ESP Application on Combustion of High-sulfur Heavy Crude Oil

GE Jielong, ZHANG Ye, XU Xiaofeng, SHEN Zhiang, ZHANG Peifang
(Zhejiang Feida Environmental Science & Technology Co., Ltd, Zhuji Zhejiang, 311800)

Abstract: The specialties of the flue gas and dust produced by combusting the Orimulsion oil are shown here. The research is carried out for the technology that the electrostatic precipitator (ESP) collects the multiple dust after dry ammonia desulphurization through the execution of Zhanjiang power project. The reasonable proposal is also supported here.

Keywords: Orimulsion oil, Ammonia, Desulphurization, ESP

1 INTRODUCTION

Orinoco region in Venezuela, South America, abounds with naphthenic heavy crude oil called Orimulsion, which is non newtonian fluid constituted of 70% heavy crude oil and 30% emulsion. This is a special kind of oil resource of low cost, high calorific value (27 MJ/kg-29 MJ/kg) and high sulfur content.

With the rapid economic development, China's energy imports grows quickly, especially oil. In order to achieve the diversification of energy, the authority tries to combust this oil for power generation in 2×600 MW units of Zhanjiang power plant. Zhejiang Feida Environmental Science & Technology Co.,Ltd constructed the ESP and addictive ammonia storage and injection system of the project, and ALSTOM KK provided technical consultation.

2 OIL QUALITIES AND CHARACTERISTICS OF FOUE GAS AND DUST

2.1 Oil Qualities

Physical and chemical parameters of emulsified No. 400 oil from South America are shown in Table 1.

Table 1 Physical and Chemical Parameters of Orimulsion

Items	Unit	Prefix	No. 400 oil
Viscosity (30 ℃ 100S-1)	mps·s	cP	≤400
Average Diameter	μm	d	14-20
Density	g/cm^3	p	1.009-1.013
Superior Calorific Value	MJ/kg	Qgr·ar	29.6-31.0
Hydrogen Content	%	Har	7.2
Sulfur Content	%	Sar	≤3.0
Vanadium Content	ppm	V	≤360

2.2 Characteristics of Flue Gas and Dust

Several characteristics of Orimulsion content were found after analysis: (1) high sulfur content; (2) the ash content is lower than coal and higher than normal crude oil; (3) high precious metal content of Vanadium, about 360 ppm; (4) high humidity of flue gas.

V_2O_5 formed by Vanadium combusting has very good selective catalytic activity, and is used as catalyst which oxidizes SO_2 to SO_3 in sulphuric acid industry. Because of high Vanadium content of Orimulsion, a greater amount of SO_2 in flue gas which formed by combustion will be oxidized to SO_3, than means high SO_3 in flue gas. Meanwhile, because of higher flue gas humidity than coal-fired boiler and high solubility of SO_3 in water, high concentration SO_3 obviously increase the flue gas acid dew point, and causes great low temperature erosion risk to relative devices such as ESP after boiler and ID fan because sulfuric acid fog. Although wet limestone-gypsum flue gas desulfurization (FGD) device is constructed after ESP, spray collection efficiency of fine particle aerosol smaller than 0.5 μm which formed by SO_3 moisture absorption is very low, and “white smoke” appears at the outlet of chimney.

In order to solve problem of acid erosion and “white smoke”, project adopted ammonia gas injection for dry FGD (SO_3) before ESP device.

Main content of gas formed by Orimulsion combustion is indicated in Table 2.

Table 2 Main Parameters of Flue Gas

Flue Gas Content (Standard Dry Air)	Unit	Amount
CO_2	%	14.38
N_2	%	83.01
SO_2	ppm	2468

2.3 Fly Ash Characteristics after Dry FGD

Relatively larger particle size cokes and fine carbon black particles which generated in the process of oil combustion can improve the collection of ESP because of the effect to dust resistivity. Meanwhile, carbon black is bad to dust collection due to reentrainment.

Compound dust characteristics of oil combustion flue gas after ammonia injection desulfurization are: total dust concentration which includes ammonium sulfate is 1200 mg/Nm^3, median-particle-size is smaller than 0.5 μm, theoretical packing density is 100 kg/m^3, high moisture absorption, and resistivity is $6.5\times10^9\Omega\cdot$cm.

3 DESIGN OF ESP

3.1 Project Situation

Zhanjiang 2×600 MW units use Orimulsion as fuel, and two units were constructed in Nov. 2006, and equipped with three-field ESP. The calculated dew point of flue gas generated by combustion of quality designed Orimulsion is about 149℃, and flue gas designed temperature when the boiler runs at full load operation is 154℃, so actual flue gas temperature may be lower than flue gas dew point when boiler runs at low load. In order to prevent the flue duct system after boiler and ESP device from acid erosion, ammonia gas injection system is designed at the inlet duct of ESP. Ammonia gas can neutralize the SO_3 in the flue duct, and decrease the dew point. However, ammonium salts generated by neutralization such as ammonium sulfate, ammonium hydrogen sulfate have strong hygroscopicity and erosion. Some anti-erosion materials are also adopted in ESP, and washing cleaning system is set up.

3.2 Guarantee of Dust Emission

Flue gas and dust characteristics at the inlet of ESP are: (1) dust concentration which includes ammonium sulfate is 1.2 g/Nm^3; (2) resistivity is $6.5\times10^9\Omega\cdot$cm, easy to be charged and agglomerated; (3) dust has certain viscosity, low reentrainment effect; (4) low dust density, only 100 kg/m^3; (5) particle median-particle-size is smaller than 0.5 μm.

Although all the dust is fine dust, corona blocking doesn't happen in the first field because of low dust concentration and smaller electrode distance of the first field than other fields. Due to suitable resistivity, the dust is easy to be charged, agglomerated and collected by ESP, and reentraiment is inhibited in the condition of reasonable interval rapping. So three fields ESP is designed under the guarantee of airflow distribution uniformity, and dust emission of 40 mg/Nm^3 can be absolutely accomplished.

3.3 Guarantee of Anti-erosion and Security

In order to solve the problem of low temperature erosion to the devices after boiler because of SO_3 formed with Orimulsion combustion, injecting ammonia gas into the inlet of ESP is adopted. Grid shaped nozzles make the ammonia gas uniformly distributed in the flue cross section. Turbulence devices near the nozzles can quickly neutralized the SO_3 in the flue, meanwhile absorb some of SO_2, and flocculent ammonium hydrogen sulfate and ammonium sulfate are formed. The main reaction equations:

$$SO_3+H_2O+2NH_3 \rightarrow (NH_4)_2SO_4 \quad (1)$$

The main reaction equations:

$$SO_3+H_2O+NH_3 \rightarrow NH_4HSO_4 \quad (2)$$

$$SO_2+H_2O+NH_3 \rightarrow NH_4HSO_3 \quad (3)$$

$$SO_2+H_2O+2NH_3 \rightarrow (NH_4)_2 SO_3 \quad (4)$$

Ammonia injection point after coal economizer is beneficial to decrease the acid erosion to the boiler system, but possibly causes blocking of the heat exchanger component. So the optimal ammonia injection point is at the outlet of air exchanger. Neutralizer is gaseous ammonia or aqueous ammonia, and the key point is quickly gasification and uniformly distribution in the airflow. If aqueous ammonia is used, it is necessary to select wear-resistant and anti-blocking high efficient nozzles, to make sure the aqueous ammonia uniformly distributes in the airflow as fine droplets and been quickly gasified. So the ammonia can fully contact with the SO_3 in the flue gas and prevent scaling in airflow.

Moderate excessive ammonia can make the product is almost stable saturated sulfate which has low moisture absorption and deliquescence, so it helps to the collection of ESP. However excessive ammonia causes secondary pollution and increases the cost, so online testing devices for ammonia escape should be installed at the outlet of ESP.

Ammonium hydrogen sulfate shows the appearance of melting at the temperature of 147℃, and has strong adhesion force. It is difficult to remove by rapping if it adheres on the electrodes in ESP, and will affect the discharge characteristics; if accumulated in the hopper, it may cause short circuit in the electric field and affect the security of ESP. Moreover, ammonium hydrogen sulfate has strong acid erosion to components of ESP, so shell, hoppers and head plates use anti-erosion steel (NS1), and electrode uses stainless steel.

Security consideration: (1) as dangerous chemicals, storage and use of ammonia strictly abides by the regulation; (2) set up ammonia-sulfate-ratio low limit alarm, large amount of ammonium hydrogen sulfate or ammonium sulfite formed in the condition of excessive low ammonia-sulfate-ratio will lead to deterioration of ESP performance condition.

3.4 The Guarantee of Anti-erosion and Security

Ammonium salt especially ammonium hydrogen sulfate or ammonium sulfite has certain viscosity, and will form scaling on the electrodes and inside components. Despite these salts have good water solubility, they will affect the discharge characteristics even harm stable working when accumulated. So water flush cleaning system is installed in the ESP, nozzles need to clean electrodes and head plates, and stainless steel are used for nozzles and pipes. When the operation condition begin to deteriorate, scaling on the electrodes need to be cleaned in time.

To prevent low temperature erosion in the hopper, and make sure the hopper dry quickly after cleaning, electric heating system is set up outside the hopper, and its working temperature is about 140 ℃.

Considering the viscosity of dust, the inclined angle of hopper is designed above 70°, which is larger than the rest angle of mixed dust.

Slug-flow silo-pump is used for the transport of low density and flocculent mixed dust. Silo wall rappers and cleaning hand holes are set on the hopper.

4 ESP OPERATION AND PROBLEMS

4.1 General Operation

The units were put into operation in the fourth quarter of 2006, and passed 168 hours trial run test in Dec. Generally speaking, the ESP run stably and reached the emission standard. However the factor such as unstable oil supply made the boiler run under long term low load operation, even can't run continuously, and affected the stability of ESP.

There was no SO_3 online testing device before the ESP, and the test data of ammonia online detector at the ESP outlet was unstable. To prevent from forming large amount of viscous ammonium hydrogen sulfate, ammonia in practical use was excessive, and consequently the ammonia emission can't meet standard.

4.2 Other Problems

(1) The combustion condition of boiler was unstable. Especially in low load operation, high carbon yield fly ash which was not completely burned out had high temperature cores, and reburned when accumulated in the hopper, greatly threatened the security of ESP.

(2) The distance between hopper and silo-pump was too long, and pipe aperture was small. Star-shaped discharge valves, silo wall rappers and slug-flow silo-pump transportation can't reach the requirement of unobstructed dust discharge and transportation in the practical application. Low density and flocculent mixed dust had low fluidity, and was difficult to freely fall into the silo-pump. Thus the mixed dust can't be discharged easily but accumulated in the hopper. That caused electric short circuit and affect the stable operation of ESP.

(3) The unstable operation condition caused great temperature fluctuation in ESP. Because temperature fluctuated frequently near the acid dew point, the mixed dust easily adhered on the electrodes, and increased the water flush cleaning frequency, affected the stable work of boiler.

(4) The ammonia quantity was not optimal, and was excessive sometimes.

(5) Silo wall rappers had poor effect to improve the fluidity of low density, flocculent and viscous mixed dust. Frequently use of rappers diminished the lifetime of heating electronic components.

5 CONCLUSIONS AND SUGGESTIONS

(1) Resource utilization of high calorific value meets the policy of energy saving and pollutant reduction. Dry ammonia FGD and mixed dust collection by ESP for high sulfur flue gas are technically feasible, and dust emission can meet the standard in application.

(2) The stable working of boiler is the precondition of ESP's performance and security. The reburning of high carbon yield dust will seriously threaten the security of ESP, so we suggest installing naked fire online monitor in ESP.

(3) We also suggest installing SO_3 online testing device before the ESP. As an assistant mean of controlling ammonia emission, it can decrease not only ammonia escape but also the formation of unsaturated ammonium salt such as ammonium hydrogen sulfate.

(4) We suggest changing the integrated allocation form of conical hoppers, rotary valve , silo wall rappers, plate electric heater and slug-flow silo-pump transportation. Use large angle (or right angle) slender-ship shaped hopper and chain conveyor with scrapers for dust discharge. Add gas gun, which use dry air for power on the flank of hopper, for timing pulse dust cleaning. And use steam coil pipe heater outside the hopper.

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