Design and Application of Inlet Nozzle of Dry Desulphurization ESP

ZHAN Qiuyue
(Fujian Longking Co. Ltd, Fujian 364000, PR China. E-mail: zy2220782@sina.com)

Abstract: The gas distribution of ESP is effected by the design of inlet nozzle. In this paper, based on the gas character of CFB-FGD dry desulphurization, the design of inlet nozzle and gas distribution of ESP after desulphurization were analyzed, which can guide the detailed design of inlet nozzle with high concentration.

Keywords: Dry desulphurization, ESP with high concentration, inlet nozzle, gas distribution

1 INTRODUCTION

Since developing CFB-FGD technology in 1980 s, the CFB-FGD technology is widely applied in power plants, steel, waste incineration and other industry. At present, the largest running unit is 660 MW. The CFB-FGD is the major desulphurization technology with better economy after limestone/gypsum wet technique. The CFB-FGD is the integrative dry desulphurization technology with desulphurization and dust removal. The sketch of technology process is showed in Fig. 1. The flue-gas enters the absorption tower of CFB from the bottom, occurs chemistry reaction with absorbent in absorption tower which removes the acidity gas i.e. SO_x, HCl, HF and so on. The flue-gas of high concentration dust with absorbent and reaction production enters ESP. The clean flue-gas is exhausted into the atmosphere by fan.

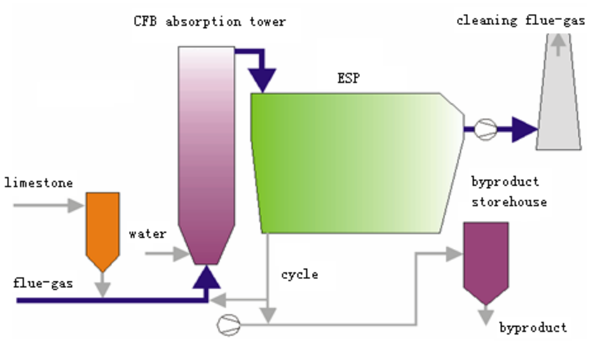


Fig. 1 Sketch of CFB-FGD technology process

Since reaction of dry desulphurization, character of flue-gas and dust has changed, which makes the general ESP hard to adapt to. Aimed at the flue-gas character of CFB-FGD technology, special ESP must be designed to solve the problem of high concentration and humidity and the efficiency of desulphurization and dust removal can achieve the standard.

2 FLUE-GAS CHARACTER OF CFB-FGD

Compared with general flue-gas, there is a lot of change in flue's component, temperature, humidity, particle concentration, etc. Such as (1) For satisfying the establishment of CFB, the dust concentration is as high as 600 g/Nm^3–1000 g/Nm^3 in outlet of absorption tower, more than 10 times of the general flue-gas; (2) spraying a number of cooling atomization water into absorption tower, which can increase the 5%–7% humidity of flue-gas up to 10%–12%, and reduce the temperature to around 70 □. Increasing humidity through spraying water is equivalent to traditional water condition, which makes the dust resistance in the scope of 10^9 Ω–10^{10} Ω·cm to be propitious for dust removal; (3) Almost remove all SO_3, the flue-gas dew point is the water dew point which is about 40 ℃–50 ℃; (4) As the desulphurization products mainly include $CaSO_3$, $CaSO_4$,$CaCO_3$, which is more viscous, they ask for a higher-intensity rapping requirement.

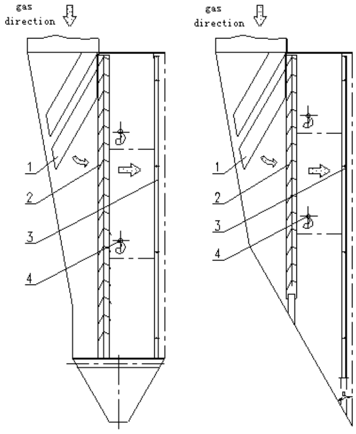
3 DESIGN OF INLET NOZZLE OF ESP ZAFTER DESULPHURIZATION

Based on the flue-gas character, BS high concentration ESP can be used as CFB-FGD devices. However, it need to make two aspects improvement on the inlet nozzle. On the one hand, there is a hopper for inlet nozzle of traditional BS ESP, but without any hopper in the inlet nozzle of desulphurization ESP, showed in Fig. 2. The angle α between vertical and bottom plates without hopper is less than 30°, For avoiding ash deposit and letting ash flow into hopper smoothly. On the other hand, desulphurization ESP commonly adopted single inlet nozzle, which can connect with desulphurization tower conveniently. The level outlet on the side at the top of desulphurization tower connected with the inlet nozzle of ESP, which is propitious to the gas distribution, and with no drift. Therefore, an oversize inlet nozzle with large horizantial span should be designed for CFB-FGD equipment of large units.

3.1 Setting of Guidance Plates

Since the connection of absorption tower and ESP inlet adopted abnormity pipe, in order to ensure the gas uniform distribution, the guidance plates need be set up in transition section, which can pre-assign the gas distribution along the width of electric field. The structure sketch of guidance plates setting in the inlet nozzle of high concentration ESP after desulphurizaiton showed in Fig. 3. In design, the diffuse angle

β is more than 45°.



(1-pre-removal equipment, 2-baffle plates,
3-gas distribution plates, 4-rapping equipment)

Fig. 2 Structure of inlet nozzle before and after improvement

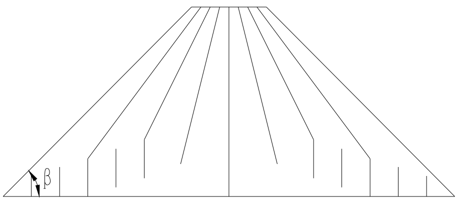


Fig. 3 Sketch of guidance plates

3.2 Pre-removal Equipment

In order to reduce the dust concentration of electric field and meet the need of gas distribution in high concentration condition, the dobule-level open upward maze-trough plates was set at the top of inlet nozzle (i.e. former distributary plates, showed in Fig. 4), which can play a role of pre-removal dust through collision, gravity and so on. About 20%–30% of dust with the concentration of 1000 g/Nm^3 after dusulphurization was collected before get into the field. The dust collected fell into the hopper of first electric field which significantly reduce the load of electric field. At the same time, through the effective arrange of trough plates perpendicular to the flow in the width of electric field, the upper flow in the width of electric field can be distributed. In order to prevent ash deposit in trough plates, a certain angle was designed between trough plates and horizontal line, and pneumatic hammer was set on the corresponding place of external wall plates of nozzle.

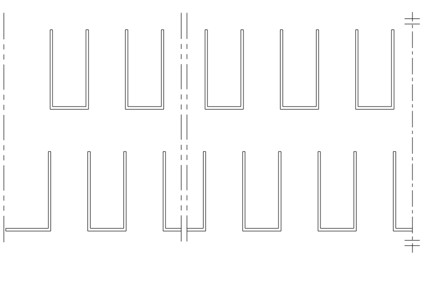
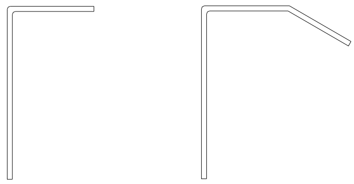


Fig. 4 Layout of trough plates

3.3 Design of Gas Distribution Device

Multi-layer baffle plates (distribution plates) were set in the middle part of inlet nozzle, showed in Fig. 5, Fig. 5 (a) is 90° bending plates, Fig.5 (b) is the combination bending plates after improved on the basis of (a). The former can improve the dispersion and distribution of flue gas when the flue gas through the 90° deflexion, and on the other hand, due to collision effect, the particles lost momentum and sedimentated because of gravity. The combination bending plates can much change the flow direction, while sedimentating dust. It were mainly used in the lower part of inlet nozzle.



(a) (b)

Fig. 5 Model of baffle plates

In the afterbody of inlet nozzle, a layer orifice plate was set for gas uniform distribution equiment.. The main aim is dividing the large-scale turbulences into small-scale turbulences through increasing the local resistance, which weaken the strength of turbulence in small space, making the gas near the laminar state, and then improving the ESP efficiency.

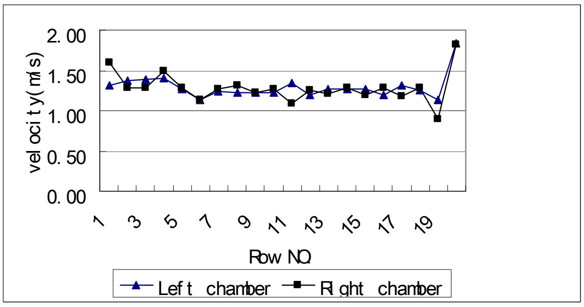
Note that ,since the high dust concentration of inlet flue-gas and big viscous of desulphurization ash, the rapping device was set for distribution plates and orifice plates. The rapping device is side rotary-type hammer similarly the collection plates.

4 MODEL EXPERIMENT AND LOCALE TESTING

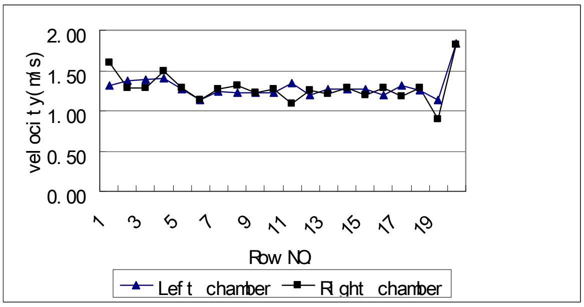
Taking CFB-FGD ESP of 2×300 MW unit in Shanxi Huaneng Yushe power plant as an example to introduce the gas distribution testing of pilot-scale and full-scale ESP.

4.1 Test of Pilot-scale ESP

According to the fluid dynamics theory, the flow velocity distribution should be large on upper, small on lower in the inlet of first electric field in the high concentration ESP, which is propitious for collecting dust. The relative RMS value σ of velocity in horizontal plane is not more than 0.25. When completing the design of inlet nozzle, the gas distribution was tested in the pilot-sacle ESP (with CFB absorption tower) with the scale of 1:10. The test data indicated that the velocity in the upper and lower sections is larger, which is smaller in middle section; on the same height, the velocity is more uniform, the average velocity in passage is smaller than in section. The curve of velocity distribution of electric field section is showed in Fig. 6. Apparently, the gas distribution in vertical section is not reasonable. So the gas distribution device should be adjusted according to the inlet dust distribution. Reference [1] also noted that when the dust particles entried into electric field, they fell down because of their gravity, which resulted in larger concentration in the middle and lower parts of electric field. In order to uniform the electric field load, the velocity at upper should be larger than which at lower.



(a) Row direction



(b) Column direction

Fig. 6 Model velocity distribution before adjustion

In order to achive the effect of large velocity at upper and small at lower in the first electric field, a baffle plate should be assembled on about upper part of former wall plate of inlet nozzle, which can used to weaken the gas velocity in lower part and increase the gas velocity in middle part. However, the velocity in lower part is still large, so another baffle plate was assembled about 1 meter lower. To prevent ash blocking, the width of baffle plates should not be too wide. After a number of model experiments, the hole opening rate of orifice plate and multi-layers baffle plates before oriflce plate were adjusted.

(1) Since the change of concentration gradient is very big after high concentration dust enters the electric field, dust concentration has a small distribution on the upper part while distributing largely on the lower part in the electric field section. For easily to collect dust, the gas velocity in the lower part should be smaller than average velocity. The upper part hole opening rate is designed to be higher than the lower part. Because of the large velocity in upper and lower part, the hole opening rate has made corresponding adjustment, like Fig. 7. After adjustment, the test result indicated that the gas velocity in the lower part of first electirc field entrance was bigger than the average velocity, the gas velocity in middle part had been improved and the velocity in upper part had tended to be more reasonable. The row velocity is bigger in the lower part of second electric field entrance and the velocity is smaller than the averange velocity in the middle and upper part. After adjusting the hole opening rate, the gas distribution uniformity has changed much better.

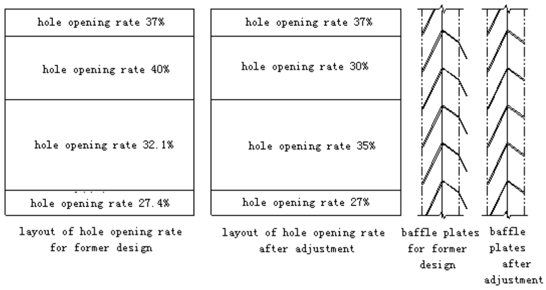


Fig. 7 Distribution of orifice plates and baffle plates

(2) For adapting the high dust concentration in entrance, the velocity should be further reduced in the lower part. The latter half of all vanes on the lower part of baffle plates faced the electric field were removed, which reduce the baffle paltes to guide the gas flow to lower part. Moreover, we can add the wind wall between each electric fields, which would prevent the high concentration charged praticles flying into the next electric field and can reduce the dust concentration in the last electric field. Adding wind wall can also reduce the lower flow velocity of each electric field entrance, preventing the dust to be carried off by gas and causing the dust re-entrainment before fall into hoppers.

After this adjustment, on the same height of cross section, the velocity difference between every points is small. In the same gas passage of cross section, the velocity in upper part is more than lower part. The curve is closed to the ideal distribution curve in the Figs. 5-7 of literature [1]. Acrroding the judging method of gas distribution uniformity in literature[1], the gas distribution uniformity has achieved qualified level in the first and second electric field entrance. Along the height of electric field, the curve of velocity field is showed in Fig. 8.

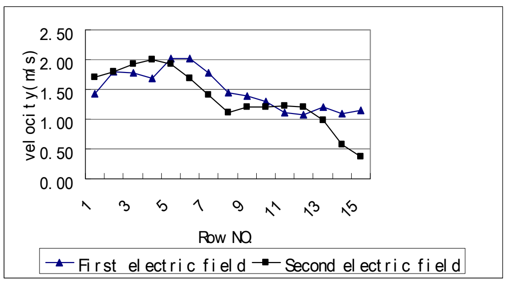
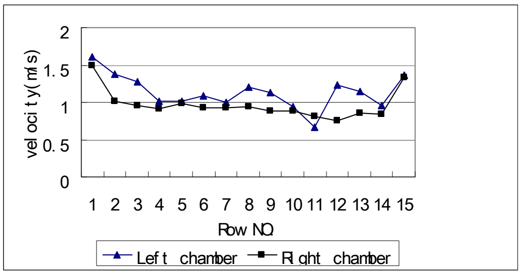


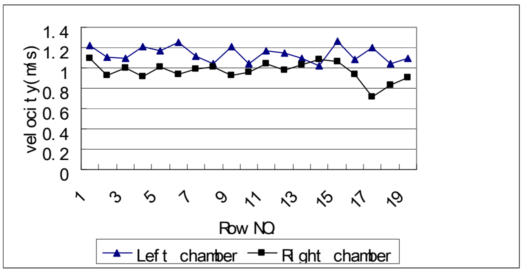
Fig. 8 The curve of model velocity field after adjustment

4.2 Gas Distribution Testing on Site

On the full-scale ESP, the gas distribution testing was carried on, which used to validate the adjustment scheme of gas distribution. The testing data of cold testing and thermal performance experiment indicated that the adjustment scheme is feasible, each indicator met the requirement. The velocity distribution of the first electric field is shown in Fig. 9. It indicated that along the height direction of electirc field, the curve is quite smooth and the distribution is uniform, except that the partial velocity is bigr in the first line caused by insulator dust cover; along the width direction of electric field, the distribution is also uniform, completely achieved the prospective gas distribution demands. Compared with model experiment: the distribution is consistent along the width direction of electric field and the curve of velocity distribution is more smooth than modle testing result along the height dirction of electric field. It showed that local testing result is better than model testing, which validated the gas distribution device of model expriment is feasible. Also the performance testing of ESP indicated that under the condition of entrance concentration as high as 1000 g/Nm^3, the emission density is lower than 50 mg/Nm^3 and the dust removal efficiency is as high as 99.995%. The ESP has already ran for more than 3 years yet with the dust emission still lower than 50 mg/Nm^3.



(a) Row direction



(b) Column direction

Fig. 9 Locale velocity distribution

5 CONCLUSIONS

The high concentration ESP with single extra large upper inlet wind nozzle after CFB-FGD desulphurization has been successful applied in nearly ten units of 300 MW and 200 MW. After many years' run, it indicated that the nozzle structure type can satisfy the desulphurization requirments. In the situation of 1000 g/Nm^3 entrance concentration, the dust emission can be lower than 50 mg/Nm^3 and meets the national standard.

REFERENCES

1. Liu Houqi, Lin Hong; electrostatic precipitator, china architectrue & building press, December, 1987.
2. Li Zaishi, selection installment and operational management of ESP, China electric power press, June, 2005.
3. The pipe design technology regulation of flue-gas, wind and pulverized coal in thermal power plants. China Electric Power Press, 2001.
4. Proceedings of the fourth science and technology conference of Longking, 2007.