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Design of Desulfurization and Denitration Experiment Table

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Abstract

Design Background. With the continuous development of industrial trade in China, the domestic social economy has grown significantly. But at the same time, along with the many benefits of industrial production and creation, because coal-fired power plants in the power industry will produce a lot of harmful gases, these harmful gases will not only harm people's respiratory systems, but may also seriously affect the normal operation of society. The primary energy consumption is mainly coal in our country, and the main use way of coal is combustion. Coal combustion will produce dust, sulfur oxides, nitrogen oxides and harmful heavy metals. The proportion of coal with high ash content and high sulfur content in power coal of our country is relatively large, and it has not been processed by washing. Therefore, the total pollutant emissions of coal-fired power plants are large and concentrated, which become one of the most important air pollution sources in our country. At present, environmental problems such as smog, acid rain, greenhouse effect, and ozone layer destruction are becoming more and more serious, coal-fired pollution has become an important issue restricting the sustainable development of economy and society in our country, and has attracted great attention from the society. Therefore, this design will focus on the removal of sulfur oxides and nitrogen oxides from the gas emitted by power plants.

Keywords

Desulfurization and denitration, experiment table.

1. The Formation Mechanism of Nitrogen Oxides and Sulfur Oxides

1.1. The Formation Mechanism of Nitrogen Oxides (NO_x)

Nitrogen oxides are mainly composed of nitric oxide (NO) and nitrogen dioxide (NO_2), they are collectively called are NO_x. In most combustion ways, the main component of nitrogen oxides produced by coal combustion is NO, which accounts for about 90% of the total of NO_x. In the atmosphere, NO will be rapidly oxidized to NO_2. During the combustion process, there are two main ways for the formation of NO_x: one is that organic combination in the heterocyclic nitrogen oxides in the coal are thermally decomposed in the high-temperature flame and further oxidized to produce NO_x; the other is that the nitrogen in the air for combustion reacts with oxygen at high temperature to produce NO_x. Research believes that there are three types of NO_x generated in the combustion process: thermal, rapid and fuel type. The fuel type has the highest share among them.

1.2. The Formation Mechanism of Sulfur Oxides (SO_x)

The sulfur in coal reacts with oxygen during the combustion process to form SO_x. The sulfur dioxide released by burning coal exceeds 85% of the total sulfur dioxide emissions, which cause serious air pollution. Sulfur dioxide is a colorless, transparent, and pungent smell gas. Sulfur dioxide touches water to generate sulfurous acid, which is the main component of acid rain. If sulfur dioxide touches water vapor indoors, it will corrode the metal parts of the building, and

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the construction of the house will reduce the life span. If the concentration of sulfur dioxide in the atmosphere is too high, it will have an impact on the human body and may increase the incidence of respiratory diseases, even cause ulcers and pulmonary edema, until death by suffocation.

2. Desulfurization and Denitration Principles of Flue Gas

2.1. Flue Gas Denitration Technology

The nitrogen oxides in the flue gas and the solution of the reducing agent (such as ammonia, urea) sprayed into the flue gas will produce an oxidation-reduction reaction under appropriate conditions (the catalyst may be required). N_2 and H_2O which are harmless to the environment are generated and discharged into the atmosphere.

2.2. Flue Gas Desulfurization Technology

2.2.1. Wet Flue Gas Desulfurization

The desulfurization process is carried out in the solution, and the desulfurization agent and the desulfurization products are in the wet state, and the reaction temperature of the desulfurization process is lower than the dew point. The wet desulfurization process is a gas-liquid reaction, with fast desulfurization reaction speed, high desulfurization efficiency and high calcium utilization rate. There is limestone-gypsum method, sea water method, ammonia method, magnesium oxide method and so on. Solid gypsum generated by sulfur is removed or reacted with alkali to generate soluble salt to be removed.

2.2.2. Semi-Dry Flue Gas Desulfurization

It is carried out in gas, solid and liquid three phases, the sensible heat of the flue gas is used to evaporate and absorb the water in the liquid, so that the final product is a dry powder. The system is simple, the investment cost is low, and the floor space is small, but the desulfurization rate and absorbent utilization rate are low. There is mainly rotary spray drying method, furnace spraying calcium tail humidification activation method, flue gas circulating fluidized bed desulfurization technology, and humidifying ash circulating desulfurization technology.

2.2.3. Dry Flue Gas Desulfurization Technology

The reaction is completely carried out in a dry state, and the reaction product is also in dry powder form, and there are no problems such as corrosion and condensation. There is mainly high-energy electron activation oxidation method, charged dry powder jet desulfurization method, activated carbon adsorption method. Molecular decomposition, physical adsorption and chemical adsorption are used to remove sulfur by electron impact.

2.3. Desulfurization and Denitration Principle of Metal Oxide

The metal oxide in the carrier, SO_2 and O_2 in the flue gas react to form sulfate, the sulfates can be used as NH_3 selective catalysts for the reduction of nitrogen oxides and nitrogen, so achieve the purpose of desulfurization and denitration. Metal sulfate and methane will form simple substance metals and metal sulfides under the reduction reaction, in the flue gas generated by the operation of thermal power plant boilers, metal oxides are generated by oxidation to achieve coordinated control of desulfurization and denitration. The metal oxide desulfurization and denitration technology includes many processes, of which the CuO process is the most common; the common carriers of this process are SiO2, Al_2O_3 and activated coke, the SO_2 removal rate exceeds 90%, and the NO_x removal rate can reach 75%-90%.

2.4. Simultaneous Desulfurization and Denitration Technology of Urea Wet

As a strong reducing agent, urea is weakly alkaline, can effectively remove SO_2, and the desulfurization product ammonium sulfate can be recycled; it also has good performance when removing NO_x; urea can produce oxidation-reduction reactions with NO_x to produce harmless N_2, which avoid the generation of secondary pollution. Simultaneous desulfurization and denitration use urea method, the best mass fraction of urea solution is 10%, and the best liquid-gas ratio is 10L/m^3; under the above optimal operating conditions and the NO_x oxidation degree is 50%, the desulfurization efficiency can reach 98%, the denitration efficiency is 48%.

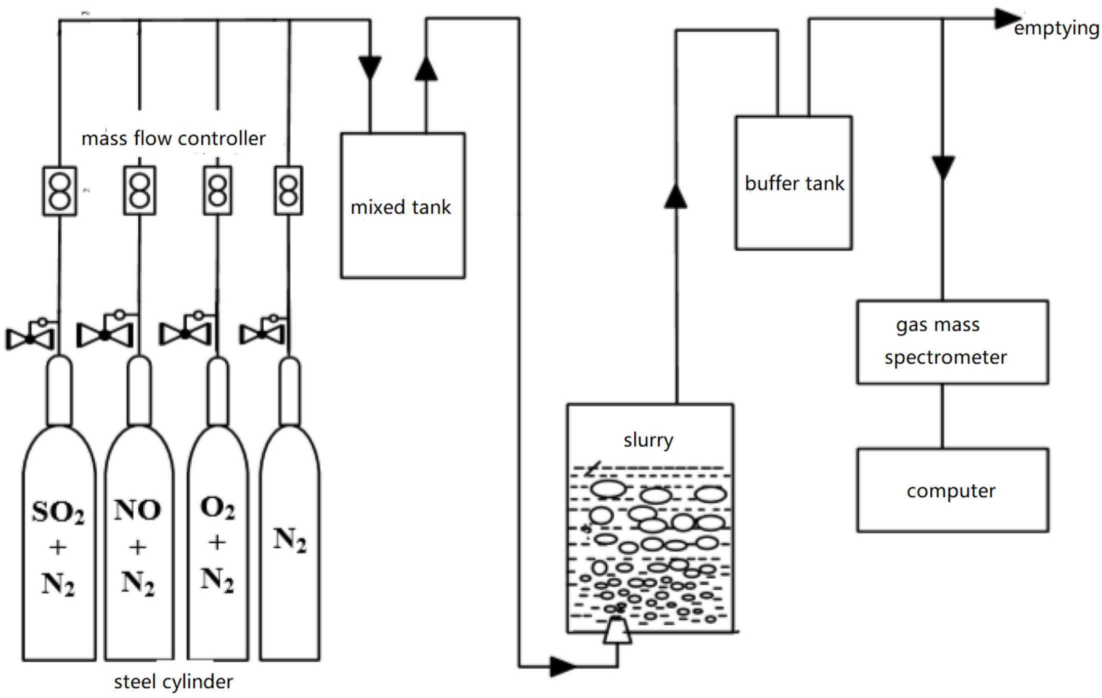
2.5. Steel Slag Wet Combined Desulfurization and Denitration Technology

The steel slag contains $Ca(OH)_2$, MgO, C_2S, C_3S and other alkaline substances, which can promote the absorption of SO_2 and NO_x. During the pretreatment stirring process of steel slag, the alkaline substances dissolve and the gel active substances (C_2S, C_3S) produce hydration reaction to form $Ca(OH)_2$ and $Mg(OH)_2$. In the process of desulfurization and denitration, due to the presence of alkaline substances such as $Ca(OH)_2$, MgO, C_2S, C_3S, etc. in the steel slag, it has a high pH buffering ability, which is beneficial to the removal of SO_2 and NO_x. Under the best experimental conditions, the removal rates of SO_2 and NO_x are 70.9% and 69.6%, respectively.

3. Experimental Table Building

By comparing the urea wet method and steel slag wet desulfurization and denitration efficiency, the steel slag wet combined desulfurization and denitration technology was decided to adopt. Our country's iron and steel industry produces a large amount of solid waste every year, the most prominent is the steel slag produced during the steelmaking process. There are many raw materials, and the tailings after desulfurization and denitration can be used as cement retarders, which has high economic effect.

3.1. Schematic Diagram of Experimental Device



As shown in the figure above, the gas supply system is supplied by steel cylinders, and the flow of each gas is controlled by the mass flow meter. The gas to be processed is first introduced into the steel cylinder, mixed in the mixing tank, and then flowed into the waste slag slurry for desulfurization and denitration. If the gas to be processed is a mixed gas, only a certain cylinder is used. The remaining gas flows out of the slurry and enters the buffer tank after the reaction, the concentration of the remaining nitrogen oxide and sulfur oxide is analyzed in the gas mass spectrometer, and the result is input into the computer to obtain the desulfurization and

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denitration efficiency and the final nitrogen oxide and sulfur oxidation concentration. If the concentration of each gas in the mixture to be reacted at the beginning is unknown, a gas mass spectrometer is installed after the mass flow meter to analyze the concentration of each gas before the reaction starts.

Steel slag is taken from steel slag powder with less than 75μm particle size, and the slurry with certain concentration is prepared in ascheduled ratio, and after pre-treated and stirred for 10 hours, the on-site slurry is simulate. The concentration of each component of steel slag slurry is shown in the figure below:

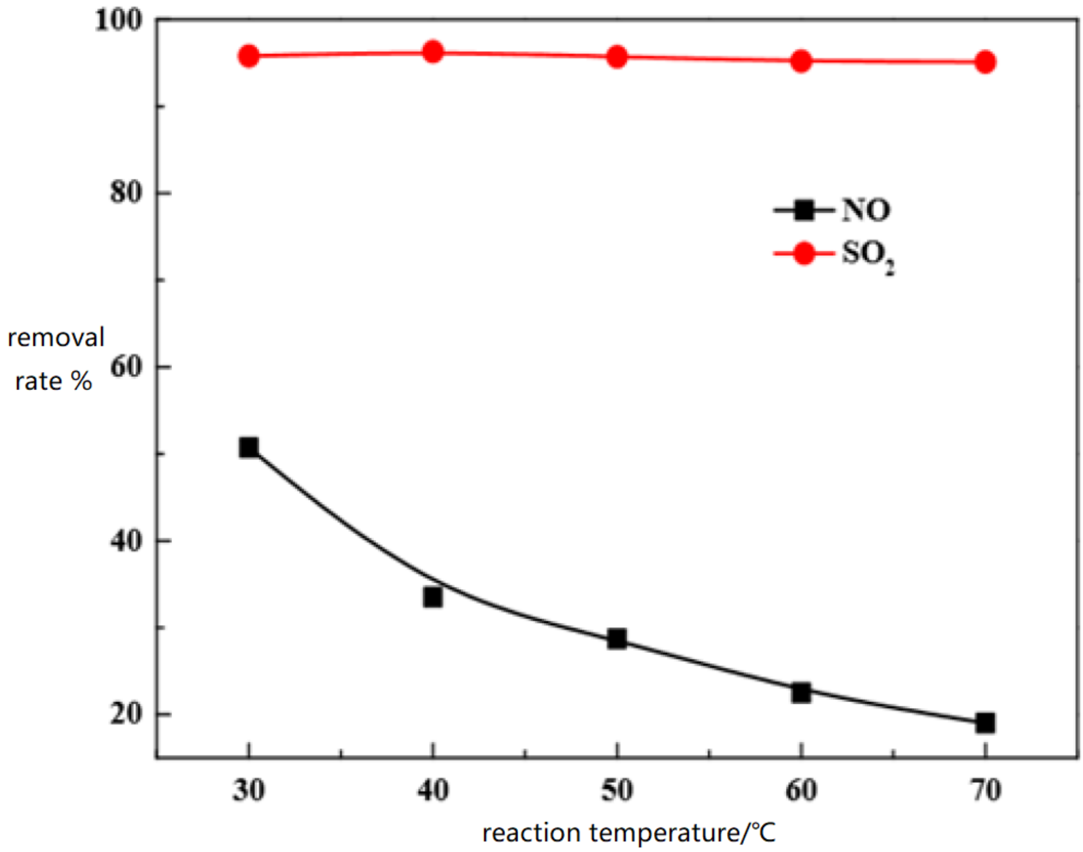
raw material steel slag composition	CaO	SiO_2	Fe_2O_3	$A1_2O_3$	MgO	SO_3	MnO	Others
content/wt.%	59.16	12.79	1.075	5.89	3.22	0.77	0.57	6.85

3.2. Calculation of Removal Efficiency

$$\eta = \frac{C_{in} \quad C_{out}}{C_{in}} \times 100\%$$

In the above formula, η is the removal rate of SO_2 or NO, C_{in} is the concentration of inlet SO_2 or NO (mg/m3), and C_{out} is the concentration of outlet SO_2 or NO (mg/m3).

3.3. The Influence of Slurry Temperature on Removal Rate

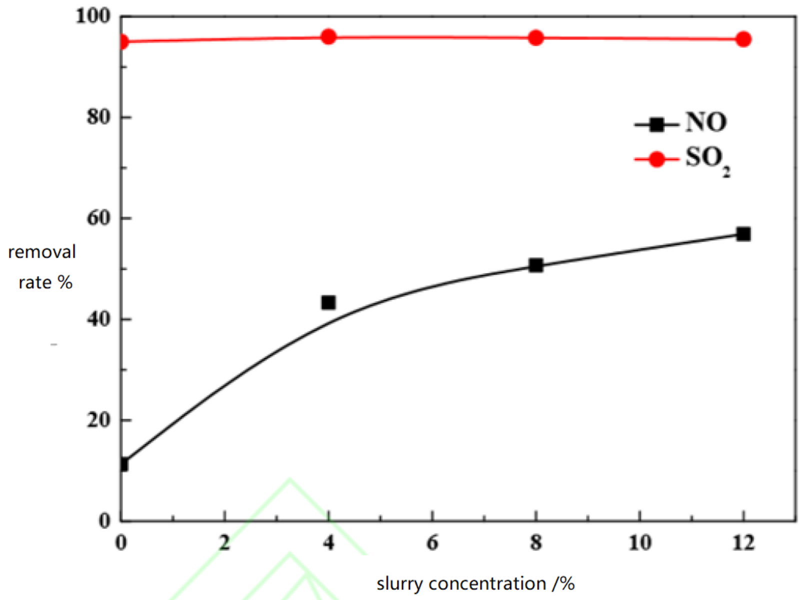


As the temperature increases, the denitration efficiency decreases. While SO2 has greater solubility in water, the solubility of SO2 changes relatively small in the temperature range of 30-70°C. Gas-liquid mass transfer is not a control step, so temperature has little effect on the removal rate of SO2.

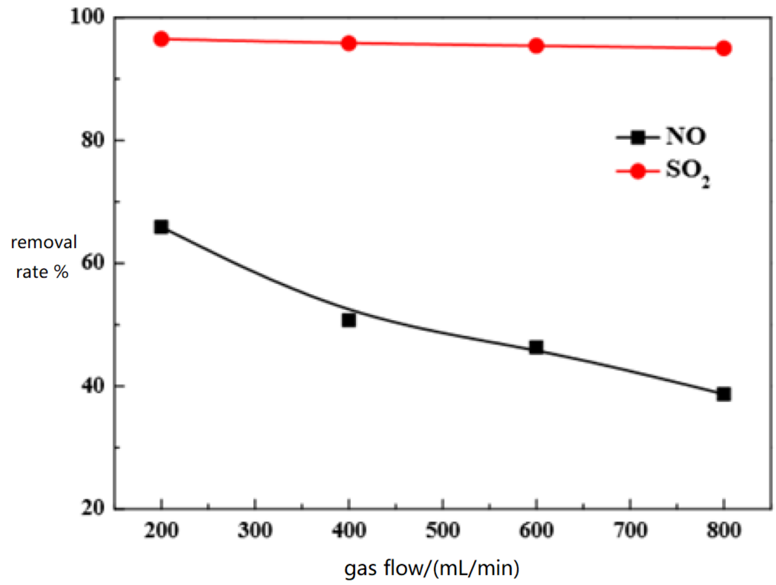
3.4. Change of Slurry Concentration to Removal Rate

As the concentration of the slurry increases, the denitration efficiency also increases; the reason is that the pH value of the initial slurry will increase with the increase in the mass concentration of the slurry; the pH value of the slurry determines the absorption and reaction environment of NO in the slurry. the higher the pH, the higher the denitration efficiency. However, the large density of steel slag and the high concentration will increase the difficulty of spraying and transportation, after comprehensive considerations, 8% slurry concentration is selected as the optimal operating condition.

The changes are shown in the figure below

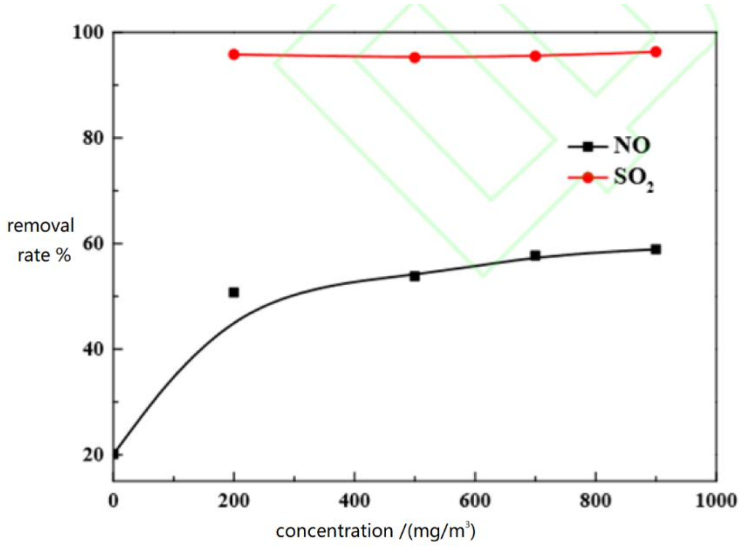


3.5. Change of Flue Gas Flow Rate on Removal Rate



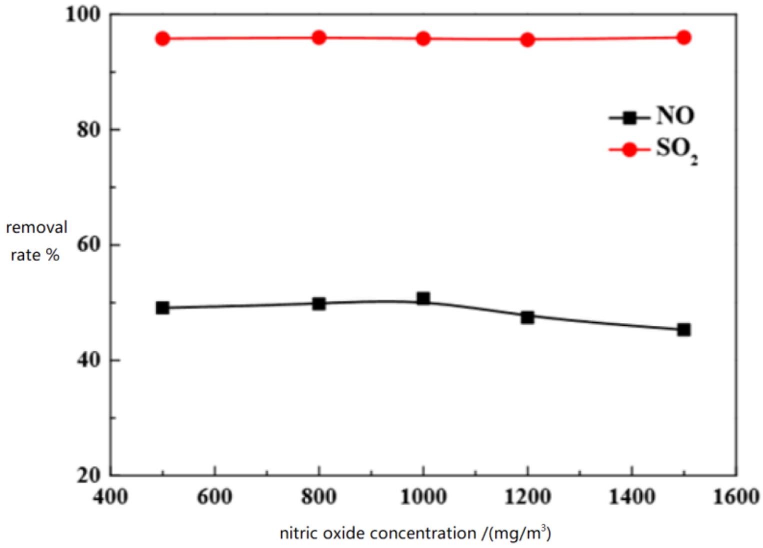
In the experiment, the volume of steel slag slurry remains constant, so changing the flue gas flow rate also changes the gas-liquid contact time. As the flue gas flow increases, the denitration rate decreases more rapidly, and the desulfurization rate is basically unaffected. With the increase of the flue gas flow rate, the retention time decreases, it is not conducive to the full contact of gas and liquid. SO_2 is soluble in the slurry in a very short contact time. Therefore, as the flue gas flow rate increases, the desulfurization rate is basically unaffected, while the denitration rate decreases more rapidly. Considering the desulfurization and denitration efficiency and operating costs, the optimal condition for flue gas flow is 400mL/min.

3.6. Change of Initial SO2 Concentration to Removal Rate



As the SO_2 concentration in the system increases, the NO removal rate increases. Because SO_3^{2-} existing in the system can react with NO in the solution to form a complex, at the same time, the oxidation product of N, NO_2 can react with SO_3^{2-} and HSO_3^- in the solution and be absorbed. The higher the concentration of SO_2 in the gas phase, the greater the driving force of SO_2 mass transfer, and the greater the concentration of SO_3^{2-} and HSO_3^- ions generated in the system, thereby improving the denitration efficiency. When the SO_2 concentration increased to 400mg/m^3, the NO removal rate remains basically unchanged.

3.7. Change of Initial NO Concentration to Removal Rate



Under the condition relatively low SO_2 concentration load, with the increase of flue gas NO concentration, the effective absorption capacity and contact reaction time of NO absorption reaction in the absorption liquid d not change much, and the NO removal rate do not change significantly. With the further increase of NO concentration, the promotion effect of SO2 on NO removal is weakened, and the NO denitrification efficiency has been reduced.

4. Design Improvements

The removal of NOx is mainly because the steel slag slurry absorbs NO_2 generated by the reaction of NO and O_2, and N_2O_3 combined with NO2 and NO. The denitration efficiency of the existing steel slag desulfurization and denitration technology is low, this discovery provides an idea for the next step of research on strengthening denitration, namely part of NO is oxidized to NO_2 through gas phase pre-oxidation, then NO_2 and the remaining N_2O_3 combined by NO and NO_2 2 can be quickly and efficiently absorbed by the steel slag slurry, so as to reach the NO_x standard or even the ultra-low emission standard, which is conducive to the engineering application of steel slag wet desulfurization and denitrification.

5. Conclusion

After analysis of steel slag wet desulfurization and denitration, it can be known that the slurry temperature, slurry concentration, flue gas flow rate and initial SO_2 concentration all have a greater impact on the desulfurization and denitration efficiency. The steel slag method can achieve simultaneous flue gas desulfurization and denitration, and has significant effects and simple process.

The increase of the slurry concentration will increase the pH value of the system and promote the removal of NO; the increase of the flue gas flow means the decrease of the retention time, reduce the gas-liquid contact time, resulting in the decrease of desulfurization and denitration efficiency. Therefore, the retention time should be increased while considering the processing cost.

Under the optimized conditions of the laboratory: the temperature is 30°C, the slurry concentration is 8%, the flue gas flow rate is 400mL/min, the denitration rate is 50.7%, and the desulfurization rate is higher than 95%.

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