The Research on ESP Adaptability for Chinese Coal Under 30mg/m^3 Dust Emission

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1 Abstract:

Electric precipitator plays an absolutely leading role in countries such as Europe, America, Japan, etc. which have issued much more strict dust emission regulation. But the emission standard of 30mg/m^3 to be stipulated by China makes china's some management departments and users express concern about the ESP. 122 types of China domestic coal which are used in Chinese power plants in recent 3 years are analyzed, furthermore, the performance of ESP which are in operation is studied. The textual criticism on ESP adaptability for China domestic coal is fulfilled. The result shows that ESP can meet the dust emission demand of 30mg/m^3 with good economy for 86.06% of the China domestic coal. Thus, ESP still has continuing broad adaptability and is the most ideal dust removal equipment which is wholly suited to conditions in China.

Keyword：30mg/m^3; dust emission regulation; coal; electrostatic precipitator; adaptability

2 Foreword

The development history of electrostatic precipitator has more than 100 years. It has already become the preferred products of industrial dust removal equipments, especially in thermal power industry, due to its unique advantages such as high efficiency of dust removal, a wide range of adaptation, low operation costs, high reliability, easy to use and no secondary pollution, etc. "China's Dust Emission Standard" was proposing to increase the maximum emission standards from 50mg/m^3 to 30mg/m^3. Whether ESP is still adapting for Chinese coal, according to the high standard emission requirements, is the focus issue which ESP industry should pay attention to. This article is based on the components, contents and distributions analysis of coal, flying ash samples, and the analysis of its impact on ESP performance and the statistics of measured results of Chinese ESP Projects and economic analysis to study ESP adaptability for Chinese coal under 30mg/m^3 dust emission.

3 The statistics of Chinese 122 types coal, flying ash samples' components, contents and distributions

The author analyzed 122 kinds of coal's coal, flying ash samples' main components, which are using in 138 ESP projects of Coal-fired Power Plants which are bided from 2006 to 2008 in China. The main components, contents and distributions are shown in Table 1.

Table 1 The main components, contents and distributions of Chinese coal, ash samples

component	range	average value
S_{ar}	0.11%~5.13%	0.87%
Na_2O	0.02%~3.72%	0.69%
Fe_2O_3	1.52%~25.88%	7.84%
K_2O	0.12%~4.17%	1.16%
MgO	0.17%~6.37%	1.35%
Al_2O_3	9.04%~46.5%	26.33%
SiO_2	20.7%~70.3%	50.18%
CaO	0.6%~28.47%	6.34%

4 The analysis of coal, flying ash compositions impact on ESP performance

4.1 Basic formula of ESP efficiency and average migration velocity ω_k

Deutsch Equation has been the ESP design formula:

$$\eta = 1 - e^{-\omega \bullet A/Q}$$

Where as: η—collection efficiency of the precipitator (%), Q—gas flow through the precipitator (m^3/s), A—the effective collecting plate are of the precipitator (m^2), ω—migration velocity (m/s).

This formula still applies now. But the weak points are that it assumes particle size is a constant, the mixture of dust and air in the very distance space is completely homogeneous, and these assumptions rarely appear.

In 1964, the Swedish expert Sigvard Matts modified Deutsch Equation and used average migration velocity into the concept.

$$\eta = 1 - e^{-(\omega_k \bullet A/Q)k}$$

Where as k is a constant. $\omega_k = f(\eta)$ curve has different forms when choosing different k values. When k=1, ω_k equals to ω , it is Deutsch Equation. Many data shows that when k=0.5, $\omega_k = f(\eta)$ is nearly the constant. ω_k is no longer tending to the required efficiency. It can be seen as Precipitation Parameter. As ω_k overcomes many applications' size distribution problem is made it more convenient to use,and applies in a wider range of collecting efficiency.

4.2 The analysis of coal, flying ash compositions impact on ESP performance

Factors which affect ESP performance are complex, but generally they can be divided into three catalogues. First of all is working conditions (i.e., coal composition, flying ash composition, flue gas composition, dust size, etc.). Secondly is technical condition of ESP. Thirdly is operating conditions. The first factor's coal, flying ash compositions have maximum influence on ESP performance among three of them.

4.2.1 The influence of coal composition

The main factors that will influence on ESP performance are S_{ar}, water and ash among the coal compositions, whereas S_{ar} has most influence on ESP performance. Coal with high S_{ar} content, its gas contains more SO_2. Under certain conditions, SO_2 will turn into SO_3 with a certain percentage. Also, SO_3 can easily adsorb on the surface of dust and improves the surface conductivity of dust. Under the working conditions, the higher the S_{ar} content, the lower the dust resistivity. It will take advantage of collecting dust with a higher ω_k and play a benefit effect on ESP performance.

As shown in Fig.1, the author was using ω_k to characterize ESP performance and computing the curve between one typical coal of 122 types Chinese coal with S_{ar} content and ω_k.

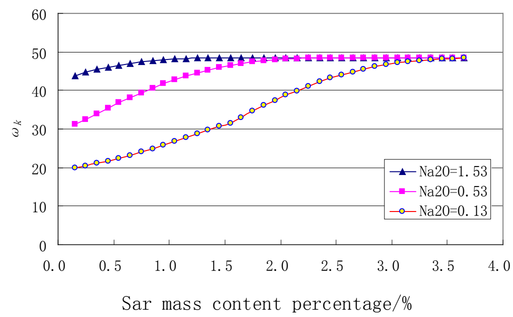

Fig.1 the relationship between ω_k and S_{ar} content

Three curves in the Figure 1 correspond to the changes between three different Na_2O contents in ash and ω_k. From Figure 1, we can see that: With the increase of S_{ar} content, the overall trend of curve is upward. It shows that the S_{ar} in coal will have a beneficial effect on ESP performance. In another word, with the increase of S_{ar} in coal, it is propitious to enhance dust removal performance of ESP. S_{ar} impacts on the dust removal performance has a direct relationship with alkaline oxides, namely S_{ar} and alkaline oxides in the ash (mainly composed of Na_2O, Fe_2O_3) result the influence on the dust removal performance. S_{ar} plays a leading role on ESP performance when S_{ar} is high in the coal and S_{ar} is relative weaker when S_{ar} is low in the coal. ESP performance is mainly depending on alkaline oxides in the flying ash, water content and temperature in the flue gas.

The impact of water is obvious. Coal with high water, the humidity of gas is also large. So the dust's surface conductivity is good, and the resistivity is lower. Water plays an important role in ESP performance in the high water content coal-fired boiler.

The level of ash in the coal directly determines the dust concentration in the flue gas. For a specific process, ω or ω_k will increase when dust concentration is increasing. However, when dust concentration is too large, it will produce sealing of corona. When flue gas contains high dust concentration in the same dust export emissions, the design of collecting efficiency requirements are high. And at the same time, it will consume a large amount of surface conductive materials and reduce a lot of beneficial effects on high-sulfur, high-water. In general, high level ash effects on ESP performance is detrimental.

4.2.2 Flying ash composition's influence

Flying ash mainly includes Na_2O, Fe_2O_3, K_2O, SO_3, Al_2O_3, SiO_2, CaO, MgO, P_2O_5, Li_2O, MnO_2, TiO_2 and combustible flying ash and other components. Na_2O, Fe_2O_3, Al_2O_3 and SiO_2 effect ESP performance a lot and the others affect less. In this article, it will not be discussed. As shown in Fig.2, 3, 4 and 5, the curves show the relationship between Na_2O, Fe_2O_3, Al_2O_3 and SiO_2 and ω_k.

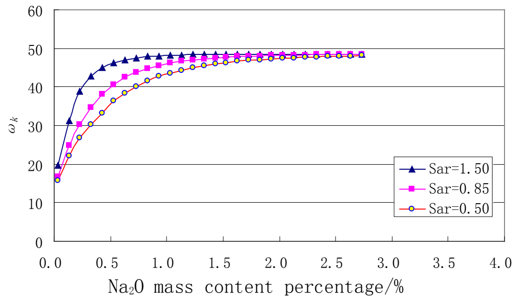

Fig.2 the relationship between ω_k and Na_2O content

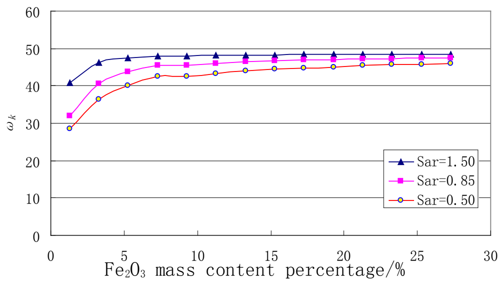

Fig.3 the relationship between ω_k and Fe_2O_3 content

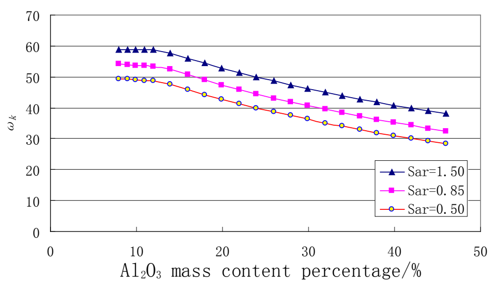

Fig.4 the relationship between ω_k and Al_2O_3 content

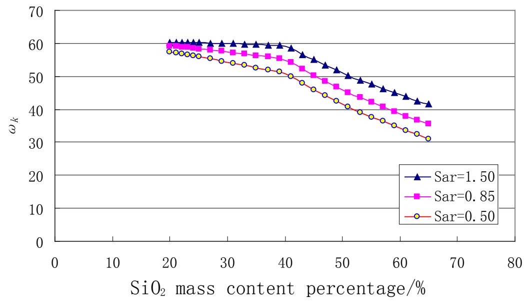

Fig.5 the relationship between ω_k and SiO_2 content

Three curves in the Figure 2, 3, 4 and 5 correspond to the changes between three different S_{ar} contents in coal and ω_k. Na_2O and Fe_2O_3 play advantaged influence on dust removal performance. However, Al_2O_3 and SiO_2 play disadvantaged influence on it. Flying ash compositions effect on ESP performance is directly related to S_{ar} content. And the influence on dust removal performance is the comprehensive results of flying ash composition and S_{ar}. S_{ar} plays a leading role when Na_2O, Fe_2O_3 contents are smaller and Na_2O, Fe_2O_3 play a leading role when Na_2O, Fe_2O_3 contents are bigger.

5 The research on ESP adaptability under 30mg/m^3 dust emission

5.1 Evaluation of ESP dust precipitation degree for Chinese coal

Generally speaking, coal and flying ash compositions have a direct impact on ω_k value. As shown in Table 2, the value of ω_k can evaluate the dust precipitation degree of ESP. The bigger the ω_k value, the better the ESP's collecting efficiency. Thus, the ESP performs much better.

Table 2 Evaluation of ESP dust precipitation degree for Chinese coal

ω_k	precipitation degree
$\omega_k < 25$	difficult
$25 \le \omega_k < 35$	a bit difficult
$35 \le \omega_k < 45$	general
$45 \le \omega_k < 55$	a bit easy
$\omega_k \ge 55$	easy

5.2 The statistics of Chinese coal and flying ash ω_k analysis

In this article, 122 types Chinese coal, flying ash samples were calculated and its ω_k distribution shown in Fig.6. From the figure we can see that ω_k varied from 20 to 63.1, with an average of 45.26. The dust removal performance of three types coal which occupy 2.46% of total coal are difficult when ω_k <25. The dust removal performance of fourteen types coal which occupy 11.48% of total coal are a bit difficult when 25≤ ω_k <35. The dust removal performance of forty types coal which occupy 32.79% of total coal are general when 35≤ ω_k <45. The dust removal performance of forty-nine types coal which occupy 40.16% of total coal are a bit easy when 45≤ ω_k <55. The dust removal performance of sixteen types coal which occupy 13.11% of total coal are easy when ω_k ≥55. All in all, dust removal performance of coal samples which occupy 86.06% of the total coal are general.

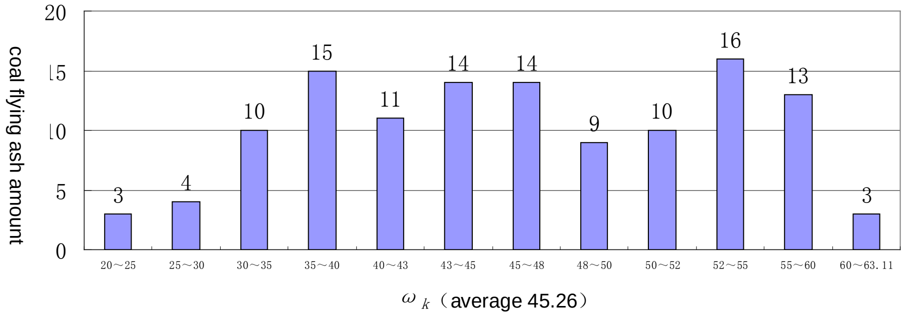

Fig.6 The distribution of of 122 types Chinese coal, flying ash samples

5.3 ESP measured results analysis

The author counted the tested measured results of China domestic 100 sets of over 300MV units supporting ESP during July 2004 and December 2009. The measured collecting efficiency which meets the design ensured efficiency has 96% of the total ESP. Under the circumstances of electric field number is essentially four and specific dust collection area is less than 110 $m^2/(m^3/s)$, ESP of the export dust concentration ≤50 mg/m^3 occupy 60% of the total number, and ESP of the export dust concentration ≤30 mg/m^3 occupy 18% of the total number among them.

Meanwhile, the author counted the tested measured results of China domestic 175 sets of over 600MW units supporting ESP during January 2002 and April 2010. All of the measured ESP meet the design requirements. Under the circumstances which are low electric field number and low specific dust collection area of electric field number is essentially four and specific dust collection area is 80～110m^2/（m^3/s）, 83 sets ESP of export dust concentration ≤50mg/m^3 occupy 47.4% of the total tested number, and 22 sets ESP of the export dust concentration ≤30mg/m^3 occupy 12.6% of the total tested number.

5.4 The using status of overseas ESP

Based on information, we can know that American dust emission limits are 20 mg/m^3, while the using ratio for ESP is 80%. Germany and other European countries dust emission limits are 30mg/m^3, while the using ratio for ESP is more than 85%. Recent years,
in order to apply in the low-sulfur coal, ESP specific dust collection area is 120～150m^2/（m^3/s）, homopolar distance is 400mm and the actual dust emission is 10～20mg/m^3. Japanese dust emission limits are 20 mg/m^3 and they are almost using ESP. They are using low-temperature and mobile electrode ESP technology to achieve low emissions requirements. It is worth mentioning that if coal-fired power plants in the above mentioned developed countries are using wet flue-gas desulphurization, almost all of the dust removal equipments are using ESP, due to the wet flue-gas desulphurization has about 60% collecting efficiency.

Based on analysis, it can be drawn that for the majority Chinese coal, 30 mg/m^3 or even lower export dust concentration can be achieved when ESP are using the right electric field number and specific dust collection area.

5.5 Economic analysis

When reaching 30mg/m^3 dust emission condition, we can create a new set of 600MV units supporting dust removal equipment as example (for flue gas volume is at 3,600,000m^3/h, electricity fee is at 0.4Yuan/kWh, operating time is at 7500h/year), several key design parameters of dust removal equipment is set to: (1) ESP has two kinds of specifications: 5 electric fields, specific dust collection area is about 110m^2/（m^3/s） and 6 electric fields, specific dust collection area is 135 m^2/（m^3/s）. (2) Bag Filter: The filtration velocity is 1m/min. Bag: PPS, importing fiber, 550g/m^2, PTFE surface treatment and the life cycle is counting for 3 years. (3) Electric Fabric Filter: The electric area is 2 electric fields, 90% collecting efficiency and filtration velocity is 1.2m/min. Bag: PPS, importing fiber, 550g/m^2, PTFE surface treatment and the life cycle is counting for 4 years. ESP and Electric Fabric Filter are both using energy saving operating mode.

Based on the calculating, it can be drawn that the power consumption costs of 5 electric fields ESP, 6 electric fields ESP, bag filter, electric fabric filter (including the induced draft fan, air compressor system) are 1.92 million, 2.13 million, 4.83 million and 4.22 million Yuan respectively. On this basis, it can be calculated together with the cost for replacement of wearing parts that the annual operating costs are 2.31 million, 2.52 million, 8.71 million and 5.88 million Yuan respectively. The one-off investment cost coefficients of 5 electric fields ESP, 6 electric fields ESP, bag filter, and electric fabric filter are 1.02:1.2:1:1.15. If the one-off investment cost of bag filter is 30 million Yuan, the proportions of the total cost of 5 electric fields ESP, 6 electric fields ESP, bag filter, and electric fabric filter are 0.88:1.03:1:1.04 after one year, 0.47:0.54:1:0.80 after ten years and 0.35:0.40:1:0.72 after thirty years.

Based on the above information, the energy consumption, operating cost and total cost of equipment are the lowest under energy saving operating conditions of ESP. The economy of ESP is much more notable when the operating time is longer. The total cost of 6 electric fields ESP is about half of bag filter after the equipment is running ten years. ESP not only has a wide range of adaptability, even by using 6 electric fields ESP, but also still has a better economy under 30mg/m^3 dust emission standards.

6 Conclusions

Based on the analysis of coal, flying ash compositions impact on ESP performance, the statistics of Chinese coal and flying ash analysis, ESP measured results analysis and economic analysis, it can be drawn that the number of coal which suit ESP dust removal occupy 86.06% of the total amount when we are using appropriate number of electric field and specific dust collection area under 30mg/m3 dust emission standards. While ESP still has a better economy and it is still the ideal dust removal equipment which suits China's national conditions.

7 Literature

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