Strategy for the Separation of Azeotropic Mixture by Pressure Swing Distillation

Seema Kakade[1], Rajendra Ugwekar[2] and Sanjay Shirsat[3]

[1,2,3] Department of Chemical Engineering, Laxminarayan Institute of Technology, Rashtrasant Tukadoji Maharaj Nagpur University, Nagpur-440033, India

Abstract

Pressure swing distillation (PSD) is a technique coming forward as a strong alternative to the conventional separation methods for separating azeotropes. The conventional pressure swing distillation involves two columns operated at two different pressures. This work puts forward a new three column oressure swing distillation strategy for the separation of azeotropic Isobutyl Alcohol (IBA) - Isobutyl Acetate (IBAc) mixture. Two of the columns are operated at atmospheric pressure while third at a lower pressure. CHEMCAD (version 6.5) software is used to perform the simulations to get the optimized configuration which gives minimum energy requirements. The proposed process comes out to be more energy efficient when compared to the conventional two column techniques.

Keywords: *Pressure swing distillation; Isobutyl alcohol; Isobutyl acetate; Simulation*

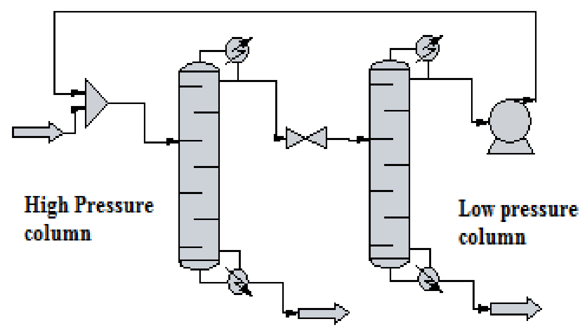

Figure 1. Conventional two column PSD process for separation for IBA-IBAc

1. Introduction

Azeotropes are widely encountered mixtures in the chemical industry and their separation is process of great speculations. There are many techniques used for the separation of such mixtures. Pressure swing distillation (PSD) is one such process which is widely being considered as an alternative to other methods like extractive distillation (Berg nd Yeh An, 1988, Doherty and Malone, 2001), reactive distillation (Maier et al, 2000) of late, membrane pervaporation (Fleming, 1992), adsorption (Garg and Ausikaitis, 1983). The Vapour-liquid equilibrium of a mixture is affected by changes in pressure (Seader and Henley, 1998). This fact makes the basis for pressure swing distillation where in the azeotropic point is jumped over by changes in pressure and the desired separation is achieved. The choice of suitable operating pressure can shift the azeotropic point considerably and a highly pure product can be obtained. In the conventional pressure swing distillation process two columns (Seader and Henley, 1998) are used which are operated at different pressures. A typical pressure swing distillation strategy with two columns for the separation of Isobutyl Alcohol (IBA) from Isobutyl acetate (IBAc) is shown in the Fig. 1.

IBAc is widely used as a solvent for coatings, inks, adhesives, industrial cleaners, degreasers etc. IBA-IBAc forms an azeotrope at 86 mol% of IBA. In the two columns technique first column is operated at atmospheric pressure while the second column is operated at lower pressure (Munoz et al, 2006). In this process IBAc comes out as the bottoms from the high pressure column (HPC) and IBA in the bottoms from the low pressure column (LPC). The distillation can continue in the LPC since the azeotropic point is jumped over and since the activity coefficients are crossed the higher volatile component (IBA) comes through the bottoms of the LPC. Many studies are reported in the literature for this scheme for different azeotropes (Frank 1997, Mulia-Soto nd Flores-Tlacuahuac, 2011).

2. Choice of Operating Pressure

Choosing the operating pressures for the columns is an important step in the design of PSD scheme. A pressure is selected such that the azeotropic point is shifted sufficiently. The azeotropic composition of IBAc as a function of pressure is shown in Figure 2 for IBA-IBAc mixture.

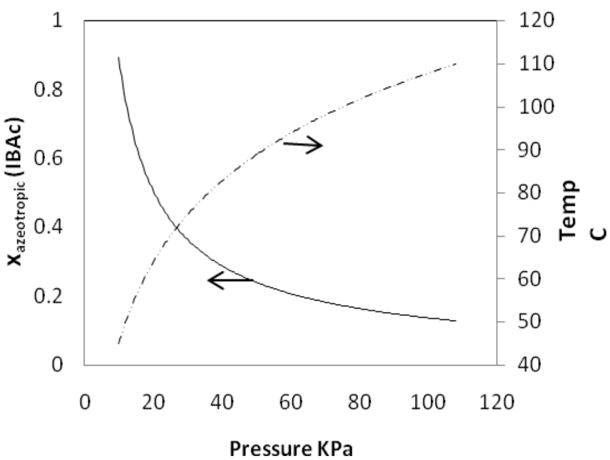

Figure 2. Azeotropic composition and temperature as function of Pressure

Pressure (KPa)	Azeotropic mol fraction of IBA
20	0.49
101.325	0.86

Table 1. Azeotropic composition at different pressures

Table 1 shows azeotropic composition of IBA-IBAc at different pressures. An operating pressure of 101.325 KPa in HPC and 20 KPa in LPC is selected. The azeotropic composition shifts from 86 mol% of IBA at 101.325 KPa to 49 mol% at 20 KPa, which is sufficient to continue the separation.

3. New Strategy

In this work we propose a novel strategy for the PSD for the separation of IBA-IBAc, the flow sheet is given in Figure 3. In this process we use three columns instead of the two columns in the conventional PSD process. The feed (flow rate 24 kmol/hr) is mixed with the recycle stream the output is divided in two streams, which are fed to two columns operating at 101.325 KPa. In these columns separation occurs to the azeotropic point and 99.5% IBAc is obtained as the bottom product.

The distillates of both columns are mixed and sent to a third column operating at lower pressure 20 KPa. Because the feed composition is more than the azeotropic point at 20 KPa, the activity coefficients are crossed and the distillation is continued further, IBA is the bottom product of the low pressure column with 98.5 % purity. The distillate of this column is recycled back.

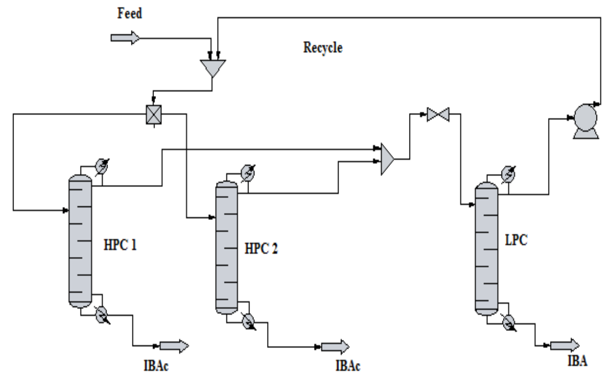

Figure 3. Three column process PSD for the separation of IBA-IBAc

3.1. Simulation and Optimization

Simulation is carried out for the process using CHEMCAD V. 6.5. Number of stages, feed stage location, reflux ratio are selected as the optimization variables. Optimization is done to find out the configuration with minimum reboiler heat duty (RHD). The purity of the product is set as constraints to get 99.5% IBAc and 98.5% IBA

3.2. Sensitivity Analysis

The temperature and liquid composition profiles for the three columns are shown Figure 4 and 5 respectively. Similar trend is observed in the temperature profiles in the three columns.

The temperatures are almost steady for most of the stages and at some point the temperatures shoot up due to the proximity to the reboiler which is as expected. The liquid composition profiles of IBA and IBAc for the HPC cross at some stage because of the formation of azeotrope.

Since the feed composition to the low pressure column is above the azeotropic point the composition profiles for the LPC do not cross

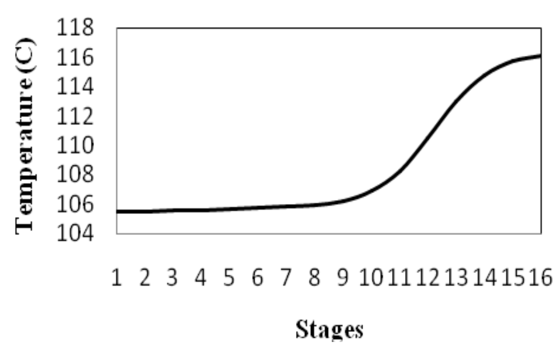

Figure 4. Temperature profile in HPC and LPC

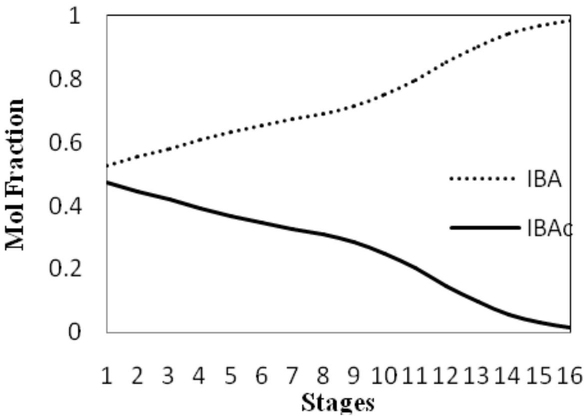

Figure 5. Liquid composition profile in HPC and LPC

4. Result and Discusion

4.1. Effect of number of Stages

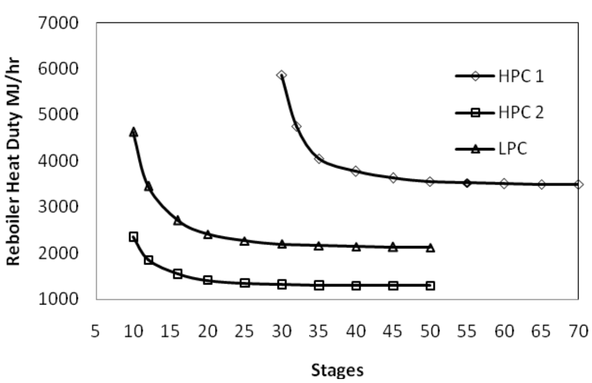

Figure 6. Variation of Reboiler duty with number of stages

The number of stages in all the three columns is varied to get a configuration which requires minimum RHD. It is observed from Figure 6 that as the number of stages is increased the RHD goes on decreasing till the number of stages 35, 16 and 16 in HPC 1, HPC 2, and LPC respectively. After this point there is no significant decrease in the RHD. This trend is observed for all the three columns.

4.2 Effect of Reflux Ratio

It is observed that as the reflux ratio is increased the RHD decreases first and then starts increasing. This is seen in figure 7.

For given number of plates and reflux ratio there is a feed stage giving minimum reboiler heating duty. The optimum is observed at reflux ratio 2, 1.5 and 1.5 for HPC 1, HPC 2, and LPC respectively.

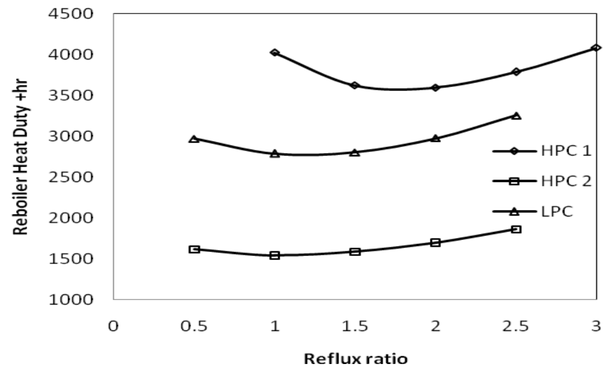

Figure 7. Variation in Reboiler duty with reflux ratio

4.3 Effect of Recycle Flow Rate

The variation in recycle flow rate has two effects, as the recycle flow rate is increased the reflux ratio decreases, and the RHD decreases initially attains a minimum and then starts increasing, as is seen in Figures 8.

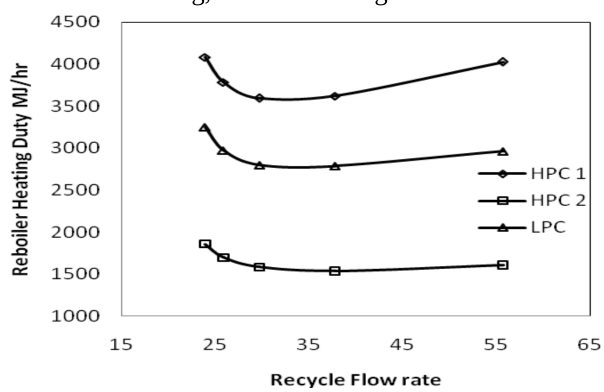

Figure 8. Variation in Reboiler duty with reflux ratio

Similar trend is observed for all three columns. Minimum RHD is obtained for a recycle flow rate of 29.71 Kmol/hr. The optimum configuration thus found is given in the Table 2.

Table 2: Optimum configuration for the three column strategy

Column	***HPC1***	HPC2	LPC
Operating Pressure (KPa)	101.325	101.325	20
Numbar of Stages	35	16	16
Feed Stage	23	8	8
Reflux Ratio	2	1.5	1.5
Reboiler Duty (MJ/h)	3594.9482	1585.4387	2800.3403

4.4. Comparison with two column processes

Table 3: Comparison with two column process

Process	***IBA purity***	IBAc Purity	RHD (MJ/hr)	Feed (kmol/h)
Three Column	98.5	99.5	3594.9482	24
Two Column	98.5	99.5	3119	15.91

Table 3 shows the energy consumption for the two columns and the three columns pressure swing distillation process. It can be seen from Table 3 that the three column process consumes more energy than the two column process, but the three column process has a capacity 1.5 times that in the two column process which compensates the energy consumption, which increases just by a little margin.

The most important factor to evaluate a process is the energy consumption. The energy consumption studies for the two column process for the separation of IBA-IBAc have been reported by many authors.

5. Conclusions

This work suggests a new process with three columns for the separation of IBA-IBAc by pressure swing distillation. The process simulation and optimization is done using CHEMCAD v 6.5 on variables such as number of stages, reflux ratio and recycle flow rate, with the total reboiler heating duty being the constraint of the problem. A configuration that requires minimum RHD is obtained.

This new process is compared to the conventional two column pressure swing distillation process. The feed flow rate for the suggested three column process is 1.5 times that in the two column process in the previous studies (Munoz et al, 2006) but still the total RHD is larger by only a small margin. Thus the new process comes out to be an energy efficient process, with sufficiently lager capacity.The better your paper looks, the better the Journal looks. Thanks for your cooperation and contribution.

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Seema Kakade currently is the research scholar in the Department of Chemical Engineering, Laxminarayan Institute of Technology, Nagpur and published three research papers in the national and international journals. She is the recipient of UGC fellowship.

Dr. Rajendra Ugwekar is Associate Professor and Head of the Department of Chemical Engineering, Laxminarayan Institute of Technology, Nagpur. He has published more than thirty papers in the national and international journals and editor of two international books. His experience in the industry and teaching is about 30 years. He completed number of research projects sponsored by various agencies.

Dr. Sanjay Shirsat is Assistant Professor in the Department of Chemical Engineering, Laxminarayan Institute of Technology, Nagpur. He has published thirteen papers in the national and international journals. His has fifteen years of teaching experience. He is a life member of the ISTE.