Effect of coal moisture on denitration efficiency and boiler economy

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ABSTRACT: Taking a coal-fired unit as the research object, the denitrification efficiency and cost of SCR system are analyzed under burning-coal with different moisture. Though thermal calculation, the gas inlet temperature at SCR system was calculated, then the denitrification efficiency was gotten from the graph of denitrification efficiency and SCR system inlet temperature. Then the costs of the coal and SCR system operation were estimated . The results showed that as the coal with 35% moisture dropped to 15% moisture, the gas inlet temperature of SCR system deceased about 10˚C,denitrification efficiency increased to 67.4% from 54.3% and the cost of coal and SCR system operation dropped more than 24 million a year.

INTRODUCTION

Coal quality is an important factor influencing the boiler running economy and environmental protection. In reality, due to factors such as the unstable coal quality , a variety of non-designed coal has been burned to meet the coal combustion and environmental requirements. Based on the above reasons, this article will study on the relationship among the moisture content in the coal and SCR inlet smoke temperature and denitration efficiency and so on.Many scholars have conducted in-depth study and achieved fruitful results about the content of this article.Including the influence of coal quality on the exhaust temperature, boiler efficiency, coal consumption[1,2]slagging,the stability of combus-tion[3] and the change on the boiler thermal effi-ciency[4]. Coal moisture changes have the effect on the power plants economy[5-7].

On the basis of previous studies and in the view of environmental protection, this paper will focus on the influence of coal moisture on the denitration efficiency and economy. First we should calculate the coal moisture influence on the SCR inlet smoke temperature. Then, building a relationship between coal moisture and denitration efficiency according to the SCR inlet smoke temperature and denitration efficiency curve. Thus it is concluded that the influ-ence of coal moisture on the denitration effici-ency.Using the calculation results to discuss further the situation of the boiler economic operation. It provides the reference for the denitration efficiency improved and costs reduced.

Research object

Taking a power plant boiler and its checking coal types of Guangdong as a object, its as-received moisture was 35% and the calorific value is 12800 kJ/kg. Gradually reducing the moisture on the basis of this standard was 35%, 30%, 25%, 20%, 15%. The other components changed accordingly. The change of calorific value can be calculated accord-ing to the following formula (1)[8] .

The influence of coal moisture on received low calo-rific value:

$$Q_{ar0,net,p} = (Q_{ar1,net,p} + 25M_{ar1})\frac{(100-M_{ar0})}{(100-M_{ar1})} - 25M_{ar0} \quad (1)$$

where $Q_{ar0,net,p}$ is the low calorific value of raw coal; $Q_{ar1,net,p}$is low calorific value of changed coal;M_{ar0} is the water of raw coal; M_{ar1} is the water of changed coal.The calculation results are listed in Table 1.

Table.1 The elemental and industrial analysis of coal

Coalquali-ty	Moisture (%)	Carbon(%)	Hydrogen(%)	Oxygen (%)	Nitrogen(%)	Sulfur(%)	Grey(%)	Low calorific valuekJ·kg^{-1}
Raw coal	35	34.35	2.85	10.64	0.70	1.08	15.7	12800.0
Coal mois-ture cha-nges	30	37.00	3.07	11.46	0.75	1.17	16.5	13976.9
	25	39.64	3.29	12.28	0.81	1.25	17.7	15153.8
	20	42.28	3.51	13.10	0.86	1.34	18.9	16330.7
	15	44.92	3.73	13.92	0.92	1.42	20.1	17507.6

The composition of each element were received as standard

The former electric power ministry to the power plant coal quality parameters range have a clear a regulation that the coal quality parameters based on boiler designed coal, such as in Table 2.

Table. 2 Coal quality allowed change range

Coal quality	V_{daf} deviation (%)	A_{ar} deviation (%)	M_{ar} deviation (%)	$Q_{net,ar}$ deviation (%)	ST deviation (%)
Lignite	—	-5~+5	-5~+5	-7~+7	-8

Where V_{daf}, Aar and Mar are the absolute deviation from designed value;$Q_{net,ar}$ and ST are the relative deviation from designed value.

Coal moisture range is from -5% to 5% . Due to the reasons such as power plant coal storage conditions and the type of coal and the weather changes, the scope of boiler coal moisture change is difficult to meet the above requirements.Therefore, studying the effect of moisture on SCR inlet smoke temperature has a realistic significance. In addition, the require-ments of water deviation between the largest and smallest is about 10%.However the water deviation calculated is about 20% considering the actual situa-tion.

Results and discussion

This paper is calculated to full capacity for the same boiler and coal. The moisture in coal were 35%, 30%, 25%, 20%, 15%, respectively.Then the thermodynamic calculation for coal with different water were carried out[10].Some results are listed in Table 3.

Table 3 the part thermodynamic calculation results

Computer projects	Raw coal	Moisture changes			
Moniture in coal/%	35%	30%	25%	20%	15%
Smoke quantity/$m^3 \cdot kg$	5.24	5.87	5.94	6.02	6.17
Theoretical combution temperature/°C	1814.73	1859.52	1907.63	1940.5	1954.56
Exhaust gas temperature/°C	150.60	143.10	135.50	130.80	128.80
Boiler thermal efficiency/%	91.65	91.87	92.46	92.74	93.14
Fumace exit gas temperature/°C	996.25	997.72	994.52	987.96	985.48
Actual fuel consumption/$kg.h^{-1}$	222233.6	219483.0	215461.4	212864.8	210956.4
SCR inlet smoke temperature	414.95	414.98	413.94	410.87	405.93

The coal calculated is derived from raw coal which changed water content. In order to analyze the subsequent boiler economy, different moisture of coal consumption(B') have converted into corresp-onding raw coal consumption(B) according to the type (2) in the Table 3.

$$B = B' \cdot \frac{100 - M'_{ar}}{100 - M_{ar}} \qquad (2)$$

where Mar is the raw coal moisture, Mar is the moisture of coal quality after changed.We can see from Table 3 that coal consumption is arising trend with the increase of coal moisture.This is because the reduced moisture increase calorific value.When the water rose from 15% to 35%, coal consumption rose from 210956.4$kg \cdot h^{-1}$ to 222233.6 kg h^{-1}. Unit fuel can produce smoke gas quantity from 6.17 $m^3 \cdot kg^{-1}$ down to 5.24 $m^3 \cdot kg^{-1}$ and reduce the rate of 9.53%.

The influences of coal water on the smoke temperature

The relations between coal with different water and SCR inlet smoke temperature, combustion and exhaust temperature are shown in Fig 1. As you can see, SCR inlet smoke temperature with the same as outlet smoke temperature from heating surface with declining coal moisture. This is a real downward trend.When moisture content decreased from 35% to 15%,SCR inlet smoke temperature dropped nearly 10˚C. Theoretical combustion temperature rose from 1814 ˚Cto1954 ˚C and rose by about 140 ˚C.Exhaust temperature reduced from 150˚C to 128˚C and fell by about 22˚C.

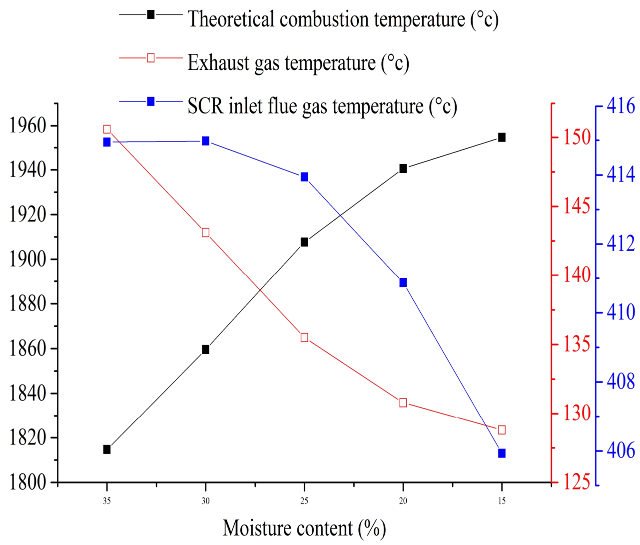

Fig. 1 SCR inlet temperature ,exhaust temperature and smoke theoretical combustion temperature

This trend may be due to the reason that coal moisture increased from 15% to 35% making calorific value of coal fell.The theoretical com-bustion temperature will be greatly reduced. At the same time, it also will lead to a rise in coal consumption.Therefore, the smoke quantity will rise sharply. Increased smoke volume and lower com-bustion temperature will reduce the effect of heat convection at the heating surface.The flue gas temperature dropped amplitude decreases and the logarithmic temperature difference of heating sur-face reduces.So the temperature dropped along the gas flow direction become smaller.The SCR inlet smoke temperature and exhaust gas temperature are increased.

The influences of coal moisture on the denitration efficiency

The relations between SCR inlet smoke tem-perature and denitration efficiency are shown in Fig.2.The figure shows that when SCR inlet smoke temperature changes in the range of 380˚Cto 396 ˚C, the denitration efficiency increased with the rise of the flue gas temperature. Denitration efficiency reached the maximum when the flue gas temperature is 396˚Cor so. So the plant denitration system optimum reaction temperature is 396 ˚C.When the smoke temperature continues to rise, denitration efficiency began to decline.When the smoke temperature rise to about 410˚C, denitration efficiency would be reduced to 59.8%.

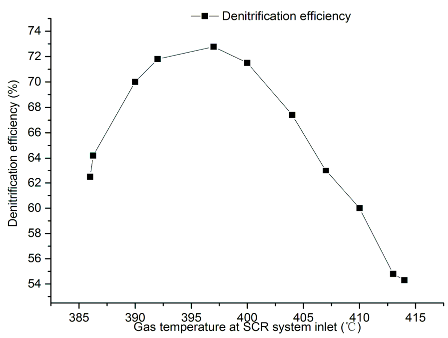

Fig. 2 Influence of flue gas temperature on the denitration efficiency

According to the Fig.2 and the calculated SCR inlet smoke temperature, we get the relations among coal moisture, SCR inlet smoke temperature and denitration efficiency. It is listed in Table 4.

Table. 4 Relations among coal moisture, SCR inlet smoke temperature and denitration efficiency.

Computing projects	Raw coal	Moisture changes			
Moisture in coal/%	35%	30%	25%	20%	15%
SCR inlet smoke temperature/°C	414.9	414.9	413.9	410.8	405.9
Denitration efficiency/%	54.3	54.3	54.8	60	67.4

Table. 4 shows that when raw coal moisture up to 35%, denitration efficiency is about 54%. Denitration efficiency increases when the raw coal moisture falling.Coal moisture decreased from 35% to 15%, the denitration efficiency increased from 54.3% to 67.4%.The reasons for the trend is likely to be SCR inlet smoke temperature (denitration temperature) of the research units is higher than that of catalyst optimum reaction temperature.When the denitration temperature is greater than the optimum reaction temperature, the NH_3 will react with O_2 and NO_X generated. Den-itration efficiency become lower because of higher concentration of NO_X[11-13]. It appears a phenom-enon that denitration efficiency decreases with the increase of denitration tem-perature .

The influences of coal moisture on the denitration cost

Fuel consumption decreased by 11277.2 kg/h when coal moisture decreased from 35% to 15%.According to the provided data from power plant, a ton coal prices by 360 yuan and the boiler running 6000 h a year, which can get coal cost down 24.3588 million yuan a year. Coal moisture content is reduced causing nitrogen element content is relatively higher, but the total coal consumption is decreased. For convenient, SCR inlet NO_X concentration is calculated according to the designed standard of 550 mg/m^3. NO_X emissions can be calculated from the smoke gas quantity and denitration efficiency. The environmental protection department for NO_X emissions proves fee methods[14]. With 200 mg/m^3 for the prescribed discharge standards can calculate the corresponding NO_X fines. Further increases in denitration effi-ciency will increase ammonia consumption and the cost of denitration. Ammonia consumption costs will be achieved under the condition of ammonia nitrogen ratio 1:1. 2 and ammonia price 3000 yuan a ton. This article will ignore other costs such as the artificial and denitration operation electricity. It is adopted that small proportion in the cost of coal and denitration .All the results are listed in Table 5.

Table 5 The summary of estimated cost（ten thousand yuan a year）

Moistue in coal (%)	Coal-fired cost	Polluta-nts fines	Ammonia consumption cost	Combined cost
35	48002.46	2985.52	425.68	51413.66
30	47408.44	3303.08	470.96	51182.48
25	46539.66	3245.32	472.15	50257.13
20	45978.80	2875.56	517.60	49371.96
15	45566.58	2380.44	590.58	48537.60

Table 5 shows that coal cost can save 24.3588 million yuan/year when the coal moisture content decreased from 35% to 15% .At the same time due to the denitration efficiency increased and pollutant emissions reduced,and the charges for pollutant emissions reduces about 6 million yuan a year.With the corresponding cost of ammonia caused by the increase of ammonia consumption increased about 1.65 million yuan a year.Through comprehensive analysis,with the Coal moisture reduction, it is that the cost of coal will be reduced. With denitration efficiency increased , the cost of denitration operation would be blow down.At the same time the catalyst is not easy to jam because coal moisture reduced.The service life of the catalyst improved can save catalyst replacement cost indirectly.So the reduced coal moisture will eventually bring the high economic benefits for power plant.

Summary and conclusions

This paper conducted thermodynamic calculation aiming at a coal-fired units checking coal with water content of the different types.It analyzed the influence of coal moisture on the flue gas temperature at heating surface, especially the influence on SCR inlet smoke temperature.The calculation results show that:

1)With coal moisture content decreased from 35% to 15%, the overall declining SCR inlet smoke temperature showed a declining trend and the falling range is about 10 ˚C.

2)With coal moisture content decreased from 35% to 15%, the denitration efficiency increased from 54.3% to 67.4% and ascensional range is about 13%.

3)With coal moisture content decreased from 35% to 15%, the coal consumption of unit reduced. The coal cost has fallen dramatically and saved 24.3588 million yuan a year.

4)Denitrationefficiency increased when the coal water reduced. Pollutant discharge fees dropped by about 6 million yuan a year.But the cost of ammonia consumption increased about 1.65 million yuan a year.

5)In a word, when the coal moisture content decreased from 35% to 15%, total coal and denitration operation cost down 28.76 million yuan a year and greatly reduces the power plant operation cost.At the same time pollutant emission reduction can reduce the environmental pollution.So, reducing the coal quality water not only has economic benefits but also the environmental benefits for power plant.

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