Journal of Quality and Technology Management
Volume IX, Issue I, June 2013, Page 155 – 161

AN OVERVIEW ON PERVAPORATION (AN ADVANCED SEPARATION TECHNIQUE)

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ABSTRACT

Pervaporation (PV) is an advanced separation technique capable for separating mixtures which were abstrusely separated ever before. It is an energy intensive, economical, safer and green separation technology. It competes with all the available conventional separation techniques with leading perspectives. This study, supported with solid facts and comparisons, explains the importance of pervaporation technique to achieve multiple separation objectives.

Keywords: *Membrane Separation Technique, Pervaporation, PV Applications, PV Advantages.*

INTRODUCTION

Azeotrope, heat sensitive mixtures, nonvolatile mixture and mixtures with relative volatility nearly equal to one are difficult to separate (Chen et al., 2010, Dobark et al., 2010). Different unit operation techniques like adsorption, extractive distillation, distillation of azeotropic mixtures and liquid-liquid extraction are in exercise in chemical engineering practices for the separation of such mixtures (Pakkethati, et al 2011). But all of these conventional separation techniques demand extensive amount of energy, external entrainer and downstream processing to recover key component (Baker, 2007). These techniques often cause product contamination and environmental pollution (Afonso and Crespo, 2005). In order to enhance the efficiency of separation process an advanced separation technique pervaporation (PV) has been introduced. It is an economical, energy saving and safe membrane separation technique (Ding et al., 2012, Liu et al., 2012, Cai, et al, 2013). It provides efficient separation at normal operating conditions without using any external chemical separating agent or any other downstream processing (Nunes and Peinemann, 2006; Bahara, 1998). Industrial growth is always associated with exponential energy demands and a more precise control on the environmental pollution. In order to fulfill the increasing energy requirements and environmental safety, alternative energy sources should be introduced and ongoing processes should be revamped to make them energy saving and environment friendly. Pervaporation technique fulfills all these requirements successfully and is on the way to conserve the energy and protect the environment for future. A comparison of different characteristic parameters for pervaporation process with other separation techniques is given in table 1. In this process feedstock is slightly pre-heated to increase trans-membrane flux rate and provided with a pressure greater than the atmospheric pressure to avoid vaporization of feed. Under these conditions, the feed mixture is fed into the PV-Membrane Module. Permeate, in vapor form, is condensed in a condenser and recycled if necessary. The retentate is cooled down usually by pre-heating the fresh feed and is stored in the product storage tank. In this way pervaporation process ends up with a product of ultrafine purity by using an economical and safer operational mode, without any external chemical entrainer or downstream processing (Usman et al., 2009, Sunitha et al, 2012).

Pervaporation is a membrane separation process conducted by partial vaporization using a nonporous membrane. The driving forces which cause the transport through the selective membrane are chemical potential difference, partial pressure difference and membrane transport rate (Nunes and Peinemann, 2006; Braisher et al., 2006). Membrane serves as a selective transport barrier during the separation of solute from the bulk solvent. Membranes used for the pervaporation process are nonporous made up with synthetic polymeric composite material having high functional selectivity (Yampolskii and Pinnav, 2006, Wee et al, 2010, Roda et al., 2011). Name of this membrane-based process is a contraction of permeation and evaporation, representing two basic steps of the process i.e. the permeation through the membrane and then its evaporation into the vapor phase. The feed constituent which passes through the membrane is termed as permeate and the remainder of the feed stream which retains on the membrane is termed as retentate (Perry and Green, 2008). Membrane Modules used for the pervaporation process are available with various fabrication designs e.g. tubular, plate and frame, spiral-wound, hollow fibrous, capillary fiber etc. In pervaporation-

Module liquid feed mixture associates the upstream side of the membrane. One component of feed (solute) is transported through the membrane preferentially and is removed as a vapor from the downstream side. Basic schematic diagram for pervaporation process is shown in Fig 1. The selective transport through the membrane is followed by a three step mechanism termed as Solution-Diffusion Model which involves sorption, diffusion and desorption (Baker 2007; Nunes and Peinemann, 2003).

APPLICATIONS

Pervaporation has a large list of industrial applications for the separation of liquid mixtures. Although it is a developing industrial membrane separation process but still its leading perspectives have compelled the industrialist to fabricate pervaporation plants which are effectively playing their role in production. Typical separations being conducted by pervaporation technique are separation of azeotropic mixtures in chemical process industries, organic-organic separation, separation of dissolved organics from water, separations in petroleum and petrochemical industries, increasing distillation column efficiency by hybrid pervaporation unit, increasing reaction yield by Perstillation and water and waste water treatment etc. (Baker 2007; Afonso and Crespo, 2005; Perry and Green, 2008).

PV PROCESS "A GREEN SEPARATION PROCESS"

"Green Separation Processes" is a universally accepted term being used worldwide only for those processes which are environment friendly. In the context of increasingly stringent legislation in environmental protection rules and regularities, there is an exponential increase in interest for the development of more environment friendly processes and techniques. Pervaporation process is an integral part of the Green Separation Processes as It does not need any hazardous or toxic chemicals for separation, but only a selective membrane, it does not discharge any hazardous effluent stream, it is not going to become a part of global warming, no air, water or ground pollution involved in the process, a noise free process. So pervaporation technique does not involve any factor relevant to environmental safety that limits its development or use (Afonso and Crespo, 2005; Usman et al., 2009). However, pervaporation process even has some disadvantages. So some advantages and disadvantages of pervaporation process are given in table 2.

CONCLUSION

By studying the pervaporation process description, advantages & disadvantages, descriptive comparison, diagrammatic comparison, areas of application and its environmental impacts comparison with other competitive separation techniques, Pervaporation proves itself an economic, efficient and green separation technique. It possesses leading perspectives as compared to the other conventional separation system.

Table 1: comparison of PV process with other separating processes (Baker, 2007; Afonso and Crespo, 2005; Usman et at., 2009; McCabe et al., 2004)

Characteristic Parameter	Separation Techniques			
	Azeo/ Extractive Distillation Technique	**Liquid- Liquid Extraction Technique**	**Drying Agents Technique**	**Pervaporation Technique**
Separating Medium	Heat	Immiscible Liquid Interface	Solid Sorbent	Membrane
Separation Driving Force	Relative Volatility	Partitioning Between Phases	Water Adsorbing Tendency	Concentration & Partial Pressure Difference
Separating Equipment	Distillation Column	Mixer – Settler & Dist. Column	Autoclave & Dist. Col.	Membrane Module
External Chemical Separating Agent	Benzene/ Glycerin etc.	Different Entrainers/ Solvents	Calcium Oxide/ Calcium Sulphate etc.	No Chemical Required
Downstream Processing	Recovery of Additional Solvent Required	Recovery of Additional Entrainer Required	Recovery of Drying Agent Required	No Downstream Processing Required
Operational Pressure	High	Medium	Medium	Low
Operational Temperature	High	Medium	Medium	Medium
Energy Consumption	High	High	High	Low
Space Requirement	High	High	Medium	Low
Operating Hazard	High	Medium	Medium	Low

Characteristic Parameter	Separation Techniques			
	Azeo/ Extractive Distillation Technique	Liquid- Liquid Extraction Technique	Drying Agents Technique	Pervaporation Technique
Maintenance Cost	High	Medium	Medium	Low
Operating Cost	High	Medium	Medium	Low
Capital Cost	High	Medium	Medium	Medium
Environmental Impact	Susceptible to Cause Pollution	Susceptible to Cause Pollution	Susceptible to Cause Pollution	Green Separation (Environment Friendly)
Product Purity	Fine	Fine	Fine	Ultrafine
Overall Recommend-ation	Good	Good	Good	Best

Table 2: Comparison of advantages and disadvantages of PV process (Baker, 2007; Afonso and Crespo, 2005; Usman et at., 2009; McCabe et al., 2004)

Advantages of PV	Disadvantages of PV
• Capable of Breaking Azeotropes • Separation of Heat Sensitive Substances • No Chance of Product Contamination • Involves Simple Process Schematics • No Need of Heavy Equipments (e.g. Distillation Columns, Condensers, Reboilers etc.) • Energy Saving Process • Continuous Production System • Involves Low Operational Temperature • Involves Low Operational Pressure • Flexibility in Operating System • Multistage System can be Used • Low Operating Cost • Low Maintenance Cost • Low Capital Cost • Environment Friendly and pollution free Technique (Green Separation Technique) • Results in High Purity Product.	• Pervaporation separation system requires purified feed • Temperature reduction in Pervaporation reduces the transmembrane flux

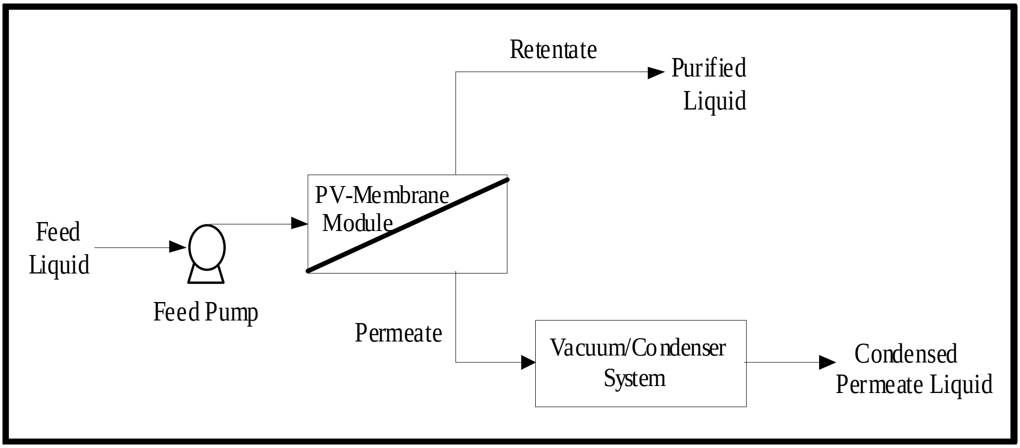

Figure 1: Schematic Diagram of the Fundamental Low Pervaporation Process (Baker, 2007)

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