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Improvement of Simulation Method for Propylene Distillation Column based on Aspen Plus

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Abstract

Aspen plus chemical process simulation software was used to simulate the propylene distillation unit. Based on the study of multivariable influencing factors of propylene distillation column operation, the influence of simulation optimization sequence on distillation effect was compared and analyzed In order to provide more accurate and reasonable operation parameters for practical operation, the determination of initial value of simulation input, the best recovery range at the bottom of tower, the best mass reflux ratio and other optimization parameters are used as the new initial value of simulation input.

Keywords

Aspen Plus; Propylene Rectification; Simulation Method.

1. Introduction

At present, researchers use different simulation software to simulate and optimize the propylene distillation column, but do not involve the influence of the optimization sequence of multivariable factors on the propylene distillation effect, only analyze the influence of single variable factors on the operation of propylene distillation column. [1]

Aspen Plus software is used to simulate the steady-state process of propylene distillation column. Combined with software analysis tools, the operation optimization of two propylene distillation columns is carried out. The influence of optimization order of multivariable factors on propylene distillation effect is analyzed, and more reasonable optimization simulation steps are determined, which can be used to guide the operation optimization of similar distillation columns.

2. Steady state simulation of in two columns

2.1 Establishment of Aspen Plus steady state model for propylene distillation

In this simulation, RADFRAC module of distillation in Aspen Plus software is directly used for accounting. Aspen Plus Model of parallel operation of propylene distillation two columns is shown in Figure 1.

The simulation process mainly includes the following steps:

1) definition of simulation process;

2) input of design condition parameters;

3) selection of physical property equation;

4) selection of RADFRAC module calculation type;

5) output of simulation results. [2, 3]

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2.2 Double tower design accounting

Taking c-5501a column of propylene distillation column as an example, the simulation results show that the mass flow rate, pressure and vaporization rate are consistent with the design value, and the composition of each material flow has certain deviation, which leads to certain deviation of temperature, density, viscosity and other parameters, but they are within the allowable relative error range (Table 1), meeting the design index requirements. [4]

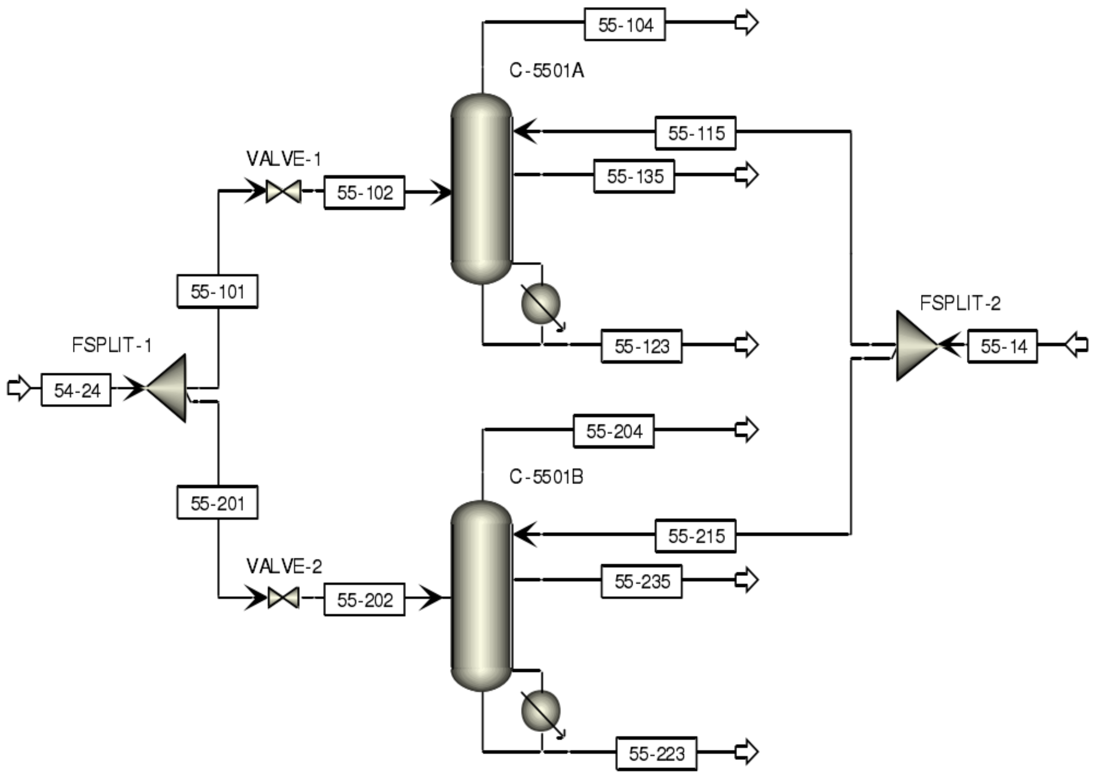

Figure 1. Aspen Plus model of propylene distillation columns in parallel

Table 1. Relative error of simulation results

Project	PROPYLENE			PROPANE		
	Design value	Analog value	Relative error	Design value	Analog value	Relative error
T/℃	44.399	44.392 2	-1.53E-04	56.117	56.202	1.51E-03
MA(w)	1.170 3E-9	9.429 6E-10		3.61E-03	3.614 4E-3	
PD(w)	2.954 9E-10	2.327 6E-10		9.099 7E-3	9.099 9E-3	
C3H6(w)	0.996	0.996 013	1.30E-05	0.094 9	0.094 33	-6.01E-03
C3H8(w)	3.84E-03	3.84E-03	-1.04E-04	0.806 2	0.806 3	1.02E-04

3. Study on improved method of double tower optimization

3.1 Operation optimization of propylene distillation column

Due to the fluctuation of raw material supply and equipment, it is difficult for the cracking furnace to meet the design stable feeding and distribution requirements. Under the condition of limited operating data, to achieve the optimization of propylene distillation operation, it is necessary to simulate and analyze the operation under different composition and different feed quantity, and then determine the optimal operating conditions.

The simulation and optimization of propylene distillation column are carried out in the following steps: Determination of initial value of simulation input - selection of optimal feed position -

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Determination of optimal reflux ratio - optimal bottom recovery range - other optimization parameters (such as cold reflux temperature, propylene reflux concentration, side line recovery, etc.)

3.2 Simulation analysis of the effect of optimization sequence of multivariable

3.2.1. Influencing factors on propylene distillation

The steady-state operation of propylene distillation column mainly involves five operation variables.

1) Feed (feed flow, composition, temperature, hot state of feed);

2) Reboiling (rising steam speed in tower, heating capacity of evaporation kettle); [5]

3) Tower pressure (pressure, temperature);

4) Reflux (reflux ratio, reflux temperature, overhead refrigerant volume);

5) Recovery (tower top recovery, side line recovery, tower bottom recovery).

3.2.2. Research on Optimization order analysis of multivariable influence factors

Due to the influence of off design conditions of cracking furnace, the most obvious changes in feed composition are propylene and propane, so the contents of other components remain unchanged, while the contents of propylene and propane are relatively up-regulated or down regulated in the simulation process. The simulated feed composition changes are shown in Table 2.

Table 2. Simulation of feed composition

C_3H_8	C_3H_6
0.0479	0.9483
0.0518	0.9444
0.0575	0.9387
0.0671	0.9291
0.0768	0.9195
0.0864	0.9098
0.0960	0.9002
0.1057	0.8905

The unit is operated in parallel with two towers, and the reflux ratio and the recovery at the bottom of the tower are taken as the influencing factors of priority optimization. The optimization principle is to ensure the separation accuracy of propylene mole fraction ≥ 0.996 at the top and ≤ 0.1 at the bottom of propylene distillation column. Considering the actual fluctuation of the unit, the propylene loss rate at the bottom of the tower is controlled at about 0.075.

1) Optimization sequence 1: Determination of initial value of analog input - Determination of optimal mass reflux ratio - optimal bottom recovery range - other optimization parameters.

Taking the initial design values of 39 768 kg / h of feed, 0.047 9 of feed propane mole fraction and 2 017.49 kg / h of tower bottom as input values, the mass reflux ratio of 9.5-14.4 was simulated by using sensitivity analysis tool to determine the optimal reflux ratio, as shown in Figure 2.

It can be seen from Figure 2 that when the simulation initial value is fixed, with the increase of reflux ratio, the propylene concentration at the top of the tower increases and the propylene concentration at the bottom of the tower decreases. When the reflux ratio is 14.39, the propylene mole fraction at the top of the tower is 0.9962, and the propylene mole fraction at the bottom of the tower is 0.1. At this time, the optimal reflux rate is set at 450000kg / h, which has reached the upper limit of the design reflux rate.

Taking the initial design values of 39768kg / h feed rate, 0.0479% feed propane mole fraction, 395109kg / h tower top reflux and 6500.1kg/h side line recovery as input values, the sensitivity analysis tool is used to simulate the 1500-4500kg / h tower bottom recovery to determine the optimal tower bottom recovery, as shown in Figure 3.

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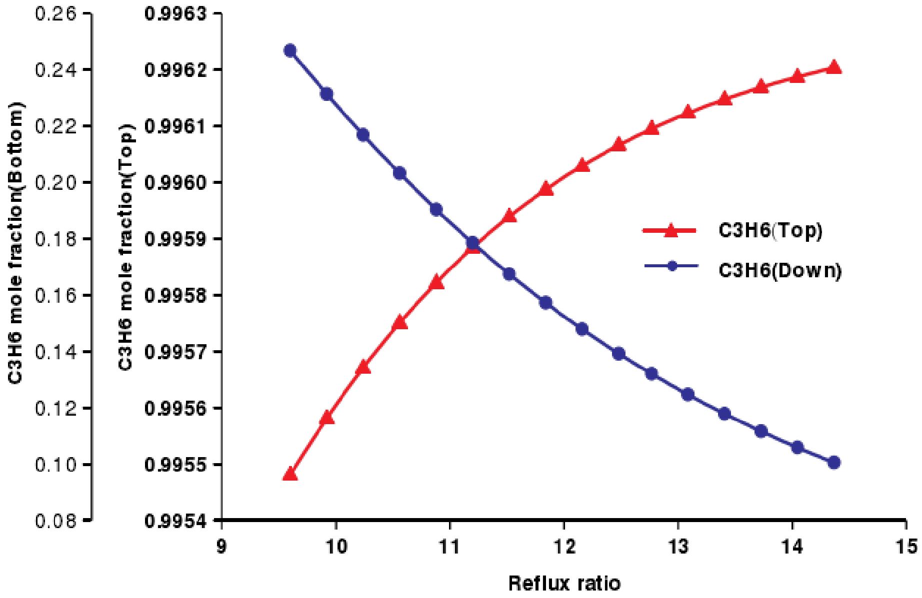

Figure 2. Distribution of C_3H_6 at various quality reflux ratios

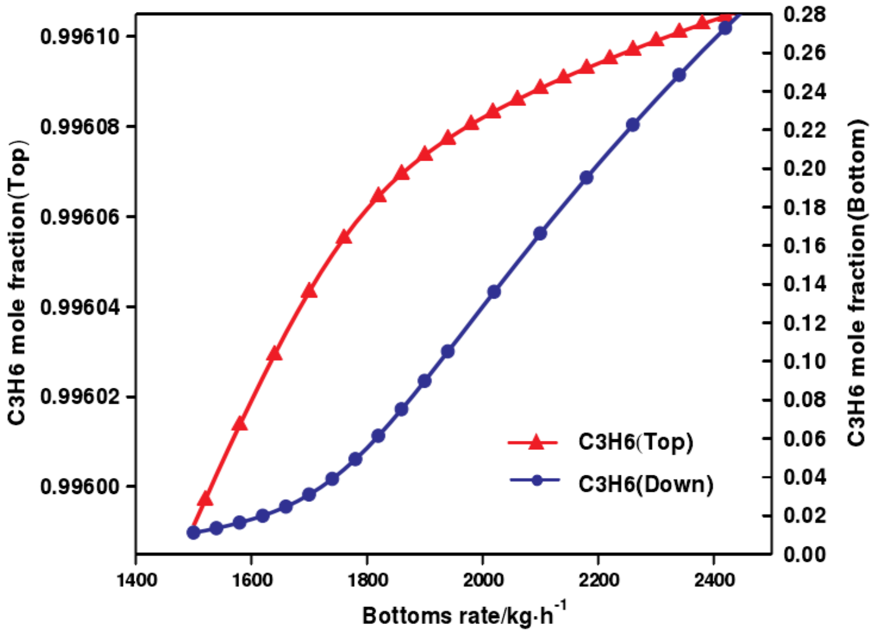

Figure 3. Distribution of C_3H_6 at various outputs

It can be seen from Figure 3 that when the given initial simulation value is fixed, with the gradual increase of tower bottom recovery, the propylene concentration at the top of the tower presents an increasing trend (first rapid and then gentle), and the propylene concentration at the bottom of the tower also presents an increasing trend (first gentle and then rapid). When the recovery at the bottom of the tower is between 1540 kg / h and 1940 kg / h, the propylene content at the top and bottom of the tower can meet the separation accuracy requirements. Considering the influence of actual production load change or other factors, the optimal recovery at the bottom of the tower is finally controlled at 1860 kg / h.

Taking the design feed rate of 395109 kg / h and the feed composition of propane mole fraction as 0.0518, 0.0575, 0.0671, 0.0768, 0.0864, 0.0960 and 0.1057, respectively. Set them as the initial input values and use the same method to simulate the optimization sequence 1. The simulation results are shown in Table 3.

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Table 3. Optimal operation conditions under different feed composition (sequence 1)

C_3H_8/mol	Backflow /($kg\cdot h^{-1}$)	Tower top temperature/℃	Tower bottom temperature/℃	Heat load of Reboiler/MW	Simulation results C_3H_6(mol)	
					Tower top	Tower bottom
0.047 9	≥450 000	44.392 3	58.050 1	40.714 2	0.996 195	0.047 04
0.051 8	≥395 109	44.393 0	57.224 3	36.149 9	0.996 051	0.078 66
0.057 5	≥394 000	44.393 2	56.905 2	36.042 8	0.996 032	0.076 05
0.067 1	≥422 000	44.392 8	56.661 5	38.337 6	0.996 101	0.059 50
0.076 8	≥447 000	44.392 4	55.873 3	40.370 1	0.996 159	0.089 49
…	…	…	…	…	…	…

2) Optimization sequence 2: Determination of initial value of analog input - Determination of optimal bottom recovery range - Determination of optimal mass reflux ratio - other optimization parameters. When the feed propane mole fraction is 0.0479, the simulation optimization process is consistent with the simulation of the optimal bottom recovery range in optimization sequence 1, and the results are the same as those shown in Figure 3. The simulation optimization operation is the same as before, and the results are shown in Figure 4.

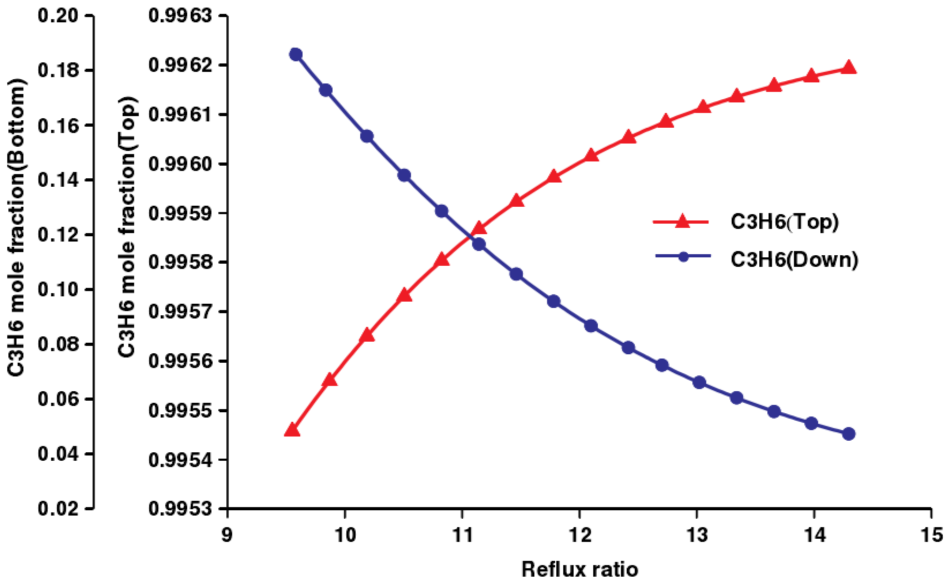

Figure 4. Distribution of C_3H_6 at various quality reflux ratios

It can be seen from Figure 4 that when the mass reflux ratio is above 12.0, the separation accuracy meets the requirements. Taking the design feed rate of 395109kg / h and the feed composition of propane mole fraction as 0.0518, 0.0575, 0.0671, 0.0768, 0.0864, 0.0960 and 0.1057, respectively. Set them as the initial input values and use the same method to simulate the optimization sequence 2. The simulation results are shown in Table 4.

Table 4. Optimal operation conditions under different feed composition (sequence 2)

C_3H_8/mol	Backflow /($kg\cdot h^{-1}$)	Tower top temperature/℃	Tower bottom temperature/℃	Heat load of Reboiler/MW	Simulation results C_3H_6(mol)	
					Tower top	Tower bottom
0.047 9	≥379 000	44.393 1	57.588 6	35.697 4	0.996 044	0.075 60
0.051 8	≥382 109	44.393 1	57.224 4	36.149 9	0.996 048	0.078 65
0.057 5	≥387 000	44.393 0	56.909 6	36.705 1	0.996 054	0.075 19
0.067 1	≥394 000	44.393 0	56.422 3	37.174 1	0.996 052	0.075 72
0.076 8	≥399 000	44.393 0	56.074 3	37.643 2	0.996 055	0.075 07
…	…	…	…	…	…	…

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3.3 Comparison and analysis of distillation effect of propylene column

From the simulation results of optimization sequence 1 and optimization sequence 2, the backflow rate and reboiler load of sequence 2 are better than those of sequence 1, and the separation effect is better; when the propane content of feed is too high, the mass reflux ratio exceeds the design upper limit, and the simulation optimal value cannot be obtained; From the influence of mass reflux ratio and bottom recovery on the propylene content at the top and bottom of the tower, when the influence factor of bottom recovery is optimized first, an optimal value is determined and the reflux ratio is continuously optimized. With the increase of top recovery, the propylene content at the bottom of the tower decreases gradually, which will not lead to excessive propylene loss at the bottom of the tower when the bottom recovery is continuously optimized after the optimization of reflux ratio situation.

3.4 Application of improved optimization method for double tower operation

According to the actual production demand, the optimization simulation of operation conditions under different feed conditions (flow rate and temperature) was carried out, and other process parameters were optimized to determine the optimal operation conditions under different feed composition and feed load, so as to provide reliable theoretical operation data for the stable production of propylene distillation.

4. Conclusion

According to the actual production demand, the key to improve the accuracy of simulation results and the efficiency of simulation work is to reasonably select the variable influence factors and simulation optimization order in the operation optimization of propylene distillation column. The reasonable operation optimization steps of propylene distillation in ethylene plant are determined, which can be used in the operation optimization process of similar propylene distillation tower to guide the actual production.

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