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Modelling of divided wall column

László Szabó, Miklós Balaton*, Sándor Németh, Ferenc Szeifert
Department of Process Engineering
University of Pannonia, Egyetem Str. 10, H-8200 Veszprém, Hungary,
szabol@fmt.uni-pannon.hu

The rectification is the most often used fluid separation technology. The improvement of the distillation equipment and process is significant (Haddad and Manley, 2008) because the rectification has relatively low energy efficiency. In practice, the aim is the separation of the multi-component mixture. This task can be solved with a number of columns depending how many components there are or one column with side product(s). This paper focuses on how to find a better structure with minimal energy consumption. The divided wall column (DWC) system is a promising energy-saving alternative for separating multi-component mixtures (Serra et al, 1999).
The innovation of this equipment is a wall which divides the space in of the tower so the feed and the side stream-product zones are separated. This wall prevents contamination of the side stream by the feed stream. The dividing wall column has greater efficiency than common column sequence (Hernández et al V, 2006). The conventional columns with side stream are also convertible to DWC.
In this paper different constructions of the DWC were investigated with simulation experiments. The structure of the column was implemented in Aspen Plus^{TM} simulator using the Radfrac unit of the software. The effects of the main parameters of the divided wall column like split ratio of the liquid and vapor stream, height of the wall, vertical position of wall, and the heat transfer of the wall were analyzed.

1. Separation task

Separation of a ternary-mixture (benzene, toluene, o-xylene) was investigated. Normal boiling temperature of the components can be found in the Table 1. The mass flow of the feed stream was 90 kg/h. The mass fractions of the components were the following: 0.333 for the benzene, 0.333 for the toluene, 0.333 for the o-xylene. The boiling points of the components are far from one other, and there is no azeotrope formation. The 99% purity of the products was required.

Table 1:Boiling point of the components

	Boiling point (°C)	Feed concentration (kg/kg)
Benzene	80.1	0.33
Toluene	112.1	0.33
o-Xylene	144.4	0.33

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2. Implementation of the dividing wall column

In chemical industry flowsheeting simulators are used for design and research work. With these simulators the user can define the structure of the technology as a flowsheet. The blocks (units) represent the main equipments, and the connect lines show the streams. The simulator also includes the models of the equipments. The model of the DWC is not included in any flowsheeting simulators. To solve that problem the column was divided in four parts (Figure 1) and each part was simulated using an existing model of the software (Adrian et al, 2004). The parts are the following: the top partition (above the divider wall, with condenser and reflux drum), the bottom partition (under the wall, with reboiler), and the feed and the product partition separated by the wall. The four parts are performed with four rigorous (Radfrac) units.
Heat transfer between the feed and product zone was also calculated. The driving force of the heat transfer is the temperature difference between the two zones. The product of the heat transfer coefficient and the surface of the heat transfer were defined as a model parameter. The dimension of the DWC are equal to the dimension of a column with sidestream which can solve the separation task. The number of stages in the column is 23. There are the feed and the side stream in the middle of the column (the 12th stage from the top). The sum of the surfaces of the feed and side-product partition is equal to the surface of the top and bottom partitions.

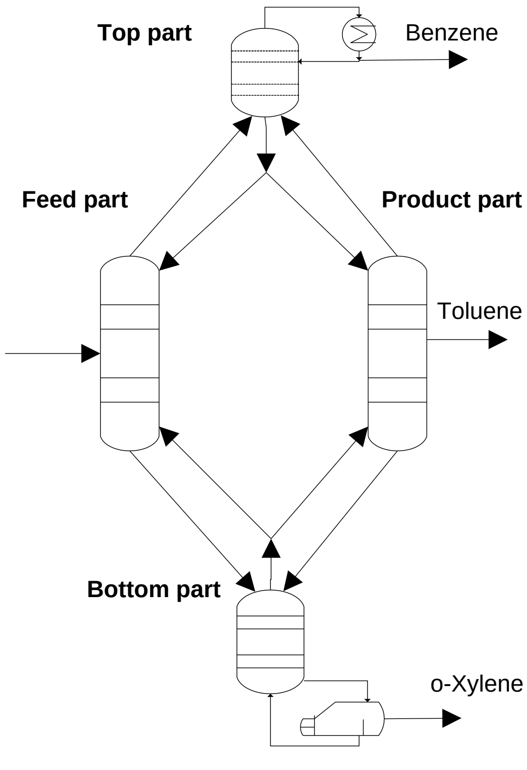

Figure 1: Structure of the simulator

3. User interface of the simulation

A user interface was created for the simulation, because the parameter-determination of the four blocks was difficult. The Aspen Plus™ was connected to Microsoft Excel in order to have an easy-to-use graphical user interface. The user may set the parameters of the DWC in an Excel worksheet. The Excel calculates the parameters of the four partitions, and sends the data for the Aspen Plus™. The simulation software sends back the results data of DWC. The results can be shown in an Excel worksheet.

4. Vertical position of the wall

It was investigated how the heat duty of the reboiler was changing with the vertical position of the wall. The length of the wall was equal to the height of nine trays tall. The number of stages had not been changed, and the numbers of stages in the feed and product partitions were equal. The central position (when stage number of the bottom and the top partition was equal) was marked zero in the Figure 2. In the negative range the top partition has more stages than the bottom partition. The surfaces of the feed and product zone were the same.
As Figure 2 shows, the energy consumption is the lowest when the top partition has the same number of stages as the bottom partition. The asymmetry increases the energy consumption. One of its reasons may be that the components have the same mass fraction in the feed.

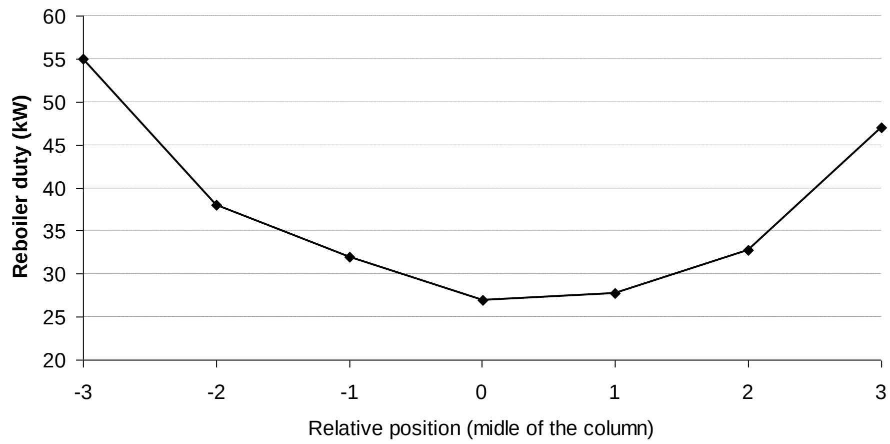

Figure 2: Effect of the vertical wall position

5. Height of the wall

It was investigated how the heat duty of the reboiler was changing with the height of the wall. The central vertical position wall was analyzed from the previous part. The surfaces of the feed and product zones were the same. As Figure 3 shows, the energy consumption is the lowest when the length of the wall was equal to the height of nine trays.

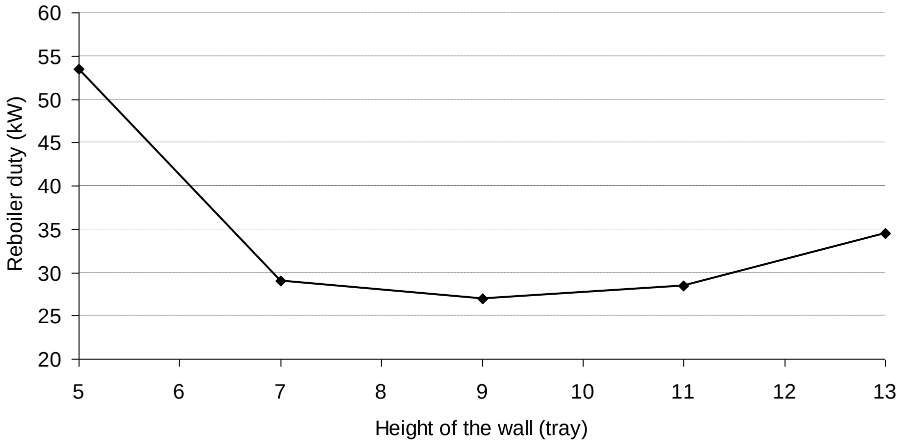

Figure 3: Effect of the height of the wall

From the five to the nine units tall wall the energy consumption is decreasing higher wall than that slightly increases the reboiler heat duty. The effect of the wall is not significant when the length of the wall was lower than nine units tall. If the wall is higher than nine units, the number of stages in the top and the bottom partitions decreases. That is why the reboiler duty and the reflux increase for suitable separation.

6. Split ratio

It was investigated how the heat duty of the reboiler is changing with the split ratio. The split ratio means the ratio of the surface of the feed and product zones, and the proportion of the vapor and liquid phases under and above the wall. The split ratio equals to the quotient of the surface of the feed zone and the all the surface. The height of the investigated wall was nine unit tall and the vertical position of the wall was central. The result of the investigation is shown in Figure 4Figure . At 50% the minimum energy consumption is minimal.

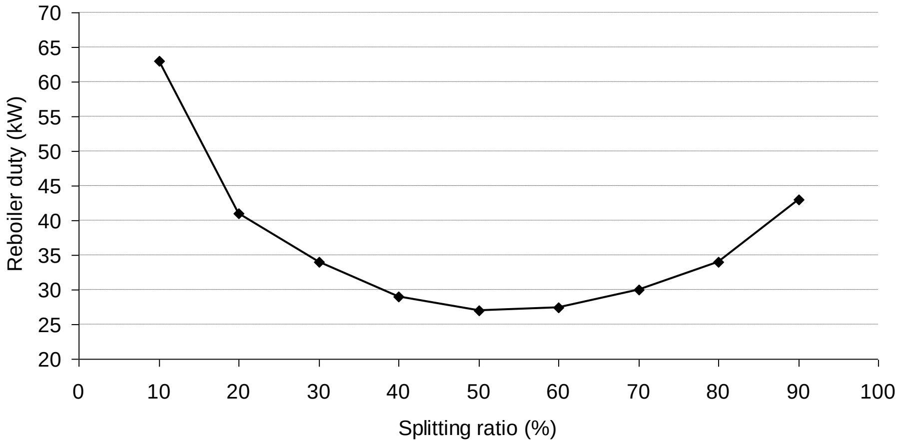

Figure 4: Effect of splitting ratio

7. Comparison of the DWC and column with side stream product

In the previous sections the optimal parameter combination of the DWC was studied. In this section, this construction is compared with a column with sidestream product which can solve the separation task. The reboiler heat duties of the equipments were compared in a range of the feed rate. The results are shown in Figure 5. It can be seen that the DWC is better in terms of reboiler heat duty than the classical construction.

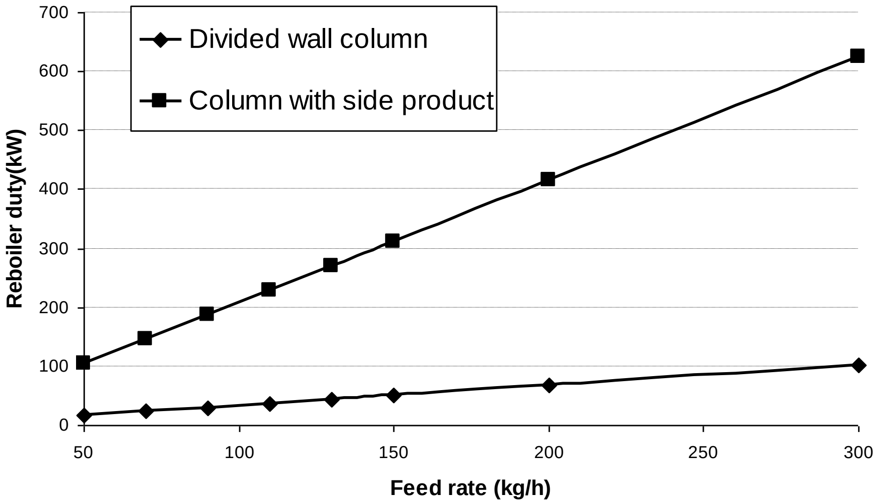

Figure 5: Comparison of the DWC with the side stream column

8. Conclusion

Different constructions of the DWC were investigated with simulation experiments. The structure of the column was implemented in Aspen Plus^{TM} simulator using the rigorous (Radfrac) unit of the software. The column was divided in four parts. These parts were implemented with different blocks. The heat transfer between the feed and product zone was also calculated. User interface of the simulation was also created. The effects of the main parameters of the divided wall column like split ratio, height of the wall, vertical position of wall were analyzed. The optimal parameter combination of the DWC was determined. This construction was compared with column with sidestream product which can solve the separation task. In this case the DWC is better than customary construction.

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