Optimal Design of Energy-Efficient Integrated Distillation Processes for Multicomponent Ideal and Non-Ideal Mixtures by Use of the Vmin-Diagram

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Optimal design of energy-efficient integrated distillation processes for multicomponent ideal and non-ideal mixtures by use of the Vmin-diagram.

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The dividing wall distillation columns (DWC) find increased use in industrial practice. The benefits are the combined savings in both energy and capital cost. Most of the industrial applications are three-product columns, but also 4-product DWCs have been constructed. A simulation study has shown that a four-product DWC with multiple partition walls for an aromatics feed can save up to 50% energy compared to conventional sequences. The internal arrangement is more complex and it is important to predict the necessary internal flow rates both for making proper sizing of the internals and also for control structure design. Thus, there is a need to focus on development of simple-to-use methods for making assessment on how complex columns like the DWC will perform for any given application. This paper will demonstrate the usability of the Vmin-diagram method for quick assessment of column configurations for multicomponent separation.

The Vmin-diagram is obtained from feed data only, and gives a direct picture of the minimum vapor requirement for any specification of product splits. It is particularly well suited for fully thermally coupled distillation configurations like the generalized Petlyuk arrangements and dividing wall columns. The Vmin-diagram was first presented by Halvorsen and Skogestad (2003). The deduction was based on the simplifying assumptions of constant molar flows, constant pressure and constant relative volatility and then the Underwood equations were used to formulate analytical expressions for calculation of any property of the system. The concept, however, is by no mean limited to ideal assumptions and the Underwood equations. We show how the Vmin-diagram can be made by a few simple simulations on any commercial process simulator.

The construction and interpretation of the diagram and usage for design of DWC columns will be presented in some detail. Some typical design questions that can be answered are:

What is the minimum vapor flow in a DWC for a set of feed conditions?

How shall the internal flows be distributed?

How can the operating conditions be chosen for the various sections of a DWC column?

What kind of flexibility can be expected, for example what kind of feed variations can be handled and what is the tolerance for operational parameters like the vapor split and the liquid split?

The intention is to provide a versatile and reliable tool to simplify the process of designing and operating DWC columns and thereby lower the threshold for industrial use of this energy- and capital-saving technology.

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