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Comparison of sequential and simultaneous draining in periodic cycled separation columns

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Highlights

- Development of models for sequential and simultaneous drained cyclic distillation
- Comparison of tray efficiency for different draining methods
- Comparison of developed models with theoretical expectations

1. Introduction

Periodic (or cyclic) distillation is an intensified distillation process first proposed in the 1960's [1], where the liquid and the vapor phase flows are divided in two separate periods [2,3]. The two periods are a vapor flow period (VFP) and a liquid flow period (LFP). During the VFP, the liquid holdup(s) on the trays are in fixed positions, while vapor flows through the column. During the LFP, the liquid is drained from one tray to the tray below, followed by a new VFP and so forth. By operating a distillation in cyclic mode, the separation efficiency has been shown to be higher than for conventional distillation [3]. When replacing a conventional distillation column with a cyclic distillation column, a smaller column with fewer trays is needed for the same separation [1]. Depending upon the design, energy consumption may also be reduced. This expands the range of options for designs [2,3].

The theory of cyclic distillation was developed during the 20th century. However, industrial applications are only slowly coming along [3]. A serious problem with the first generation of realizations was the need for improved liquid flow control. This problem was solved in different ways during the 1980s. In recent years, new trays [4] have made it possible to operate any size column in periodic mode and thus making cyclic distillation feasible in large scale. With this tray design there is still an issue regarding the need for interrupting the vapor flow during LFPs. This can cause significant pressure dynamics. An alternative tray design has been developed that implies draining of the trays occur sequentially instead of simultaneously [5].

The currently available models are relatively simple. These models are often based on mass balances and neglect effects of pressure drop, energy transfer and variations of the point efficiency. Furthermore, it is only the more recent models that allows multi-component mixtures and non-linear phase equilibrium. In addition to this, (nearly) all existing models address simultaneous draining, which means there is a need for models that describes the sequential draining for comparison

2. Methods

Simple linear phase equilibrium models for binary mixtures are developed for both the sequential and the simultaneous draining method. These simple models are suitable for describing stripping, absorption and high-purity distillation and are convenient for analysis.

With the developed models, the efficiencies for the two draining methods are compared to each other and to theoretical expectations.

3. Results and discussion

With the developed models, the two draining methods presented for cyclic distillation have been compared to each other and theory. There are currently no comparisons available in the literature. The comparisons are focused on the tray and the overall separation efficiencies.

The difference in draining methods is expected to have an effect on the separation efficiency. When a column is drained sequentially, there is an empty tray at greater fractions of time. This will affect the overall tray efficiency. On the other hand, the rest of the trays still undergo VFP when another tray is being drained, which could be an advantage. Our analysis will investigate these conflicting effects.

4. Conclusions

Cyclic distillation is an intensified process that increases the separation efficiency compared to conventional distillation. There are two liquid draining methods available, sequential and simultaneous draining, which each have its own advantages and disadvantages. Simple models have been developed to describe a cyclic distillation process with either sequential or simultaneous draining. The developed models for the two draining methods are compared to each other and to the theoretical expectations.

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