insulation transformation of various boiler lining thermal insulation. In these studies, there is a major trend that using fibre spray technology transform boiler lining thermal insulation. Fibre spray technology is a new energy-saving construction technology which is applied to energy conservation, thermal insulation and other fields in developed countries widely. The fibre spray technology is that pretreated bulk mineral fiber cotton and special binder are spraied under certain pressure by special fiber spray machine simultaneously, then cotton fibers and the binder, which are mixed evenly outside the gun, are sprayed to the sprayed surface.This will be the inner or outer insulation layer to form a thermal insulation structure that is thickness uniformity, overall seal and seamless and high strength. This technology has the advantages of the fast construction speed、outstanding thermal insulating effect, the whole spray layer seamless and long service life[1,2].Now, it has become a mature technology to replace traditional construction technology.

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In our country ,furnace lining construction of existing thermal recovery boiler is consisted of composite materials of high-purity fiber blanket + ordinary fiber blanket from the hot surface to cold surface,outer layer tile 0.5mm aluminum foil[3].The main issues of thermal insulation construction of existing thermal recovery boiler is reflected in three aspects: (1) thermal insulation performance of thermal insulation construction is unsteady. The fiber of thermal insulation construction is eroded by continuously smoke erosion and loss so that thermal insulation performance even worse, which result in greater heat loss and higher temperature of furnace outer surface;(2)due to linear contraction of thermal insulation materials, lap joints portion of thermal insulation materials appear gap and local thermal bridge so that local outer surface temperature of furnace is too high;(3) there is difficult to ensure the construction quality for sphere and abnormal structure, and need more staff.

Thermal insulation effect of thermal recovery boiler directly affects the output of steam parameters and the effect of viscous oil thermal recovery, There is of great importance that studying on new-type and high-effective thermal insulation construction of thermal recovery boiler to control the outer surface temperature , reduce heat loss, ensure dryness of steam as well as promote energy conservation of viscous oil thermal recovery process.

2. New thermal insulation construction design of Thermal Recovery boiler

New thermal insulation construction of thermal recovery boiler use fiber spray thermal insulation program, its structure is consisted of high-purity aluminum silicate fiber and common aluminum silicate fiber[4,5]. Due to the inner of thermal insulation construction contact with the smoke and flame inside the furnace directly whose temperature is higher, so the inner use high-purity aluminum silicate fibre spray thermal insulation material of high-temperature resistance, Outer use common aluminum silicate fibre coating to reduce thermal insulation material cost.

When designing the thermal insulation construction, We adopt the insulation structure optimization design method, as well as consider the safety temperature of thermal insulation material.

(1)The optimization design method of thermal insulation construction

Optimization method of thermal insulation construction is a kind of method which refers to the lowest total annual cost of work to calculate thermal insulation thickness. The main purpose of thermal insulation of equipment and pipeline is to reduce heat loss, save fuel and cost. But the thermal insulation of equipment and pipeline should be invested. In order to achieve economic effect of thermal insulation, optimization method requires that the annual apportioned cost of thermal insulation project and annual maintenance fees do not exceed the cost of saving fuel. Given pipe diameters and insulation materials and different thermal insulation thicknesses, by comparing the total cost (total cost of annual operation) which include annual heat loss, annual apportioned cost of thermal insulation project (depreciation cost) and annual maintenance fees, the thermal insulation thickness corresponding to the minimum value of the total operation cost is known as the "economic thickness".

Economic thickness of thermal insulation material is calculated as:

$$d_2 L_n \frac{d_2}{d_1} = A_2 \sqrt{\frac{\lambda BH}{AN}\left(t_1 - t_K\right)} - \frac{2\lambda}{a_2} \tag{1}$$

$$\delta_0 = \frac{d_2 - d_1}{2} \tag{2}$$

Where:

A_2 —constant, according to legal metrology unit of the People's Republic of China A_2=3.795, according to measurement units of metric A2=2;

λ —the conductivity of thermal insulation materials in an average state, W/(m·K);

B —heat price, Yuan/J;

H —annual operation time, h;

A —unit price of thermal insulation construction (investment cost of thermal insulation), Yuan/m^3;

N —apportioned rate per year of thermal insulation project investment, %;

t_1 —the inner surface temperature of thermal insulation layer, ℃;

t_k —the air temperature around the outer surface of thermal insulation layer, ℃;

α_2 —convective heat transfer coefficient of the outer surface of thermal insulation layer and the air, W/(m^2·K);

δ_0 —economic thickness of thermal insulation layer, m;

d_1 —inner diameter of thermal insulation layer, m;

d_2 —outer diameter of thermal insulation layer, m;

(2)Safe operating temperature

According to the design specification of thermal insulation equipment and pipeline and general provisions of industrial furnaces thermal insulation technology, he safe operating temperature of thermal insulation material take 90% of the highest operating temperature. Interface temperature of thermal insulation layer should not exceed the safe operating temperature of thermal insulation materials, and should leave room temperature.

The highest operating temperature of both common aluminium silicate fibre spray materials and high-purity aluminium silicate fibre spray materials are 700℃ and 1200℃ respectively, so the safe operating temperature are 630℃ and 1080℃ respectively. The highest temperature of the furnace is 950℃, lower than 1080℃. Therefore, the inner spray materials using high- purity aluminium silicate fibre can meet the requirements. For security purposes, the design temperature of interface between ordinary aluminum silicate and high-purity aluminum silicate should not exceed 500℃.

When calculating temperature of interface between common aluminum silicate and high-purity aluminum silicate, we must firstly calculate heat loss of the boiler, then calculate the interface surface temperature by the heat loss. Heat loss of boiler is calculated as:

$$\Phi = \frac{t_n - t_f}{\ln\frac{d_w}{d_n} / 2\pi\lambda l + \frac{1}{h\pi d_w l}} \tag{3}$$

Where:

Φ ——heat loss of thermal recovery boiler, W;

λ —thermal conductivity of thermal insulation structure, W/(m· K);

d_w —outer diameter of thermal insulation structure, m;

d_n ——inner diameter of thermal insulation structure, m;

h ——convective heat transfer coefficient of the outer surface of boiler and the air, W/(m^2·K);

t_n ——The inner surface temperature of boiler thermal insulation layer,℃;

t_f ——the air temperature,℃.

Common aluminium silicate and high-purity aluminium ailicate surface temperature is calculated as:

$$\Phi = \frac{t_n - t_1}{\ln \frac{d_1}{d_n} / 2\pi\lambda_1 l} \quad (4)$$

Where：

λ_1 ——thermal conductivity of inner layer high-purity aluminum silicate, W/(m·K);

d_1 ——outer diameter of inner thermal insulation structure, m;

t_1 ——contact surface temperature, ℃.

Calculation results of thermal insulation thickness of thermal recovery boiler are shown in table 1, thermal insulation construction diagram is shown in Figure 1.

3. Test and analysis of thermal insulation effect

In order to test application effect of lining thermal insulation construction of composite aluminum silicate fibre spray, we transform the transition section of 23 t/h boiler of the thermal insulation condition. For intuitive contrast, while we test thermal insulation effect of using the same time with the former and no transformation transition section of boiler.

3.1 Test results

When testing the thermal insulation effect, we test 3 times for transition section of transformation boiler and no transformation boiler in the field, the running time were 1 month,3 months and 5 months respectively. Testing contents include: outer surface temperature of boiler, heat flux density of outer surface, the air temperature and indoor wall temperature. Test results are shown in Table 2.

3.2 Calculation results and test analysis

According to the test data, in order to compare thermal insulation effect of prior to and after of transformation, we calculate thermal conductivity of insulation construction of two boilers. The calculation results of construction thermal conductivity are shown in Table 3.

As can see from Table 4, with prolonging of using time, change of new aluminum silicate spray thermal insulation construction is smaller than traditional. After 9 months, thermal conductivity of new aluminum silicate spray thermal insulation construction increase 0.008

W/(m·K),increased by 5.6%.However, thermal conductiveity of traditional thermal insulation construction increased 0.023 W/(m·K), increased by 14.7%.It can be seen stability of new thermal insulation construction is better. In the case of the same running time, thermal conductivity of spray thermal insulation construction is smaller than traditional. That is to say that thermal insulation effect of new aluminum silicate spray thermal insulation construction is better than traditional thermal insulation construction's. It can be see that aluminum silicate spray thermal insulation, whose characteristic is jointless and high strength and so on, apply to lining thermal insulation of thermal recovery boiler.

4. Conclusions

In this paper, we design the new aluminum silicate spray thermal insulation construction of thermal recovery boiler,and transform a transition section of thermal recovery boiler, as well as compare and test its thermal effect, Test results show as follows:

1、Thermal recovery boiler lining thermal insulation with composite aluminum silicate fibre spray thermal insulation construction, whose thermal conductivity is smaller than traditional thermal insulation program's, reduce heat loss of steam injection boiler and the outer surface temperature of boiler, the thermal insulation effect is remarkable greatly.

2、With prolonging of using time, thermal insulation performance of new thermal insulation construction does not significantly decrease. Construction stability is better than traditional thermal insulation construction. So the thermal recovery boilers lining thermal insulation is a worthy of popularizing program.

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TABLE 1 THERMAL INSULATION CONSTRUCTION OF INJECTION-STEAM BOILER DESIGN RESULTS

boiler parts		***radiation section***	***transition section***
hot surface temperature/℃		700	900
thermal insulation layer thickness/mm	high-purity aluminium silicate	70	100
	common aluminium silicate	130	240
The total thickness of the insulation structure/mm		200	240

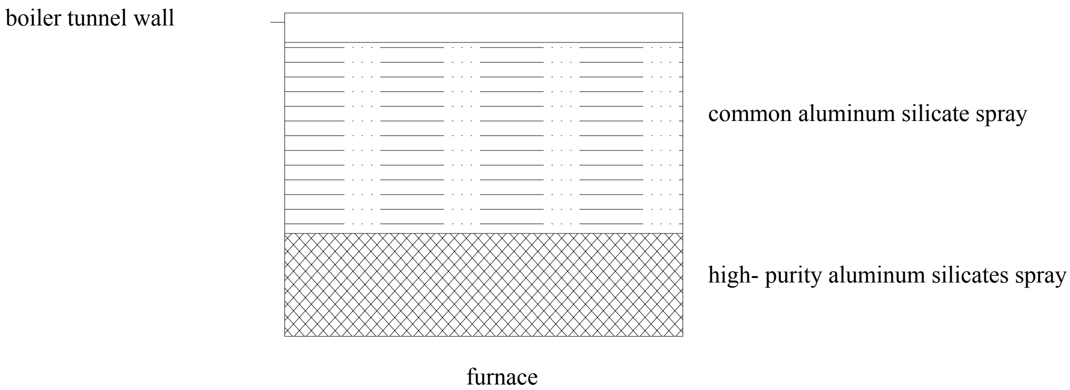

Figure 1 Thermal insulation construction of steam injection boiler diagram

TABLE 2 TEST RESULTS AFTER THERMAL INSULATION TRANSFORMATION IN THE FIELD

Running time /month	***Testing object***	***outer surface temperature/ ℃***	***heat flux density of outer surface/ (W/m²)***	***the air temperature/ ℃***	***indoor wall temperature/ ℃***
1	transformation boiler	65.7	446.5	24	34.3
	no Transformation boiler	76.0	588.5		
5	transformation boiler	66.1	461.1	23	34.7
	no Transformation boiler	77.8	627.0		
10	transformation boiler	67.3	478.2	23	33.9
	no Transformation boiler	80.8	668.7		

TABLE 3 COMPARISON TO CALCULATION RESULTS OF THERMAL CONDUCTIVITY

	running time/ month	***transition section of transformation boiler***	***transition section of no transformation boiler***
construction thermal conductivity/W/(m·K)	1	0.145	0.156
	5	0.148	0.167
	10	0.153	0.179

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