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Review on Direct-Contact Membrane Distillation and Supercritical CO_2 Brayton Cycle Systems for Water Cogeneration

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Abstract

Membrane distillation is a new desalination process that uses low-grade heat to produce clean water. Membrane distillation (MD), in contrast to energy conversion with reverse osmosis, uses the excess heat produced by the Brayton cycle for desalination processes without the need for great energy. The Brayton cycle of sCO_2 *is viewed as a viable key motivator of the integrated power system, heating, and cooling, with the potential to boost efficacy. Because of its compact construction and great efficiency, in recent decades, it has been used forseveral heat sources. In this study, a literature study was conducted related to membrane distillation with a direct-contact process and a closed Brayton cycle of supercritical* CO_2 *for the cogeneration of water.*

Keywords: *Membrane distillation, Direct contact membrane distillation, Cogeneration, Supercritical* CO_2 *Brayton cycle.*

1. INTRODUCTION

Membrane distillation (MD) is a vapour pressure-focused estrangement method that utilizes a permeable aquaphobic sheath that acts as a hindrance for fluid while allowing vapour to pass by all the way through. MD has a lot of products in the context of seawater management and mineral water manufacture, involving salt removal, because of its substantial rejection rate of nonvolatile substances, brine treatment, and wastewater treatment. The low operating temperature of MD is also advantageous for excess heat usage in the energy industry for the cogeneration of water.

Amongst numerous productions of electricity using waste heat prospects, this cycle is regarded as the next power generation method and is a viable choice for the cogeneration of waterenergy in conjunction with MD. This is because the Brayton cycle rejects a considerable quantity of waste heat at temperatures around 100 °C, creating it a viable high-temperature supplier for MD. Another enticing component of cogeneration is the possibility of combining the Brayton cycle with solar panels, which are frequently used in arid/semiarid environments. MD is critical in this situation for producing clean drinking water and backup water for cycle cooling via seawater sources. Provided the temperatures, the need to satisfy water demand, as well as the avaricious bunch characteristics, it is in both economic and engineering interests to investigate MD-sCO_2 Brayton cycle cogeneration for increased productivity and financial feasibility.

2. SUPERCRITICAL CO_2 BRAYTON CYCLE SYSTEMS

Xu et al. [1] proposed a system of integrated design for the direct contact membrane distillation (MD) Brayton cycle of supercritical CO_2, into which discarded energy after the Brayton cycle of CO_2 at supercritical is employed by membrane distillation. To optimizethe cogeneration cycle and its thermo-economic analysis, a model was developed and used in this research paper called Mixed-integer nonlinear programming (MINLP).

The MD system explored in this paper exhibits great energy and exergy efficiency, as well as significant economic and environmental benefits. Okatiet al. [2] assessed the energy, exergy, economic, and environmentally friendly performance of a membrane distillation with direct contact centered as a salt removal factory that uses geothermic, and waste heat-up energy as major current resources. They validated their mathematical modelling with the prior experimental evidence.

The findings of Lisboaet al. [3] showed that combining the progress of casings and waste heat retrieval is the utmost efficient method in the direction of improving the viability of membrane distillations in contradiction of additional thermal-founded water treatment processes plus making distillation with membrane a commercial applications reasonable alternative for brine and seawater desalination.

In a research paper by Alharbiet al. [4], a combined system for electricity and freshwater production has been presented, and a complete analysis has been conducted from the thermodynamic and exergo-economic perspectives. The excess heat on or after aBrayton cycle having a recompression with sCO_2pre-cooler is used to power the multi-effect desalination (MED) system in this arrangement. Under the same operating conditions, the SCRBC/MED system performance was compared to that of a stand-alone SCRBC.

Liuet al. [5] evaluated recent supercritical Brayton cycle (SCBC) examination and improvement based on specific factors: distinct SCBC structures, sources of heat applied to different grades, the effect of parameter indexes on performance, comprehensive sCO_2 test loop, and layout of most important elements. Corresponding to the literature assessment, the SCBC is a cycle with extensive application possibilities given the comparatively great efficiency, straightforward design, and small modules.

Cogeneration of water and electricity by combining solar/thermal accumulators and filtration techniques is among the greatest encouraging techniques for addressing the difficulties of energy and water deficiencies in distant regions. In this work, Chenet al. [6] investigatedthe localized cogeneration of energy/water witha system that combines distilled solar/thermal collectors with a vacuum membrane distillation system.

Choiet al. [7] optimized the components for direct contact membrane distillation (DCMD) using computational fluid dynamics (CFD) and an experimental model. A design of experiments (DOE) and CFD approach has been applied to assess the interactions between component geometry components and then in what way they influence the implementation of a DCMD process.

A 2-D mathematical example of a DCMD module for desalination and wastewater treatment has been developed by Ismailet al. [8]. This model was used to examine the susceptibility of the sculpted distillation component's simulated membrane flux of vapour to various frequently applied hypotheses and generalizations linked to bulk transfer through the layer. The model was also used to investigate the effect of a modest pressure variation throughout the membrane.

Yanget al. [9] studied a new collective heating, power system, and cooling that uses an SCBC as the principal motivator and recovers a portion of the high-temperature rejected in the low-temperature recuperator besides a portion of the warmth emitted into the environment for heating or cooling. The entire system is assessed by using the multi-purpose genomic procedure technique to locate the Pareto frontier and the Method for Order Liking by Parallel to Ideal Methodology to determine the best result.

Koutaet al. [10] investigated the operation and price of a lunar power rise combined with SCBC for power generation combined with multi-purpose dehydration together with thermal vapour compression purification technique for freshwater generation. The investigation is carried out in two alternative supercritical cycle setups: the SCBC regeneration and recompression cycles.

Memonet al. [11] research suggesteda unique combined DCMD and humidification–dehumidification purification method powered by a fixed-plate accumulator which collects solar energy. The FPC system heats seawater, which is then fed into the DCMD system to recover freshwater.

Zhu et al. [12] study presented a new hybrid approach comprised of DCMD and photon replacement membrane fuel cell that creates freshwater from saltwater by harnessing excess heat from the PEMFC to increase order efficiency. The numerical prototype of the mix PEMFC-DCMD method is built to investigate the effect of supply inlet high temperature and DCMD feed and saturate intake current rates upon cross-model operation.

Maestre-Cambronelet al.[13]introduced an assessment of a unique WHR system thermionically comprised of a Whirlwind Duct heat injection connected to the drain flow of a 2000 kW biological gas engine driving an SCBC. It has two modes of operation: recompression and regenerative. According to the findings, installing the Vortex Tube enhances exergy and energy efficiency by 1.85 % while decreasing exergy destruction by 4–8 %.

Zhaoet al.[14] proposed a new cross-system prototype based on a DCMD and aDSSC is suggested to harvest the long-wavelength illumination transferred by the DSSC to produce freshwater.Taking into account numerous permanent losses inside the system, the specifications of the hybrid systems,DSSC, and DCMD have been numerically quantified, and the cross-system implementation restrictions are examined.

Sharanet al. [15] stated that the sCO_2 Brayton cycle also has the advantage of rejecting waste heat at higher temperatures (> 70 °C). A MED system is integratedwithSCBC to create freshwater without becoming a pernicious burden on the power plant is discussed in this work. The focus of this article is on integrating MED along with the sCO_2 stream departing the recuperator. Used for the simultaneous production of power and fresh water, a new way of integrating MED with the SCBC is suggested.

3. CONCLUSION

As a result, from the literature review discussed above the different areas that will be covered in this study are as follows:

- Brayton cycle rejects a considerable quantity of waste heat at a temperature around 100 ^{o}C, making it a viable heat source for MD.
- This temperature is used to desalinate the water by Direct-contact membrane distillation.
- The SCBC is gaining traction in comparison to other energy cycles because of its enhanced efficiency, small turbomachinery, and additional advantages.
- The techno-economic study demonstrates that integrating MD with a sCO_2 stream is always preferable to producing the distillate using an isolated reverse-osmosis system.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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