IOP Conf. Series: Earth and Environmental Science **153** (2018) 062073 doi:10.1088/1755-1315/153/6/062073

# Field Study on the formation and emission characteristics of $PM_{2.5}$ in coal fired power plant unit

**Yongjun XIA[1], Guohui HUANG [2], Yunpeng ZHU[1], Qian WANG[1]**

([1]Jiang Xi Electric Power Science & Research Institute of National Grid，Nanchang 330096, Jiangxi Province, China)

([2]China Power Investment Corporation Jiangxi branch xinchang power Ltd., Nanchang 330117, Jiangxi Province, China)

**Abstract:** Particulate matter(PM) measurements were performed at the inlet and outlet of Fabric filter(FF) and the outlet of limestone-gypsum wet flue gas desulfurization (WFGD) tower at a 220MW pulverized coal fired power plant unit, and the PM formation characteristics, the performance characteristics of FF and the influence of WFGD to PM emission were discussed. The results showed that PM were of bimodal size distribution .The concentration of PMs larger than 2.5μm reduced in the WFGD while PMs less than 2.5μm particularly the PM diameter around 0.5μm increased due to the ultrafine PM aggregation as well as new PM formation from gypsum slurry entrainment.

## 1 Introduction

Coal occupies about 60% in China's primary energy structure. More than 55% of the coal consumed annually is used as coal-fired power generation, and large quantities of particulate matter are generated during coal-fired power generation. The resulting air pollution has drawn widespread attention[1-2]. Fine particulate matter emitted by power plants is an important source of smog pollution in China. $PM_{2.5}$ can unhindered access to the human lungs and severely compromises the health of the human respiratory system [3] .

In view of the emission of particulate matter in coal combustion process, all the coal-fired power plants in China adopt the dust collector for particle control, including electrostatic precipitator (ESP) and bag filter (FF). Different types of precipitator dust removal mechanism is different ,and shows different technical characteristics and effects in practice. Relevant scholars have done a lot of research on the role of ESP in the actual power plant. Liu Xiaowei et al [4] for particulate sampling of 200MW coal-fired boiler，found that the electrostatic precipitator have good Removal effect to particles of size above 2.5μm , <2.5μm particle removal effect is relatively low. Zhou Ke et al. [5] carried out on-site particle testing of two 300MW coal-fired power station boilers equipped with a four-field electrostatic precipitator. The results showed that the particles were bimodal in ESP and the removal efficiency of particles with particle size of 0.1-2.0μm was low, It is considered that this is due to the particle size segment being in the transition zone of the two dust removal mechanisms. Li Zhuang [6] carried out particulate sampling for electrostatic precipitator, bag filter and electric bag composite dust collector, The test results show that the dust removal efficiency of the bag filter and the bag filter is higher than that of the electrostatic precipitator, especially for the small size particles.

At present, the electrostatic dust removal mechanism and technical characteristics of the study has been very full, but there are few researches on the way of bag dust removal. In this paper, a 200 MW blast furnace gas-fired boiler equipped with bag filter is studied. The generation characteristics of the PM, the dust removal characteristics of the bag eliminator and the influence of WFGD system on particulate emission characteristics are studied.

## 2 Experimental part

*2.1 Unit parameters and coal quality characteristics*

The test is carried out on a domestic 200MW blast furnace coal-fired boiler,the boiler type is WGZ670 13.7-8 type high voltage intermediate reheat, natural circulation and solid slag discharge. Boiler installation RMD-27000 bag filter, is a long bag low pressure pulse bag filter system, using pulse jet cleaning method, it's design dust concentration <20mg / $m^3$. The flue gas from pulverized coal combustion passes through the economizer, SCR, FF and WFGD to enter the stack for discharge. Coal was given as a kind of mixed coal with the fineness of 11.8mm during the tests. Table 1 shows the results of a base-based industrial analysis and low-level heat generation.

Table.1 Proximate analysis and calorific value of coal

| Mixed coal | M（%） | A（%） | V （%） | FC（%） | Qnet.ad（J/g） |
|---|---|---|---|---|---|
| | 1.28 | 25.38 | 22.38 | 50.96 | 24971 |

*2.2 Test conditions and methods*

The sampling locations set in this test are located at the FF inlet, the FF outlet and the chimney inlet respectively. FF entrance set two horizontal distribution of sampling points, the vertical direction is located at the center of the flue. FF outlet sampling points set in the flue after the booster fan, there are two vertically distributed sampling points, the horizontal direction is located at the center of the flue. Chimney entrance sampling points located in the post-WFGD flue and vertical distribution, the horizontal direction is located at the center of the flue.

The LPI sampling system was adopted in the experiment, which mainly included: (1) Cyclone, which can intercept particulate with the diameter greater than 10μm of the flue gas hollow, and make the particles entering the LPI in the next stage all under 10μm; (2) LPI Divided into 13 levels to collect particles of different particle sizes, sampling particle size range of aerodynamic diameter: 0.0281 ~ 10μm; (3) A vacuum pump that draws the flue gas steadily and continuously from the flue to ensure that there is a 10 L / min gas flow rate at LPI at rated conditions; (4) A thermal insulation device that heats the sampling system so that the temperature of the sampling system Flue gas temperature close to (135 ℃), to avoid condensation of acid flue gas components in the deposition [7](As shown in Figure 1).

Adding the weighed aluminum film to the LPI's 13th grade respectively before sampling, carry on the parallel sampling test at the entrances, exits and chimney entrances of the bag filter under the same load condition. After sampling, the aluminum film was weighed by the balance of 1 millionth, then the difference was obtained before and after sampling. The concentration of three particles was obtained by calculation. The dust removal characteristics of the bag filter and the influence of WFGD on the emission characteristics of the particulate matter were further analyzed .

## 3 Results and discussion

*3.1 Characteristics of particles mass concentration and particle size distribution*

After using the LPI sampling system for parallel sampling and then graded and averaged to obtain the mass concentration of the particles before and after the bag filter. And calculate the particle size of each particle size concentration in the proportion of $PM_{10}$. As shown in Figure 2.

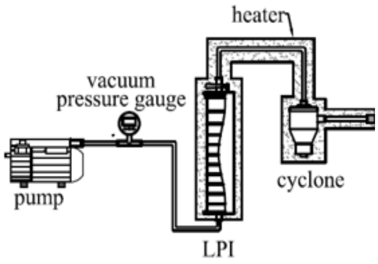


Fig.1 LPI sampling system

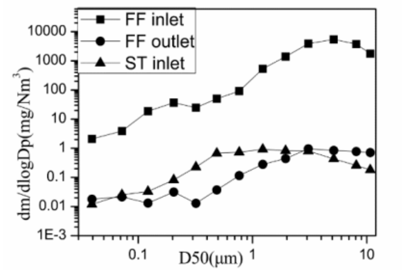


Fig.2 PSD of PMs at the inlet and outlet of FF as well as the inlet of stack

Table 2 Ratio of $PM_{0.2}/PM_{10}$, $PM_1/PM_{10}$ and $PM_{2.5}/PM_{10}$ at each sampling site

| | $PM_{0.2}/PM_{10}$ | $PM_1/PM_{10}$ | $PM_{2.5}/PM_{10}$ |
|---|---|---|---|
| **Pre-dust collector** | 0.64 | 4.38 | 32.97 |
| **After-dust collector** | 3.23 | 13.13 | 44.51 |
| **Chimney entrances** | 9.28 | 51.79 | 82.92 |

It can be seen from Figure 3 that at the inlet of the bag filter, the particlesare bimodally distributed, including the ultrafine mode with a peak particle size of 0.2 μm and the coarse mode with a peak particle size of about 6 μm.The calculated concentrations of $PM_{0.2}$, $PM_1$ and $PM_{2.5}$ before dust removal are 22.497mg / $m^3$, 154.498 mg / $m^3$ and 1161.821 mg / $m^3$ respectively. Among them, $PM_{0.2}$ accounted for 0.64% of the total mass of $PM_{10}$ (As shown in table 2), indicating that the proportion of ultrafine particles before dusting in the total mass of fly ash is relatively small, as reported by McElory et al. After the flue gas passes through the bag filter, particle size of each particle concentration significantly reduced, the concentrations of $PM_{0.2}$, $PM_1$, $PM_{2.5}$ and $PM_{10}$ are reduced to 0.028 mg / $m^3$, 0.113 mg / $m^3$ and 0.862 mg / $m^3$ respectively, Among them, the proportion of $PM_{0.2}$ to the total mass of $PM_{10}$ increased to 3.23%, indicating that the removal efficiency of bag filter for small particle size was lower than that for large particle size. When the flue gas passes through WFGD, the concentration of particles with particle size> 2.5μm decreases, while the particle concentration with particle size <2.5μm increases, the concentrations of $PM_{0.2}$, PM1 and $PM_{2.5}$ increase to 0.099 mg / $m^3$ , 0.552 mg / $m^3$ and 0.884 mg / $m^3$ respectively, an increase of 253.57%、 387.61% and 130.2% respectively.

### *3.2 Dust removal characteristics analysis of bag filter*

According to the changes in particle concentration of different size particles before and after bag filter, draw the bag filter dust removal efficiency curve, as shown in Figure 3.

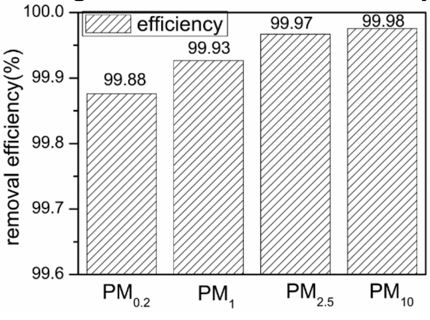


Fig.3(a) PM removal efficiency at different size section of FF

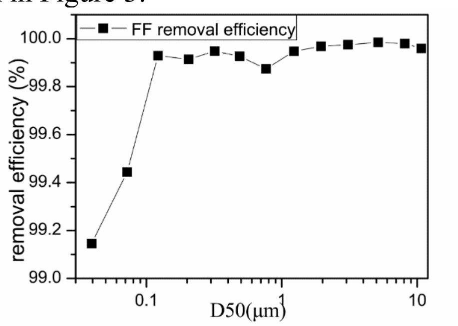


Fig.3(b) The removal efficiency of FF

It can be found that the removal efficiencies of bag filter for $PM_{0.2}$, $PM_1$, $PM_{2.5}$ and $PM_{10}$ are 99.88%、99.93%、99.97% and 99.98% respectively. With the reduction of the particle size, the removal efficiency decreases. The removal efficiency of large size particles is very high, while the removal efficiency of ultrafine particles below 0.2μm is low. We analyze the bag filter for the removal of ultrafine particles low efficiency mainly includes two reasons: (1) Bag filter In the work process, the collected fly ash will form a gray layer on the surface of the bag. With the continuous accumulation of the ash layer, the flue gas will increase through the resistance of the bag to form a tiny "pinhole" , "Pinholes" further impede the passage of large particles , the impact on the penetration of ultrafine particles is relatively small; (2) The bag filter adopts the method of pulse jet cleaning, the ultrafine particles after the jet cleaning are more likely to remain in the chamber of the dust collector, and it is easy to penetrate the bag when the flue gas is treated again. Those two reasons limit the ability of the bag filter to intercept ultrafine particles, resulting in the appearance of a penetrating window.

*3.3 WFGD on the emission characteristics of particulate matter*

Comparing the particle concentration changes of bag filter exit and chimney inlet, then formulation the following formula.

$$(D_{ff} - D_{wfgd})/ D_{ff} *100\% \quad (1)$$

Among them, Dff on behalf of the bag filter outlet particulate matter mass concentration, Dwfgd on behalf of WFGD export particulate matter mass concentration. According to the above formula, can obtain the influence of WFGD on the concentration of different size particles.As shown in Figure 4.

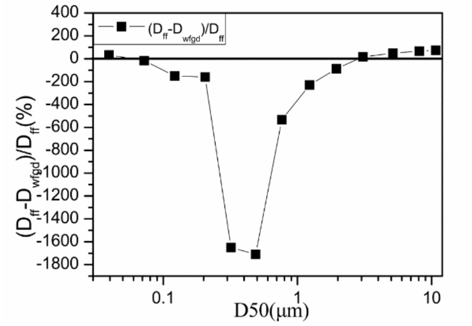


Fig.4 The influence to PM emission characteristics of WFGD

As can be seen from Figure 5, WFGD has a certain removal effect on the particles of >2.5μm, and at the same time, the concentration of the small particles in the flue gas will be greatly increased. The particle concentration of 0.5μm increases most significantly. Analysis of the role of WFGD on the particulate matter is mainly divided into two aspects: (1) The gypsum slurry in WFGD have a washing effect on the particulate matter in the flue gas, intercepting part of the particulate matter; (2) During operation of the WFGD, part of the gypsum slurry is carried by the flue gas and forms new gypsum solid particles as the water evaporates. In addition, the WFGD internal high-humidity environment, will exacerbate the collision and agglomeration of ultrafine particles to form a larger particle size of new particles. Combining with Figure 5, WFGD mainly has the effect of capturing particles of size> 2.5μm, and the larger of the particle size, the more obvious of the effect. Therefore, the concentration of particles < 2.5μm after WFGD increased. The particle size of gypsum produced by WFGD is about 0.5μm, and the ultrafine particles also collide and grow up to about 0.5μm. As a result, the concentration of particles near the particle size of 0.5μm is greatly increased [8].

In the meantime, the increase of the small particle size after WFGD in this study was significantly larger than that reported in the literature. The analysis is as follows: The bag filter is more efficient, especially for the small particle size removal efficiency is higher than the ordinary electrostatic dust removal mode, resulting in WFGD entrance small particle size concentration is low, then the proportion of newly formed particles in WFGD to the total amount of particles increased, which led to a large increase in the concentration of small particles after WFGD.

## 4 Conclusions

In this paper, a LPI sampling system was used to test on-site particulate matter of a 200MW coal-fired generating unit in China. The generation characteristics of the particulates, the dust removal characteristics of the bag filter and the influence of the wet limestone-gypsum desulfurization system on the particulate emission characteristics were studied.Got the following conclusion.

(1) There is a clear bimodal distribution of PM particles. The proportion of ultrafine particles in the total PM is low, accounting for only 0.64%.

(2) The removal efficiency of bag filter for $PM_{0.2}$, $PM_1$, $PM_{2.5}$ and $PM_{10}$ are 99.88%, 99.93%、99.97% and 99.98% respectively.Bag filter on the overall removal of particulate matter is very efficient, but the removal of ultra-fine particles low.This is mainly due to dust attached to the bag and formating "pinhole" in the dust removal process, ultrafine particles penetrate these "pinhole" to be easier than the larger size particles. In addition, the small size particles are more likely to remain in the chamber during the cleaning process, which is easy to penetrate into the bag during the flue gas treatment.Those two reasons leads to the low efficiency of the bag filter in removing ultrafine particles .

(3) When the flue gas flows through WFGD, the concentration of particles with size> 2.5μm is increased, while the particle concentration with size <2.5μm drops sharply.WFGD primarily cleans up and intercepts particles> 2.5 μm, causing their concentration to decrease, and this effect is more pronounced with particle size increasing. During operation of the WFGD, the gypsum slurry is carried by the flue gas, resulting in the generation of new solid gypsum particles after evaporation and the collision, At the same time, the ultrafine particles in the flue gas inside WFGD collide, agglomerate and grow up. These two processes form particles with size of about 0.5μm. Therefore, when the flue gas flows through WFGD, the concentration of particles with size of about 0.5μm is obvious increase.

## References

[1] Junping Si, Xiaowei Liu, Minghou Xu, et al, Yong-Chil Seo. Effect of kaolin additive on PM2.5 reduction during pulverized coal combustion: Importance of sodium and its occurrence in coal. Applied Energy,2014, 114: 434-444.

[2] HONG Liang, WANG Lipeng, QI Hui et al. Experimental research on agglomeration characteristics of fine particulate matters in Shajiao C Power Plant[J]. Thermal Power Generation,2014,43(9),124-128.

[3] ZHAO Chengmei, SUN Junmin, DENG Yinsheng et al. Physiochemical characteristic of fine particle(PM2.5) in fly ash from coal combustion[J]. Research of Environmental Sciences, 2004,17(2)：71-75.

[4] LIU Xiaowei. Study the influences of combustion conditions and coal characteristics to inhalable particles[D]. Wu Han, HUST, 2008.(in Chinese)

[5] ZHOU Ke. The properties and control of fine particulates generated from coal combustion[D].Wu Han, HUST,2011,21-25.(in Chinese)

[6] LI Zhuang. Research on PM2.5 production and emission characteristics of thermal power plant pulverized coal boiler [D]. Harbin, Harbin Institute of Technology, 2013,1-2.

[7] SI Yanhong, WU Huacheng, ZHOU Weiqing et al. Analysis on the common problems of PM2.5 emission sampling methods in coal-fired power plants[J]. North China Electric Power, 2015，43-47.

[8] ZHOU Ke, NIE Jianping, ZHANG Guangcai et al. Emission characteristics of particulate matter from coal-fired plant equipped with WFGD[J]. Thermal Power Generation, 2013,42(8),81-85.