Research on Key Technologies of Ocean Thermal Desalination

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Abstract—Due to the process of urbanization and industrialization, the crisis of freshwater resources has become a problem to be solved by mankind. Although the traditional low-temperature multi-effect distillation method, multi-stage flash evaporation method and reverse osmosis membrane method seawater desalination currently occupy the mainstream position [1], low-temperature multi-effect distillation method brine evaporation temperature cannot exceed 70 ℃, reverse osmosis membrane method has the characteristics of high requirements for seawater pretreatment, and multi-stage flash evaporation method has the defect of high energy consumption. Therefore, ocean temperature difference can be used as a renewable energy source. Due to the huge reserves, about 10TW (10x1012W) that can be developed and utilized in the world is recognized by the international community as one of the most potential energy sources[2]. This article first describes the significance of the development of ocean temperature difference energy and the current research status of ocean temperature difference energy seawater desalination; secondly, it takes the ocean temperature difference energy seawater desalination method as the research object, based on the technical difficulties of ocean temperature difference energy seawater desalination and the process of the seawater desalination method that reduces the temperature difference. Four aspects put forward the main factors to improve the performance of the system; finally, it is concluded that the transformation of the key technological achievements of the ocean temperature difference energy seawater desalination method will provide more energy-saving, environmentally friendly, and more efficient for the comprehensive development and utilization of marine engineering, offshore oil drilling platforms, and islands. High-quality freshwater resources.

1. Introduction

As of the end of the "13th Five-Year Plan" period, my country's seawater desalination utilization has only completed less than 50% of the planned output. The reason is that the high cost of water produced by the high consumption of fossil fuels in seawater desalination is the main problem that restricts the development of its industry. Therefore, the development and utilization of new energy for seawater desalination has become the key direction of future application development. In recent years, the use of wind energy, nuclear energy, solar energy, wave energy, tidal energy, liquefied natural gas (LNG), thermal energy, biomass energy, ocean temperature difference and other new energy sources for seawater desalination technology is deepening. In response to the use of these new energy sources, the state has also issued many supporting policies. For example, in recent years, the country has vigorously developed wind power, but due to unstable conditions and other reasons, wind power has caused a large amount of
power abandonment and a serious waste of resources. Therefore, in order to promote the healthy and sustainable development of wind power, according to the The Measures for the Supervision of the Purchase of Renewable Energy Electricity (Order No. 25 of the China Electricity Regulatory Commission) and other special supervision of wind power consumption in key areas[3]; Furthermore, the energy structure adjustment, the Ministry of Land and Resources and the Bureau of Energy issued relevant measures to support natural gas infrastructure Support the development of shale gas industry and promote the large-scale utilization of natural gas. All these will drive the integration and development of clean energy technology and desalination industry. As a renewable energy source, seawater temperature difference energy is an important form of ocean energy. It generally refers to the thermal energy of the water temperature difference between ocean surface seawater and deep cold seawater. The surface of the ocean converts most of the solar radiant energy into hot water and stores it in the upper layer of the ocean [4]. Due to its huge reserves, it is recognized by the international community as one of the most potential energy sources. China’s oceans are vast, and most of them are in tropical and subtropical regions. According to preliminary calculations, the theoretical storage capacity of China’s ocean temperature difference energy reaches 1.19~1.33x1019KJ, and the technically available ocean temperature difference energy is about 8.33~9.31x1017KJ (calculated with a thermal efficiency of 7%), The potential installed capacity in the actual available temperature difference energy is 1.32~1.48x109KW, which is mainly distributed in the South China Sea and the eastern waters of Taiwan [5]. The use of ocean temperature difference for seawater desalination plays a very positive role in alleviating the current energy shortage, the increasing scarcity of freshwater resources, and the deterioration of the ecological environment.

2. research status of marine thermoelectric desalination

In 1881, the ocean temperature difference energy was first proposed by the Parisian physicist J.D’Arsonval of France to use the ocean temperature difference to generate electricity [6]. After years of research and development, Tianjin University of my country conducted a theoretical study on the hybrid ocean thermal energy utilization system in 2004, and compared the two hybrid forms. The warm seawater first enters the flash evaporator and then enters the evaporator is more conducive to production. Fresh water is produced, and warm sea water enters the evaporator first, and the maximum heat energy is used for power generation, so it is more suitable for occasions where power generation is mainly conducted. At the same time, the fresh water production rate of the experiment is 8.3kg/h [7].

Based on the ocean temperature difference energy, Zhejiang University in my country used the difference between the surface temperature of 29 degrees Celsius and the depth of 10 degrees Celsius to transport seawater using the principle of siphoning, and designed a set of ocean temperature difference energy with a freshwater output of 5kg/h. The desalination device firstly concludes that the fresh water production is linear with the increase of the surface seawater flow at the beginning, and then the increase tends to be slow. Due to the limitation of the evaporator structure, even if the surface seawater flow continues to increase (greater than 600L/h), the fresh water The output tends to stabilize. Secondly, it is concluded that the fresh water production increases with the increase of the deep seawater flow in the initial stage. When the deep seawater flow reaches 550L/h, there is a turning point, and the increase in freshwater production gradually decreases. When the deep seawater flow reaches 650L/h, the freshwater The output reaches its peak, and the experimental process is shown in Figure 1.

At present, there is no example of sea water desalination using the energy of ocean temperature difference energy to generate electricity. Although there are papers for research, there is no project. The focus of the paper is on ocean temperature difference energy power generation instead of seawater desalination.
3. PREFACE DEVELOPMENT POTENTIAL OF OCEAN TEMPERATURE DIFFERENCE ENERGY DESALINATION METHOD

(1) The ocean temperature difference energy seawater desalination method is more energy-efficient
The ocean temperature difference can use the temperature difference between the ocean surface and the deep layer as a driving energy for seawater desalination technology. The fresh water can be used as a medium to directly absorb the water vapor evaporated from the hot seawater, thereby becoming more efficient.

(2) The energy efficiency ratio of ocean temperature difference for seawater desalination
The ocean temperature difference can use seawater desalination to replace the condensation process by absorption under the low temperature difference between the cold and hot ends. Compared with the traditional condensation method, the efficiency is increased by 3 to 5 times.

(3) Ocean temperature difference can make sea water desalination safer
The ocean temperature difference can be used for seawater desalination. The evaporation temperature is lower than normal temperature, and the application heat source temperature is also lower. Compared with the high-temperature multi-effect or solar-focused seawater desalination method, it has no pressure hazard and is safer.

(4) The system is simpler
Low-temperature hot water or surface seawater can be used as a heat source, and fresh water can be produced as long as there is a temperature difference of more than 10°C. The system is simple and the cost of desalination of seawater is lower.

(5) More suitable for island applications
Generally, other auxiliary heat sources are not needed, and it is more resistant to typhoons than other desalination equipment, and is more suitable for island applications.

(6) It is a beneficial supplement to other desalination methods
It can be used as a useful supplement under other working conditions where other desalination methods are inconvenient, such as having unique advantages in miniaturization and miniaturization.

(7) Unique advantages in the use of deep seawater
The difference in ocean temperature can be used for desalination. Deep seawater can be used as cooling water to produce fresh water, which is not possible with other desalination methods.

4. technical difficulties of ocean temperature difference energy seawater desalination
This technology has always been the key point of seawater desalination technology as the technical difficulty of ocean temperature difference. There are a large number of papers at home and abroad. At
present, there are no recognized research results on the mechanism of gas absorption and desalination, especially for different processes and media. Pressure, etc., absorption desalination efficiency will directly affect the seawater desalination effect of the unit. In this paper, based on the data of the existing ocean temperature difference energy seawater desalination test prototype, the research on the efficient absorption desalination technology in the ocean temperature difference energy seawater desalination system is carried out, and the factors affecting the absorption desalination effect are preliminary studied. Through the research and improvement of the absorption desalination mechanism, the technical problems such as uneven liquid distribution thickness and insufficient contact between the heat exchange tube and the solution in the existing absorption desalination technology are solved.

In practical applications, the surface temperature of tropical or subtropical seas is 30°C, especially in shallow sea areas, where the deep seawater temperature is above 20°C, and the vertical seawater temperature difference is even lower than 10°C. The small heat exchange temperature difference causes the condenser The volume is huge, the cost is increased, and it is difficult for industrial application.

5. seawater desalination process to reduce temperature difference

As shown in Figure 2, the working circuit of the unit consists of a hot sea water circulation circuit, a cold sea water circulation circuit, a fresh water circulation circuit, and a fresh water drainage circuit. Its working principle is as follows: When working, the sea water solenoid valve 1 is opened, and the hot sea water flows through the sea water solenoid valve 1 into the generator set 3. Due to the high pressure difference between the two ends, the hot sea water completes the power generation work in the generator set 3, and then enters the evaporation chamber 2, where it is evenly sprayed on the packing 5 by the spray system 4 inside the evaporation chamber 2. Because the interior is in a vacuum, the hot sea water evaporates a large amount of water vapor, and the concentration increases while the temperature decreases until the saturated steam state of the hot sea water balances with the saturated steam state of the fresh water inside the absorption chamber 12. The sea water flows through the sea water check valve
15, and is driven out of the unit by the sea water pump 16 to complete the working cycle of hot sea water; the fresh water in the fresh water storage tank 14 is driven by the fresh water circulation pump 11 and enters the heat exchanger 10, after being cooled by the cold sea water. The temperature drops, and then enters the absorption chamber 12, and after being sprayed by the spray system 4 inside the absorption chamber 12, it is evenly distributed on the packing 5 inside the absorption chamber 12. Due to the low temperature, the saturated vapor pressure is low, which will absorb from the evaporation. The higher-pressure water vapor evaporated by the hot seawater in the chamber 2 is in equilibrium with the saturated steam state of the hot seawater inside the evaporation chamber 2, and the quality of the low-temperature fresh water that has absorbed the water vapor increases, and returns to the fresh water storage tank 14 to complete the fresh water working cycle; The cold sea water is driven by the cold sea water circulation pump 8, enters the heat exchanger 10, cools the fresh water inside the heat exchanger 10, and exits the unit after the temperature rises to complete the working cycle of the cold sea water.

This process adopts an absorption method to absorb higher-temperature water vapor with low-temperature fresh water instead of the traditional condensation method, so it is different from the existing condensation method for seawater desalination. Compared with the prior art, the present invention has the following remarkable effects:

1. Use hydrophilic fillers to increase the absorption surface area of low-temperature fresh water. Within a volume of 1m³, the absorption surface area can reach more than 700 square meters. Compared with the traditional condensation method, not only the area is increased, but the absorption effect is better than the condensation effect.

2. In the absorption chamber, the low-temperature fresh water absorbs the water vapor from the evaporation chamber. There is no problem of heat exchange temperature difference, which is equivalent to reducing the condensation heat exchange temperature difference. Compared with the traditional condensation method, the steam condensation efficiency is higher, especially in The effect is more obvious when the vertical seawater temperature difference in shallow waters is less than 10℃.

3. There is no heat exchange tube in the steam generation-absorber, and there is no scaling problem caused by the evaporation of seawater. When cold seawater and fresh water are exchanged for heat, there is no phase change or crystallization.

4. The structure is simple and easy to implement, so the failure rate is low, and the detachable plate is used to replace the heat exchanger, which is more convenient for maintenance.

5. A generator set is installed during the process of hot sea water entering the steam generator-absorber. Because the low-temperature fresh water maintains the vacuum inside the steam generator-absorber, there is a higher pressure difference between the two ends of the generator set, which improves the overall efficiency of the unit.

6. MAIN FACTORS TO IMPROVE SYSTEM PERFORMANCE

1. Improvement of heat exchanger

Aiming at the shortcomings of the heat exchanger in the prototype, such as large mass and large volume, the high-tech and efficient plate-fin heat exchange technology can effectively improve the performance of the unit. As shown in Figure 3, it not only increases the heat exchange area per unit volume, but also improves the performance of the unit. Heat transfer coefficient.

Fig. 3 Schematic diagram of fin structure section
(2) Liquid cloth and membrane technology

As early as 2010, data analysis found that in the absorption chamber, the absorption area cannot reach the design area. The reason is that the flow rate of the absorber spray pipe is small, the spray effect is poor, the filler is poorly hydrophilic, and the unit surface area is small. As a result, the absorption area is smaller than the design area.

The absorption efficiency directly affects the effect of the unit, and the efficiency of the unit can be improved by improving the pipeline flow, spraying effect, and packing.

Strengthen the absorption pipeline, design a new pipeline to become a separate circulation system, and redesign the process according to this pipeline. On the one hand, the new absorption pipeline increases the amount of liquid distribution and improves the spraying effect. On the other hand, it reduces the concentration of the absorption solution and the temperature of the solution in the absorber.

Improve the spraying effect. The spraying effect is the key to high-efficiency liquid distribution. The uniform, continuous, and spraying method and mechanism with good atomization effect are beneficial to improve the efficiency of the unit.

(3) Filling improvement

The packing determines the absorption area and gas flow rate. Research and design new filler materials and filling methods. Under a certain volume, the larger the area of the filler, the better, the larger the gas flow channel, the better, the greater the hydrophilicity, the better, and the smaller the quality. The project team made a lot of investigations based on the existing packing, and finally selected the stainless steel wire mesh packing. Compared with the polypropylene polyhedral ball used before, the stainless steel wire mesh filler has the advantages of large specific surface area and good wettability.

(4) Lower the temperature of the absorption liquid

It can continue to strengthen the cooling effect of the absorption liquid, and continuously reduce the temperature of the absorption liquid entering the absorption chamber, which is beneficial to enhance the absorption effect and improve the efficiency of the unit.

7. CONCLUSION

This paper studies theoretically a seawater desalination system based on the principle that lower temperature fresh water absorbs seawater vapor instead of condensation. First, it is proposed to use high-area low-temperature water to efficiently absorb water vapor to improve the efficiency of seawater desalination; secondly, to use high-efficiency liquid and membrane technology to increase the absorption surface area to increase the efficiency of the unit; third, to use surface activity enhancement technology to improve the absorption effect and increase seawater desalination The key technology of water output. The transformation of the technological achievements will provide energy-saving, environmentally friendly, and more efficient high-quality freshwater resources for the comprehensive development and utilization of marine engineering, offshore oil drilling platforms, and islands.

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