Research on Vibration Period Optimization of Electrostatic Precipitator

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Abstract: The normal operation of the vibration equipment and the dust removing equipment of EP is an important factor to ensure EP in a safe, stable and efficient running and has a direct influence on the efficiency of EP and the working life of the related equipments. According to statistics, in electrostatic precipitators which collection efficiencies were less than 95%, it was mostly caused by the bad vibration effect. The vibration periods of each electric field were analyzed by researching the rule of ash-deposition; the influence of boiler load, fly ash coefficient, carbon content in fly ash and dust content consistency in flue gas on vibration period was analyzed by calculating with vibration period calculation formula; giving an example to show the EP at a coal-fired boiler, the vibration periods of each electric field which were calculated theoretically based on the coal and the evaporation capacity were compared with the actual vibration periods to ensure and adjust vibration periods.

Keywords: Electrostatic precipitator; Electric field; Rule of ash-deposition; Vibration period; Optimization

1 INTRODUCTION

The air pollution is smoke pollution and the most pollutants is from power industry, especially from thermal power plant. The dust produced by the coal combustion pollutes air environment and has direct effect on the safety of electric power production, so the power industry always pays attention to the dust treatment.

The collection efficiency of EP depends on whether the dust could be discharged and collected by positive plate, as well as whether the dust could be vibrated and dropped into ash bucket without secondary blowing dust. It is an important link that the ash deposited on polar plates and lines is vibrated and dropped into ash bucket. The ideal ash cleaning is that the ash which consists of different properties dust can be vibrated and dropped without the problems of the running of EP, such as secondary blowing dust, reverse corona or the quick destruction of polar plates and lines.

2 THE DISTRIBUTION OF ASH DEPOSITED ON POLAR PLATES AND LINES

The properties of deposited ash are different according to different electric fields, different polar plates in the same electric field and different positions on the same polar plate. The specific conditions are: (1) Along the flow direction, the amount of dust is great, the particle size is big and the adhesion force is very small in the initial electric field, the situation is contrary in the latter electric field. In a electric field, the dust is finer and the adhesion force is bigger in the front polar plates than those in the latter. (2) Along the height of the electric field, the amount of dusts deposited on the upper part of the polar plate is greater and the size is finer than the lower part because the dusts floating in the upper of the electric field are fine. The difference of property of dust is obvious in the first electric field, but in the second, third and fourth the difference is not obvious because the concentration of dust is small, the remaining dusts are very fine and the distribution is almost uniform.

3 THE DETERMINATION OF THE VIBRATION PERIOD

Whether the ash blocks could drop into the ash bucket depends on the vibration period which has effect on the collection efficiency. The complete vibration period consists of the vibrating time and the stopping time. The vibration period studied in this article is the stopping time.

A suitable vibration system is very important to collection efficiency of EP. The request of vibration system is: when the dusts adsorbed by the electrode surface were deposited to certain thickness and coagulated to flake, the dusts can be vibrated with moderate force and dropped into ash bucket flakily in order to avoid the secondary blowing dust.

The principle of the vibration on the positive plate is: in order to avoid the secondary blowing dust, it can be rapped continuously and all of the positive plates can be rapped simultaneously. Because of the differences of the dust concentration and of the dust properties in every electric field, the vibration periods should be determined respectively. When there is three electric fields in EP, in general the amount of dusts is 70% and the vibration period is short and the force is low in the first electric field because the dusts are coarse and low specific resistance, while the amount of dusts is 6% and the vibration period is long and the force is high as the dusts are fine and high specific resistance in the last electric field. The amount of dusts collected is 20% and the property of dust, the vibration period and the vibration force are between those in the first and third electric field.

The vibration period is determined by orthogonal method but rather complicated. The vibration period to the positive plates are set on the basis of the operation experience: the rapping time is 5 minutes and the stopping time is 8 to 15 minutes in the first electric field, the rapping time is 5 minutes and the stopping time is 20 to 30 minutes in the second electric field; the rapping time is 5 minutes and the stopping time is 30 to 40 minutes.

The cleaning of the corona line is the important condition to ensure the efficient operation of EP. The vibration period should be short as the dusts deposited thickly enough on the corona line cause the low collection efficiency and the failure of EP. The vibration period on the corona line should be short, while the vibration period on the collecting plates should be fitly longed.

4 THE CALCULATION OF THE VIBRATION PERIOD

4.1 The Calculation of the Amount of the Flue Gas

The elemental analysis composition of coal used in some thermal power plant, as shown in Table 1.

Table 1 The Elemental Analysis Composition of Coal

Car	Har	Oar	Nar	Sar	Aar	Mar
42	1.62	3.02	0.91	0.45	50	2

The theoretical air quantity:

$v^0=0.0889(C_{ar}+0.375\ S_{ar})+0.265H_{ar}-0.0333$

$O_{ar}=4.077\ (Nm^3/kg)$

The practical flue gas quantity:

$V^0{}_Y=0.01866(C_{ar}+0.375\ S_{ar})+(\alpha-1)\ v^0+0.79\ v^0$

$+0.008\ N_{ar}+0.111\ H_{ar}+0.0124\ M_{ar}+0.0161\alpha v^0$

$=6.3569\quad (Nm^3/kg)$

Correction:

$V_Y=V^0{}_Y*(273+t_{py})/273\qquad m^3/kg$

t_{py}=130℃–150℃

The flue gas quantity is 9.3845 m^3/kg when the temperature of the flue gas is 130□ by calculating.

4.2 The Calculation of the Flue Gas Flow

It is known that the specified evaporation rate Ds of 11# boiler in Handan thermal power plant is 610 t/h and the maximum evaporation De is 670 t/h.

When $Ds=De$=670 t/h, the amount of the flue gas Q=120×104 m^3/h;

When Ds= 0.5De, Q'=7×105 m^3/t. The relation between Q and Ds is:

$Q=20+10\ Ds\ /67$

When the boiler load is 50%, 70%, 80%, 90%, 100% respectively, the amount of flue gas flux is shown in Table 2, the relationship between the evaporation rate and the flue gas flux is shown in Fig. 1.

Table 2 The Amount of the Flue Gas in Different Loads

Specified Evaporation Rate Ds (t/h)	335	469	536	603	670
Flue Gas Flux Q (×104m^3/t)	70	90	100	110	120

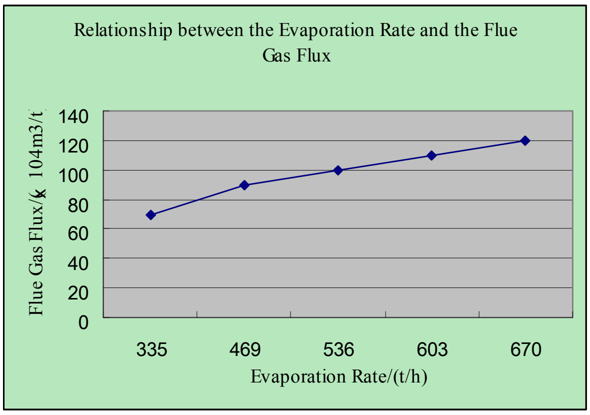

Fig.1 Relationship between the Evaporation Rate and the Flue Gas Flux

4.3 The Calculation of the Collection Efficiency in Every Electric Field

The dust collection area is 2247.5 m^2 and the design collection efficiency ≥99.7%.

$\eta=[1-(1-\eta_1)(1-\eta_2)(1-\eta_3)(1-\eta_4)]\times100\%=99.7\%$

It is esteemed that $\eta_1=\eta_2=\eta_3=\eta_4$, so η is:

$\eta=[1-(1-\eta_1)^4]=0.997$, $\eta_1=0.766$。

So $\eta_1=\eta_2=\eta_3=\eta_4=0.766$

4.4 The calculation of inlet dust concentration in flue gas at 130 □ in every electric field

$C=(a_{fh}A_{ar}/100V_Y)[100/(100-C_{fh})]\qquad kg/\ m^3$

It is known that a_{fh}=0.9–0.95, C_{fh}=5%–10%.

The dust consistency in the first field inlet is shown in Table 3.

Table 3 The Dust Consistency in the First Field Inlet

Fly Ash Coefficient a	Carbon Content in Fly Ash c	Ash Aar	Dust Consistency C (kg/m^3)
0.9	0.05	50	0.047975
0.95	0.1	50	0.050666
0.91	0.06	50	0.048513
0.92	0.07	50	0.049051
0.93	0.08	50	0.049589
0.94	0.09	50	0.050128

The dust consistency(kg/m^3) in the secondary electric field is 0.011226, 0.011856, 0.011352, 0.011478, 0.011604, 0.011730.

The dust consistency(kg/m^3) in the third electric field is 0.0026269, 0.0027743, 0.002656, 0.0026859, 0.0027153, 0.0027448.

The dust consistency(kg/m^3) in the third electric field is 0.00061470, 0.00064919, 0.00062159, 0.00062849, 0.00063539, 0.00064229.

4.5 The Calculation Formula of vibration Period

On the premise of the cleaning electrode, the vibration force should be reduced as low as possible. The collection efficiency will be reduced if the electrode is too clean leading to reentrainment generally. It is suitable that the thickness of the deposited ash is between 31 mm in practice. The dusts drop in flakes using the low- intensity continuous beating.

$$t=d/(CQ\eta n/\rho A) \quad (1)$$

where d is the average thickness of the deposited ash on the positive plate; ρ is the bulk density of dusts; A is the dust collection area; η_n is the collection efficiency of the electric field; Q is the amount of the flue gas; C is the dust concentration.

4.6 The Vibration Period in Different Loads

On the basis of formula (1) the vibration periods of every electric field are calculated in the boiler load of 50%, 70%, 80%, 90%, 100%, respectively.

The changes of the vibration period in the first electric field as the changes of the boiler load are shown in Table 4 and in Fig. 2.

In the first electric field, the vibration period is decreased as the increase of the boiler load with the increase of the amount of the flue gas and the dust deposited on the positive plate in per time. It is linear relationship between the boiler load and the vibration period, and the vibration period should be changed when the boiler load changed.

Table 4 The Change of the Vibration Period with the Boiler Loads in the First Electric Field

Average Thickness of the Deposited Ash d(m)	Dust Concentration C(g/m^3)	Flue Gas Flux Q(m^3/s)	Collection Efficiency	Bulk Density of dusts (kg/m^3)	Dust Collection Area A(m^2)	Vibration Period (s)
0.005	47.975	194.4	0.766	700	2247.5	1101.10
0.005	47.975	250.0	0.766	700	2247.5	856.217
0.005	47.975	277.8	0.766	700	2247.5	770.534
0.005	47.975	305.6	0.766	700	2247.5	700.440
0.005	47.975	333.3	0.766	700	2247.5	642.227

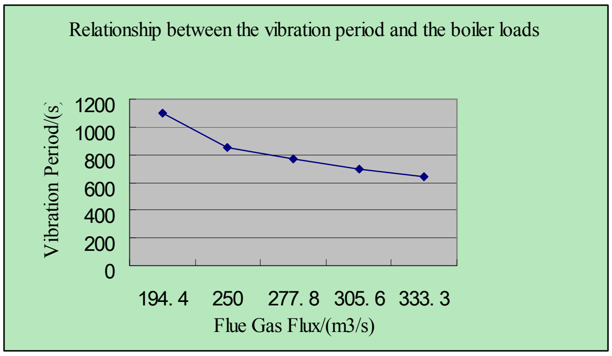

Fig. 2 Relationship between the vibration period and the boiler loads

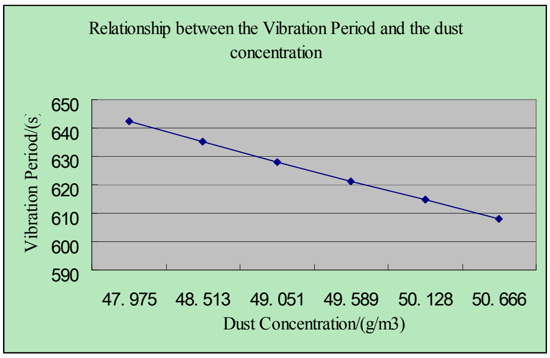

Fig. 3 Relationship between the vibration period and the dust concentration

Table 5 The Change of the Vibration Period with the Dust Concentration in the First Electric Field

Average Thickness of the Deposited Ash d(m)	Dust Concentration C(g/m^3)	Flue Gas Flux Q(m^3/s)	Collection Efficiency	Bulk Density of dusts (kg/m^3)	Dust Collection Area A(m^2)	Vibration Period (s)
0.005	47.975	333.3	0.766	700	2247.5	642.227
0.005	48.513	333.3	0.766	700	2247.5	635.105
0.005	49.051	333.3	0.766	700	2247.5	628.139
0.005	49.589	333.3	0.766	700	2247.5	621.324
0.005	50.128	333.3	0.766	700	2247.5	614.643
0.005	50.666	333.3	0.766	700	2247.5	608.117

4.7 The Vibration Period in Every Electric Field in the Different Dust Concentration

The changes of the vibration period in the different dust concentration are shown in Table 5 and in Fig. 3.

The relationships between the vibration period and the dust concentration in the secondary, the third and the fourth electric fields are similar to those in the first field which the amount of the dusts collected in per time increases as the dust concentration increases leads to the reduction of the vibration period. Compared with the practical vibration period, the positive plates are vibrated so frequently that the positive plates and the vibration devices are destroyed and the energy is consumed largely, in the meanwhile, the dedusting effect is bad because of the secondary blowing dust. It is suggested that the vibration period should be inceased.

Similarly, the suitable vibration period is important to the corona line. The suitable vibration period is beneficial to the corona discharge.

5 CONCLUSIONS

It is very important to study the vibration period which has direct relationship with the collection efficiency and the operation of EP. The properties of ash deposited in different electric fields and on the different parts of every electric field and the influence of the ash on the vibration period were studied. With the example of some coal-fired power plant, the vibration period of every electric field was shortened as the increase of the boiler load and the concentration of the dust using the formula of the vibration period and the vibration period should be adjusted on the basis of actual situation. Compared with the practical vibration period, the coal-fired power plant was advised to extend the vibration period in order to enhance the efficiency.

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