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Complex flue gas cleaning of thermal power plants

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Abstract. Currently, there are significant emissions of pollutants from electric power facilities in our country. At the TPP, sulfur and nitrogen purification technologies are practically not used, most of the installed ash collectors operate with low efficiency and using outdated technology, and environmental indicators are significantly inferior to foreign analogues. At the same time, there is experience in the development and development on an industrial scale of various methods and tools that provide a significant reduction in emissions of particulate matter, sulfur oxides and nitrogen. The article considers an example of such a technology. For particle cleaning, a ceramic high-temperature filter with a catalytic coating is used to selectively remove nitric oxide when interacting with carbomide. The sulfur is removed by chemical neutralization with a lime sorbent.

1. Introduction

Attention to the environment preservation is growing all over the world due to the projected accelerated development of the global economy [1]. Great importance is given to the problem of solid waste and to air pollutants exposure minimization. One of the objects of special attention is acid rain caused by the formation of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) when burning fossil fuels and waste.

Energy providing enterprises (power plants, boiler houses) are one of the largest sources of air pollution. Modern flue gas cleaning systems do not correspond to the increase in emissions and stricter environmental standards, therefore, to solve the problem of atmospheric pollution, it is necessary to develop new methods of high-temperature gas cleaning [1].

2. Materials and methods

In the process proposed, three pollutants (SO_x, NO_x and particles) are removed from the flue gas in a high temperature bag filter[2-4]. The process includes ejection injection of calcium-based sorbents ($CaCO_3$, Ca $(HCO_3)_2$, for SO_2 binding, selective catalytic reduction (SCR) of NO_x with ammonia (NH_3) or ammonia compounds (urea, $(NH_4)_2SO_4$,) and solid particles trapping in a high-temperature filter made of fibers or granules by catalytically activated metal oxides (Ti, V, Fe oxides) with compressed air pulse regeneration (figure 1).

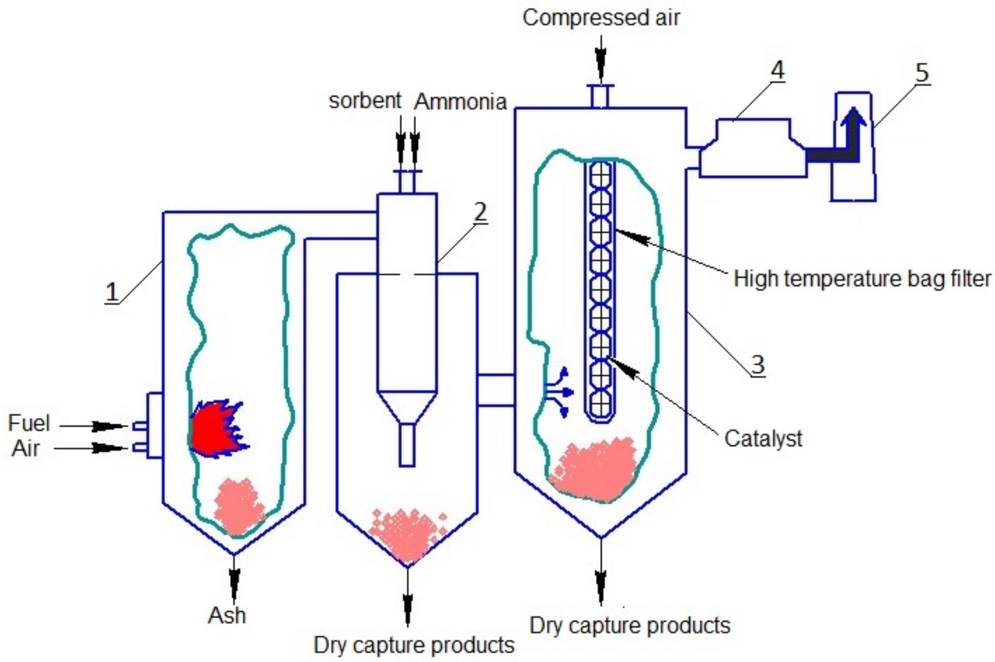

Figure 1. The proposed scheme for cleaning gases of thermal power plants using waste products as fuel: 1-furnace, 2- ejector scrubber; 3- high temperature bag filter; 4- waste heat exchanger; 5 - pipe.

3. Results and Discussion

Filtering ceramic elements that are used to purify gas emissions with an operating temperature of up to 900 ^{o}C were investigated in this work. Ceramic filter elements are made in the form of solid candles, with low density and high porosity. They are made monolithically from aluminosilicate fibers[5].

Optimization of the regeneration system is one of the most important tasks in filters operation. The studies were carried out on an experimental unit [6]. The purpose of the study was to determine rational values of the parameters of the compressed air pulse pressure, pulse duration, nozzle diameter and configuration, residual hydraulic resistance, which prevents re-deposition of removed particles.

The application of ceramic elements for high-temperature cleaning of flue gases makes it possible to increase the cleaning efficiency and use of the heat of exhaust gases while increasing the equipment reliability and reducing economic costs.

In this case, the neutralization of harmful gas components will occur through the following chemical reactions.

Lime (limestone) method [7-10]:

$$\begin{gathered} CaCO_3 + SO_2 \rightarrow CaSO_3\downarrow + CO_2 \\ CaO + SO_2 \rightarrow CaSO_3\downarrow \\ 2CaSO_3 + O_2 \rightarrow 2CaSO_4\downarrow \text{ - gypsum} \end{gathered} \quad (1)$$

Ammonia-thermal reduction method[11-12]:

$$6NO + 4NH_3 = 5N_2 + 6H_2O, \quad (2)$$

Active chemisorbent can be added to the flue gas after the fuel combustion boiler, for example, into the gas path or a special reactor. In this case, the flue gas can be conditioned by the introduction of additional water for the process greater efficiency. The introduction of chemisorbent after the boiler eliminates the risk of the operation deteriorating of the latter. In recent years, interest in such methods has increased due to low capital investment and operating costs.

As a chemisorbent, it was decided to use calcium carbonate, obtained as a by-product in the manufacture of ammonium nitrate phosphate fertilizer at the OJSC "Minudobreniya" plant.

The data prove high efficiency of sulfur oxides trapping at the level of 99 - 99.4% (figure 2).

Preliminary results show that with a stoichiometric ratio Ca/S at the inlet of about 2.0, SO_2 emissions are reduced by 80-90%, which is significantly more than expected 70%. It corresponded to a residual concentration of <30 mg / m^3. This is partly due to the higher degree of capture and the sorbent deposition on the bag filter (not more than 10 mg / m^3).

The degree of gas purification from nitrogen oxide is 90-94%, which is due to the presence of ammonia impurities in the sorbent. This creates conditions for the selective catalytic reduction of nitrogen oxides.

In the process of flue gases cleaning with ammonium carbamide the reduction of nitrogen oxides to molecular nitrogen occurs in a vapor-gas mixture, sulfur dioxide reacts with the formation of ammonium sulfate:

$$4NO + 2CO(NH_2)_2 + O_2 = 4N_2 + 2CO_2 + 4H_2O$$
$$2NO_2 + 2CO(NH_2)_2 + O_2 = 3N_2 + 2CO_2 + 4H_2O \quad (3)$$

When carbamide is added to the sorbent, the efficiency of nitrogen oxides trapping increases to 97-98% (figure 3).

The results of the NO_x reduction tests with the TiO_2 catalytic coating showed a reduction efficiency within 90%, which was achieved with the NH_3 / NO_X ratio = 0.85, and which made it possible to maintain nitrogen oxides concentration at the outlet of the unit equal to <70 mg / m^3.

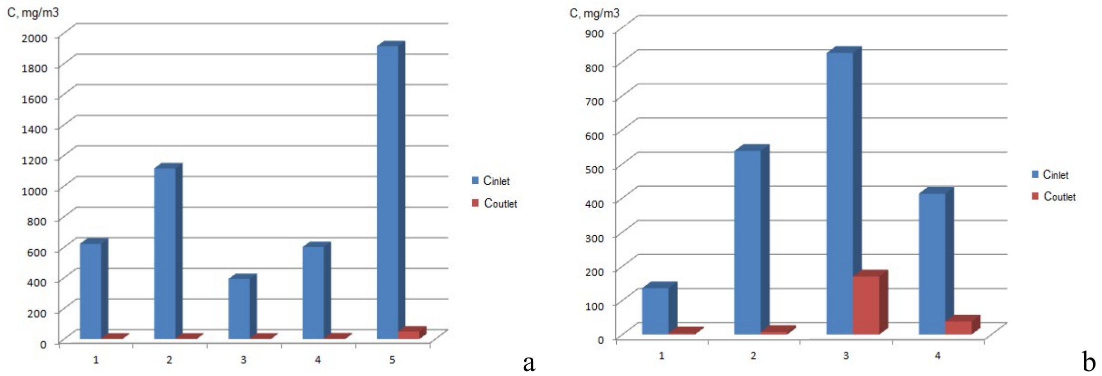

Figure 2. Efficiency of SO_2 capturing with active calcium carbonate (a) and with carbamide (b).

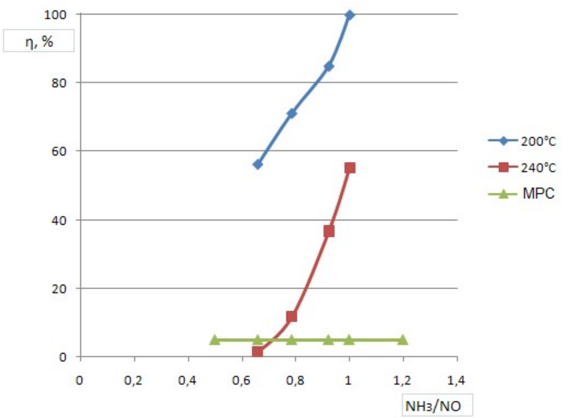

Figure 3. Efficiency of nitrogen oxide capture on the stoichiometric ratio NH_3 / NO MPC – (Maximum Permissible Concentrations).

A comparison of the efficiency of a high-temperature flue gas cleaning unit using waste products as fuel with the data from scientific- and information sources is carried out [7-12].

4. Conclusion

This process developed has several potential advantages:

1. Processes implemented in one technological unit are used to clean flue gases from a complex of dissimilar pollutants. The compactness of the treatment unit together with low capital costs (CAPEX) make this method economically viable;
2. Preliminary removal of solid particles and sulfur oxides preserves the catalytic activity of the filter for a longer time;
3. Dry introduction of the sorbent does not affect the thermophysical characteristics of the flue gases, which can be used to utilize their heat;
4. Removal of acidic components on the filter eliminates the condensation of acid vapors in heat exchangers, contributing to their durability.

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