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Insight into separation of azeotrope in wastewater to achieve cleaner production by extractive distillation and pressure-swing distillation based on phase equilibrium

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There are a large number of azeotropes in the binary system of alkanes and alcohols in the industrial wastewater from the reaction of vanadium pentoxide with alkanes to produce alkylvanadate. In order to protect the environment, utilize resources and clean production, the extractive distillation process with high boiling solvent as extractant is usually used to separate the azeotropes in industrial products. However, some intermediate-boiling solvents compared with the two key components to be separated are used as extractant in extractive distillation. In this work, the binary azeotropic system of n-heptane and isoamyl alcohol in wastewater was separated by extractive distillation with intermediate-boiling solvents, pressure-swing distillation and pressure-swing distillation with thermal integration. The binary interaction parameters of isoamyl alcohol and butyl acetate were obtained by correlating and regressing the experimental data of vapor-liquid equilibrium at atmospheric pressure. Taking total annual cost minimum as the objective function, the optimal design parameters of the three processes were obtained by sequential iteration method. Compared with the extractive distillation and pressure-swing distillation, pressure-swing distillation with thermal integration can save the cost up to 29.38%, increase the thermodynamic efficiency up to 445.39%, reduce the global warming potential up to 39.34% and the decrease the acidification potential up to 39.34%. This work provides an effective reference for better separation of azeotropes and wastewater treatment.

Introduction

The United Nations announced more people have died from drinking unclean water than from war. In many parts of the world, water contaminated with bacteria, antibiotics, disinfectants and hormones has serious negative effects on the environment and public health. Most human activities produce wastewater, and more than 80% of the world's wastewater is discharged into the environment without treatment. Attention must be paid to wastewater treatment.

N-heptane and isoamyl alcohol can form the minimum boiling azeotrope and the azeotropic composition of 88.87 mol% n-heptane and 11.13 mol% isoamyl alcohol at 1 atm.`

Basis of design and analysis

1.1 Property method

Butyl acetate was selected as the intermediate solvent to separate the azeotropic system of n-heptane and isoamyl alcohol.

The missing binary interaction parameters of isoamyl alcohol and butyl acetate were obtained by vapor-liquid equilibrium experiment by the modified rose type recirculating equilibrium still .

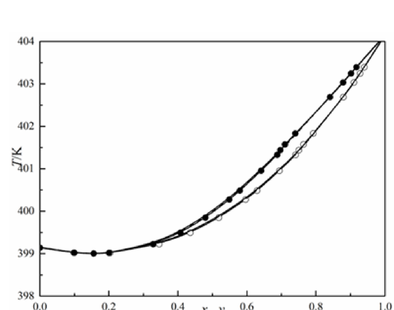

Fig. 1. T-x-y diagram for the binary system of isoamyl alcohol (1) + butyl acetate (2) at 101.3 kPa.

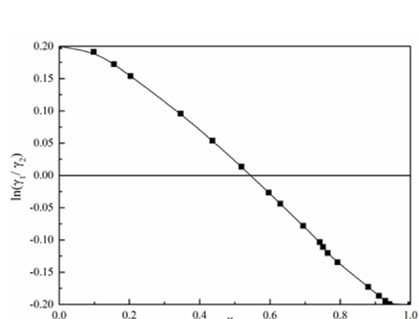

Fig. 3. The diagrams of ln (γ1/γ2) vs x1 for the binary system of isoamyl alcohol (1) + butyl acetate (2).

1.2 Analysis

The y-x deviates from the diagonal obviously, indicating that the relative volatility of azeotropic system of n-heptane and isoamyl alcohol was improved after adding butyl acetate.

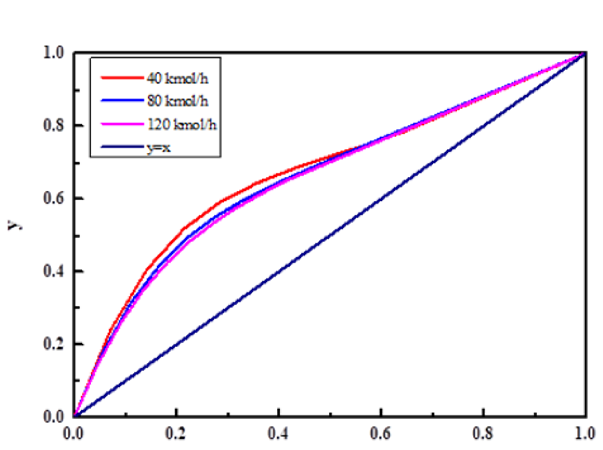

Fig. 2. The y-x phase diagram of n-heptane- isoamyl alcohol system.

Taking the extraction effect and economic cost into consideration, the amount of extractant was determined as 120 kmol/h.

Pressure had a great influence on the azeotropic composition of the system of n-heptane and isoamyl alcohol, so pressure-swing distillation process can separate the azeotropic system effectively.

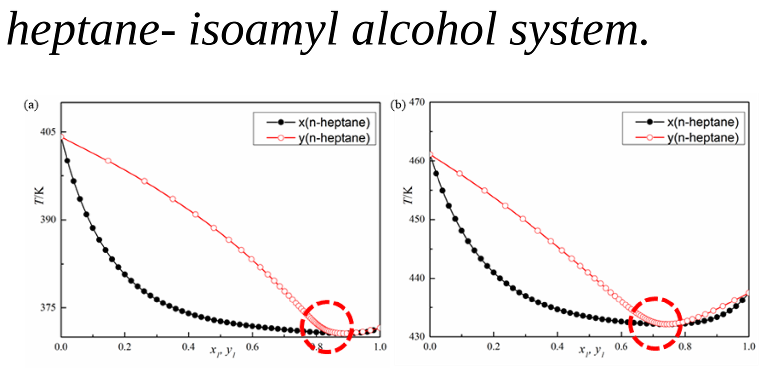

Fig. 3. The T-x-y phase diagram of n-heptane-isoamyl alcohol system at (a) 1 atm and (b) 5atm.

Flowsheet simulation

2 Process

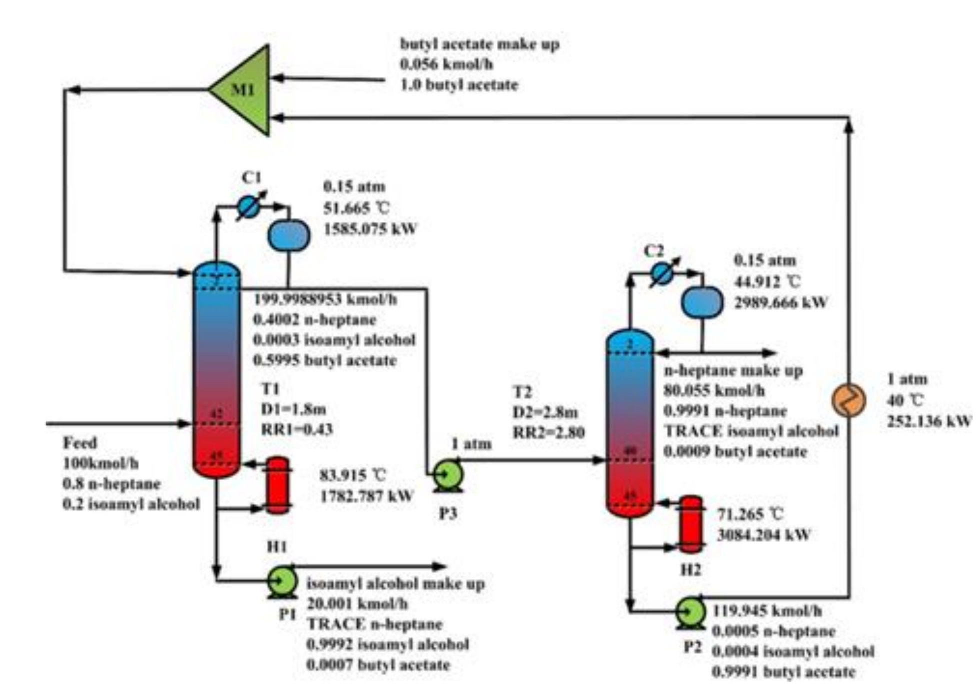

Fig. 4. The most energy-efficient process of extractive distillation

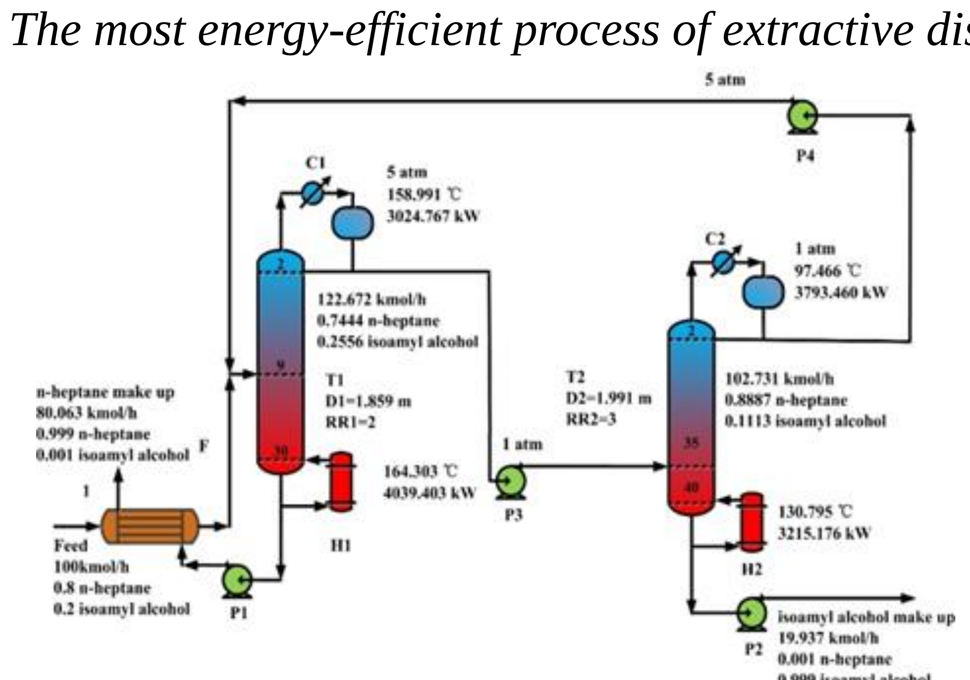

Fig. 5. The most energy-efficient process of pressure-swing distillation .

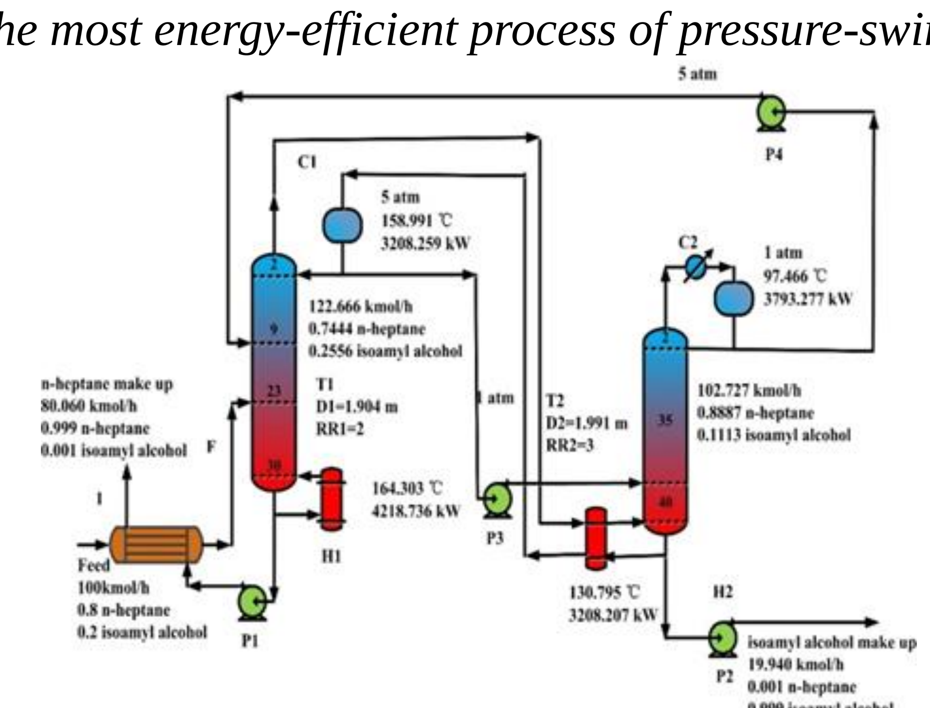

Fig. 6. The most energy-efficient process of pressure-swing distillation with full thermal integration process.

Conclusion

In this study, extractive distillation process, pressure-swing distillation process and heat integration technology were selected to separate azeotrope. In this work, butyl acetate was selected as the intermediate boiling solvent, and the missing BIPs of isoamyl alcohol and butyl acetate were obtained by VLE experiment. The feasibility of the three process for the separation of azeotropes was studied by sensitivity analysis of the effects of relative volatility and pressure.

The results have shown that compared with extractive distillation and pressure-swing distillation process, the pressure-swing distillation with full thermal integration process had the lowest TAC, the highest thermodynamic efficiency and the lowest carbon emission.