Flue Gas Conductivity and Efficiency of ESP

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Abstract: In today's operation of ESP, various manufacturers have encountered some problems. Most ESPs smoke seriously and the concentration of dust emission fails to reach emission standards though they are normal designed, manufactured and installed with no apparent defects. Some are frequently retrofitted but less effect. To this, the thesis is mainly focused on the electrical conductivity of mixed gases in a boiler and the relationship between the electrical conductivity and the dust specific electric resistance as well as their effects on ESP efficiency. The operation of ESP will be recognized from another perspective and can be debugged more scientifically so as to achieve purposes of high-efficiency and energy saving.

Keywords: electric strength, electrical resistivity, mixed gas, screen

1 INTRODUCTION

Electrostatic precipitator(ESP) is well known for dust collection. It is more than 100 years ago, professor F.G. Cottrell invented the ESP in California State University in 1907. Since large application in coal fired power plant in 1923, 84 years has been past. The technologies of ESP has matured to be applicated in others fields, including chemical engineering, metallurgy, power station, cement production, paper production and so on. Several dozens of ESP manufactories in China has designed and produced several thousands ESPs, almost one thousand of them were from Zhejiang Feida Group. Most of these ESPs had good performance and made a significant contribution to pretecting the air environment. While some of them performed poorly. Not only the air environment, but also the image of manufatories were damaged. After ESP modification in several power stations, we found flue gas conductivity was the main factor. It had a good relationship with dust collecting efficiency. Based on that, we realized that basic research on ESP was very important for improving dust collecting efficiency. Actually, some experts have already done some work on flue gas conductivity, and found out that changing the power control mode and developing high frequency power source can be used for different types of coal. Not only the dust collecting efficiency can be improved, but also the energy consumption can be reduced.

2 DISCUSSION ON ESP PRINCIPLES

With regard to the principle of dust collection in ESP, large amount of free electron and ion will be generated to form a corona zone around the discharging electrode when there is high voltage loads. Dust can be charged and move forward to the collecting electrode when they come through the space between corona zone and collecting electrode. Electric field force is the driving force of dust movement, and it is proportional to the charging capacity of dust and electric field strength.

$$F_e = QE \tag{1}$$

where F_e—Driving force;
Q —Charging capacity;
E —Electric field strength.

The principle of dust collection described above is simple, but it is the basic conception of ESP and important way to go deep into ESP. Intensive research on charging characteristic of dust in electric field can benefit the improvement of ESP efficiency.

Besides electric field force, dust in the flow gas is also acted upon horizontal flow force F_Q. As described in Fig. 1, F_Q is perpendicular to F_e.

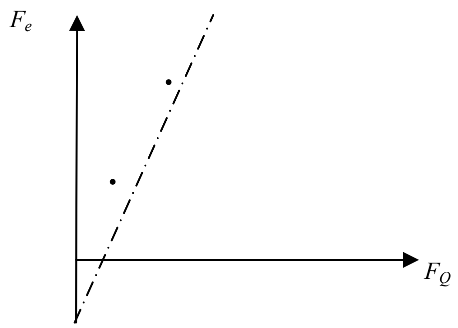

Fig. 1 Forces on dust in electric field

As the exist of F_Q, the composition force on dust is a vectorial force. The time of dust arrive at collecting electrode is extended. If Fe is small enough, dust will flow out of the ESP before arriving at collecting electrode because of flow force, and collecting efficiency will decrease to zero. So the factors, which decrease electric field force Fe and the way to increase it will be studied deeply.

In ESP, it is necessary to load a high voltage on the discharging electrode to form a strong enough electric field strength between the electrodes. Normally, electric field strength is proportional to collecting efficiency, but sometime, it is not. The electric field acting on dust is small although tens of thousands voltage is loaded between electrodes. Why it happens? Here a new method will be used to analyze the reason besides collision charging between ion and dust.

A function describing dust moving velocity[1] is given:

$$\omega = \frac{PE_pE_ca^2}{6\pi\mu} \quad (2)$$

where ω— dust moving velocity;

P—dielectric coefficient;

E_p— electric field strength of collecting electrode;

E_c— charging field strength;

a — dust radius;

μ — gas viscosity.

E_c is also called electric field strength which acts on dust, and it is related to attenuation extent of electric field force.

Function 2 correctly describe the relationship between dust moving velocity and other factors in ESP. Two of them must be concerned: dielectric coefficient P and charging field strength E_c. Generally speaking, P is a constant and E_c is closing to E_p. So function 2 can be simplified as function 3:

$$\omega = P\frac{E_p{}^2a^2}{6\pi\mu} \quad (3)$$

Actually, large number of onsite experience has proved that P is not a constant and E_C is vairable. Dielectric coefficient P decide the value of E_C. Both of them can influence dust moving velocity ω. This is the reason why dust collecting efficiency is decreased, and how will be discussed as follows

The free electron in the electric field moved directly and screened the electric effect of metal, and then the inner electric field intensity decreased. In the ESP, the electric field power was transfer by intermediate medium. It can be seen from the Fig. 2.

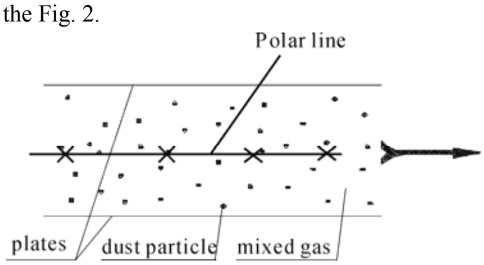

Fig. 2 Dust particle and mixed flue gas

The flue gas included the dust particle and mixed flue gas, and the mixed flue is the medium of electric field power, that is dielectric constant P. the mixed gas concludes nitrogen, carbon dioxide, carbon monoxide and sulfur dioxide. They are conductive in the high voltage electric field, the gas became the electron stream if they are broken down, and the electron stream was the screen of the electric field as the Fig. 3.

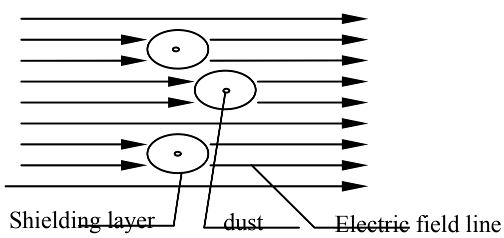

Fig. 3 The power line around the dust was screened by gas

There is a obvious conflict in the ESP when it was running: the dust need the driving force to reach the collect plane in the electric field force, while the mixed flue gas was broken down in the high voltage electric field, then the electron stream will screen the electric field, the electric field intensity was weakened. So how can we solve the contradiction? It can be analyzed from the conductive characteristics, in the ESP, the conductive of dust was showed as resistance, which is the ratio of voltage and current in unit, the formula is as follows:

$$R = V/I \ (y \cdot 10^x \ \Omega) \quad (4)$$

what is the relationship between the charge extent and R? based on the molecule structure principle, any substance was made from molecule, and plenty of atoms made up the molecule, while there are atomic nucleus with the positive electricity and electron with negative electricity, the electron revolved around the atomic nucleus, and the electron in the outer layer will move out, the Fig. 4 is as follow:

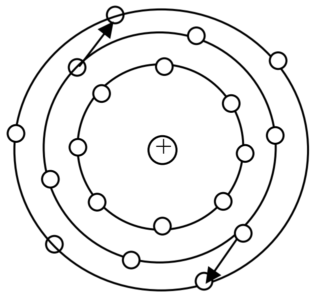

Fig. 4 The trajectory of electron movement

The atom lose their electric charge balance, then the dust was moved to anode, the trajectory of charge dust is similar with trajectory of electron, the only different point is the expression way , the form is the conductivity and the latter is resistance .

It can obtain the large current in the lower current when the resistance was small. And the bondage power of atomic nucleus in the dust with low resistance was little, the electron moved out easily, the high resistance dust was the opposite condition, which is means in the same electric field power; the charge amount was inversely proportional to the resistance.

$$Q = E/R \quad (5)$$

where: Q—charge amount of dust;

E—the electric field intensity;

R—the resistance of dust.

The relationship between Q and R is as follow in Fig. 5.

Let Q be the charge amount of different resistance, there was little electric field of low resistance, and the electric field has direct ratio relations with resistance, and the relation is as Fig. 6.

It is difficult to sampling the mixed flue gas for its conductivity, so it only simulation analyze the flue gas. But whatever kinds of coal, the concentration of nitrogen and carbon monoxide is 85% in the mixed flue gas, and the ionization voltage value of gas is 10 eV-25 eV, so it can be supposed a fixed value, And the conduction process is similar with charge process. The lower resistivity, the large conductivity, and this is the best condition of mixed flue gas. But in the actual situation, the resistivity value is usually under R12, and it related the efficient of combustion, it is also the main reason of collect the high resistivity ash, the resistivity is R11,and the electric field is e11, their relation is as Fig. 7.

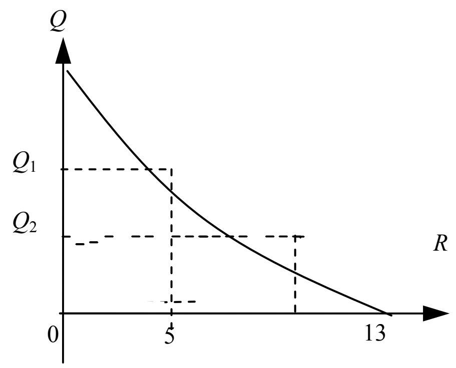

Fig.5 The relationship between *Q* and *R*

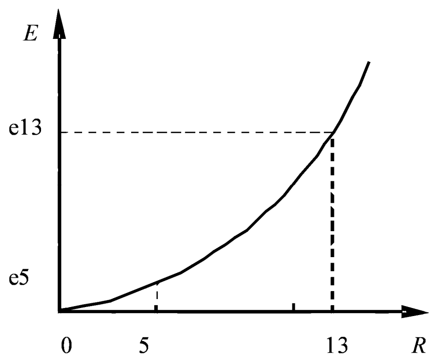

Fig. 6 The relationship between *E* and *R*

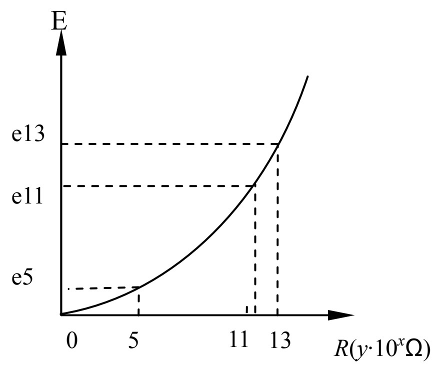

Fig. 7 The relation between resistively and electric field

From Fig. 7, the electric field of small resistivity of dust is small than that is in mixed flue gas, that is the area under *R*11, e11.

The fixed flue gas would not been broken down in the necessary electric field, then the electrostatic precipitator designed normally can reach the design demand after debugging.

When the operational voltage has reached the conductivity area or breakdown area, the efficient of de-dust is decrease as the increase of voltage, because the avail electric field was been shielded.

The power plant with 75 t/h in Shijiazhuang had the several smoking problem, the carbon concentration of dust had reached to 53%, and resistance was 5.7×10^6. The voltage was 50-60 thousand volt, and the current is about 400 mA, the operational parameters all are in the normal range, but the emission concentration was about 200 mg. the techno-section decided to increase the efficient by changing the matching way, but it had no obvious effect, then change the operational voltage to 35 thousand volt, the voltage is out the conductivity area, and the screen effect disappeared, the smoking problem was solved, and the consumed power was only 4.1 thousand volt, even closing the third electric field ,there still was not the problem of smoking

High resistivity dust was been broken down easily with the increasing electric field intensity, so the effect of dust cleaning was lower. In this kind of rebuild- project, the effect of removal dust will not obvious by increasing the voltage. Some people think that this is the back corona phenomenon, but the condition of back corona is that there was dust in the plate. Actually there will be back corona phenomenon without dust.

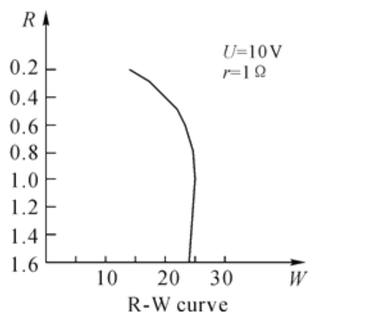

Fig. 8 Reflected the relation between U and *R* (*U*=10 V, *R*=1 Ω), the curve changed when the out resistivity is lower than inner resistivity. And for the high resistivity dust, it is difficult to charge and discharge ,but it can be solved by clean the dust

Above all, the total resistivity of electric field in electrostatic precipitator is a variable, and the reason is the change of conductivity, it increased with the rise of electric field until it broken down and it is the low voltage and large current condition.

It is hard to enhance the collection efficiency of high resistivity dust only by adjust operation parameters. For low resistivity dust, we can reduce the operation voltage to make the electric field intensity in order to avoid the conduction region of mixed gas. When it comes to high resistivity dust, the same method will make the dust can not be charged for low electric field intensity and it will also lead to low collecting efficiency. How can we solve this problem?

(1) Debug the electric field parameter curiously and choose suitable power supply to reduce the influence of conductive gas
(2) Flue gas conditioning to increase the conduction threshold value of the mixed gas and decrease the resistivity of dust, such as adding water and air, however they both have negative effects.
(3) Reduce the distance between plates and decrease the operation voltage to make the mixed gas achieve stronger electric field force without breakdown.

3 ESP DEBUGGING

3.1 The Operation Curve of ESP

Hot-state operation debugging plays an important role in enhancing the efficiency of ESP. From the analysis given in this paper we know that conduction zone especially the breakdown zone of the mixed gas must be avoided to ensure high operation efficiency. From the upper analysis and years of exploration, we can draw the conclusion that the normal operation curve is shown in figure 9.

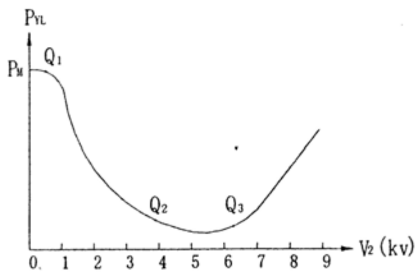

Fig. 9 Operation curve of ESP

The X coordinate stands for operation voltage while the Y coordinate stands for gas emission amount in outlet. The highest emission amount is set to be P_M .

We can see from figure 9 that when voltage is zero, the electric field intensity is zero, so the collecting efficiency is zero and the gas emission amount is P_M; as the increasing of operation voltage, the electric field intensity increases and dust begin to be charged, so the ESP begin to work and the emission amount decreases (Q_1-Q_2); when is reaches Q_2, the electric field intensity is very high which makes all the dust charged, so the collecting efficiency is highest and the emission amount is least.

In the zone between Q_2 and Q_3, dust is charged adequately, so increasing the voltage can not enhance the collecting efficiency obviously, and this zone is the operation zone of ESP; when it comes in to Q_3, as the increasing of voltage, the electric field intensity increases and the mixed gas begins to conduct electricity, so part of electric force is neutralized which has a negative effect on the move of dust, so the emission amount increases.

3.2 Basic requirements of ESP Debugging

(1) The boiler is operated normally and the load is about 90%.

(2) No-load test and hot-state operation both have been finished in ESP; the body of ESP, power supply and the control system are all in good working condition.

(3) The weather is stable and you had better have an turbidimeter.

(4) The power supply is in “normal working” mode and “ automatically lock” condition must be closed.

3.3 Basic Methods in ESP Debugging

Under the premise of meeting the above requirements, makes an hot-state V-I characteristic curve of ESP combing the emission station of chimneys. Debugs from big to small, record the operation parameters and record the gas emission station of the according chimney. To avoid accidences, we suggest that the test begins when the power of the power supply reaches 90%. The debugging parameters are on the base of current value in high voltage station. We set a point every 100 mA when the current value is higher than 200mA and set a point every 50mA when the current value is lower than 200 mA. The stability time of every point can not less than 10 minutes. The emission state can be recorded in stages artificially. At last, choose a set of date which has minimum gas emission amount, small operation current and voltage. Considering related dates in fore and after, the working zone of ESP can be determined.

4 CONCLUSIONS

From theory to practice, ESP has a history of 200 years. Like other subjects, it will go on explore according to different working stations to play its due role.

In my consideration, the conductivity of mixed gas is the main factor influencing the efficiency of ESP and it has a close connection with dust resistivty. If you want keep the collecting efficiency high, the working voltage must avoid the conduction zone especially the breakdown zone of mixed gas. We can expect that hot-state debugging of ESP combined with the gas emission situation can be come true. In this way, the collecting efficiency of ESP can be enhanced and power consumption of ESP itself can be reduced in the same time.

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