Application of Photocatalytic Degradation Method in the Degradation of Trace Steam Turbine Oil in Condensed Water

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Abstract. In today's thermal power plants, due to improper operation, the condensation system often drops other substances, such as turbine oil. In this way, trace oil in the condensate will contaminate the resin, corrode the thermal equipment, cause unnecessary losses to the thermal power plant, and the amount is huge. On this basis, many scholars began to study the method of removing trace oil from condensate. In this paper, we use photocatalytic degradation to help us effectively remove trace turbine oil in condensed water. Photocatalytic degradation is a chemical reaction carried out under the action of light. The photocatalytic reaction requires the reactants to absorb light energy and excite it to an excited state, and the energy source for degrading all pollutants into inorganic substances is the photon energy. This is one of the most commonly used methods for handling trace oils. This article also uses ultrasonic technology to effectively degrade trace oils. Experiments show that the photocatalytic degradation method can effectively degrade trace oil. Titanium dioxide, the catalyst used in the photocatalytic degradation method, has the best catalytic effect when the forging environment is 500°C and it is loaded twice.

Keywords: Power Plant Condensate, Photocatalytic Degradation Method, Trace Steam Turbine Oil, Ultrasonic Technology

1. Introduction
With the current complicated changes in the world situation and the rapid and healthy development of my country's national economy, the consumption of electricity by residents and businesses continues to increase, and the current main power generation method in my country is still [1] thermal power. To help thermal power plants reduce operating costs, the price of electricity produced is lower, and the cost of electricity used by residents can also be effectively reduced, improving the residents' happiness index. Water is the working fluid of thermal power plants, and our control requirements must be strict enough. Condensate [2-3] is the main source of water supply, but due to poor operation of thermal power plants, condensate is often contaminated by steam turbine oil [4], causing corrosion to thermal equipment and increasing operating costs.

In order to solve the above problems, this paper uses photocatalysis [5-6] to reduce the residual amount of turbine oil in condensate oil. Photocatalysis technology is a water treatment technology that has emerged in recent years [7]. In a sufficient time, organic matter can be completely mineralized into...
simple inorganic matter, such as carbon dioxide and water, to avoid secondary pollution. The reaction speed of the photocatalytic degradation method is relatively fast, the reaction time is generally tens of minutes or a few hours, and it can get a good treatment effect; and this degradation method can help us degrade any organic matter; the requirements for the reaction conditions are not harsh. The reaction cost is low, and the energy consumption is also low. The light energy required for the photocatalytic oxidation reaction is ultraviolet rays or the sun. The reaction conditions are simple and easy to obtain, and there is no secondary pollution [8], and the application range is wide.

In this paper, the oil content of micro-turbine oil in condensate [9] was measured. The specific method is to add an emulsifier to the steam turbine oil and water solution to make an oil-water mixture and use [10] ultrasonic technology to determine its oil content. Then use photocatalysis technology to interpret and process the trace oil in the mixture, determine the oil content after treatment, and compare with the oil content after treatment to judge the feasibility of photocatalysis technology.

2. Method and Determination of Photocatalytic Degradation

2.1 Determination of Trace Oil
Ultrasonic technology obtains the particle information in condensate by analyzing the attenuation signal of steam turbine oil in condensate. Ultrasonic attenuation spectroscopy is based on the frequency change caused by ultrasound through the particle phase contained in the continuous medium to characterize the attenuation spectrum of the particle size distribution measurement technique. The spectrum is obtained by fast Fourier transform (FFT), and the ultrasonic attenuation coefficients of different frequency components are calculated according to formula (1). \( A_0 \) is the ultrasonic amplitude, \( L \) is the distance between the sensors.

\[
\alpha = \ln(A_0)/L
\]  

(1)

Then calculate the content of trace oil according to formula (2), where \( R \) is the radius of the suspended particles; \( k_c \) is the wave number in the continuous medium:

\[
y = 1 + \frac{3\alpha}{k_c R^2} \cdot L A_0
\]

(2)

2.2 Photocatalytic Degradation
Titanium dioxide is used as a catalyst for photocatalytic reactions to degrade trace oil in condensed water. There are many factors that affect the degradation effect, such as the pH of the solution, the temperature, the amount of catalyst used to increase the reaction rate, and other factors. In other words, the photocatalytic degradation method is a chemical reaction under light irradiation. The photocatalytic reaction requires the reactants to absorb light energy and excite it to an excited state, and the energy source for degrading all pollutants into inorganic substances is the photon energy. During the photocatalytic degradation process, chemical reactions will occur to produce new substances. The photochemical reaction is the effective use of solar energy. Photodegradation usually refers to the gradual oxidation of organic substances into inorganic compounds such as water and carbon dioxide under the action of light. There are two types of photodegradation, direct photodegradation and indirect photodegradation. Direct photodegradation means that the reactant decomposes into inorganic substances by chemical reaction after directly absorbing light energy. Indirect photodegradation refers to a series of photochemical reactions that occur due to the absorption of light energy in the environment by certain substances around the reactants. This experiment uses direct photodegradation.
3. Preparation and Experimental Design of Titanium Dioxide

3.1 Preparation of Titanium Dioxide

The main method of preparing titanium dioxide is liquid-phase method, which is to precipitate or crystallize metal ions uniformly through the reaction between solutions, and then dehydrate or decompose the crystal to obtain nanoparticles. Titanium dioxide was prepared by liquid phase method. Mix 6.4ml of butyl titivates, 20ml of anhydrous ethanol, 2.0ml of polyethylene glycol and 1.0ml of acetic acid for 80min to obtain titanium dioxide solution. The photo catalyst was prepared by calcining the mixed titanium dioxide solution.

3.2 Experimental Design

Since the degradation effect is influenced by many factors, the effect of photocatalyst on the photodegradation rate of steam turbine oil was studied by using different calcination temperatures and catalyst loading times. The catalysts prepared at different calcination temperatures and catalysts with different loading times were used for photocatalytic degradation. Ultrasonic detection technology is used to detect and calculate the content of trace oil in condensate water at different time periods. The experimental results are shown in Table 1.

Table 1. Experimental results

| calcination temperature | Percentage of micro oil content after photocatalysis |
|-------------------------|------------------------------------------------------|
|                         | 2h        | 4h        | 8h        |
| 450°C                   | 0.100     | 0.095     | 0.086     |
| 500°C                   | 0.096     | 0.088     | 0.080     |
| 550°C                   | 0.099     | 0.094     | 0.085     |

4. Discussion

4.1 Influence of Catalyst Calcination Temperature on Catalytic Effect

As shown in Figure 1, add 100 ml of high-purity water to three 250-ml Erlenmeyer flasks, and 0.5 mg of turbine oil (the initial concentration of the solution of the turbine oil is 5 mg/L) to the sampler. Then 0.5 g photocatalyst was loaded at three different calcination temperatures (450°C, 500°C and 550°C) and added to three conical flasks, respectively, and the experimental temperature was set to room temperature, and then sampled every hour under closed UV once. The same amount of OP-10 emulsifier was added to the three groups of solutions, and after full emulsification, the supported photocatalyst was separated. Using ultrasonic technology, the concentration of turbine oil after photodegradation was obtained, and the photodegradation rate was further calculated. The degradation effect of photocatalyst at three calcination temperatures is shown in Figure 1.
Figure 1. Effect of Different Calcination Temperature on Photocatalysis

It can be seen from the figure that the catalyst activity at 500°C is the strongest and the catalytic effect is the best. It is not that the higher the calcination temperature, the stronger the activity of the catalyst. The higher the calcination temperature, the better the catalytic effect. But when the calcination temperature is 550°C, the catalytic rate decreases. This is because the grain size of the photocatalyst is smaller and the specific surface area is larger at the calcination temperature. The crystal form of nano-tio2 calcined at 500°C is basically anatase. It has been proved that only anatase TiO2 can play a photocatalytic role. When the calcination temperature is 550 °C, the photocatalytic activity is reduced due to the conversion of part of the titanium dioxide to rutile. Too high temperature will cause crystal growth, reduce the quantification effect of titanium dioxide, and reduce the photocatalytic activity. When the calcination temperature is 450°C, titanium dioxide anatase crystals have just begun to appear, with low content and poor photodegradation activity.

4.2 Influence of Load Times on Catalytic Effect
Figure 2. Influence of different load times on photocatalysis

We added 0.5g of titanium dioxide, which was calcined in a calcined environment at 500 degrees Celsius, to 0.5g of four oil-water mixtures with a concentration of 3mg/L composed of steam turbine oil, which were loaded once, twice, three times, and four times with glass float beads. Set the four experimental environments at 25 degrees Celsius, perform photocatalytic degradation under ultraviolet light, take samples every two hours, use ultrasonic technology to detect the samples, and use the formulas listed in Chapter 3 to evaluate trace oils. The content. After comprehensive calculation, the photocatalytic effect diagram is shown in Figure 2. From Figure 2, we can see that the catalytic effect of the photocatalyst increases with the increase of the number of loads, but when the number of loads reaches twice, in this test In the third and fourth times, the degradation effect is not obvious. Because some of the bleaching beads used in our forging catalysts have too much loaded titanium dioxide and are too dense, so in the course of the experiment, a small part of the photocatalyst will sink to the bottom of the water, but this did not happen during the first and second loading. In addition to these situations, we also found that during the three and four loading reactions, we found that the nano-silica will fall off the surface of the support. Similarly, the loading did not occur once and twice. Based on the analysis of the above experimental phenomena and experimental results, and then excluding all influencing factors of the experimental process, you can choose two times as the optimal load times.

4.3 Suggestions for Improving the Performance of Photocatalytic Degradation

Semiconductor titanium dioxide is widely used in photocatalytic degradation of organic pollutants, but mainly through the reaction of light with titanium dioxide, through the oxidation reaction of glass-based hydrogen peroxide and organic pollutants, this glass-based reaction is not selective for the decomposition of pollutants. When organic matter coexists, it first adsorbs high-concentration pollutants on its surface, while for low-concentration organic matter, the amount of adsorption is small and cannot be effectively decomposed. The photocatalyst redox mechanism of the photocatalyst is mainly by light irradiation, absorbing light energy, generating electronic transitions, generating electron hole pairs, and direct oxidation, which reduces the adsorption of pollutants on the surface, or the adsorption of oxygen radicals (OH) by hydrogen oxide. On the surface, oxygen hydroxide radicals (OH) are generated to oxidize pollutants. In production, we mainly use semiconductor titanium dioxide as a catalyst for photocatalytic degradation, so we can start from semiconductor titanium...
dioxide to improve quantum efficiency, thereby improving the photocatalytic efficiency of semiconductor titanium dioxide.

Reduce the size of silicon dioxide. When the size of semiconductor particles is in the nanometer range (1 ~ 10 nm), there is a significant quantum size effect, that is, the electrons and holes generated in the semiconductor will be limited to small potential energy geometry In size, such electrons and holes do not experience a conduction band, and the electrons in the valence band of the semiconductor delocalize. Therefore, the smaller the particles, the smaller the recombination probability of electrons and holes in the body, and the higher the efficiency of neutrinos. For example, in a silica with a particle radius of 1 micron, electrons need 10-7 s to diffuse from the body to the surface of the particle, while a silica with a radius of 10 nanometers and it takes less time to diffuse, the diffusion requires only 10 nanometers second. At this time, the band gap can increase and the edge of the band gap moves, resulting in an increase in redox potential energy, which enhances the redox capability of the semiconductor titanium dioxide photocatalyst and improves the photocatalytic activity.

Doping transition metal ions, due to the multivalence of transition metal elements, doping a small amount of transition metal ions in titanium dioxide, can introduce catalyst lattice defects or change the crystallinity of the crystal, thereby affecting the recombination time of photogenerated electrons and holes and improving titanium dioxide Photocatalytic activity; secondly, because a variety of transition metal ions have a larger absorption range, it can use solar energy more effectively.

The catalytic effect of the catalyst can also be optimized by methods such as surface photosensitization of the catalyst, auxiliary photosensitization of the added substance, surface acidification, surface porosity, etc., thereby improving the catalytic effect of the photocatalytic degradation method.

5. Conclusions

In this paper, titanium dioxide was prepared as a photocatalytic degradation catalyst by liquid phase method. The titanium dioxide was calcined at different temperatures, and the loading rate of the catalyst and the loading frequency of different titanium dioxide as the catalyst were analyzed. It was observed that under other conditions the same, only When the amount of catalyst is small, the rate of change at the same time. In this experiment, we used ultrasonic technology to detect and compare the dosage of a small amount of turbine oil in the condensed water. The results show that at a calcination temperature of 500°C, the catalytic effect of titanium dioxide is the best, and the catalytic effect of the two loadings is the best. The reactants in this reaction can provide a basis for controlling the photocatalytic degradation reaction. In this experiment, we also found that the photocatalytic reaction can effectively help us degrade organic matter, and the reaction speed is faster, which can be widely used in production.

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