Optimal Combined Process for Treating Oily Wastewater Using Membrane Distillation Technology

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Abstract. The membrane distillation technology used in this paper is a new type of wastewater treatment technology, which is now mostly used in seawater desalination and wastewater treatment. The traditional oily wastewater treatment methods have problems such as large energy consumption and low removal rate. It is proposed to use vacuum membrane distillation technology to use a large amount of waste heat in wastewater as the driving force for mass transfer to treat oily wastewater, which not only saves energy, but also effectively counteracts the problem. The solid particles, hydrocarbons and other pollutants contained in the wastewater are intercepted, so that the treated water quality reaches a certain degree of purity and meets the discharge standards. In this paper, the membrane microporous membrane used in the process of membrane distillation is targeted at the problem of membrane pollution Improved to achieve the purpose of reducing costs and increasing membrane life.

1. Introduction
At the current stage, in the treatment of oily wastewater, the traditional separation technology has been relatively developed, but there are still some aspects that cannot be controlled well. The vacuum membrane distillation technology used in the process described in this paper is a new separation technology combining membrane technology and distillation technology [1-3]; the main components of this technology are membrane and vacuum pump, which operate in the membrane distillation process It is also relatively simple, and does not require high environmental conditions, and can operate normally at low temperature and normal pressure. Oily wastewater contains a large amount of solid particles, hydrocarbons, inorganic ions, bacteria and other substances, so the water quality of oily wastewater does not meet the requirements of wastewater. Emission standards are not easy to handle. Traditional processing technologies have problems such as high cost, low removal rate, and large energy consumption. In industrial production, a large amount of waste heat is often generated. Vacuum membrane distillation is used to treat oily wastewater. Its operating temperature is low and can be used. The effective use of waste heat in oily wastewater as a heat source provides a driving force for mass transfer and has important social and economic benefits for the development and utilization of new energy.

2. Principles and Advantages of Vacuum Membrane Distillation Technology
2.1. Principles of Vacuum Membrane Distillation Technology
Vacuum membrane distillation is a membrane separation process that uses a hydrophobic membrane with the vapor pressure difference between the two sides of the membrane as the driving force for mass transfer [4]. The hydrophobic microporous membrane used in the membrane distillation process can separate aqueous solutions of different temperatures on both sides of the membrane. Separately,
one side is connected with the hot solution to be treated, and the other side is evacuated, so under the
effect of the steam pressure difference on both sides, the hot side water vapor will enter the vacuum
side through the membrane hole to condense, thereby achieving the concentration of the solution and
separation [5]; this principle is somewhat similar to the condensation of water vapor into water during
ordinary membrane distillation. At the same time, it applies membrane technology, so it is called a
membrane distillation process.

2.2. Advantages of Vacuum Membrane Distillation Technology

Compared with other wastewater treatment, vacuum membrane distillation technology has the
following advantages: (1) the hydrophobic microporous membrane used has good hydrophobicity and
non-polarity, which can reduce the interaction between membrane and water; (2) the membrane
Corrosion resistance and salt resistance, so it can treat highly salty and corrosive wastewater; (3) Its
structure is relatively simple, and the environmental conditions are not harsh; the vacuum on the
vacuum side causes the pressure difference on both sides to increase. Compared with other membrane
distillation forms, vacuum membrane distillation technology has the advantages of large membrane
flux and high processing efficiency.

3. Film Material

The material, pore size, thickness, and porosity of the membrane directly determine the working
efficiency of the membrane. Studies have shown that the optimal thickness of the membrane is 30 ~
60μm, and the pore size of the membrane is mostly between 0.1 ~ 1μm. The membrane is an organic
polymer membrane, and its membrane materials mainly include polytetrafluoroethylene (PTFE),
polypropylene (PP), polyvinylidene fluoride (PVDF), etc. [8].

| Membrane material | Surface Tension /10^-3 N·m^-1 | Thermal conductivity/ W·m^-1·k^-1 | Thermal stability | Corrosion resistance | Hydrophobic |
|-------------------|-------------------------------|----------------------------------|-------------------|----------------------|------------|
| PTFE              | 9-20                          | 0.25                             | Stronger          | Stronger             | Strong     |
| PVDF              | 30                            | 0.19                             | Strong            | Strong               | General    |
| PP                | 30                            | 0.17                             | Stronger          | Stronger             | Strong     |

Comprehensive consideration, this process uses a polyvinylidene fluoride (PVDF) flat film as the
base film, and applies surface reduction method to prepare thin film CNTs (carbon nanotubes) with a
metal layer on the surface, and prepares a transition metal loaded on only one surface of the polymer
film Homogeneous film of additive TiO₂.

4. Application in the Treatment of Oily Wastewater

In the process of oilfield mining and chemical production, a large amount of oily waste water will be
generated. The components of oily waste water are more complex and generally contain oil,
emulsifiers, fatty acids and other components. Traditional oily wastewater treatment methods such as
chemical, mechanical, and thermal methods have problems such as high cost, difficulty in operation,
and low efficiency [6]. The vacuum membrane distillation technology is introduced here. According to
the surface characteristics of hydrophobic microporous membranes, Optimize the operation mode to
achieve high-efficiency separation and realize the treatment of oily wastewater [9]; some studies have
shown that membrane distillation technology can effectively separate organic substances such as oil
and fat in oily wastewater. First, three polypropylene capillary membranes were selected and the direct
contact type was used. Membrane distillation and vacuum membrane distillation treat olive oil
industrial wastewater. The permeation flux of direct contact membrane distillation is 6.5L / (m²·h),
and the permeation flux of vacuum membrane distillation is 19L / (m²·h). The removal rate of
pollutants is as high as 99.6% [10]; it can be seen that it is efficient and feasible to use membrane
distillation technology to treat oily wastewater.
5. Membrane Fouling
Membrane fouling is an important factor affecting membrane flux and membrane service life, and is a major problem that affects membrane distillation efficiency and stability for a long time. Fouling is usually formed on the surface of the membrane or inside the membrane pores, which will cause the membrane's permeability to decrease. If it is not handled in time, it will cause damage to the membrane, which indirectly increases the cost of oily wastewater treatment; the main form of membrane pollution for inorganic pollution, organic pollution and microbial pollution.

5.1. Inorganic Pollution
Inorganic pollution generally refers to inorganic fouling. Inorganic fouling is caused by the precipitation of minerals in wastewater. In addition, cement and corrosion products in wastewater can also form inorganic fouling on the membrane. For example, when treating high-salt wastewater, when the soluble ions in the medium exceed the equilibrium solubility product, inorganic salt scale will form. In the process of membrane distillation, the main reason for the formation of inorganic fouling is that with the progress of membrane distillation, the water in the original solution continuously evaporates, so that the solution is in a supersaturated state and the temperature changes continuously. Physical cleaning, chemical cleaning, and operating conditions are carried out in three aspects.

5.2. Organic Pollution
Organic pollutants usually refer to the adsorption and deposition of specific organic substances on the surface of the hydrophobic membrane, and the gel formed on the surface of the membrane. These organic pollutants will not be easily removed without the use of corresponding chemical reagents. In addition, the formation of organic pollutants can also be controlled by physical control methods, heating pretreatment methods, acidic organic liquid washing methods, and directly changing the hydrophilicity of the membrane surface. In the treatment of oily wastewater, in order to prevent petroleum derivatives from Pollutants are formed on the sediment, and the wastewater can be ultra-filtered in advance.

5.3. Microbiological Pollution
The main biological pollution refers to the pollution of microbial metabolites, which is caused by the growth and accumulation of microorganisms on the membrane surface. The high temperature and high salinity of the concentrated liquid during the membrane distillation process are not conducive to the growth of microorganisms, so the application of membrane distillation technology during the treatment of wastewater, there are fewer biological pollutants produced on the membrane, but biological pollutants still exist on the inevitable membrane. The most commonly used fungicides and descaling agents for treating biological pollutants are H_2O_2 and NaClO [11, 12].
6. Specific Introductions to This Optimized Process

6.1. Process Flow Chart

![Process Flow Chart](image)

Figure 1. 1. Water bath heating pot; 2. Storage sewage container; 3. Pipe; 4. Peristaltic pump; 5. Insulation layer; 6. Condenser; 7. Purified water collection container; 8. Metal film; 9. Pressure gauge; 10. Vacuum pump

6.2. Main Technologies and Performance Advantages of This Process

This process is mainly applied to the treatment of oily wastewater in oil fields, and is also suitable for oily industrial wastewater with a certain temperature.

6.2.1. Vacuum membrane distillation technology

Vacuum membrane distillation technology (VMD) uses a vacuum pump to maintain a negative pressure state on the permeate side of the membrane, thereby increasing the vapor pressure difference between the two sides of the membrane to improve membrane permeability.

6.2.2. Metal oxide functional composite film

(1) Polyvinylidene fluoride flat film has good abrasion resistance, mechanical and mechanical properties, and has good resistance to pollution and radiation; (2) CNTs (carbon nanotubes) can effectively improve the retention of composite films, as the intermediate transition layer can provide a membrane structure with high porosity and pore density; (3) TiO₂ in the metal oxide functional composite film used in this process has the ability to degrade pollutants, and under certain conditions, catalytic degradation remains Membrane fouling particles on the membrane surface or inside the membrane pores can slow down membrane fouling and enhance the anti-pollution performance of the composite membrane.

6.3. Specific Implementation Plan

(1) First set the raw material liquid storage device and place it in a water bath, in order to keep it at a certain temperature to complete the membrane distillation process; (2) The raw material liquid storage device is directly connected to the peristaltic pump. The peristaltic pump is This experiment provides power to enable the raw material liquid to enter the membrane module smoothly and complete the cycle; (3) Assemble the membrane module, install the metal membrane, one side of the membrane is the feed side, and the other side is the water vapor transmission side; the membrane module After installation, it is connected to the other end of the peristaltic pump; (4) pressure gauges are installed on the feed side and water vapor transmission side of the membrane module, and pressure gauges are installed on the feed side and water vapor transmission side of the membrane module; (5) membrane
The lower part of the water vapor transmission side of the module is connected to the cooling collection device; (6) The upper side of the water vapor transmission side of the membrane module is connected to the vacuum pump; (7) The upper end of the feed side is connected to the return liquid storage device to form a circulation device; (8) Open the peristalsis pump, the material liquid begins to pass through the membrane module, most of the material liquid will return to the circulation device, a small part of the liquid enters the water vapor transmission side through the membrane hole in the form of water vapor; (9) the water vapor transmission side is connected to the Vacuum pump To maintain a certain pressure difference on both sides, determine the most suitable pressure difference through the pressure gauges on both sides to achieve the most optimal and reasonable treatment effect; (10) Water vapor flows through the serpentine condenser to condense into water and flows into the purification Water collection device; (11) In order to prevent the heat loss of the material liquid during the circulation, the heat insulation layer is covered outside the circulation pipeline; (12) The material liquid will be in the process of the material liquid passing through the membrane module and continuously circulating Gradually becomes a concentrate.

6.4. Application and Prospect of the Process

This process uses a vacuum membrane distillation technology combined process, which uses a large amount of low-grade heat in oily wastewater as the driving force to treat sewage. Among them, waste heat as low-grade thermal energy is often easily ignored. Traditional oily wastewater treatment methods have large energy consumption and costs high, incomplete treatment and other problems, using this combination process, reasonable and effective use of low-grade thermal energy, reducing the use of other energy sources and unnecessary waste, energy saving and environmental protection; improved metal oxide functional composite film will be effective It can slow down and control the pollution of membrane and prolong the service life of membrane. The adoption of this process is not only in line with the concept of contemporary energy saving and environmental protection, but also can greatly reduce the treatment cost of oily wastewater.

7. References

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