**Development of Hybrid Membrane Separation-Distillation Processes for Propylene-Propane Separation**

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**Highlights**

* Evaluation of energy consumption of hybrid membrane separation-distillation processes
* Energy consumption of the hybrid process is 83% less than that of distillation process
* Capital cost divided by the payback time of membrane separation unit was estimated

**1. Introduction**

Energy-saving of separation process is a problem in order to reduce greenhouse gas emission, because the separation process accounts for about half of the energy consumption in the chemical industry [1]. In the chemical industry, diversification of raw materials is proceeding. An as example, in propylene production, the propylene content in the mixture fed to the propylene purification column is 98% for the ethylene center, whereas it is 90% for the propane dehydration process. Although distillation is widely used for these separations, reduction of the propylene content leads to increase of energy consumption. Therefore, it is necessary to develop an alternative energy-efficiency separation process. As an energy-efficiency separation process, membrane separation has attracted attention [1]. However, since membrane separation is not suitable for high throughput, it is difficult to replace the distillation process of propylene separation with membrane separation. To solve this problem, there is hybridization of membrane separation and distillation as one of the candidates. In the design of hybrid process, it is necessary not only to clarify the configuration that can reduce the energy consumption but also to achieve cost reduction. This study clarifies the influence of the configuration of the hybrid process on energy consumption for separation of propylene/propane mixture and discusses the cost of the separation membrane unit.

**2. Simulation model**

For a case study, the propylene content in the feed was set as 90 mol%, and the feed flow rate was constant at 1433 kmol/h. As the product specifications, the propylene content was 99.5 mol%, and the recovery ratio of propylene was 99.5%. The thermodynamic properties were estimated using the Peng-Robinson model. **Figure 1** shows the schematic diagrams of hybrid membrane separation-distillation processes. The hybrid process consists of one distillation column and one membrane separation unit. The stage numbers of the distillation column was fixed at 230 stages. The pressure of the distillation column was 2040 kPa. As membrane separation performances, the propylene permeability was 1×10-6 mol/(m2･s･Pa), and the propylene selectivity was 100. The pressures of permeate and feed side were 2040 and 200 kPa. All simulation were performed by Pro/II (ver. 9.4).



**Figure 1.** Schematic diagrams of hybrid membrane separation-distillation processes.

**3. Results and discussion**

The energy consumptions including duties of reboiler and compressor of Case 1 and 2 were minimized when the membrane areas were 355 and 413 m2, respectively. The energy consumption of Case 1 and Case 2 were 50.5 and 48.1 GJ/h. There results correspond to energy saving of approximately 82 and 83% compared to the distillation process. Based on the results, this study estimated the cost reduction by reducing energy consumption. Here, the costs of the steam and the electricity was assumed to be 13.28 and 16.8 $/GJ [2]. The operating time per year was set to be 8322 hours [2]. As a result, the annual operating costs for the distillation process, Case 1 and 2 were 3.09×107, 6.12×106, and 5.87×106 $, respectively. If the difference of operating cost between the distillation and the hybrid process is greater than the equipment cost divided by the payback time, total annual cost (TAC) of the hybrid process is reduced. Therefore, the upper limit of the equipment cost divided by payback time for Case 1 and 2 are 2.48×107 and 2.50×107 $.

**4. Conclusions**

This study evaluated the energy consumptions for the hybrid processes of Case 1 and 2, and found that energy savings of 82 and 83% can be achieved in Case 1 and 2, respectively. Based on the results, this study estimated the upper limit of the equipment cost divided by the payback time of the membrane separation unit.

**References**

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**Acknowledgment**

This work was partially supported by NEDO, JAPAN, in the project of “Development of energy-efficient basic chemical production processes with innovation separation technologies”.