Development of Turbulent Agglomeration Devices

Weikuo Zhang*, Bo Xu, Zonghui Li

Huadian Electric Power Research Institute Co., LTD., Beijing, China
*Corresponding author e-mail: weikuoz@163.com

Abstract: The capture rate of ultra-fine particles emitted by the coal-fired power plant is low, which is easy to enter the human body, and it is very harmful. The capture of ultra-fine particles will be the focus and difficulty in the development of dust removal technology. Turbulent agglomeration technology is a simple, economic and efficient method. This paper introduces the research and development process of turbulent agglomeration devices, and provides references for understanding the turbulent agglomeration technology of ultra-fine particles.

1. Introduction

As the main way of coal consumption, coal-fired power generation has caused increasingly serious pollution to the environment for a long time, which involves controlling the emission of particles in coal-fired flue gas. In some areas of China, particle emission is required to be less than 5mg/m³, which undoubtedly puts forward stricter requirements for the existing dedusting technology and equipment of coal-fired power plants. The mainstream device for controlling soot emission in coal-fired power plants is electrostatic precipitators, and the capture rate of ultra-fine particles is low. These fine particles occupy a small percentage of mass, but are difficult to be removed by conventional dust removal devices and can be absorbed by the human body. Therefore the pollution of the fine particle has become the focus of the whole society, and strengthening the collection of fine particulate will be a new direction for the development of dust removal technology.

The traditional dust removal device has limited control over fine particles or the cost is too high, and promotes the accumulation and growth of fine particles through physical or chemical actions, making it easy to be captured by subsequent dust removal equipment, so as to improve the efficiency of particle collection. Moreover, the agglomeration technology does not need a large number of rectification of the existing dust removal device in the power plant, the cost is low and the operability is relatively strong. At present, the main agglomeration methods are: electric, magnetic, chemical, thermophoretic sedimentation, and turbulent agglomeration, etc. Among these methods, the equipment of turbulent agglomeration is simple, economical and efficient, and easy to realize. Turbulent agglomeration refers to the difference in velocity between different particles in the turbulence field. Due to the action of inertia, large particles will pass through the turbulence vortex, and fine particles will rotate with the vortex, so that fine particles will collide with the larger particles and adhere to the large one.

This paper mainly introduces the research and development process of agglomeration device, and provides a reference for comprehensive understanding of the turbulent agglomeration method of ultra-fine particles.
2. Research of turbulent agglomeration devices

Mi et al. [2] studied the turbulent agglomeration technology of ultra-fine particles, and developed a set of bipolar charged turbulent agglomeration device (as shown in Figure 1(a)). Three kinds of vortex sheet structures are shown in Figure 1(b), which are rectangular, zigzag and trapezoid. These vortex sheets all have two forms of "Z" and "I".

The turbulent agglomeration device is divided into two parts: large and small vortex section. The incoming flue gas first passes through the large vortex sheet, plays a role of smoke and dust diversion. Then flows into the small vortex sheet region. The small-scale turbulence produced by the small vortex sheet draws the fine particles into the vortex area, which improves the collision efficiency between particles and the effect of turbulent convergence. The large particles pass through the turbulent vortex and collide with the fine particles in the small-scale vortex. Fine particles adhere to and accumulate on large particles and are removed by the subsequent dust collector.

In addition to the experimental research, Mi also numerically studied the particle movement speed, trajectory, pressure change, and agglomeration effect of the device. The results show that the faster velocity of the flue gas, the higher turbulence effect on the fine particles, and the more probability of collision and agglomeration between the fine particles. While the large particles are less affected by the turbulence, so that the speed difference between large and fine particles leads to the obvious relative motion between them, and increases the turbulent agglomeration effect of the large and fine particles. However, with the increase of vortex sheet, the turbulent flow is strong, which improves the agglomeration effect of particles, but the resistance is also increased accordingly. The optimal design criterion of turbulent agglomeration is to increase the turbulent residence effect and control the pressure drop. Therefore, the size, number and arrangement of vortex sheets need to be verified by calculation and experiment.

Chen et al. [4] carried out experimental research by installing a turbulent agglomeration device in the front flue of a 300 MW coal-fired electrostatic precipitator. The experiments show that particles volume ratio with particle size of 2.65 and below 10.48 μm decreased by 56.7% and 62.3% respectively. The removal efficiency is increased to 99.77%, which reduces the smoke and dust emission concentration after electrostatic precipitator by 26.34mg/Nm³. The experiment shows the good effect of the agglomeration device to control the emission of ultra-fine particles.

Zheng et al. [3] designed a particle agglomerator as shown in Figure 3; and numerically studied the influence of the coupling different agglomeration mechanism models and Population Balance Model on the agglomeration process of turbulent particles. He considered the influence of the repulsive potential energy Umax between particles on the agglomeration rate; He also introduced the trapping
efficiency to modify the agglomeration core, and compared the modified turbulent agglomeration model with the experimental results.

Fig. 3. Schematic of the agglomeration device (Zheng)

Zhang et al.\cite{5} conducted a pilot test on the effect of Z-shaped zigzag element agglomerator on the particles removal, and compared with the numerical simulation results. He also studied the agglomeration effect of distance between the elements, the angle of elements and the concentration of particles. The agglomeration effect of fine particles was about 50%.

Fig. 4. Layout and structure diagram of agglomeration device (Zhang)

3. Conclusion
Turbulent agglomeration technology can effectively control the emission of fine particles, and it is simple, economic and efficient. Based on the existing power plant dust removal devices, simple rectification can be carried out, which is suitable for large-scale applications. However, the technology started late in China, and is not mature enough. At present, most of the technology is still in the laboratory stage, and further efforts are needed to put it into practical application.

Acknowledgments
This work was financially supported by “CHDER Key Program (CHDI.CB-2016-06)” and “China Huadian Co. Key Program (CHDI.SF-2018-01)”

References
[1] Minghou Xu, Wenyi Wang et al. New progress in research on fine particles removal technology of coal-fired power plant[J]. Proceedings of the CSEE, 2019, 39(22): 6627-6639.
[2] Jianchun Mi, Cheng Du, Liqing Yang. Devices and methods for promoting particle interaction, China, CN201010504951.4(P) 2011-4-6.
[3] Jianxiang Zheng, Shuai Xu, et al. Study on agglomeration model of ultra-fine particles and agglomeration in turbulent coalescer[J]. Proceedings of the CSEE, 2016, 36(16): 4389-4395.
[4] Donglin Chen, Kang Wu, et al. Experimental study of ultra-fine particle agglomeration device installed on a 300 MW PC-fired boiler[J]. Chinese Journal of Environmental Engineering, 2015, 9(4): 1926-1930.
[5] Pengfei Zhang, Jianchun Mi, et al. Influences of elemental arrangement and particle concentration on fine particle amalgamation[J]. Proceedings of the CSEE, 2016, 36(6): 1625-1632.