Research Paper Engineering

Hybrid Separation Technology- A Step for Azeotropic Separation

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ABSTRACT

Separation processes account for 40 to 70% of both the capital and operating costs of a broad range of industries. Separation operations significantly impact energy consumption, manufacturing profits and product costs. The state-of-the-art-energy and energy savings in distillation-is the theme of this Paper. Distillation is the workhorse of the chemical and petroleum industries, for producing high purity chemicals & for recovering organic solvents from waste streams. Unfortunately, distillation is energy intensive. It consumes large quantities of energy in the form of steam, cooling tower water, chilled water, or refrigerated brine. The greatest energy reduction in the immediate future could be accomplished by operating existing distillation systems more efficiently. Over the years, there have been many searches for lower energy alternatives or improved efficiencies in existing separation & purification technology. Distillation is going to enjoy its supremacy over other separation operations, until and unless the new ventures warrant the use of new and economically viable alternative separation techniques.

We can also use this technology for system forming azeotrope we remove product and azeotrope recycle azeotrope to membrane layer and separate it. Without doing any alteration in the existing column though also we can improve purity of product with Hybrid technology.

Key Words: Distillation, Hybrid Separation, Azeotrope, Membrane, Adsorption, Extraction

1.0 Introduction

Separation technologies include distillation, extraction, adsorption, crystallization and membrane-based technologies, in addition to a few more. These processes play a variety of roles in industry: the removal of impurities from raw materials, the purification of products from by products and the removal of contaminants from air and water effluents. Overall, these processes account for 40 to 70% of both the capital and operating costs of a broad range of industries. Separation operations significantly impact energy consumption, manufacturing profits and product costs. For example, of the 5.8 quads(1 quad = 170 million bbl of oil) of energy consumed by the chemical process industries(CPI) annually, about 43% goes for separation processes.

A mixture is a system that is analysed in terms of two or more different entities; e.g. air can be taken as a mixture of nitrogen and oxygen (but can be taken as a pure substance if composition does not change), a fully-ionised plasma can be taken as a mixture of ions and electrons, the contents of a boiler can be taken as a mixture of liquid and its vapour, the contents of a commercial butane bottle can be taken as a mixture of liquid and vapour, each one being a mixture of butane and propane, etc. We analyse here mixtures of simple non-reacting chemical substances that form a single phase or a multiphase system, but that they exchange species between phases or with the environment.

Most substances found in nature are mixtures of pure chemical elements or compounds: air, natural gas, seawater, coffee, wine, gasoline, antifreeze, body fluids, etc. The reason for this widespread occurrence is that there is a natural tendency for entropy to increase by the mixing (although energy minimisation might work against, as in liquid vapour equilibrium). Thus, some energy has to be applied to separate a mixture in its components. Furthermore, some energy is also applied in many practical cases to accelerate the natural mixing process, notably by mechanical stirrers, vibrations and ultrasounds, or electromagnetic forcing; in flow systems, nozzles, swirls, colliding jets, or pulsating injectors are commonly used for the same purpose.

Liquid mixtures may be formed from two liquids (e.g. water and ethanol), from a liquid and a gas that dissolves in the liquid, or from a liquid and solid that dissolves in the liquid. In most cases one liquid is preponderant and is called the solvent, and the rest of substances (gases, liquids and solids) are called solutes, the mixture being named solution. The thermodynamics of liquid mixtures is usually rather complex, except for mixtures of similar-molecule liquids (e.g. hydrocarbons), where an ideal model similar to a gas mixture can be applied. In most cases, however, there are energetic and volumetric effects and some 'excess functions' must be added to the thermodynamic formulation. The limits of solubility's are very difficult to predict.

2.0 Hybrid Separation Technology

To date hybrid systems have seen limited use in the chemical and petroleum industries. Reverse osmosis is used to concentrate wastewater feeds to evaporators as well as organic acid/water feeds to distillation columns. Pressure swing adsorption units, using molecular sieves, are used to dehydrate azeotrope mixtures. Pervaporation membranes are used for both purposes. Industrial experience has been that marginal payouts are to be expected if energy savings is the only benefit. (Humphrey and Keller, 1997). In addition, there are improved mass separating agents on the market today that are not being used extensively by the industry.

Hybrid processes were evaluated to identify R&D required to significantly reduce the energy consumption of separations schemes by supplementing the capability of distillation with another separations technology. This includes augmentation and/or retrofitting of existing distillation columns with alternative technologies (membranes, adsorption, extraction, crystallization, absorption, etc.) to debottleneck processes and reduce energy use. It does not assume that changes in other parts of chemical flow sheets

(New catalysts, new reactors, etc.) will be made to reduce the load on separations equipment. This approach takes advantage of existing depreciated capital investment, while adding novel emerging separations technology, to produce an optimum separation scheme.

Several R&D opportunities for hybrid systems were identified for the chemical industry, primarily for adsorption, extraction, and membrane separations. Fewer opportunities with significant energy-saving potential were identified for absorption and crystallization. Although distillation is the major consumer of energy in the refining industry, few practical opportunities were identified

Implementation of hybrid systems to achieve debottlenecking will be technically easier and more economical than replacing distillation systems with alternative technologies. For example, most membrane processes today cannot produce the high-purity products required of distillation applications. However, it may be possible to make technical advances that will take advantage of their overall energy efficiency by using membranes as a pretreatment step followed by a traditional distillation step. Recent advances in the development of new solvents also make extractive distillation a potentially viable alternative.

2.1 Adsorption Hybrid Systems
Hybrid distillation-adsorption processes involve making a rough separation with distillation followed by polishing with adsorption.

Application Areas
- Integrated Liquid Phase Adsorption
- Bulk Adsorption

Technical Opportunities
- Public adsorbent performance data base
- Molecular simulation of solute – adsorbent interaction
- Molecular design of adsorbents
- Development of fouling resistant adsorbents or guard bed technology
- Optimization and integration of PSA cycles

Barriers
- Recognition of strategic importance
- Lack of understanding of surface chemistry/physics at molecular level
- Computational power
- Lack of adsorbent data, design methodology and novel materials
- Lack of pooled experimental data
- Narrow range of experimental data

Enabling Technologies
- **Integrated process simulator to model complete hybrid process**
- **Molecular simulation**
- **Advanced computational capability**

2.2 Extraction and Absorption Hybrid Systems
Hybrid extraction-distillation processes generally involve transferring a component of a liquid mixture into a solvent followed by an easy distillation to separate the solvent and transferring component

Application Areas
- Olefin / paraffin separations (gas and liquid mixtures)
- Phosphoric Acid
- Cumene / phenol
- P-Xylene
- Organic / water mixtures
- Acids in water
- N-paraffin / iso-paraffin

Technical Opportunities
- New, high capacity, selective, contaminant resistant, non-toxic, solvents
- Novel, low solvent inventory, contactor designs

Barriers
- Lack of selection criteria for optimum contactor configuration
- Solvent cost
- Limited solvent selectivity / capacity
- Solvent stability
- Contaminant resistant process scheme
- Solvent toxicity
- Inadequate predictive capability for solution thermodynamics (solubility, etc.)
- Emulsion and foam formation

Enabling Technologies
- Integrated process simulator to model complete hybrid process
- Predictive algorithms for solution thermodynamic
- High throughput solvent screening methods

2.3 Membrane Hybrid Systems
Research opportunities exist for membrane hybrid systems, but significant investment in membrane technology has already occurred to date. Membranes should primarily be considered for augmenting distillation for relatively "clean" separations, such as gas recovery. Energy savings of 33% have been estimated for hybrid technologies involving membranes and distillation (Humphrey, 1991).

Pervaporation is the most widely practiced membrane-distillation hybrid system, particularly for ethanol-water separations. This is an important separation process considering the predicted rapid growth of ethanol as a fuel additive.

The use of these membrane systems is presently limited by the thermal stability and low permeation of the membrane. Higher selectivity/flux membranes that can withstand aggressive organic mixtures may be required for distillation applications for hybrid membrane systems.

Application Areas
- **Azeotrope breaking (CO2 / C2H6 separation)**
- **Pre-concentrator for distillation**
- **Bulk gas separations for low-temperature streams where existing polymers could be applicable**
- **Vent gas recovery for refining and olefin/paraffin separations**
- **Desalination/RO for phosphoric acid and caustic applications**

Technical Opportunities
- Pilot plant demonstrations of existing materials in specific applications
- Model Predictive Control (MPC) for membrane process
- Material compatibility studies for entire systems (not just membrane materials)
- Improved membrane chemical stability
- Better scaling to reduce costs

Barriers
- High pressure drop across membrane for low pressure applications
- Solute selectivity
- Chemical, environmental, and temperature stability
- Fouling
- Limited membrane life due to membrane degradation

Enabling Technologies
- Integrated process simulator to model complete hybrid process
- Predictive membrane and module performance models

4.0 Case Study: As discuss above ethanol water separation is taken as case study here the figure below shown the separation by hybrid separation techniques (distillation followed by per vaporation). In second figure again optimization of that process was done to reduce the operation cost of unit.

Sr. No	Parameter	Column 1	Column 2	Remarks
1	Flow rate in Kg/Hr	1175	1175	--------
2	Reflux ratio	3.262	1.38	Reduce by 58%
3	Column diameter in m	0.875	0.679	Reduce by 22%
4	No. of Plates	80	84	Increase 4 plates
5	Distillate rate in Kg/Hr	992.7	1046.3	Increase by 5%
6	Bottom rate in Kg/Hr	254.3	254.3	-------------
7	Recycle permeate in Kg/Hr	72	125.6	Increase by 74%
8	Membrane Area in m2	324	428	Increase by 32%
9	Product rate in Kg/Hr	920.7	920.7	------------

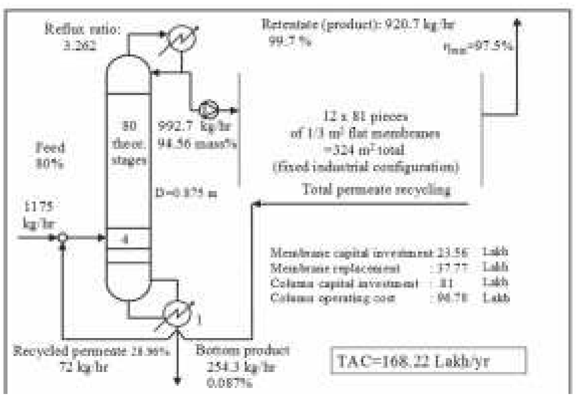

FIGURE: 1 Basic Hybride Separation Technique for Ethanol Water Separation

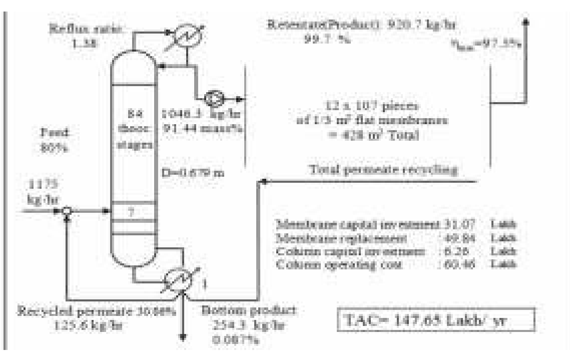

FIGURE 2 : Optimised Hybride Separation Technique for Ethanol Water Separation

5.0 Conclusion

By examining the above design alternatives we can say that both design are based on superstructure having same feed condition though also changing design parameters we increase purity with law operating cost per year in second alternatives reduce reflux ratio so, distillate product flow rate increase the same is feed to membrane with higher flow area (increase membrane capital cost) in second case column cost is drastically reduced about 92 % ,so that column operating cost also decreases at last we can save about 15 % in cost.

For Existing Distillation unit it is quite difficult to start with hybrid separation technology because of high capital investment for smaller units, but for new plants it is more advantageous to go for this technology. We can also use this technology for system forming azeotrope we remove product and azeotrope recycle azeotrope to membrane layer and separate it. Without doing any alteration in the existing column though also we can improve purity of product with Hybrid technology.

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