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Control of an energy-saving side-stream extractive distillation process with different disturbance conditions

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ABSTRACT

It is important to study the dynamic controllability for the side-stream extractive distillation due to its superiority of energy saving. Control structures of the side-stream extractive distillation process are special and complex due to the instability of side-stream flow rate. In this work, the dynamic control of the side-stream extractive distillation was explored for separating azeotropic mixture of acetone and methanol. The detailed control structures were used to investigate the control strategies of side-stream extractive distillation. During the whole design process, the control of flow rate on side stream is a key factor for achieving this process efficient control. A new control structure combining a component controller and a side-stream throughput valve was proposed to achieve good dynamic performance for the side-stream extractive distillation process when ± 10% disturbances were introduced, but it is difficult to control the ± 20% feed disturbances. In addition, the side-stream extractive distillation takes about a longer time to reach a steady state while maintaining the purity of products, compared with conventional process. Research on control performance is of great significance to the development of energy saving technology for side-stream extractive distillation.

1. Introduction

For chemical production purposes, distillation is by far the most commonly used separation technology due to its advantages in operation and control [1–3]. It separates mixtures by heating streams to vapor-liquid phases based on differences in relative volatility or boiling points of the components. In addition, some special distillation methods were developed to separate azeotropic mixtures effectively, including pressure-swing distillation [4–7], azeotropic distillation [8,9], extractive distillation [10–15], catalytic distillation [16,17], etc. Extractive distillation is one of the effective methods to separate binary azeotropic mixtures or close boiling point mixtures. Although extractive distillation technology is widely used, one major obstacle is the huge energy requirements [2].

There is a great deal of papers on energy saving technology of extractive distillation as well as the corresponding design, and many achievements have been made to date [18–29]. Chien et al. [9] investigated a heterogeneous azeotropic dividing-wall column for separating water and pyridine using toluene as solvent and the dividing-wall column provided great energy savings. Li et al. [12] provided three energy saving extractive distillation processes for separating toluene and 2-methoxyethanol to achieve energy saving. The results show that extractive dividing-wall column has better performance in terms of economy. Zhao et al. [19] proposed a thermally coupled ternary extractive distillation process for separating tetrahydrofuran/ethanol/water using a mixed solvent (ethylene glycol and dimethyl sulfoxide) as entrainer to achieve energy saving and reduce annual total cost. An et al. [30] developed a new two-column extractive distillation system based on a three-column conventional process. The new alternative process is energy saving by combining extractive distillation column and preconcentration column. Li et al. [31] explored an energy saving technology of extractive distillation process by combining intermediate heating and heat-integrated technology. They designed a novelty extractive distillation process using a side reboiler to reduce the energy requirement. Aniya et al. [32] designed a extractive distillation process with different class of entrainers for tert butyl alcohol dehydration. The results show that the energy saving effect of extractive distillation using solvent and salt as mixed solvent is the most significant. Although some process intensification technologies reduce the energy consumption of the process and improve the economy, it makes the process more complicated than conventional process and makes the operability and control more difficult. In addition to studying the energy saving technologies of extractive distillation, dynamic control strategy is an important factor that must be considered in the process of chemical

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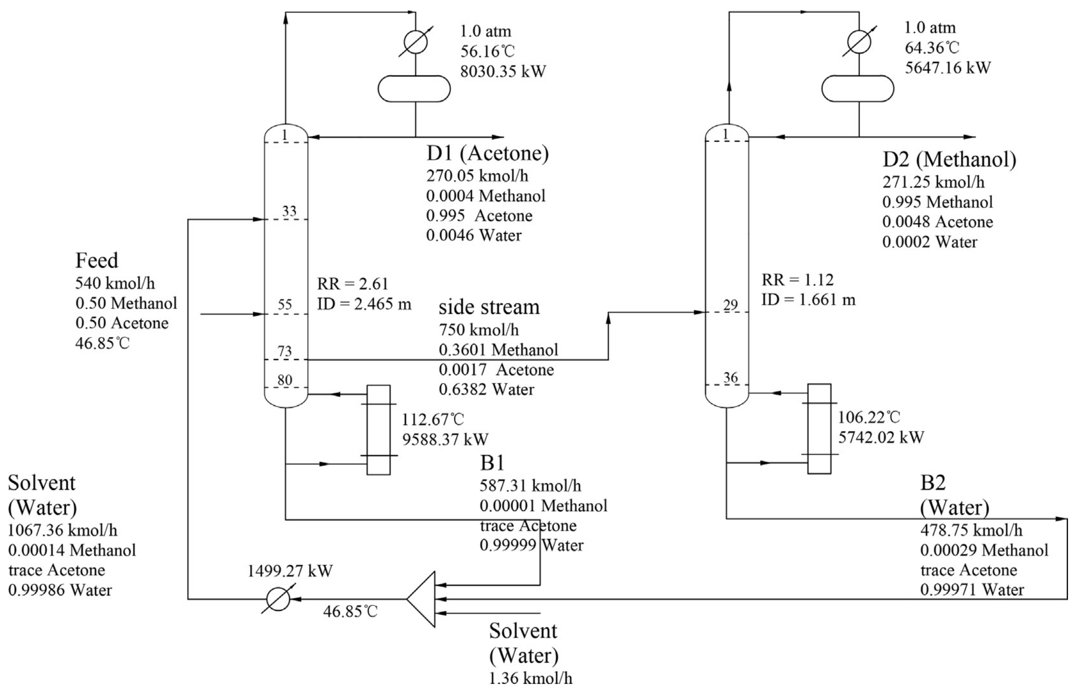

Fig. 1. Flowsheet of side-stream extractive distillation system.

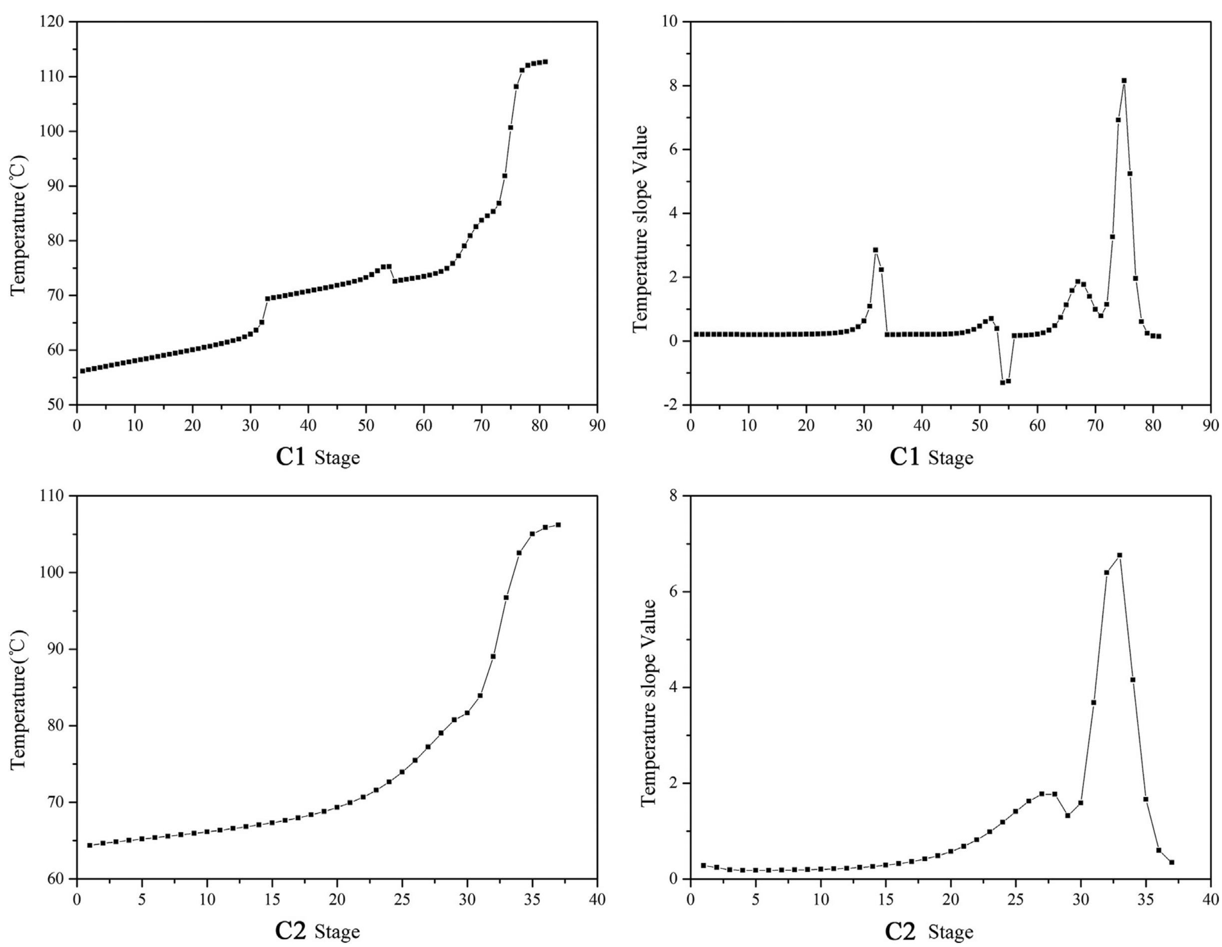

Fig. 2. Temperature and temperature slope profiles of side-stream extractive distillation.