Modelling and Simulations of a Rate-Based Diabatic Distillation System

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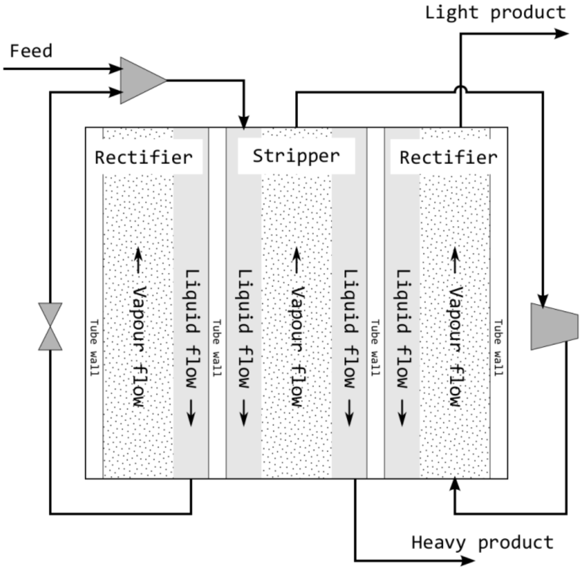
Abstract

A tray less distillation system with heat transfer from rectifier to stripper has been defined and studied. Without trays, the separation process has to be modelled using a rate-based approach, i.e. the result of the difference in component fluxes between the liquid and the vapor phases. The rectifier and stripper are separate chambers in this concept, and the rectifier is operated at higher pressure than the stripper. This implies that the rectifier will be hotter than the stripper, enabling heat transfer from rectifier to stripper. The stripper is here an evaporator, and the rectifier a condenser. The pressure in the rectifier is achieved by mechanical vapor recompression, the compressor being the primary energy input to the process. This is known from the HIDiC type distillation system. The studied concept is a step towards modelling the ideas presented in patents (Eckey, 1959), (Jensen, 1966), and (Jensen, 1992) which claim low energy input and low height of theoretical plates, compared to conventional distillation. The lack of trays and packings in the stripper should allow processing of feed streams that are either viscous and/or contain solids.



To further the understanding of such a distillation system, a rigorous model was derived. The purpose of the model is to provide the insight required to make design and operation decisions. The lowest layer of the model describes material and energy fluxes across the vapor-liquid interface and these flux equations are adaptable to multiple components by including more of the same type of equations. The fluxes make up in/out terms for the flowing bulk phases. This level of detail allows investigation of how well material and energy need to transfer, in order for the system to be practical, and can be adapted to different transfer coefficient models. The model was constructed incrementally from flux equations to bulk phases in a single chamber. Two chamber models were then coupled with heat integration over the wall and flow connections from the bottom of the rectifier to the top of the stripper. This has been modelled in steady-state with no explicit geometry, with the spatial variable being a generic contact area, which applies across the entire vapor-liquid-wall-liquid-vapor interface. A dynamic model, which is needed for control systems design, needs to be developed in future work.

A separation task resembling the task of concentrating dilute ethanol produced in a fermentation process was simulated as a case-study. These results verified qualitatively that the model is able to simulate the rate-based heat integrated distillation concept. The case task was to distillate a feed flow of 100 mol/s mixture of 97 mol% water and 3 mol% ethanol to satisfactory purities. The purities obtained were 99.7 mol% water in the bottoms product and 83.4 mol% ethanol in the top product, which is near the azeotropic composition. This was achieved with an area of 300 m^2, a top reflux ratio of 30, and a bottom reflux ratio of 1. The operating pressures were atmospheric pressure in the stripper and 2.5 bar in the rectifier.

Eckey, E. W. (1959). *Patent No. 2871250.* United States of America.
Jensen, E. (1966). *Patent No. 3282326.* United States of America.
Jensen, E. (1992). *Patent No. 19900912219.* Europe.