

Numerical Analysis of the Factors about Combustion Stability on Boiler

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Abstrak

Melalui penelitian bubuk batubara terbakar dan mekanisme pembakaran terus-menerus, simulasi numerik boiler 300MW berbahan bakar bubuk batubara secara tangensial dengan perangkat lunak Coal-fire, dan menggabungkan data operasi boiler, hubungan yang sesuai antara hasil simulasi numerik dan pembakaran stabilitas ditetapkan. Hasilnya menunjukkan bahwa abu yang menguap lebih tinggi, isi lebih rendah dan kelembaban batubara, membantu aliran udara bubuk batubara untuk terbakar. Bubuk batubara yang lebih halus lebih mudah terbakar. Ketika beban boiler berkurang, itu akan mempengaruhi karakteristik "penyalan oleh diri sendiri" dari boiler bubuk batubara tangensial, dan akan menyebabkan pembakaran tidak stabil.

Kata kunci: boiler, sifat batubara, simulasi numerik, stabilitas pembakaran

Abstract

Through the research of the coal pulverized catches fire and steadily combustion mechanism, the numerical simulation of the 300MW tangentially pulverized coal fired boiler by Coal-fire software, and combine the operating data of the boiler, the corresponding relation between the result of numerical simulation and combustion stability have been established. The result indicates that the higher volatile matter, lower content of ash and moisture of the coal, it helps the coal pulverized air current to catch fire. More fineness coal pulverized is favorable to catch fire. When boiler load reduced, it will influence the characteristic "lighted by itself" of the tangentially pulverized coal fired boiler, and it will cause combustion unstably.

Keywords: boiler, combustion stability, numerical simulation, nature of the coal

1. Introduction

The 300MW tangentially pulverized coal fired boiler is one of the major equipment of power plants in China, and its operating conditions largely determine the economy and security of the entire plant's operation. So, the lack of mature theory and experience of the design and operation of the boiler resulted that cold and hot position test are required to determine the parameter of operation and design. In such kind of test, the cycle of the test is long and the cost is huge and it's difficult to get comprehensive and satisfactory data [1-3]. It's necessary to understand the inside process and fully simulate the turbulent flow through the numerical method.

Most of the existing literatures use general-purpose numerical software, Fluent for example, to study the combustion property of pulverized coal [4-8]. Because this kind of software did not consider the characteristics of the four corners tangentially combustion boiler specifically, there are insufficient in aspects such as vision of the grid, the set of solver and monitoring of the residual curve. The software, which was designed by 3 domestic research institutions which include North China Electric Power University the Canadian Energy Research Center and AEA-T and was funded by CIDA project and use several years to research, was designed for combustion property of tangentially pulverized coal fired boiler [9-11]. The software can consider the structure details of the tangentially pulverized coal fired boiler in detail and made calculation mode highly fine. The software can get the distribution field of furnace temperature, flow rate, flue gas composition, the detailed distribution of field particles, NO_x, etc, which has been verified by a large number of actual data through calculation. The trend of the main parameters which was predicted by the software can meet the need of adjustment of the actual burning operation [12-15], when coal for burning and operation mode change, the

characteristic of tangentially pulverized coal fired boiler is impacted. Any widely changing parameters such as coal, secondary air distribution, the pulverized coal concentration, the boiler load and comparing the numerical results, on the basis of actual condition which is difficult to adjust in actual condition such as Coal-fired heat, pulverized coal concentration of Primary air flow and temperature, can provide theoretical support for the safe and stable operation [16-18].

2. Simulation Object

The simulation object in this article is DG1025/18.2- IV subcritical reheat, natural circulation, coal-fired drum boiler, which is produced by Don Fang boiler plant. The boiler has Π -type arrangement and a single furnace, with pulverized coal storage system, DC swing burner, dry ash extraction. The entire group of burner include 5 layers of the primary air vent, 9 layers of secondary air vents and one layers of tertiary air vents.

Considering the impacts of changes of coal, pulverized coal fineness, load, secondary air distribution and tertiary air stop voting on changes to the boiler combustion characteristics [19], [20]. Table 1 shows two kinds of boiler burning coal elemental analysis, and the conditions of the boiler for the numerical simulation shows as Table 2.

Table 1. Burning coal elements of boilers

Coal	Car(%)	Har(%)	Oar(%)	Nar(%)	Sar(%)	Aar(%)	Mar(%)	ar,et,ar (kJ/kg)	Vdaf(%)
1	70.8	4.5	7.1	0.7	2.2	11.7	3.0	27800	24.7
2	58.2	4.3	6.3	1.1	0.8	28.1	1.2	22825	24.0
3	56.04	3.06	7.09	1.23	0.1	24.84	7.64	22306	22.28
4	67.34	3.98	10.81	0.73	0.01	10	7.13	18862	18.75

Table 2. Summary of numerical simulation of the conditions for the various conditions

Load (%)	Coal	Pulverized coal mass flow rate of each nozzle (kg/s)	Primary air velocity (m/s)	Pulverized coal concentration (kg/ kg)	The velocity of second air(m/s)				Tertiary air velocity (m/s)
					1	2	3	4	
100	Lean coal	2.25	31	0.45	53	45	34	40	37
100	Bituminous coal	1.89	26	0.45	53	45	34	40	31
100	Bituminous coal	2.25	31	0.45	43	43	43	43	37
100	Bituminous coal	2.25	31	0.45	34	40	45	53	37
100	Bituminous coal	2.25	31	0.45	53	45	40	34	37
80	Bituminous coal	1.8	25	0.45	43	36	27	32	27
60	Bituminous coal	1.35	18.6	0.45	32	27	21	24	23
100	Bituminous coal	2.25	31	0.45	53	45	34	40	37

3. Boundary Condition of Numerical Calculation

The area between hopper-shaped bottom and furnace arch was selected as computation domain which adopt unstructured tetrahedral element, the furnace width direction was selected as X direction, the furnace depth direction was selected as Y direction, the furnace height direction was selected as Z direction were divided into 16 units, 508896 grids. Numerical simulation adopts three-dimensional steady-state calculation. This article adopt standard $k-\epsilon$ two-equation model to simulate turbulence meteorological flow. The solution of solid particle phase adopt random particle trajectory model. Radiation heat transfer adopt P1 radiation mode. Release of coke adopt simple method which has non-staggered grid. On the basis of residual judge convergence, the convergence criterion is that the relative error of all the computation must be less than 10^{-4} . Furnace mesh shows as Figure 1.

Through numerical calculation, we can obtain dates such as center section/ the temperature distribution of burner region, flue gas temperature distribution of furnace exit, the heat load of the furnace wall, oxygen distribution of furnace exit, CO distribution of furnace exit, Carbon content of fly ash of furnace exit, etc.

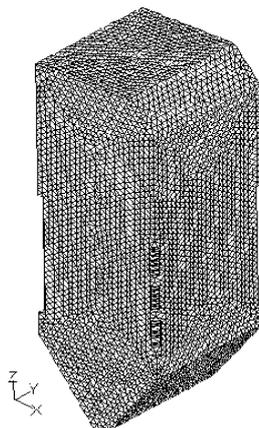


Figure 1. Furnace mesh

4. Analysis of the Numerical Calculation Result

There are many factors that can impact the ignition of Tangentially Pulverized Coal Fired Boiler and combustion stability. For the parameters that change frequently in operation, we can get the conclusion through theoretical analysis and numerical calculation. From fuel and combustion, factors that impact ignition and combustion stability mainly include ignition performance of coal itself and the way of air distribution of the burner, air temperature, air flow, wind speed, coal fineness, excess air ratio, furnace temperature.

From the factor of the furnace structure, it mainly includes heat load of cross-section and the wall of burner region. The results can be get that the relevant data such as regional wall heat load of the furnace cross-section heat load and the burner. Also the relevant data such as the temperature of the exit section, oxygen, carbon monoxide, fly ash carbon content and radioactive heating surface, heat load in the furnace exit section through numerical calculation. Establishment of burning the correspondence between the stability index and the numerical results can help us make the evaluation on fuel ignition and combustion stability. Correspondence between the combustion stability index and the numerical results are shown in Table 3.

Table 3. the corresponding relationship between the X and Y

The actual operating conditions $Y=F(X)$	Combustion stability indicators Y	The corresponding numerical results X
Pagoda down the pagoda, equal Air Distribution	Oxygen concentration	oxygen distribution of furnace exit as received basis calorific value
Coal(Volatile matter, moisture, ash)	Combustion heat of reaction	Carbon content of fly ash of furnace exit
Concentration of pulverized coal	The concentration of combustible mixture of fuel	

4.1. The Influence of Mar

The bituminous coal's moisture (Mar) change from 4.3% to 24% (assume that ash of as received basis reduce accordingly), the relationship between coal's moisture (Mar/%) and ignition temperature ($t/^\circ\text{C}$) and the relationship between coal's moisture (Mar/%) and activity energy ($E/(\text{kJ/mol})$) are shown in Figure 2.

It shows that ignition heat will increase with the bituminous coal's moisture (Mar) get bigger. At the same time the pulverized coal flow's ignition temperature will increase as ignition heat increase. Because a part of the combustion heat consumes on heating moisture and its vaporization and thermal consume a part of combustion heat, furnace flue gas temperature will reduce. It's unfavorable to ignition. On the other hand, as the inner water analysis from the pulverized coal, the porosity of cal will increase, that is the activity increases, activation energy decrease. The increasing of activation energy of coal will make pulverized coal easy fired. In

this regard, moisture in the coal is favorable to stability of ignition. Overall, the increasing of moisture in the coal will cause the difficulties of flow's ignition and make stability worse.

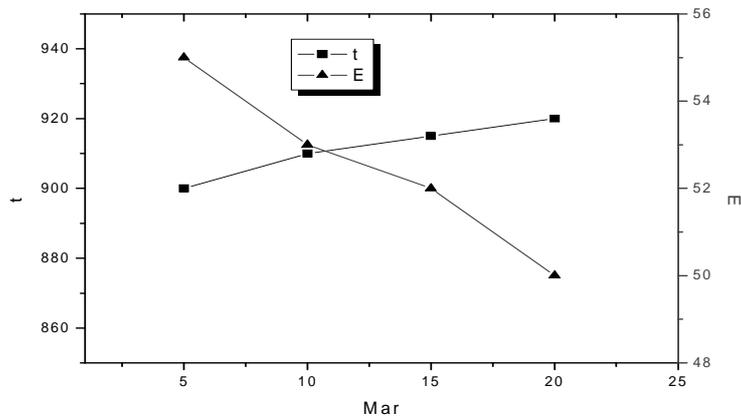


Figure 2. The relationship between coal-fired t/E

4.2. The Influence of Aar

Figure 3 shows how ash impact combustion stability. In the same case that the primary air and air quantity were constant, as the ash in the fuel increase, its ignition heat will increase. At the same time, the increase of ash will make theoretical combustion temperature decline. Because heating ash will increase heat consumption and decrease the average temperature within the furnace, pulverized coal flow will fire and combustion stability will be worse.

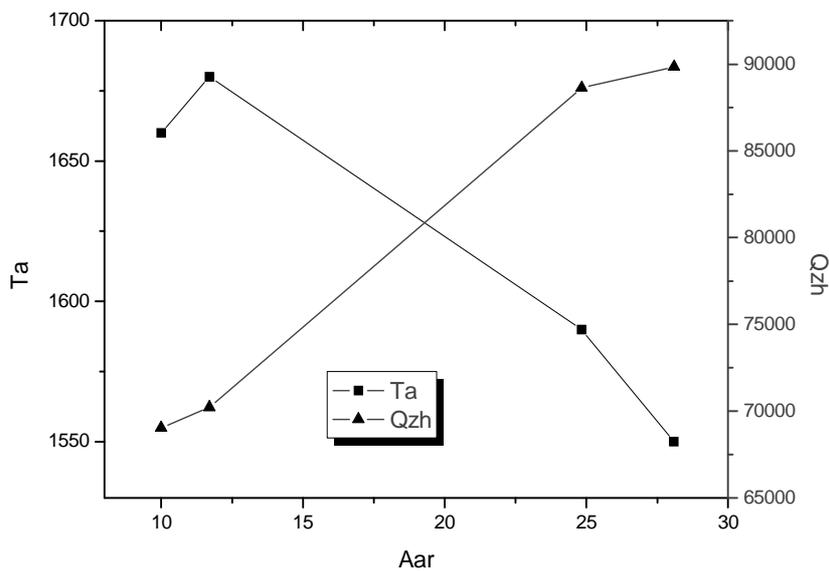


Figure 3. The relationship between Coal ash Aar/ignition heat/Ta

4.3. The Influence of Coal Fineness

The relationship between coal fineness and ignition temperature is that ignition temperature of pulverized coal decline apparently as fineness become thinner in that the decreasing of the size of pulverized coal particle can increase the relative surface area of combustion reflects and

decrease activity energy of pulverized coal particle. the decreasing of size of pulverized coal can increase relative surface and decrease the heat conduction resistance. In this way, reaction will react faster and pulverizes coal can absorb outside heat faster to fire .So in general , fine pulverized coal will burn first. Coarse pulverized coal makes ignition delay and makes combustion stability worse. This means that some boilers fueled with low volatile cal ,the peak of boiler's efficiency is not at the maximum rated load, but at the load that less than rated load. That is because pulverized coal's fineness is thinner when pulverizing system at low load.

5. Conclusions

The property of fuel and a good furnace combustion environment are the determine factors that tangentially pulverized coal fired boiler can sustain stable combustion. The quality of fuel, such as volatile, moisture and ash content, have a significant impact on ignition of pulverized coal flow and combustion stability. The coals which have a high volatile have a low ignition temperature. It's not only easy to fire, but has good combustion stability. The coals which have a high ash have a high ignition heat and it is difficult to fire. In the inner area of coal particles used for reaction will increase after internal moisture evaporate from pulverized coal, and improve its ignition capability ,but because a part of the combustion heat consume on heating moisture and its vaporization and overheat, increase the ignition heat. The overall effect makes it difficult to fire.

The ignition temperature of pulverized coal will reduce with pulverized coal fineness thinning; this is because the small pulverized coal particle size can increase the relative surface area of combustion, decrease the activation energy of the coal particles correspondingly. The small pulverized coal particle size can increase the relative surface area of combustion, and reduce the pulverized coal thermal conductivity resistance, so that the coals can absorb outside heat more quickly to reach ignition. When the boiler load is reduced, because the furnace temperature reduces to the low level, it will result in lack of heat source of pulverized coal ignition. It is not conducive to the ignition of pulverized coal. When the boiler load is reduced to a certain extent, it will endanger the stability of the fire, or even cause the flame turn off.

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