수평 사각형 비단열 증류탑의 응용

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Application of Horizontal Diabatic Distillation Column

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1. Introduction

Because a circular vertical distillation column has been used in the distillation process of industrial applications for a long time, its design and operation are well developed and field engineers are accustomed to its implementation. The requirement of large energy consumption is one of major drawbacks of the distillation process. The industrial application of DWC (divided wall column) is an attempt to reduce the high energy demand, and its performance has been accepted by the field engineers [1]. Other techniques of the energy-efficient distillation include the internally heat-integrated distillation and diabatic distillation. However, all of these techniques employ the circular vertical columns.

When a horizontal column is used in the distillation, the liquid flow can be manipulated by adjusting the inclination of the column. Slow liquid flow provides longer contact time between vapor and liquid. In a packed column the contact is properly made, provided that the packing is sufficiently wet. Diabatic operation of the horizontal column wets the packing. In the stripping section, heat supplied through the column wall makes the liquid boiled to moisturize the packing. On the other hand, column wall cooling in the rectifying section supplies the liquid on the packing surface. In the diabatic operation, a rectangular column provides larger surface area for heat transfer than a circular column. Unless the column operating pressure is high, the rectangular column is better because the large cross-sectional area leaves high throughput.

In this study a rectangular horizontal distillation column is utilized for the separation of methanol and n-propanol with diabatic operation. The performance of the proposed column is experimentally examined and compared with the results of previous study of horizontal distillation [2].

2. Experimental

1. ExperimentalSetup

A rectangular column made of stainless steel was used in this experiment. The dimensions are 7 cm wide, 10 cm high and 2 m long. In the middle of the column wall a quarter inch nipple is placed for feed supply, and the same size nipple at the left end of the column provides heavy product through a needle valve. At the right end a half inch nipple is used as a port of light product in vapor. The vapor is cooled through a water cooler to collect liquid product. Fig. 1 shows the schematic diagram of the experimental distillation column. The column is filled with 6 mm Raschig Ring made of stainless steel mesh of 0.08 mm wire. The column was inclined 3 degrees for the lower side of heavy product.

The left half of the column, stripping section, has four jacket heaters of 24 cm long installed at the column outer wall. Three jacket heaters of 29 cm long are placed at the right half of the column, rectifying section. The heaters are electric so that the adjustment of heat supply is easy. The control was conducted with a temperature controller, and the amount of heat supplied is monitored with the relay signal using a PC. Because heat supply to the column is mainly provided at the stripping section, more heaters are installed at the section. The amount of heat supply is calculated from the total time of electric connection to the heater, the summation of relay on-time. During the experiment the data collecting PC receives the temperatures of 7 heaters and light and heavy products and 7 relay signals for the later analysis of the experiment. A mixture of methanol and n-propanol was used as feed.

2. Experimental Procedure

When all the electric connections and PC are ready, feed was supplied using a metering pump until the heavy product is overflowed from the product port. Then the feed supply was on hold, and heat supply was started and controlled at the differently set temperatures. The temperature setting was the lowest at the light-product port and the highest at the heavy product. In fact the heavy side of half is the stripping section of heating, while the light side of half is the rectifying section of cooling. The mild heat supply at the cooling rectifying section compensates the heat loss at the column wall. The heating provides the vapor-liquid contact and vapor flow to the light product port by liquid boiling at the stripping section, and the cooling does the wetting of packing to provide the vapor-liquid contact at the rectifying section. The liquid flows to the heavy product port with the column inclination of 3 degrees. The feed flow rate was adjusted with the stroke control of the metering pump, and that of heavy product was done with a valve in the product line. The flow rate of light product was not controlled to maintain the column pressure low and steady. The experiment was conducted until the steady state maintained for more than an hour. The sample of products was taken during the experiment, and the compositions of feed and two products were measured with a gas chromatograph (Agilent Model 5892A, U. S. A.).

3. Results and Discussion

The horizontal distillation using a rectangular column with external heating was carried out for the separation of a mixture of methanol/*n*-propanol, and the following results were obtained and discussed with the results of previous studies.

1. Experimental Results

In the preliminary experiment the distribution of temperatures along the column length was examined for the best performance of separation. The curve numbers indicate the location of heaters starting with the one near to the light product port as shown in Fig. 1. The three heaters at the rectifying section work for cooling, and therefore their temperatures are lower or close to the temperature of light product. The temperature increase in heater 7, the fastest, and the slowest in heater 1 during startup come from the flow of heated vapor, which generated at the stripping section. While the hot vapor from the end of stripping section flows to the other end, the column temperature is raised sequentially and the orderly elevation of temperature in the first 30 minutes explains the vapor flow. The sudden drop of temperature after the initial rise was due to the introduction of feed, and thereafter all the temperatures were almost steady during the steady state operation.

The temperature of light product was measured at the product port attached to the column, which was the vapor temperature going into the condenser. The temperature is higher than the vapor temperature of the light product, because there is a stage of vapor-liquid equilibrium at the condenser. The temperature of heavy product was measured outside the product tube, which was lower than the liquid temperature. The small difference of heavy and light product temperatures is due to the position of measurement, but the temperatures are helpful to the control of product specification. The measured composition of products indicates that the column operation is adequate for the separation.

2. EnergyConsumption

Because the distillation utilizes energy as separation medium, its energy demand is high and many previous studies have been conducted to reduce the demand. The proposed horizontal distillation is also targeting to lower the energy consumption. For the comparison of energy requirement, the power consumption was measured in the experiment.

The heat was intermittently supplied by the control of a temperature controller set at a given temperature. The moments of the electric connection are displayed. When the relay is on, its status is fed to the PC in a binary signal. The sequence from bottom to top is of the heaters from the light product port to the heavy. Odd numbers indicate on, and even numbers do off. In the first 50 minutes, the on signal appears more, that explains the column heating during the startup. The bottom three are of the rectifying section, and the others are of the stripping section. The power supply to the heaters is summarized. The on time was counted from the relay signal. When a similar separation was obtained from the horizontal column, the energy requirement was The comparison indicates that 15% less energy is used in the horizontal distillation.

3. Rectangular and circular columns

A horizontal diabatic distillation was utilized in the separation of methanol and n-propanol in the previous study [2]. The difference of this study and the previous is the column size, especially the cross-sectional area of the columns. Using the rectangular column the cross-sectional area is larger than the circular column when their nominal sizes are identical. In the previous study a circular column was used for a feed flow rate of 37 mL/min, while a feed rate of 68 mL/min was processed in this study. For the passage of vapor a rectangular cross section is better for the contact between vapor and liquid in case of the horizontal column. Moreover, the rectangular column provides larger area of heat transfer for the diabatic operation.

References

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(2) Kim, B. C.; Chun, H. H.; Kim, Y. H. Emergy-efficient diabatic distillation using a horizontal distillation column. *Ind. Eng. Chem. Res*. **2013**, 52, 14927.

Fig. 1. Schematic diagram of vapor and liquid flows in a horizontal distillation column.

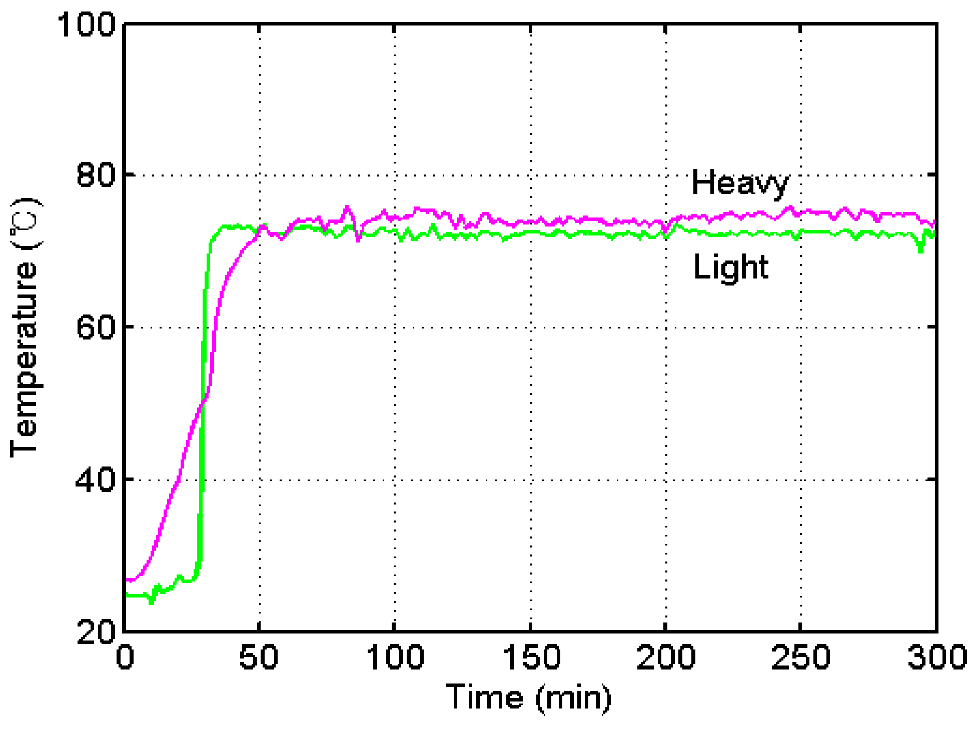

Fig. 2. Variation of product temperatures during the experiment.