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Feasibility analysis to construct dividing wall column in the process of propylene glycol production

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Abstract

The conventional process to produce propylene glycol from glycerol proposed by Andres Gonzalez-Garay and co-workers consisted of four simple distillation columns to separate five product streams. They were propylene glycol, ethylene glycol, methanol, waste water and recycle mixture. All possibilities of the fourteen sequences of separation train in this case were simulated by Aspen Plus program. The marginal vapor rate was an important indicator to select a few promising alternative sequences and then modify to two dividing wall columns (DWCs). It was found that the conventional and two alternative sequences with low marginal vapor rate were considered. The flowsheet representing the DWC was designed and simulated by Aspen Plus program. Some parameters in the column assembly were adjusted by the sensitivity analysis to obtain the same product specification. The capital and operating costs of the modified DWC were evaluated. It was found that all modified DWC showed approximately 10 - 17 % saving capital cost and 10 - 33 % saving operating cost compared to the sequences with simple distillation column. The promising sequence with two DWCs was the separation of methanol and ethylene glycol in the first DWC and the other products in the second one.

Keywords: Dividing wall column, Propylene glycol production, Aspen Plus program

Introduction

Nowadays, renewable energy plays a very important role in the world. Biofuels are the one of the major alternatives to develop the chemical industry. Due to the continuous growth of biofuel industry, it generates more by-products from the biofuel production process and these by-products can be used a feedstock in other chemical routes. One of by-products is glycerol, which can convert to many economical chemicals. The production of propylene glycol is interesting. Currently, there are many process flow diagrams of the propylene glycol production from glycerol [1, 2]. The economics and energies of this process are also analyzed. From several researches, the separation system of this process is still simple distillation column. However, the capital and operating costs of the conventional separation system may be reduced by several methods. One of alternatives is collapsing simple distillation columns to dividing wall column (DWC) [3]. Dividing wall column is an advance distillation column that can split a multicomponent mixture feed to three product streams in a column. In addition, it can reduce investment costs and save energy up to 30% when compared with the conventional column [4]. To evaluate economical aspects, the simulation of dividing wall column was performed by Aspen Plus simulator in this work. The flowsheet consisting of RadFrac unit model was designed to represent dividing wall column system. The economic consideration was reported.

Materials and methods

The conventional process of simple distillation column to separate the propylene glycol (PG) from the other products was first selected. The GB-2 process proposed by Gonzalez-Garay et al. [1] was considered as shown in Figure 1. The simulation using Aspen Plus program was proceeded. The results was compared with the work of Gonzalez-Garay et al. [1] to check an accuracy of the simulation.

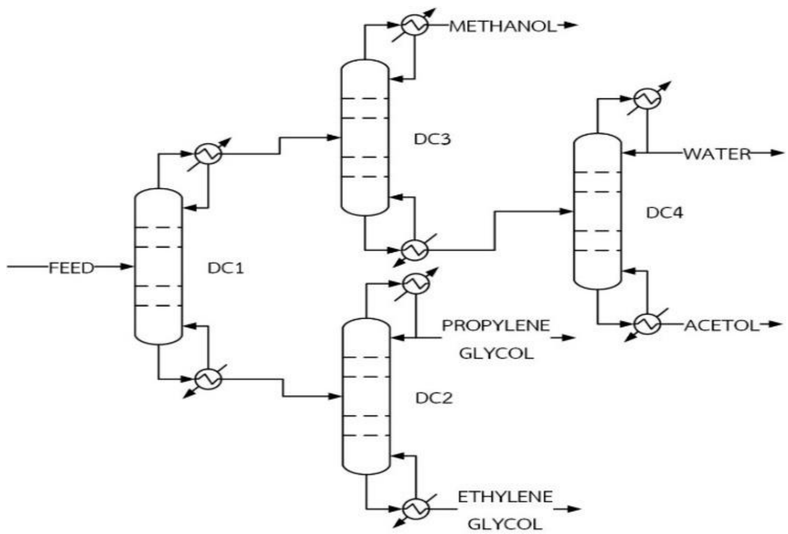

Figure 1 The conventional process to produce the propylene glycol proposed by Gonzalez-Garay et al. [1]

After simulation of the conventional process, fourteen sequences were designed and analyzed to select a few promising sequences. In this process, there were five product streams consisting of propylene glycol, ethylene glycol, methanol, waste water, and recycle mixture with acetol. To select the promising sequences, the marginal vapor rate (MVR) was defined in this case. A high vapor load led to a large diameter column and required large reboiler and condenser. Consequently, sequences with lower total vapor load would be preferred to those with a high total vapor load [3]. After selection of the suitable sequences, four simple columns were substituted by two dividing wall columns. Three RadFrac units with a mixer and a splitter was tool box to represent a dividing wall column as shown in Figures 2 and 3.

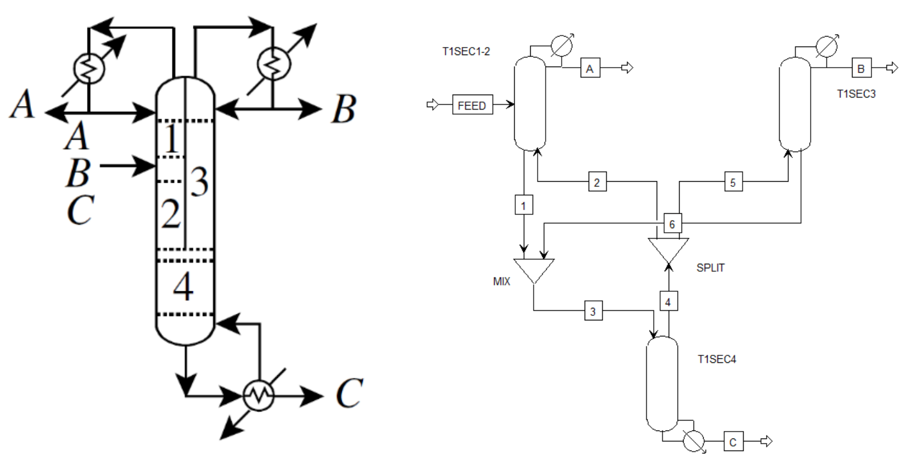

Figure 2 The flowsheet representing a dividing wall column derived from direct sequence

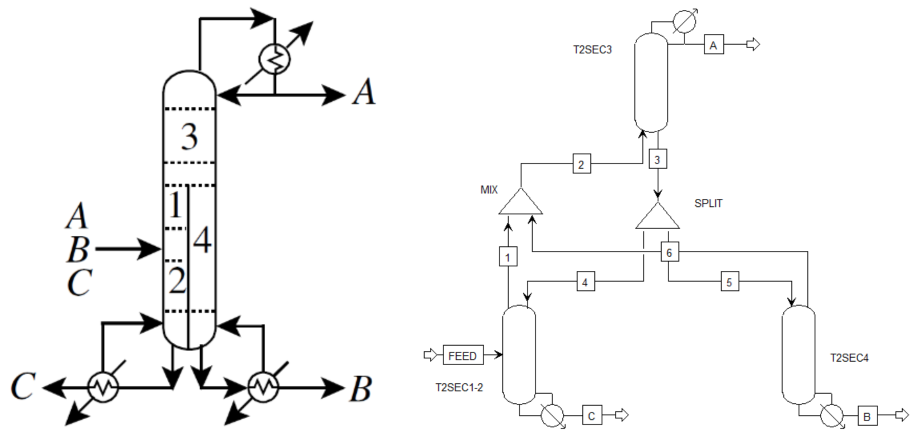

Figure 3 The flowsheet representing a dividing wall column derived from indirect sequence

The economic assessment was considered using the capital and operating costs. The capital investment consisted of the cost of equipment including distillation column, reboiler and condenser. The operating cost was the summation of steam and cooling water. The economic comparison between conventional four simple columns and two dividing wall columns was reported. The equations to calculate the equipment and utility costs were described by the work of Aurangzeb et al. [5]

Results and discussion

Figure 4 shows the comparative marginal vapor rate of fourteen alternative sequences for the separation train to produce the propylene glycol. It was also noted that the 14th sequence was obtained from the work of Gonzalez-Garay et al. [1] as shown in Figure 1. Comparing with the 14th sequence, only three sequences showed lower marginal vapor rate and therefore these four sequences were chosen to modify in the next step. The 2nd, 5th, and 8th sequences were shown in Figures 5-7, respectively. As shown in Figure 5, an arrangement of distillation columns in the 2nd sequence cannot be designed as two dividing wall columns. Consequently, three remaining sequences that had no limitation to construct two dividing wall columns were considered.

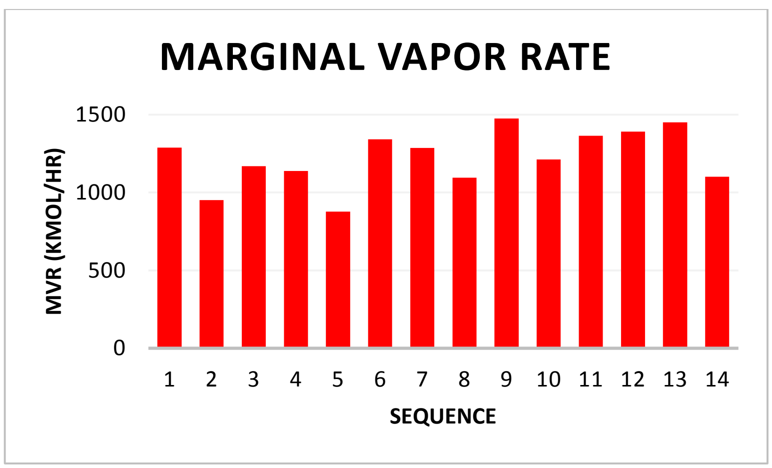

Figure 4 Marginal vapor rate (MVR) of simple distillation sequences in the process of propylene glycol production

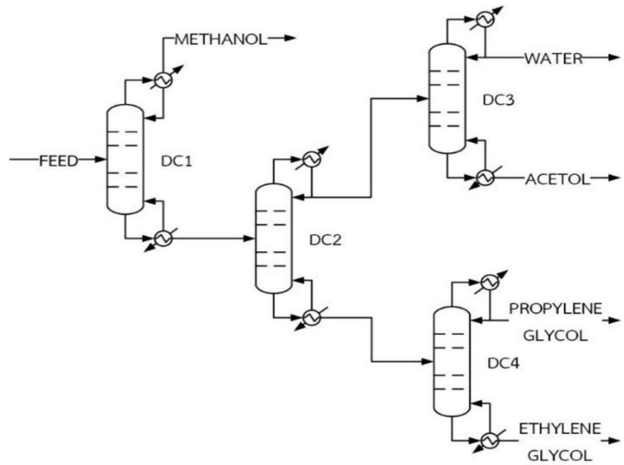

Figure 5 Process flowsheet of the 2nd sequence referred from Figure 4

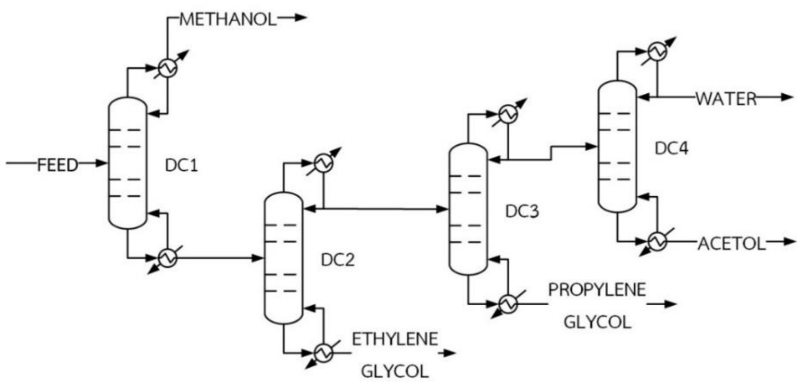

Figure 6 Process flowsheet of the 5th sequence referred from Figure 4

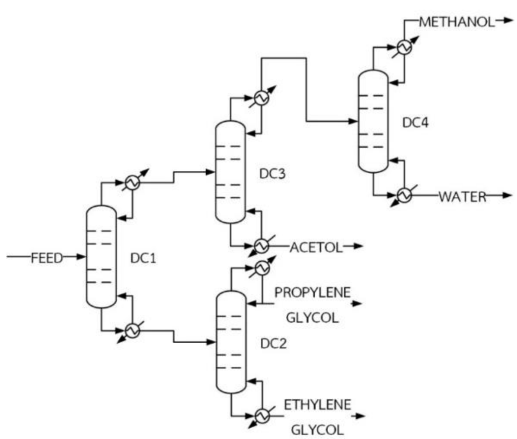

Figure 7 Process flowsheet of the 8th sequence referred from Figure 4

Before combination of two simple distillation columns to be a dividing wall column, the number of stages of some column may be adjusted. The number of stages of higher simple column was set as total number of stages in the dividing wall column. For example, if the number of stages of the first column was more than those of the second column, the number of stages of the second column was increasingly adjusted equal to those of the first column. Considering the 5th sequence in Figure 6, the former of two columns (DC1 and DC2) was direct sequence arrangement, which was represented by the process flowsheet in Figure 2. First, total number of stages for dividing wall column was fixed as 70 trays equal to the stages of DC2. The number of stages of DC1 was increased equal to the number of stages of the rectifying section in DC2. It was equivalent to 36 trays. After that, the latter of two columns (DC3 and DC4) was considered. It was an arrangement of indirect sequence as represented by the process flowsheet in Figure 3. The total number of stages for dividing wall column was set as 43 trays equal to the stages of DC4. The number of stages of DC3 was decreased equal to the number of stages of the stripping section in DC4. It was equivalent to 16 trays. All selected sequences were modified by the same procedure.

After simulation, the economic aspects were considered. The results are shown in Figure 8. They consisted of the costs of equipment and operation and the energy usage of condenser and reboiler. Modification of simple column sequence to dividing wall column sequence can reduce both investment cost and energy usage. The 14th sequence showed the most 17.0 % saving in capital cost while the 8th sequence gave the most 32.6 % saving in operating cost. This was also agreement with the most energy saving of the 8th sequence. On the other hand, the modified 5th sequence was promising in short terms due to the lowest capital cost.

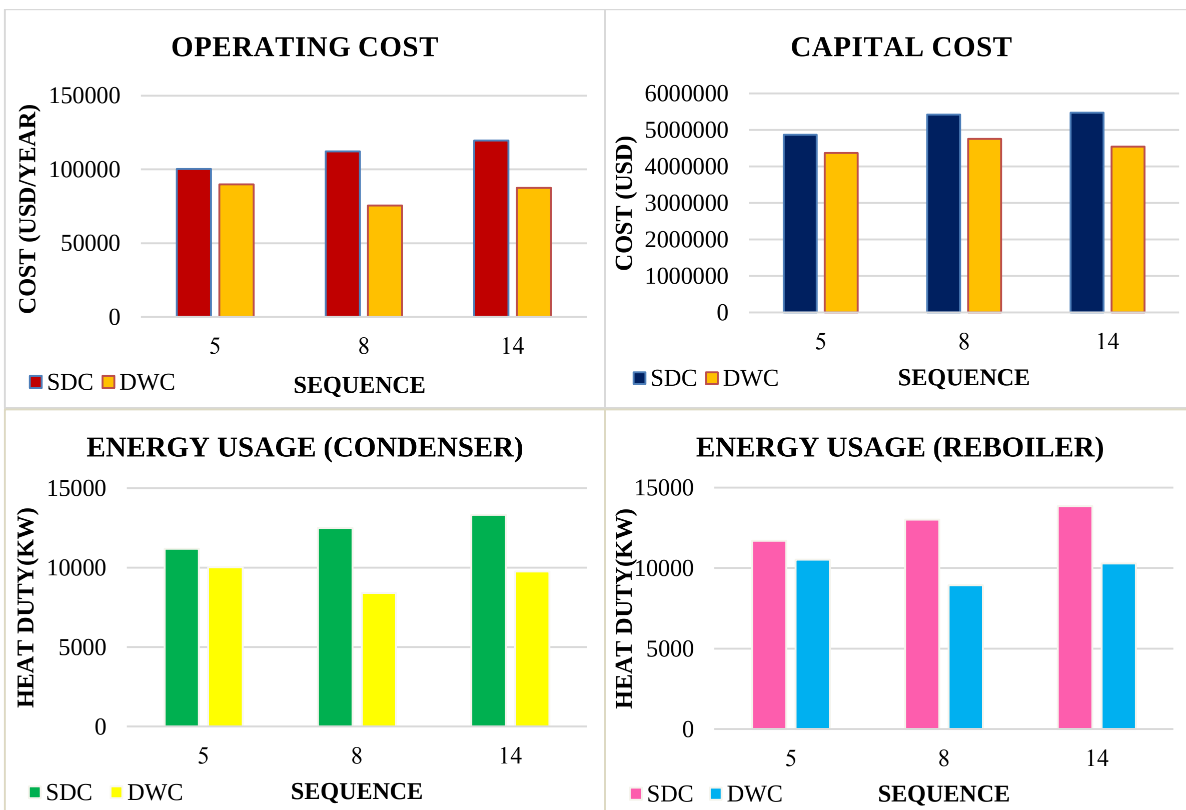

Figure 8 The comparative economic evaluation between the sequences with simple column and with dividing wall column

Conclusion

The modification of simple distillation sequences for the process to purify the propylene glycol was considered. The sequences with two dividing wall columns were designed and simulated by Aspen Plus program. It was found that 10 - 17 % saving in capital cost and 10 - 33 % saving in operating cost were obtained using the sequence of dividing wall column. The promising modified sequence with two DWCs was the separation of methanol and ethylene glycol in the first DWC and the other products in the second one.

Acknowledgements

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