Research on Computer Simulation to Thermal System of Active Lime Rotary Kiln

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Abstract—It is difficult to establish a mathematical model of heat transfer in rotary kiln, which is difficult to establish a mathematical model. Through the theoretical research and computer simulation technology of the thermal system of rotary kiln, the thermal state of the rotary kiln is simulated, and the optimal data source is provided for the design and optimization of the rotary kiln.

Keywords- Rotary Kiln; Thermal; Computer Simulation; Fluent; Lime

I. INTRODUCTION

Rotary kiln is the key equipment of the active lime. Because of the limestone can be rolling in the rotary kiln, the high temperature flue gas can be changed to the limestone and the limestone can get even the calcination. The calcination of limestone in rotary kiln is a very complicated process, which is accompanied by the chemical changes of the radiation, convection, heat conduction and the limestone. The research will analyze the thermal system of rotary kiln calcination active lime, and then according to the theoretical calculation, using fluent software simulation analysis of rotary kiln thermal state, and should be in the selection of lime calcination rotary kiln, the technology can greatly reduce the design cost.

II. THEORETICAL RESEARCH ON THE THERMAL REGIME OF ACTIVE LIME ROTARY KILN

A. Radiant Heat Transfer in Rotary Kiln

In the rotary kiln, the high temperature flue gas produced by the high temperature gas has occupied the majority of the limestone. The radiation heat transfer in the actual production is a complicated process, which not only contains the radiation of the flue gas, but also contains the radiation of the refractory materials. But in fact, the radiation of the flue gas is the main heat transfer mode, and the heat transfer in the limestone is small, and the radiation heat transfer is not considered. According to the law of conservation of heat, the gas is absorbed by the gas less than that of the gas [1].

$$q = C\left[\varepsilon_g\left(\frac{T_g}{100}\right)^4 - \alpha_g\left(\frac{T_w}{100}\right)^4\right] \tag{1}$$

The C is the thermal radiation $5.67W/\left(m^2 \cdot K^4\right)$ black body constant, ε_g for the radiation emissivity, α_g for the absorption rate, T_g is the flue gas temperature, T_w for the limestone. In the thermal simulation analysis of rotary kiln, the radiant heat of the flue gas and limestone is treated by the limestone as a black body. The body of the body is to absorb ratio equal to 0, and the reflection ratio is 100%. In fact, the limestone is gray body. If limestone is considered as ash, it must consider the multiple reflection and absorption of limestone and flue gas. However, in practice, the active lime rotary kiln can be replaced by a long high temperature flue gas. So in the calculation of radiation, we approximate the limestone as a black body.

The main content of the flue gas is nitrogen, carbon dioxide and water vapor in the process of calcination. For example, in the coke oven gas of the calcined active lime, the nitrogen content of 59.6%, carbon dioxide 26.12%, water vapor 10.65%, three of the total gas content of 96.37%. According to the basic theory of radiant heat transfer, the nitrogen is a double atom gas, and the radiation heat transfer is not contributing to [2]. Therefore, in fact, the radiation heat transfers in the flue gas of the rotary kiln, carbon dioxide and water vapor is the main radiation heat source.

According to the research of radiant heat transfer, the gas emission rate is as follows [3]: when there are two kinds of gas components in water vapor and carbon dioxide, the gas emission rate is calculated as follows:

$$\varepsilon_g = C_{H_2O}\varepsilon^*_{H_2O} + C_{CO_2}\varepsilon^*_{CO_2} - \Delta\varepsilon \tag{2}$$

Which is the result of the test $\varepsilon^*_{H_2O}$ 、 $\varepsilon^*_{CO_2}$ in a certain temperature and pressure, and C_{H_2O} 、 C_{CO_2} the correction factor of the specific conditions can be obtained through the look-up table. In the same way, the absorption ratio of flue gas and limestone is as follows:

$$\alpha_g = C_{H_2O}\alpha^*_{H_2O} + C_{CO_2}\alpha^*_{CO_2} - \Delta\alpha \tag{3}$$

In the radiation theory, we know that the temperature of the flue gas and material is the important factor of the radiation heat transfer. The accuracy of their temperature, therefore, directly affects the accuracy of the results of the radiation heat transfer. In this regard, the professional scholars have done a lot of research work, and also have a successful formula can be used for reference. Average temperature of high temperature is chamber furnace material [2].

B. Convection Heat Transfer in Rotary Kiln

In various fields, the research on the convection heat transfer of the material in the rotary kiln has a successful research, and we choose the more mature empirical formula as the basis for the calculation. In the metallurgical field, the convection heat transfer coefficient of the rotary kiln is the following formula:

$$\alpha = 10.8u_0 \tag{4}$$

C. Heat Conduction of Rotary Kiln

In the rotary kiln, the limestone and refractory materials are also subjected to high temperature flue gas heat radiation and convection heat transfer. However, due to the heating time, the surface temperature of the refractory is higher than that of the limestone. Limestone and refractory materials have poor temperature, so the presence of heat conduction in the limestone and refractory materials. According to the calculation formula of the steady state heat conduction of a cylinder:

$$\Phi = 2\pi rlq = 2\pi\lambda l \frac{t - t'}{\ln\frac{r_2}{r_1}} \tag{5}$$

D. Chemical Changes of Limestone

In the process of lime calcination rotary kiln, the heat exchange process of limestone and continuous heat source is included, and the chemical reaction process is included. In order to realize the computer simulation of lime calcination rotary kiln, the chemical change of limestone is suggested. The chemical change of limestone is assumed to be linear. According to A, the thermal absorption of limestone is linear.

$$CaCO_3 = CaO + CO_2 \uparrow -42.6kcal / mol \tag{6}$$

In the simulation analysis, the chemical reaction process of limestone is not simulated. We introduce the concept of equivalent specific heat capacity of limestone. So-called limestone equivalent specific heat capacity that is to the limestone endothermic chemical reaction process belongs to in the limestone of the specific heat capacity of to.

Limestone equivalent specific heat capacity, rotary kiln system unit time required for raw materials, limestone of the actual specific heat capacity, unit of time in the decomposition of raw materials required for the heat, when raw material content is too high, must also consider the decomposition heat is raw material from calcined to a result of a change in temperature.

In the process of combustion, the amount of smoke generated by the combustion of the fuel is very reliable. In the process of simulation, the temperature and the length of the flame are considered, but the flame is not considered, but the amount of the flue gas is increased, so that the simulation analysis can be more close to the reality, and will not affect the simulation results.

III. COMPUTER SIMULATION ANALYSIS OF ROTARY KILN FOR LIME

A. FLUENT Software

FLUENT software FLUENT software is the United States FLUENT company development of the general CFD flow field calculation analysis software, including the Dynamic International Fluent [4], Belgium Polyflow and Dynamic International Fluent (FDI) of all the technical force (the former is recognized as a viscoelastic and polymer flow simulation in the leading position, and the latter is based on the finite element method CFD software company).

FLUENT is a program for calculating fluid flow and heat transfer problems [5-6]. It provides a non structured mesh generation program, which is very effective for the relatively complex geometric structure. The grid can generate 2D Triangular and quadrilateral mesh; tetrahedron, hexahedron and three-dimensional hybrid grid. FLUENT can also adjust the mesh according to the calculation results, which can be used to solve the large gradient flow field. Since the mesh adaptation and adjustment are implemented in the required flow area, not the whole flow field, the calculation time can be saved.

B. Analysis on Coal Combustion of Active Lime Rotary Kiln

In this experiment, a two dimensional rotary kiln model is established [7-8]. The length of the rotary kiln is 70m, the diameter of the rotary kiln is 4.9M, the inner diameter is 4.5m, the inclination angle is 2 degrees, and the shape is shown in Figure 1. There is a coal burner in the middle part of the kiln, and the right side of the circular face is two air inlets, and the left end face is the air outlet. The calorific value of fuel coal pulverized coal burner is 25 080kJ/kg, the quantity of coal is 8 666kg/h. The air pressure from the burner is 15kPa, the air flow is 25000 Nm3/h and the temperature is 20. From the inlet of the air inlet into the rotary kiln, the two air pressure is -7.55Pa, and the temperature is 700.

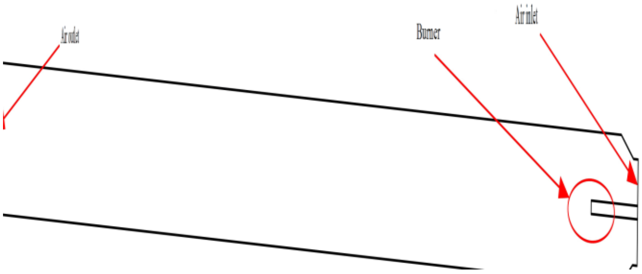

Figure 1. Two Dimensional Rotary Kiln Model.

The grid model of the rotary kiln is based on the grid model. The grid is used as the model of the rotary kiln, which is based on the grid model of the rotary kiln, and the grid is 3. 62055 nodes are 62692.

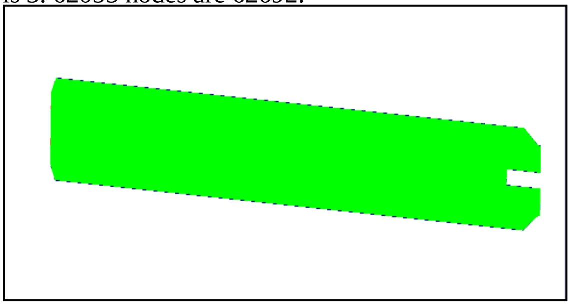

Figure 2. Computational Grid.

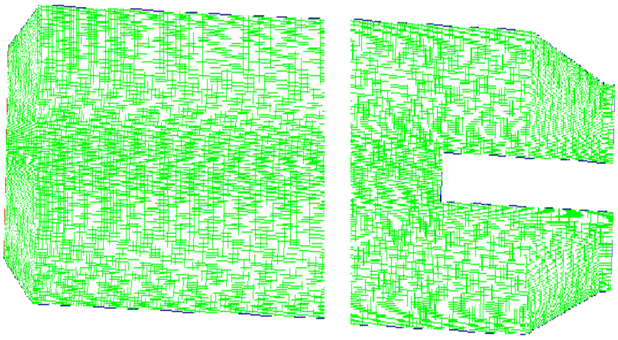

Figure 3. Local Grid Graph

The experimental results of the calculation results, compared with the temperature distribution in the furnace, the temperature distribution in the rotary kiln is 5. According to the contrast on the left side of the figure legend found that pulverized coal in rotary kiln combustion highest at 1700K, burner nozzle, in the central part of the rotary kiln formed a cone-shaped region of high temperature zone, where the temperature range between the 1500K-1700K; the high temperature zone along the direction of the head kiln temperature gradually decreased gradually, the temperature range at about 1400K-1500K; kiln temperature roughly in the 1300K-1400K; and kiln head part of the temperature is low, at around 929-1000K.

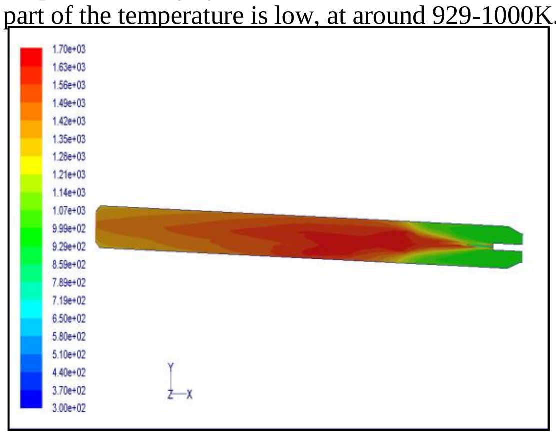

Figure 4. Temperature Distribution in Rotary Kiln

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Oxygen distribution comparison: Fig.5 is a mass distribution of oxygen in a rotary kiln. The trend of oxygen content is: in the first part of the kiln, the air inlet and the entrance of the pulverized coal are higher, the highest is 23.3%. Because of the coal combustion, oxygen consumption, the mass fraction of the left to right oxygen gradually decreased, and the oxygen content in the tail of the kiln was lowest.

From the temperature distribution of the rotary kiln, the oxygen content in a region of the coal powder nozzle is reduced gradually, which is due to the full combustion of coal, and the temperature of the cone region is high.

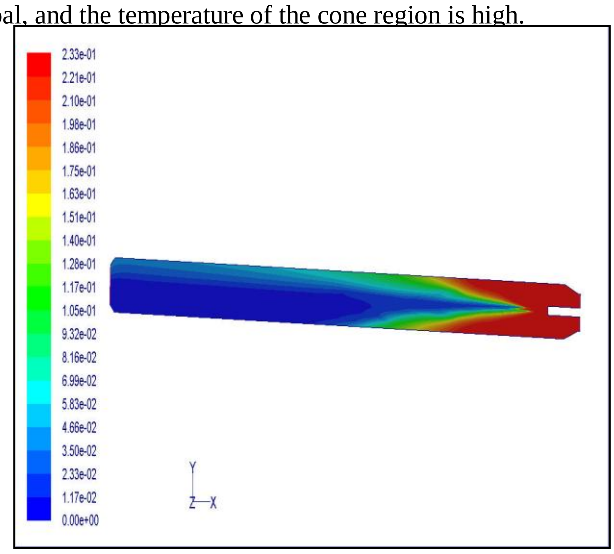

Figure 5. Oxygen Distribution in Rotary Kiln.

The distribution of pulverized coal particles: Fig. 6 is the distribution of the particles in the rotary kiln and the distribution of the residence time of the pulverized coal particles in the combustor.

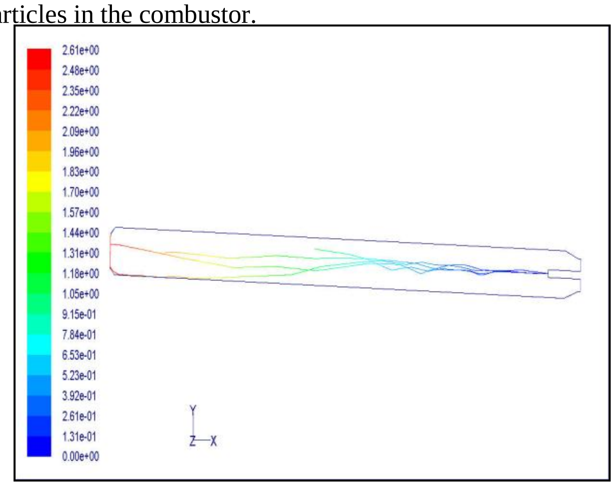

Figure 6. Distribution of Pulverized Coal Particles in Pulverized Coal Burner (8%)

IV. SUMMARY

The rotary kiln and the length of the vertical preheater is closely related to the. According to the relevant research [4] shows that in the rotary kiln calcination zone in the form of radiation heat transfer, about 80% of the total heat transfer, the remaining 20% in the form of convection heat transfer and heat conduction. The inner wall surface of the material covered by the material in the form of conduction and radiation, and it is absorbed by the heat of the kiln lining and the bottom material which is in contact with the material. In the rotary kiln, the heat transfer form of the pre decomposition zone (pre - tropical) is about 60%, and the remaining 40% is radiant heat transfer and heat conduction. In the production of lime, when the temperature of the high temperature flue gas is reduced, the radiation ability of the high temperature gas is greatly reduced. At this time, the heating of the limestone mainly depends on the convection heat transfer, but in the production of lime, the filling rate of the rotary kiln is very low, the material and the high temperature flue gas can not be fully exposed. Is the vertical preheater kiln needs to complete the convective heat transfer to preheat the chamber? Therefore, if the length of the rotary kiln is too long, the heat transfer efficiency will not increase significantly.

From the above calculation can be seen at high temperature flue gas temperature at 1100 degrees C, the thermal radiation will be greatly weakened, at this time, the heat loss of the rotary kiln, is no longer suitable for calcination in rotary kiln. Therefore, it can be seen that the high temperature flue gas at 1100 degree C is regarded as the limit point of the rotary kiln, and the heat exchange of the high temperature flue gas and limestone is carried out in the preheater. So the temperature point is an important parameter for the length of the rotary kiln.

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