Study on the Integration of Flue Gas Waste Heat Desulfurization and Dust Removal in Civilian Coal-fired Heating Furnace

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Abstract. To put the policy of civil coal governance environment, the clean and efficient use of technology and civilian campinlanlu practical application within consideration, this paper designed a set of flue gas desulfurization dust removal integration of recovery of waste heat from flue gas treatment system, in order to achieve the recovery of waste heat of flue gas and reduce civilian particulate matter and sulfur dioxide emissions. The flue gas treatment system mainly used the structure of the spiral coil heating and stainless steel tube, and will recovery the smoke waste heat ; There are three dust removal processes: the strainer mesh filtration of the entire unit, adsorption of modified activated coke and water spray cleaning; Desulfurization part was designed to operate the easy drawer cabinet structure, using the modified adsorption properties of activated coke processing SO2 in flue gas. The experimental results show that the processing system of dust removal and desulfurization efficiency is at 80%.

Keywords: Coal-fired Heating Furnace; Waste heat recovery; Desulfurization; Dust removal; Flue gas treatment.

1. Introduction
China is one of the largest coal producer and consumer countries in the world that coal energy consumption accounts for about 65% of Chinese total energy consumption, and coal-based energy supply and consumption patterns will last a long time. As a primary energy source, the coal is mainly through the combustion to get energy [1]. In the northern region, the rural residents cook and heat more using coal as fuel in winter, and burn civilian coal directly, the combustion efficiency is low. The flue gas emissions pollutants is one of the main sources causing the northern winter in recent years haze, because of the small size of civil stoves, large quantities, and not installed flue gas desulfurization and desulfurization device [2].

At present, according to incomplete statistics, the national rural residential heating stoves hold about 60 million units, and the quality and performance of civilian coal-fired heating stoves vary widely in rural areas is affected by the economic conditions, living habits and other factors. The existing types of coal-fired heating stoves, in the principle of coal combustion used the traditional layer of combustion (that is, on the coal, the ashes from the lower layer are transferred to the top of the coal along with the flame). There are many problems in this combustion: such as burning is not
enough stable, smoke dust is content, with a higher amount of SO2, black smoke is easy produced, and combustion efficiency is low. At the same time, the large amount of waste heat generated by coal-fired furnaces [3, 4] cannot be used directly, but is directly discharged into the air. Therefore, when the coal is burned, there is not enough heat, thereby to pollute the environment and waste a lot of waste heat. He Yihao [5] and others use the first law of the thermodynamics and the second law to analysis of the boiler waste heat recovery efficiency, and find ordinary coal-fired heating furnaces have more waste heat, more use value. Therefore, this paper designed a flue gas treatment system to deal with the exhaust gas from the heating furnace.

2. System Overall Design

2.1. Design Principles

- the entire flue gas treatment device can work properly is the primary principle
- meeting the basic economic conditions of the family is a basic principle
- facilitating user operation is a guiding principle

2.2. System Components and Functions

2.2.1. Flue gas waste heat recovery device. A waste heat recovery device is installed at the flue gas outlet of the heating furnace (Figure 1), and a large amount of waste heat is discharged to the outside through the waste heat recovery device for recycling, which can be used as the main heat source of the heating system.

![Figure 1. Flue gas waste heat recovery device](image-url)

The device consists of coil-structured stainless steel pipe, flue gas inlet pipe, flue gas outlet pipe, outer cylinder, water inlet and water outlet. Flue gas inlet is connected to the heating furnace flue outlet, and flue gas outlet is connected to the dust removal device. The coils (the lower part of the water inlet, the upper part of the water outlet) lead to the entire heating system, involved in the heating system of water circulation. The coil is made of ferritic stainless steel, which not only has excellent corrosion resistance, but also has high thermal conductivity and heat resistance. The entire coil structure is relatively compact, the heat transfer capacity of each ring is also large, and the heat transfer, flexible layout, safe and reliable work can be ensured by using a small number of steel pipe.

The radius of the coil is smaller than the radius of the flue gas inlet, this allows the coil to be in full contact with the flue gas. The dust removal device and the desulfurization unit have certain obstacles
to the flue gas flow, so that the flue gas just removed from the heating furnace can quickly pass through the coil, and the waste heat recovery efficiency is greatly improved.

2.2.2. Dust removal device. The dust removal device consists of two parts (Figures 2 and 3). Figure 2 Cartridge dust collector, internal dust filter, dedicated to filtering coarse and fine dust; Figure 3 Atomization device, spray tube spraying water mist dedicated to cleaning dust.

![Image 1](image1.jpg)

**Figure 2. Dust removal device**

![Image 2](image2.jpg)

**Figure 3. Desulfurization device**

The cylindrical filter cartridge directly protrudes on the flue gas pipe by its own gravity protruding part, so that the entire filter does not need to be fixed, and it will not shake due to excessive flue gas flow, and it is easy to disassemble. The upper and lower cylinders are connected by open and closed steel pipe joints. Cylindrical filter structure: divided into two layers, a large-diameter outer frame, a small-diameter inner filter screen, the upper end is all closed, and the lower end cover has a ring support. The dust filter is designed with a tilt angle. Cylindrical element filters are mainly used in stainless steel.

2.2.3. Desulfurization equipment. The desulfurization device (Figure 3) is designed as a drawer cabinet type. The principle of desulfurization is to use the adsorption characteristics of modified activated coke [6] to deal with flue gas SO2.

The desulfurization device mainly adopts dry flue gas treatment technology, which mainly uses activated coke adsorption and filtration functions, while removing SO2 and soot in flue gas, and can recover sulfur resources. The method has the characteristics of low investment, simple process and small area and so on.

2.2.4. Atomization device. The design of the atomization device (Figure 4) after the flue gas desulfurization, water mist is on the role of dust purification desulfurization.

The horizontal smoke pipe is inclined downward in the direction from indoor to outdoor, so that water droplets can flow into the water storage tank. When the soot flow reaches the level of the smoke pipe, the water spray pipe sprays water mist, and the atomization vaporizes instantly to form smaller aerosol particles, which are fully mixed in the longer chimney pipe to accommodate the mixing of smoke and water mist. When the air flows through the vertical smoke pipe, the cold air meets the condensed water and enters the lime storage tank under the action of gravity sedimentation, so as to achieve the purpose of dust removal.
2.2.5. Chimney Pipes. The entire chimney tube is made of austenitic [7,8] stainless steel, which is resistant to acid corrosion. The connection between the pipeline and the pipeline should be a continuous connection, as shown in Figure 5. The diameter of the chimney head is (9.5 ± 0.1) cm, and the diameter of the small head is (9.1 ± 0.1) cm. The required opening diameter for the chimney to extend outside the window is (9.5 ± 0.5) cm. The flue gap is sealed with refractory materials, and there will be no leakage of smoke. Fire-resistant seals are used for disassembled parts and pipe joints. During the whole experiment, the system can smoke normally without any smoke leakage.

3. Analysis of Experimental Results

The whole experiment uses Sambo small coal-fired heating furnace with anthracite as the experimental object.

3.1. Experimental Data Analysis of Dust Removal Process

Figure 6 is a graph comparing data before and after dust removal. It can be seen from Figure 6 that the content of PM10 before treatment is 2803-3824 μg/m³, and the content of PM10 after treatment is 1012-1420 μg/m³. The removal efficiency of PM10 reached 88.18%. The PM2.5 content before treatment is 167-688 μg/m³, and the PM2.5 content after treatment is 91-330 μg/m³. The removal efficiency of PM2.5 reaches 87%. After 35 minutes, experiment is carried out with coal. Before coal is burned, with the burning of anthracite, the PM10 content gradually decreases at 40 minutes, which causes a sudden increase in PM10 content, but then gradually reduces emissions. It can be seen from the figure that the PM2.5 after treatment can reach up to 330 μg/m³. Although it has not changed much compared with the previous 688, the removal effect of PM2.5 in the flue gas can still be seen. Experimental results show that the removal rates of PM10 and PM2.5 are both greater than 87%.
3.2. Experimental Data Analysis of Desulfurization Process

Figure 7 is a comparison of data before and after desulfurization. It can be seen from Figure 7, whether before or after desulfurization, as time passes, after coal causes a sudden drop in SO2 content, SO2 emissions gradually decrease within 35 minutes, because the volatile content of anthracite is very low. For flammable coal, the spray gun burns for a longer time and the flame center is lower. Therefore, the SO2 concentration of anthracite at the initial stage of combustion is lower, and the H2S concentration is higher. In this experiment, the SO2 emission concentration before desulfurization was 9.6 ppm on average, while the concentration after desulfurization was reduced to 1.8 ppm. In the experiment, the desulfurization efficiency reached 80.125%, which has reached the desulfurization efficiency requirement required by the power plant.

3.3. Experimental Data Analysis of Waste Heat Recovery Process

During the experiment, plastic hoses were connected to the two joints of the coil, and the plastic hoses entered the pool. During the entire test, the water temperature of the pool rose to 45°C, which did not eliminate the loss of the pool water temperature during the test. The data shows that the flue gas will become part of the waste heat, and if it is not used, this part of the heat will be lost. Although the impact on the entire heating system will not be too great, the heat loss can be reduced to a certain level. The waste heat recovery of the flue gas treatment system is realized.

4. Conclusion

- The system is designed with a flue gas waste heat recovery device. The core components of the coil are designed to participate in the water circulation of the entire heating system. The temperature of the pool water makes the system realize the recycling of waste heat;
- The system can treat the dust in the flue gas three times, greatly reducing the amount of dust discharged into the air, and achieving a removal effect of more than 80% in the dust;
- The structure system design of the desulfurization device with drawer cabinet is simple in structure and easy to operate. The desulfurization efficiency in the experiment is over 80%;
- The system does not produce secondary pollution during the dust removal and desulfurization process, which is convenient for post-processing;
- Sulfur resources (concentrated sulfuric acid, sulfuric acid, sulfur) can be fully recycled while processing pollution, which can realize resource sulfur and produce certain economic benefits;
- The diameter of the system pipe is variable and the size of each device of the whole system is adjustable;
- The entire equipment will apply for invention patents and be used to improve civil coal-fired heating furnaces.

Acknowledgments

This work is partially supported by Natural Science Foundation of Hebei Province (Grant
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