Survey Report on Computational Fluid Dynamic (CFD) opportunities applied to the membrane distillation process

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***Abstract* - Membrane distillation may be a technique aimed toward separating non-volatile parts like salts from liquid feed streams. 2 problems associated with MD were investigated during this study by computational fluid dynamics (CFD) simulation. The strength and efficiency of the numerical ways for getting solutions to MD membranes and module issues (e.g. temperature and concentration polarizations and, liquid flux enhancement) have given rise to the adoption of procedure Fluid Dynamic (CFD) as a wide used analysis tool to review transport phenomena for MD processes.**

***Index Terms* - Membrane distillation (MD), Computational fluid dynamics (CFD), Momentum, heat and mass transfers, Modeling and simulation Membrane and module design.**

I. INTRODUCTION

Membrane distillation (MD) may be a thermally driven method that utilizes a hydrophobic micro-porous membrane to support a vapor-liquid interface. If a temperature difference is maintained across the membrane, a vapor pressure difference happens. As a result, volatiles (water during this case) evaporates at the new interface, crosses the membrane within the vapor part and condenses at the cold side, giving rise to a internet trans-membrane water flux. Membrane distillation (MD) may be a comparatively new method and was introduced within the late 1960s [Lawson and Lloyd; 1997, Alklaibi and Lior, 2004]. At that point, MD didn't receive vital interest because of many reasons, e.g. the determined lower MD production compared to the reverse osmosis technique and inaccessibility of appropriate membranes for the method [Lawson and Lloyd; 1997; El-Bourawi, et al; 2006. The MD method received renewed interest at intervals the tutorial communities within the early of 1980s once novel membranes and modules with higher characteristics became offered [El-Bourawi, et al; 2006]. Moreover, the flexibility of MD to utilize low grade heat during a kind of waste heat/renewable energy supply had boosted the interest and analysis so as to search out appropriate application areas also as raising the merits of the technology. However, MD isn't implemented however in business for water purification or desalinization. a radical historical perspective of MD development may be found within the review articles by Lawson and Lloyd [1997], Alkaibi and Lior [2004], and El-Bourawi et al. [2006]. Membrane distillation (MD) is AN rising membrane technology supported the vapour pressure gradient across the porous hydrophobic membrane. Since only volatile vapor molecules will transport across the membranes, the feed liquid directly contacting the membrane should not be allowed to penetrate into the dry pores of the hydrophobic membranes. Membrane distillation (MD) was 1st developed in 1963 by Bodel once he patented the vapour diffusion through silicone rubber for saline water distillation [1]. the most used and studied MD configuration is that the direct contact membrane distillation wherever the new feed and therefore the cold permeate solutions are separated by a hydrophobic membrane. The feed resolution comes into contact with the membrane and evaporates, the vapour travels through the pores and condenses on the cold permeate membrane interface.[4].

II. LITERATURE SURVEY

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 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).

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

III. METHOD

A. Basic principles of the MD process

Membrane distillation is a rising non-isothermal membrane method that uses thermal energy so as to produce a vapor part of volatile molecules present within the feed stream (i.e. principally water) and condensation of the permeated vapor within the cold side (Figure 1). The driving force in MD is that the partial pressure difference between either side of the membrane pores.

The temperature difference results in a vapor pressure difference across the membrane. Because of the hydrophobic nature of the membrane, only vapor will pass across the membrane and not liquid resolution being distilled.

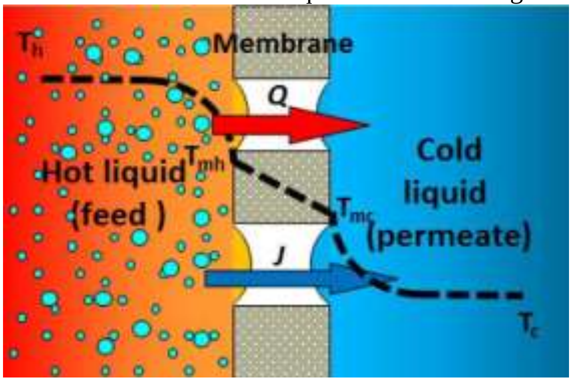

Fig.1 Basic principles of MD process

There are four major configurations for the MD method, the difference being within the technique to impose a vapor pressure difference across the membrane's pores to drive the permeation flux. In DCMD, A solution colder than the feed stream is maintained in direct contact with the distillation aspect of the hydrophobic membrane. Each the feed and distillation liquid solutions are circulated tangentially to the membrane surfaces by suggests that of pumps. The DCMD is that the simplest and also the most studied MD configuration. A stagnant air-gap is interposed between the membrane and a compression surface in AGMD mode. During this case, the distillated volatile molecules (mostly water molecules) cross each the porous membrane and also the air-gap to finally condense over a cold surface within the membrane module. Within the third MD mode, i.e. SGMD, a cold inert gas (mostly dried air) sweeps the distillation aspect of the membrane carrying the vapor molecules and condensation takes place outside of the membrane module. During this mode, owing to the heat transferred from the recent (feed) aspect via the membrane, the sweeping gas temperature within the distillate aspect will increase endlessly on the membrane module length. so as to impose the driving force across the MD membrane, vacuum is additionally applied within the distillate aspect by suggests that of a vacuum pump. The applied vacuum pressure ought to be less than the saturation pressure of the volatile molecules to be separated from the feed (hot) solution. During this configuration, condensation additionally takes place outside of the membrane module.

A variety of methods may be employed to impose this vapor pressure difference, and in general there are four kinds of MD system configurations (Figure 2): (a) Direct contact membrane distillation (DCMD), (b) air gap membrane distillation (AGMD), (c) sweep gas membrane distillation (SGMD) and (d) vacuum membrane distillation (VMD).

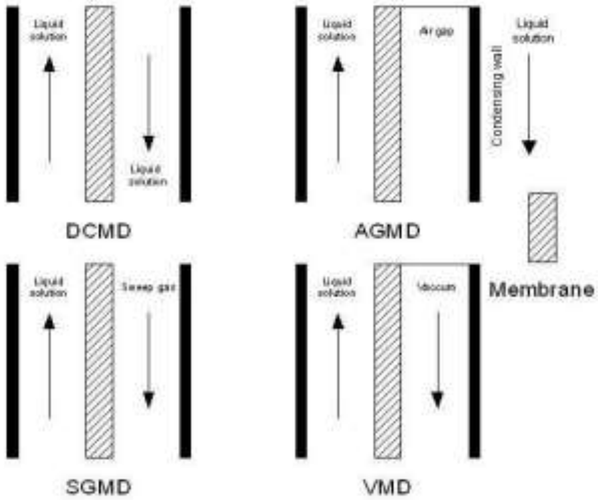

Fig.2 Common configurations of membrane distillation

B. Advantages of MD

- 100% (theoretical) rejection of ions, macromolecules, colloids, cells, and other non-volatiles
- Lower operating temperatures than conventional distillation
- Lower operating pressures than conventional pressure-driven membrane separation processes
- Low sensitivity to variations in process variables (e.g. pH and salts)
- Good to excellent mechanical properties and chemical resistance
- Reduced vapor spaces compared to conventional distillation processes

C. Disadvantages of MD

- High energy intensity (although energy, i.e. heat, is usually low grade)

- Low yield in non-batch mode; high recirculation rates in batch mode
- Sensitive to surfactants
- Undesirable volatiles such as ammonia or carbonates must be treated separately (degassing, pH control, or other methods required)

D. Computational Fluid Dynamics (CFD)

Computational fluid dynamics (CFD) is that the use of applied mathematics, physics and computational software system to see however a gas or liquid flows -- also as however the gas or liquid affects objects because it flows past. Procedure fluid dynamics is based on the Navier-Stokes equations. These equations describe however the rate, pressure, temperature, and density of a moving fluid are connected.

Computational fluid dynamics has been around since the first 20th century and lots of folks are at home with it as a tool for analyzing air flow around cars and aircraft. Because the cooling infrastructure of server rooms has increased in quality, CFD has additionally become a useful tool within the information center for analyzing thermal properties and modeling air flow. CFD software system needs data regarding the scale, content and layout of the information center. It uses this data to form a 3D mathematical model on a grid which will be turned and viewed from totally different angles. CFD modeling will help an administrator establish hot spots and learn wherever cold air is being wasted or air is mixing.

IV. CONCLUSION

Membrane distillation has been discovered 50 years ago, however thus far lacks significant industrial applications. With the fast changes in energy value and clean water shortage, the top use of MD has been expanded from initially water desalination to several alternative applications together with waste material treatment and recovery of valuable compounds. To fulfill the demands from new applications, breakthroughs in material development and membrane fabrication are created for MD membranes.

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