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Research Paper

Separation of IsoPropyl Alcohol - Water By Hybrid Distillation Pervaporation System

Engineering

KEYWORDS : IPA / Water, Pervaporation, Hybrid distillation Pervaporation

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ABSTRACT

In a membrane separation techniques, pervaporation used to purify the chemicals. Pervaporation, in its simplest form, is an energy efficient combination of membrane permeation and evaporation. Nowadays to separate alcohol-water mixture by hybrid distillation pervaporation gaining significant attention in industry. Normally Conventionally azeotropic distillation is used to remove the water from an azeotropic isopropyl alcohol (IPA) /water mixture. The aim of this paper is to show the comparative study of pervaporation over a conventional azeotropic distillation for the separation of IPA/water mixture. By the use of new technique we can reduce operating costs and waste water treatment and eliminate the use of chemical entrainer. All this aspects lead to the development and adoption of new better technology over a conventional one.

1. Introduction

Pervaporation, is combination of membrane permeation and evaporation. It's considered an attractive alternative to other separation methods for a variety of processes. Low temperatures and pressures involved in pervaporation, it often has cost and performance advantages for the separation of constant-boiling azeotropes, so it called energy efficient process. Additionally, pervaporation can be used for separation heat sensitive products, breaking azeotropes, dehydration of solvents and other volatile organics, organic/organic separations such as ethanol, IPA and methanol removal, and wastewater purification.

2. Pervaporation:

Pervaporation involves the separation of two or more components across a membrane by differing rates of diffusion through a thin polymer and an evaporative phase change comparable to a simple flash step.(1)

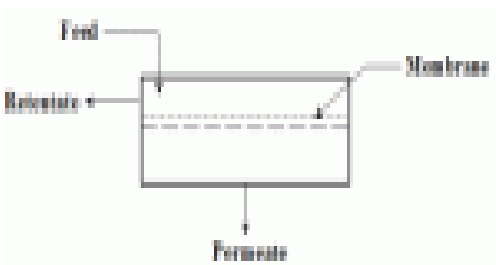


Fig .1 Overview of pervaporation process (Courtsey by www.cheresources.com)

A concentrate and vapor pressure gradient is used to allow one component to preferentially permeate across the membrane. A vacuum applied to the permeate side is coupled with the immediate condensation of the permeated vapors. Pervaporation is typically suited to separating a minor component of a liquid mixture, thus high selectivity through the membrane is essential.

Liquid transport in pervaporation is described by various solution-diffusion models. The steps included are the sorption of the permeate at the interface of the solution feed and the membrane, diffusion across the membrane due to concentration gradients (rate determining steps), and finally desorption into a vapor phase at the permeate side of the membrane.

The first two steps are primarily responsible for the permselectivity. As material passes through the membrane a "swelling" effect makes the membrane more permeable, but less selective, until a point of unacceptable selectivity is reached and the membrane must be regenerated.

The other driving force for separation is the difference in partial pressures across the membrane. By reducing the pressure on the permeate side of the membrane, a driving force is created.

Another method of inducing a partial pressure gradient is to sweep an inert gas over the permeate side of the membrane. These methods are described as vacuum and sweep gas pervaporation respectively. (1)

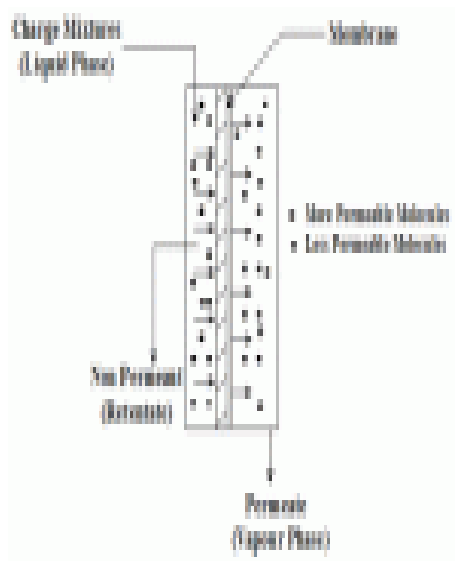


Fig.2 Schematic of Liquid Permeation (Courtsey by www.cheresources.com)

Characteristics of the pervaporation process include: (1)

- Low energy consumption
- No entrainer required, no contamination
- Permeate must be volatile at operating conditions
- Functions independent of vapor/liquid equilibrium

3. Application of Pervaporation:

- Dehydration of organic solvents (e.g., alcohols, ethers, esters, acids)
- Removal of dilute organic *compounds* from aqueous streams (e.g., removal of volatile organic compounds, recovery of aroma, and biofuels from fermentation broth)
- Organic–organic mixtures separation (e.g., methyl *tert*-butyl ether (MTBE) /methanol, dimethyl carbonate (DMC)/methanol). (2)

4. Mass Transfer Process Along Menbrane in Pervaporation

The pervaporation of dilute organic-water mixtures has been relatively well described by a resistance-in-series model. The mass transfer process of a single component across the membrane occurs in 4 consecutive steps:

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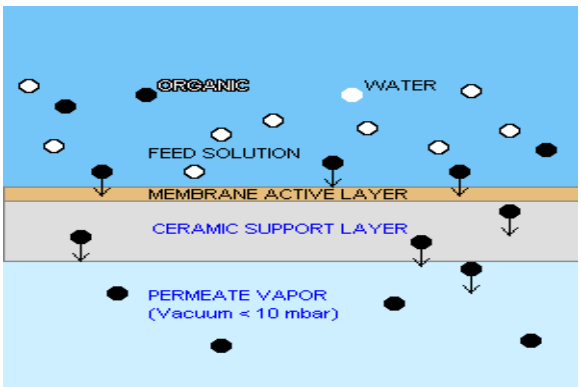


Fig. 3 Mass Transfer Process Along Menbrane in Pervaporation
(Courtsey by www.cheresources.com)

1- Mass transfer from the bulk of feed to the membrane interface.
2- Selective absorption into the membrane at the feed side.
3- Selective diffusion through the membrane.
4- Desorption into the vapor phase at the permeate side. (3)

5. Dehydration of IPA by Azeotropic Distillation

A mixture containing 50wt.% IPA and 50wt.% water is used to separate the IPA from water and to reached up to a final IPA concentration of 99.5wt.%. The temperature of the initial feed mixture is 20 ˚C.

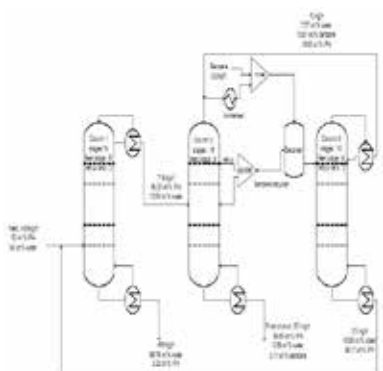


Fig. 4 Azeotropic Distillation of IPA-Water Mixture

The purification of IPA traditionally occurs through azeotropic distillation. Fig. 4 gives an overview of an azeotropic distillation process for the dehydration of IPA, using benzene as an entrainer. In a first column, the aim is to obtain a top product with a composition close to the azeotropic composition (we will consider distillation up to 86.5wt.% IPA and 13.5wt.% water). In the second column, the actual azeotropic column, an entrainer is added to break the azeotrope. The bottom stream of this column contains IPA with the final desired purity, while the top stream is a mixture of water, IPA and benzene. This top stream is sent to a decanter, where it separates in two fractions, a benzene-rich fraction and a water-rich fraction. The benzene-rich fraction is sent back to the second column, while the water-rich fraction, containing IPA, water and benzene, is sent to a third distillation column to further recover the benzene. The bottom stream of this third column is a mixture of IPA and water with almost the same composition as the initial feed mixture so it is sent back to the first column. The top stream of the third column contains water, benzene and isopropanol and is sent back to the second column. Azeotropic distillation is a very energy-consuming process and the use of an entrainer might cause un-wanted impurity in the product and side streams.

Therefore, other techniques should be considered to overcome these disadvantages.

6. Dehydration of IPA by Hydrid Distillation Pervaporation Process

A very interesting alternative might be a hybrid process combining distillation with pervaporation. First the feed mixture is sent to a distillation column to obtain a top product that has a composition close to the azeotrope (we will consider distillation up to 83.0wt.% IPA and 17.0wt.% water). The top product of this distillation column is further dehydrated by a pervaporation unit. The top product can be dehydrated up to the final desired water concentration by pervaporation (Fig. 5) or it can be dehydrated partially by pervaporation to break the azeotrope (we will consider distillation up to approximately 5wt.% water) and then sent to a second distillation column in which it is dehydrated up to the final desired IPA concentration (Fig. 5). Different types of membrane like polymeric and ceramic membrane can be used for hybrid systems. (4)

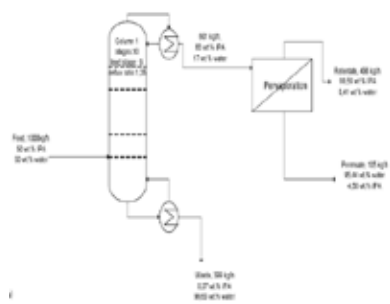


Fig. 5 Separation of IPA from water by Hybrid Distillation Pervaporation

7. Conclusion

Comparative study of dehydration of IPA for different shows that hybrid distillation of pervaporation method is better because of certain advantages. In hybrid distillation pervaporation system very low energy required compared to conventional system. Use of carcinogenic chemical like benzene as entrainer can be eliminated. Many economical study shows that capital cost and operating cost can be reduced compared to conventional methods.

REFERENCE

1. http://www.cheresources.com/content/articles/separation-technology/pervaporation-an-overiew/ referred on 15/10/2015 2. Review - Polymeric membrane pervaporation, P. Shao *, R.Y.M. Huang Department of Chemical Engineering, University of Waterloo, Ont., Canada N2L 3G1, Received 8 October 2005; received in revised form 8 October 2006; accepted 22 October 2006 Available online 7 November 2006 3. Review Separation of organic–organic mixtures by pervaporation—a review B. Smitha, D. Suhanya, S. Sridhar*, M. Ramakrishna Membrane Separations Group, Chemical Engineering Division, Indian Institute of Chemical Technology, Hyderabad, India Received 19 September 2003; received in revised form 10 March 2004; accepted 11 March 2004 4. Economic Comparison between azeotropic distillation and different hybrid distillation pervaporation system for separation of Isopropyl alcohol and water, Veerle Van Hoof , Liesbet Van den Abeele, Anita Buekenhoudt, Chris Dotremont, Roger Leysen, Separation and Purification Technology 37 (2004) 33–49 5. Pervaporation-based hybrid process: a review of process design, applications and economics Frank Lipnizki, Robert W. Field*, Po-Kiong Ten Department of Chemical Engineering, University of Bath, Bath BA2 7AY, UK Received 14 January 1998; received in revised form 21 January 1998; accepted 10 August 1998 Abstract 6. http://www.chemeng.ntua.gr/courses/mad/files/Azeotropic%20distillation_December%202014.pdf, referred on 18/11/2015