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"A REVIEW ON MEMBRANE DISTILLATION WITH DIFFERENT GEOMETRY"

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ABSTRACT

This paper reviews recent research using computational fluid dynamics (CFD) simulations to investigate the hydrodynamics conditions, heat and mass transfer in conventional and newly designed direct contact membrane distillation (DCMD) modules, such as those deploying spacer-filled feed channels. Guidelines and recommendations are presented for computational grids, numerical algorithm and schemes, spatial and temporal discretization, turbulence modellingand computational domain sizes. Most of the work which utilized CFD techniques to study DCMDsystems focused on hydrodynamics and heat transfer optimization and investigating the effect of different spacers' geometry, while few of them have tried to achieve a better understanding of the mechanisms resulting in mass transfer enhancement inside the membrane pores. This paper also reviews the different ways in which the CFD simulations are applied to improve performance of the DCMD systems.

Key Words: *Direct contact membrane distillation (DCMD); Computational fluid dynamics (CFD);Turbulence models; Heat and mass transfer; Spacer optimization.*

I. INTRODUCTION

Water scarcity is becoming increasingly serious due to the continuous population and industry growth, the deterioration of water quality due to emerging contaminants, and the adverse impact of climate change . Although the management of water demand may alleviate the situation [4], it is still necessary to secure enough water resources for water supplies. Many water purification technologies have been developed to resolve this problem, such as advanced water treatment, rainwater harvesting [7], wastewater reclamation, groundwater replenishment, and the desalination of seawater and brackish water. Desalination in particular is regarded as a promising method in regions where seawater or brackish water is available. Compared with the other means, the potential to produce freshwater from saline water streams by desalination is almost limitless. Conventional desalination technologies include multi-stage flash (MSF), multi-effect distillation (MED), and reverse osmosis (RO), which present practical problems due to their high energy consumption and discharge of harmful brine Accordingly, many works have attempted to solve these problems by developing novel techniques such as forward osmosis , capacitive deionization pressure retarded osmosis, reverse electro dialysis , and membrane distillation (MD) . Among these, of particular interest is MD, which allows for the use of renewable thermal energy and a reduction in brine generation . MD relies on the principle of diffusion and/or convection of vapor through a porous membrane due to the difference in the vapor pressure. The membrane works as a vapor gap between feed and permeate solutions, across which only volatile components are allowed to move . The temperature of the feed solution is set to be higher than that of the permeate solution to create a vapor pressure difference across the membrane. Unlike conventional distillation techniques, MD is a compact process that can be operated under a relatively small difference in temperature between the feed and permeate solutions .This permits MD to be combined with solar thermal energy or geothermal energy systems.

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There are technical challenges that have yet to be overcome for the practical implementation of MD including the fabrication of efficient membrane materials the optimization of modules the control of fouling and wetting [and the integration of MD with other technologies .Among these challenges, the development of optimum MD modules is regarded as a prerequisite for the widespread application of MD technology Currently, four main types of MD module are available: direct contact membrane distillation (DCMD), air gap membrane distillation (AGMD), sweeping gas membrane distillation (SGMD), and vacuum membrane distillation (VMD). In each case, the geometry and dimensions of a module significantly affect the capability of water production and the efficiency of thermal energy use. Unfortunately, few studies have attempted to use a systematic approach to optimize an MD module. This is mainly because the analysis of mass and heat transfer in an MD module is quite complex and cannot be achieved using a simple model.

An effective method that has recently attracted attention is the combination of CFD simulation with the design of experiments (DOE) . An advantage of using CFD together with DOE is the possibility of obtaining a systematic understanding of the interactions among design and operational variables and their impacts on the entire system [65]. This methodology has been successfully applied in different engineering fields, including micro-mixers, cooling packages and photocatalytic reactors [65,69]. However, there are relatively few studies regarding the combination of CFD and DOE for analyzing MD systems. Moreover, no work has been attempted for multi-objective optimization of MD modules by CFD combined with DOE.

In this context, the present work intends to optimize the design parameters and dimensions for DCMD modules using a combination of CFD and DOE. A CFD model that is capable of simulating three-dimensional (3D) transfers of momentum, heat, and mass inside a plate-and-frame DCMD module was developed to predict flux, the performance ratio (PR), and the permeate-to-feed ratio (ϕ_p) under various conditions. Before its application, the CFD model was validated using experimental data in a lab-scale MD system. Then, CFD simulations were carried out based on DOE to systematically investigate the effect of module dimensions (channel height, length, and width) on the performance of a DCMD module (flux, the PR, and ϕ_p). Regression equations and the response surfaces were derived from the CFD–DOE simulation results. Moreover, an optimum module dimension was proposed to allow a high flux, PR, and ϕ_p simultaneously. To the best of the authors' knowledge, the present work is the first attempt to use a combination of CFD and DOE to optimize DCMD module design. Although our paper deals with conventional plate-and-frame DCMD modules, it can be applied to optimize more complex MD modules with various heating methods. This methodology may be also used to optimize other MD modules such as AGMD, SGMD, and VMD. The focus of our paper is on the use of CFD with DOE for a rapid and systematic optimization of MD modules, which is not limited to the current module type.

II. LITERATURE REVIEW

Mohammad Mahdi A. Shirazi et al.[1] “Computational Fluid Dynamic (CFD) opportunities applied to the membrane distillation process: State-of-the-art and perspectives”, Generally speaking, it ought to be noted that CFD-based models are very qualitative. Actually, in apply the choice of the simplest case, i.e. the particular microstructure for membrane or spacer geometry and also the module geometry includes a trade-off between prices of membranes required to provide the specified production and costs of the energy supply. it's not only the price of the applied membrane; with it comes variety of MD modules, piping, fittings, pumps, compressor and vacuum pumps, and etc. Most of works on CFD approaches are investigated the DCMD method through modeling the hydrodynamics conditions and heat transfer. However, a mix of those things with mass transfer shall be studied a lot of extensively and comprehensively. Moreover, different MD configurations, particularly the SGMD and AGMD, got to be any investigated, within the case of their varied aspects, e.g. the distillate aspect and planned boundary layer conditions, as well. Any to several benefits and opportunities of CFD for modeling MD processes, there are some vital issues that shall be investigated in future works.

Ali Kargari et al.[2] “A Review on Applications of Membrane Distillation (MD) Process for Wastewater Treatment”, The MD method has been in the main used for desalination; but, the water recovery from wastewater streams is one in every of the most promising applications of MD for the longer term. It’s additionally proved to be an appropriate technology for removal of different impurities. Whereas it's capable of treating several sorts of wastewaters and brines, its ability to compete with current technologies, like ro and thermal-based water treating technologies, remains

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restricted because of its lack of experimental information in pilot scale and specific membranes and modules. On the opposite hand, finding new and appropriate applications for the MD method presently looks to be one among the most important impediments to its industrial use. Moreover, there's another major challenge against MD to be applied for wastewater treatment. Wastewater streams commonly embody several chemicals that would probably result in membrane surface fouling and membrane pore wetting. This can be because of the very fact that the deposition of those contaminants on the membrane surface may build the membrane less hydrophobic and result in pore wetting and therefore the flux decline. This can be the reason that restricted works on wastewater treatment using MD are compared with desalinization. Therefore, fabricating specific membranes for MD application in wastewater process is one in every of the promising future views.

Enrico Drioli et al.[3] "Membrane distillation: Recent developments and perspectives", Membrane distillation could be a relatively new method, investigated worldwide as a low price and energy saving different with respect to standard separation processes (such as distillation and reverse osmosis). it's one among the few membrane operations supported a thermal method. Energy consumption thus is, in theory, a similar because the traditional phase changes method. However, the specified operative temperature is far under that of a traditional distillation column as a result of it's not necessary to heat the method liquids higher than their boiling temperatures. In fact, the method may be conducted at temperatures usually below 70 °C, and driven by low temperature difference (20 °C) of the new and therefore the cold solutions. Therefore, low-grade waste and/or energy sources like star and heat energy may be including MD systems for a value and energy efficient liquid separation system. Consequently, this operation would possibly become one in all the most interesting new membrane techniques. It will overcome not only the limits of thermal systems however additionally those of membrane systems like Ro or NF. Concentration polarization doesn't affect significantly the drive of the method and thus high recovery factors and high concentrations may be reached within the operation, in comparison with Ro method. All the opposite properties of membrane systems (easy scale-up, easy remote and automation, no chemicals, low environmental impact, high productivity/size ratio, high productivity/weight magnitude relation, high simplicity operational, flexibility, etc.) also are present. This technology may be used much during a giant style of industrial and bio-medical processes as for the purification, extraction, concentration (to very high values), and final formulation of organic and inorganic species. a lot of recently, membrane bioreactors (MBRs) with membrane distillation membranes (MDBR) are developed for the treatment of commercial and municipal waters so as to exceed the boundaries of the existing MBR systems (i.e., the problem to retain effectively little size and protracted contaminants).

Hitsov et al.[4] "Modelling approaches in membrane distillation: A critical review", Membrane distillation has been discovered 50 years ago, however up to now lacks vital industrial applications. So as to optimize the technology and create it competitive to different separation techniques the MD community should have an in-depth understanding of the processes that occur within the modules and also the membranes. The mass transfer modelling of the membrane region has been lined by many alternative mechanistic and statistical models that may predict the flux with variable accuracy. More recent models like the ballistic transport model and also the structural network models are innovative and interesting to the community however haven't however been totally tested and validated. Moreover, a number of the physical phenomena that occur within the membrane like the surface diffusion have forever been neglected in MD modeling which might prove to be necessary for membrane synthesis studies.

Hsuan Chang et al.[5] "CFD simulation of direct contact membrane distillation modules with rough surface channels", rough surface channels for desalinization are conferred. The excellent model includes the trans-membrane heat and mass transfer and therefore the entire length of the module was simulated. This simulation study has clarified and confirmed the subsequent points: (1) The simulated rough surface utilized during this study provides close predictions to the experimental results. (2) In view of the numerous variations of temperature and transfer fluxes on the length of the MD modules, the simulation of the whole module, instead of a presumed representative section of the module, is important. (3) For MD modules operated with fluid flow rates a lot of more than the trans-membrane mass fluxes, as long because the trans-membrane heat flux includes the phase change heat result related to the mass flux, the exclusion of trans-membrane mass flux within the model is suitable. However, if the fluid flow rates are low, the inclusion of trans-membrane mass flux within the model is important. (4) The thermal entrance effects within the MD modules are important and can't be neglected. (5) The utilization of typical correlations developed for rigid heat

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exchangers for estimating the typical heat transfer constant of the whole MD module can't be even.

III. PROBLEM STATEMENT

While membrane distillation has a tremendous potential as a separation technology for hard streams when waste heat is available, MD is still lacking wide-spread adoption. This could be due to a lack of major reference cases where MD is applied successfully for a significant amount of time. The uncertainty associated with the long term performance and cost of the technology is driving the industry away from MD. One possible way to reduce this uncertainty associated with the technology is to carefully model the process and gather process knowledge. The models can be used to predict the process performance across production scale and operational conditions. However, modeling of MD to date is mostly limited to lab-scale.

IV. METHODOLOGY

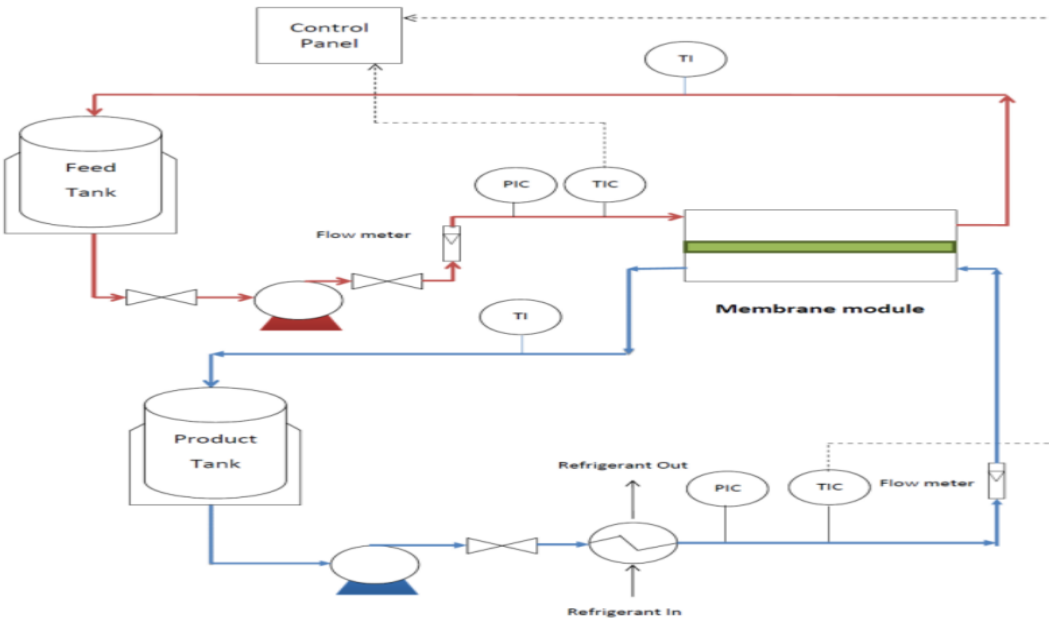

Fig.1 A general scheme of the DCMD process

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