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A new search space reduction method based on exergy analysis for distillation columns synthesis

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ABSTRACT

In distillation process synthesis as the number of components increased the number of sequences exponentially increased. Besides, there are different categories of sequences which could be considered in the synthesis. So, search space reduction methods are crucial to reduce the number of the candidates and reduce the analysis time. In the present work, a new search space reduction method based on exergy analysis is presented and applied for 3 different samples of three component mixtures (ESI > 1, ESI ≈ 1 & ESI < 1). The feed mixture has been tested under three different compositions. The results of the case study were illustrated that the new method could reduce the amount of calculation between 11 and 50%.

1. Introduction

Nowadays Distillation is the most reliable separation process which applied in chemical industries. Separating of industrial mixtures by distillation process most of the time could not be implemented in a single column. As a result a number of columns which is called distillation sequence are required to separate multicomponent mixtures and producing desired products. So there are different possible sequences which could contain less than n-1 columns (intensified or reduced), having exactly n-1 columns (basic), or with more than (n-1) columns [1].

Besides, the basic sequences are divided into two categories: simple basic sequences in which columns have one feed and two products from condenser on top and reboiler at the bottom (direct, indirect); and basic complex sequences in which at least one column has more than one feed or side products (pre-fractionator).

In recent 50 years, different kinds of configurations were presented for three components separation system: Simple sequences (Direct and Indirect), complex sequence with two one directional stream between two columns (Brugma or Pre-fractionation sequence), Thermally coupled sequences, Equivalent thermodynamic sequences (Side rectifier and side stripper configurations), Divided-wall columns and more operable arrangements of fully thermally coupled distillation columns (presented by Agrawal and Fidkowski [2,3]).

Fig. 1 presents the different categories of three component distillation sequences. A thermal coupling configuration could be generated by substitution of a condenser and/or a reboiler not associated with the final product streams with a bidirectional vapor-liquid connection. Fully thermally coupled (FTC) configurations are those in which all the vapor requirements of the sequence are supplied by a single reboiler and the entire reflux by a single condenser. The FTC with an external pre-fractionator is a Petlyuk configuration [4]. The equivalent thermodynamic configurations could be generated from the thermally coupled sequences through moving one column section associated to a condenser and/or a reboiler which provides the common reflux flow rate or the vapor boil up between two consecutive columns. Divided-wall column sequences are other categories which could be considered to reduce investment costs [4]. These configurations consist of two columns arranged in a single shell and divided by an internal wall.

In earlier approach, the experience based heuristic rules [5] were applied for designing distillation sequences. The heuristic rules might result, feasible sequences, but not necessarily the optimum sequence. The optimal sequence could be selected through a mathematical programming approach. Based on the review performed by Gridhar and Agrawal, in order to reach the optimum

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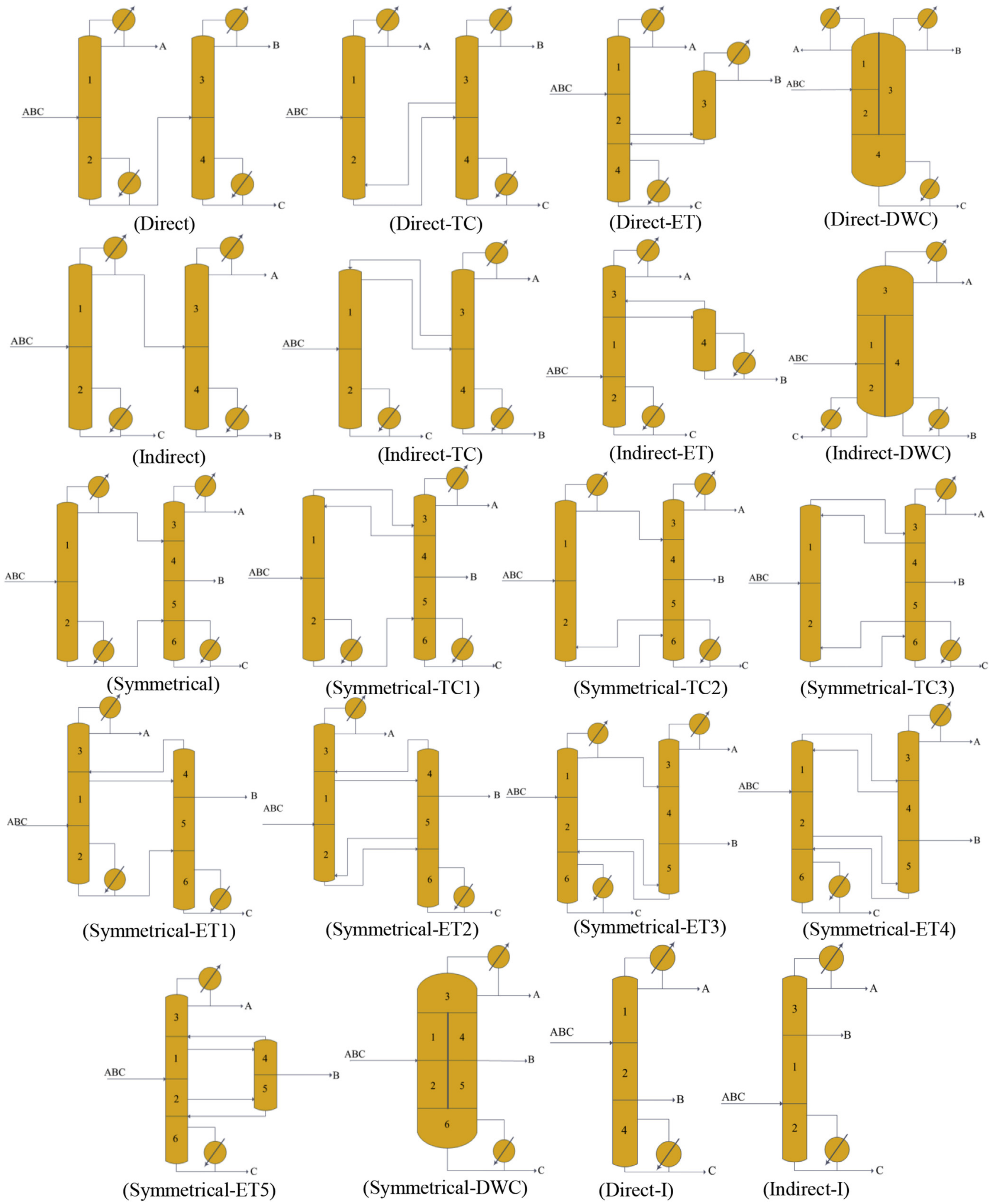

Fig. 1. Three component distillation sequences considered in this study.

sequence, the most important step is to predefine the search space as complete as possible [1]. Sargent and Gaminibandara presented one of the earliest superstructures based on "states" and "tasks" [6]. This superstructure successfully applied in mixed integer linear programming (MILP) or mixed integer nonlinear programming (MINLP) [7,8] in order to find the optimum sequence. Basic