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Experimental study on pressure drops in a dividing wall distillation column

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A B S T R A C T

Previous studies in the fields of process design and process control [1] have shown the potential benefits that can be achieved through the implementation of thermally coupled distillation sequences, in particular, the dividing wall distillation column. The dividing wall distillation column meets important goals of process intensification, including energy savings, reduction in carbon dioxide emissions and miniaturization. In this paper, an experimental study on the hydrodynamic behavior of a dividing wall distillation column is presented. Several different values for gas and liquid velocities were tested in order to measure pressure drops and identify operational regions; the air/water system was used as the basis for the experimental setup. Results regarding pressure drops (fitted to the model of Stichlmair et al.) provide operational limits for the operation of the packed dividing wall distillation column. According to the results, the experimental dividing wall column can be operated at turbulent regime that is associated to proper mass transfer.

1. Introduction

Both the design and the retrofit of chemical processes must take into account process intensification strategies. In the field of process separations, a good example of the application of the concept of process intensification is given by thermally coupled distillation. Thermally coupled distillation sequences for the separation of ternary mixtures are shown in Fig. 1. From among these sequences, the Petlyuk column (Fig. 2) has been implemented successfully in industrial practice using a single shell and a dividing wall [2].

A dividing wall distillation column can reduce energy consumption by 30–50% over conventional distillation sequences for the separation of some mixtures [3–6]. Furthermore, this reduction in energy consumption also results in lower carbon dioxide emissions and column diameter (miniaturization due to reduction in internal flows). Moreover, from theoretical analysis, it has been demonstrated that thermally coupled distillation sequences can present better theoretical control properties than conventional distillation schemes. It becomes clear then that the design or retrofit of thermally coupled distillation columns involves process intensification, i.e., reductions in energy consumption, reduction in carbon dioxide emissions and miniaturization without affecting proper operation. These benefits of thermally coupled distillation sequences have been obtained in industrial practice using the dividing wall distillation column (DWDC, Fig. 2). Such a complex distillation column is thermodynamically equivalent to the fully thermally coupled distillation column (Petlyuk column), but, in terms of analysis, it is easier to consider the Petlyuk distillation column.

Recently, additional aspects of process intensification have been taken into account in the field of distillation processes involving thermal links; for example, some theoretical studies have shown that the DWDC can be used to carry out reaction and separation in the same unit.

Previous work concerning the steady state design of the DWDC for ternary separations have explained that the energy savings achieved by this equipment are due to the side stream being extracted from the maximum in the composition profile of the intermediate component [7,8]. In addition, other studies have shown that energy consumption in the reboiler depends strongly on the values of the interconnecting flows of the DWDC [9]. Several advances have also been reported regarding dynamic behavior, where the main conclusion drawn is that the control of the DWDC is no more complicated than that of a conventional distillation column [10,11].

It is important to emphasize that most of the above referenced results are obtained using steady state and dynamic simulations considering the equilibrium stage model.

Regarding experimental studies, Kolbe and Wenzel [12] have simulated and validated their results using an experimental dividing wall distillation column. The agreement between the predicted

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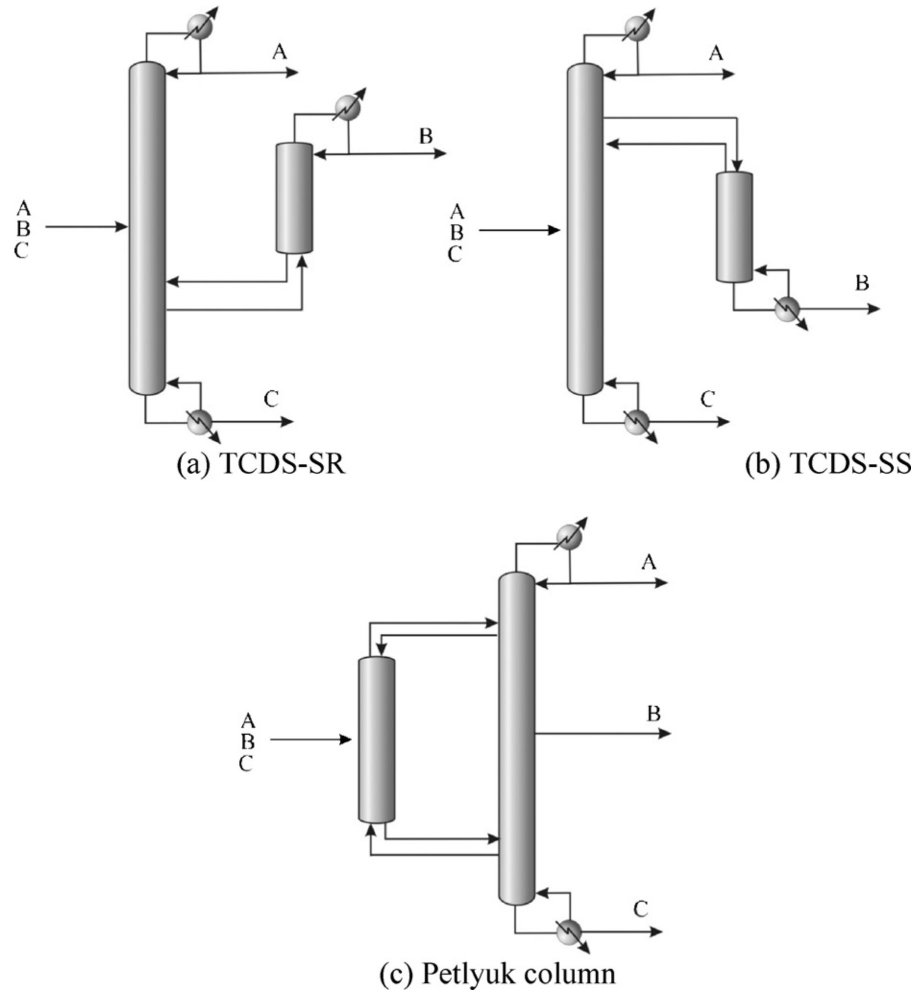

Fig. 1. Thermally coupled distillation options for ternary separations: (a) direct thermally coupled distillation sequence (TCDS-SR), (b) indirect thermally coupled distillation sequence (TCDS-SS), and (c) Petlyuk distillation column.

and experimental temperature profiles was extremely good. As a result, they concluded that proper operation of the dividing wall distillation column can be achieved without difficulties. In order to support the practical implementation and operation of the dividing wall distillation column, the control was investigated [13] using a classical proportional plus integral controller and the model predictive control. Results indicated that the model predictive controller presented better dynamic responses in terms of deviations on the controller variables and times required to achieve the changes in set points.

Sander et al. [14] have studied the hydrolysis of the methyl acetate in a dividing wall distillation column using simulation and experimental tests. They found good agreement between the theoretical studies and the experimental results, concluding that it is

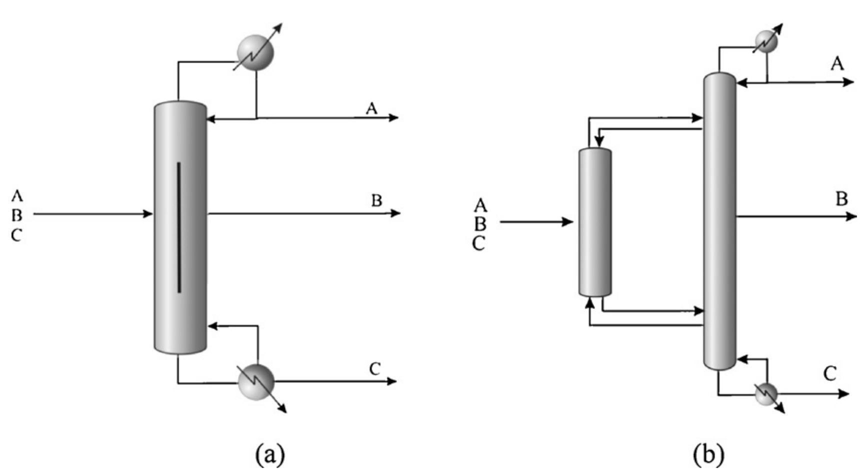

Fig. 2. (a) Dividing wall distillation column and (b) Petlyuk column.