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Operation of a Batch Stripping Distillation Column*

XU Songlin(许松林)[a,], Jose Espinosa[b], Hector E. Salomone[b] and Oscar A. Iribarren[b]**
[a] National Engineering Research Center for Distillation Technology, Tianjin University, Tianjin 300072, China
[b] Institute for Development and Design INGAR, Conicet, Santa Fe, Argentina

Abstract A stripping batch distillation column is preferred when the amount of the light component in the feed is small and the products are to be recovered at high purity. The operation modes of a batch stripping are believed to be the same as those of a rectifier. However, the control system of a stripper is different. In this paper, we explore three different control methods with Hysys (Hyprotech Ltd. 1997) for a batch stripper. The main difference is the control scheme for reboiler liquid level: (a) controlled by reflux flow; (b) controlled by reboiler heat duty; (c) controlled by bottom product flow. The main characteristics of operating a batch stripper with different control scheme are presented in this paper. Guidelines are provided for the startup of a batch stripper, the effects of some control tuning parameters on the column performance are discussed.
Keywords batch stripper, control, operation

1 INTRODUCTION

Batch process is becoming more popular as chemical process industries move toward manufacturing fine and specialty chemicals, where flexibility is a key issue due to the frequent change of product demand[1]. Batch distillation columns are inherently flexible, as a single column can separate many different components from a multicomponent feed. Thus the use of batch distillation is becoming more important for the seperation and purification of high-value chemicals in many chemical, food, and pharmaceutical industries.

Traditionally, the most popular kind of batch distillation column is the so-called rectifying column, which has a large reboiler, to which all the feed is charged, and different products are removed from the top. There are three ways to operate a rectifying column[2,3]. They are: (1) constant reflux and variable distillate composition, (2) variable reflux and constant distillate composition of key component, (3) optimal reflux policy which trades off (1) and (2) and is based on the most profitable operation.

Batch stripping column is opposed to a batch rectifier. It has its storage vessel at the top and the products leave the column at the bottom. A stripping batch distillation column is preferred when the amount of the light component in the feed is small and the products are to be recovered at high purity[4,5].

The operation modes of a batch stripping are believed to be the same as those of a rectifier. However, the control system of a stripper is different. In this paper, we explore three different control methods with Hysys (Hyprotech Ltd. 1997) for a batch stripper. The control schemes are shown in Fig. 1. The main difference is the control scheme for reboiler liquid level: (a) controlled by reflux flow, (b) controlled by reboiler heat duty, (c) controlled by bottom product flow.

The main characterics of operating a batch stripper with different control scheme are presented in this paper. Guidlines are provided for the startup and the effect of some control tuning parameters on the column performance are discussed.

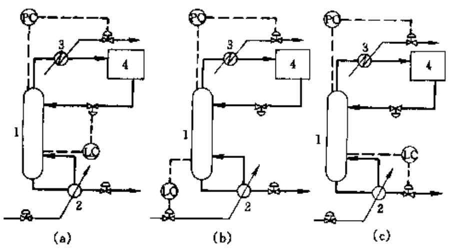

Figure 1 Control schemes for a batch stripping column
1—column; 2—reboiler; 3—cooler; 4—still;
LC—liquid level controller; PC—pressure controller

2 EXPERIMENTAL APPARATUS FOR THE SIMULATIONS

The experimental apparatus in the simulations is the same for the three control schemes. The stripping column has a reboiler, a condenser and 15 trays. The volumes of the reboiler and the condenser are $2\,m^3$ and $5\,m^3$, respectively. The diameter of the column is 0.5 m. The feed is the mixture of methanol (0.05) and ethanol (0.95)(mole fraction). The liquid percent level set point for the reboiler is 50% and the mixture takes

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** To whom correspondence should be addressed. E-mail: slxu@tju.edu.cn

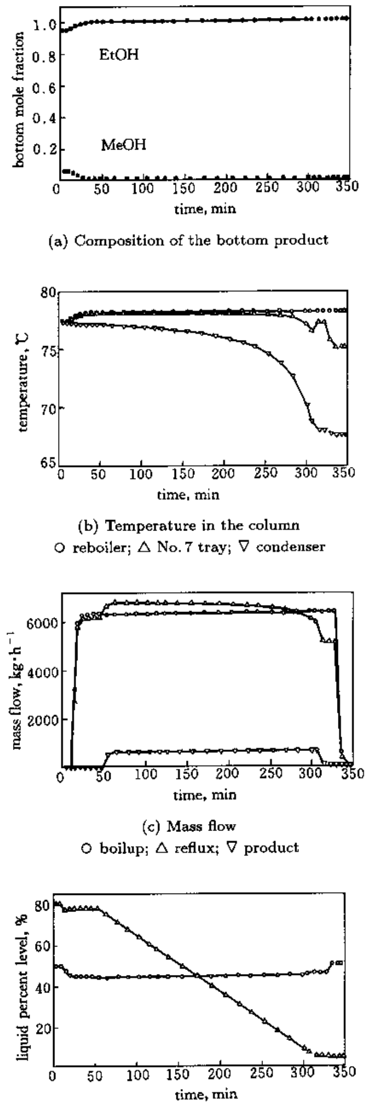
80% of the whole volume of the condenser. At the beginning, the trays are dry startup, but the reboiler is charged with the same mixture to the liquid level set point. The specification of bottom product ethanol is 0.999. All the simulated experimental procedures are that the stripper is started up till the specification of the heavy key composition is reached, then the bottom product valve is opened so that the product leaves the column, the product valve is shut down when the product composition declines to the specification.

3 RESULTS AND DISCUSSION

3.1 Control reboiler liquid level by reflux flow

In this control scheme [Fig. 1(a)], the reboiler liquid percent level is controlled automatically by reflux flow, the reboiler heat input and bottom product flow are controlled manually. At the beginning, the reboiler heat input is set fixed. The reboiler liquid level declines as the light component is vaporized, which will cause reflux flow down the reboiler automatically. The control of the reboiler liquid level is reversible, so when the reboiler liquid level is higher, there will be less reflux flow and *vice versa*. When the composition of heavy key component gets to its specification, the bottom product flow valve is opened; once it declines to the specification, the bottom product flow valve is shut down manually. In this case, when ethanol composition reaches 0.999, the bottom product flow valve is opened, when ethanol is less than 0.999 the bottom product flow valve is shut down.

The dynamic process of this operation mode is shown in Fig. 2. There is a time lag between the reboiler liquid level and reflux flow, especially when the number of stages is large. In order to get a stable reboiler liquid level control during the whole operation, two aspects should be considered carefully. One is to use an appropriate reflux valve. If the reflux valve is oversized, the reboiler liquid level controller will get more reflux flow to the reboiler than the set point when the liquid level declines. Then the reflux flow valve will be closed. This makes the reboiler liquid level fluctuate frequently. One case is shown in Fig. 3. In this situation the heavy key component composition in the bottom is unstable. The other aspect is that the tuning parameter of the reboiler liquid level should be chosen appropriately when a proportional-only bottom level controller is employed. The proportional gain K_p of the controller should be between 4.0 and 8.0. If K_p is too small, it is difficult to get a stable reboiler liquid level control. Fig. 4 shows the relation between reboiler liquid percent level and K_p for the same reboiler duty. From Fig. 4, it is obvious that if K_p is less than 4.0 the liquid percent level in the reboiler is far away from the set point level 50%. If K_p is between 4.0 and 8.0, the liquid level in the reboiler is near the set point.



(a) Composition of the bottom product

(b) Temperature in the column
○ reboiler; △ No. 7 tray; ▽ condenser

(c) Mass flow
○ boilup; △ reflux; ▽ product

(d) Top and bottom holdups
○ reboiler; △ condenser

Figure 2 Reboiler liquid level control by reflux

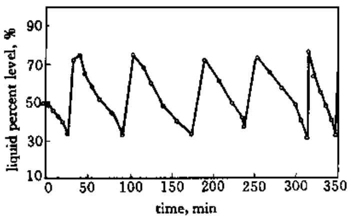


Figure 3 Fluctuation of reboiler liquid level

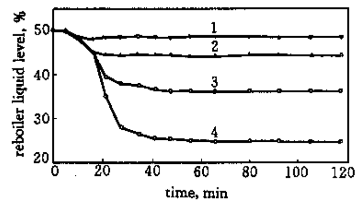
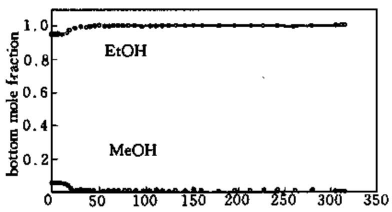


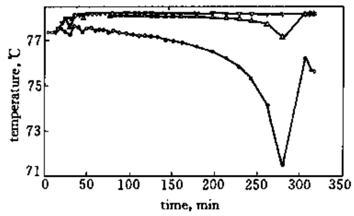
Figure 4 Effect of K_p on reboiler liquid level
K_p: 1—8.0; 2—4.0; 3—2.0; 4—1.0

3.2 Control reboiler liquid level by reboiler heat input

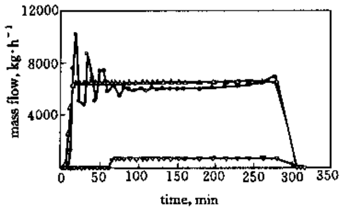
In this control scheme [Fig. 1(b)], the reboiler liquid level is controlled by reboiler duty automatically, reflux and bottom products flow are controlled manually. At the beginning, the reflux flow valve is opened to a fixed value. Reboiler liquid level increases, which will cause heat input to the reboiler. The action of the reboiler liquid level controller is direct, which means that the higher the reboiler liquid level, the more the heat input to the reboiler and *vice versa.* When the composition of the heavy key component in the reboiler gets to its specification, the bottom product flow valve is opened manually. When the heavy key component composition decreases to 0.999, the valves for bottom product and reflux flow are shut down manually. Fig. 5 shows the dynamic process of this operation mode. It is obvious that the boilup mass flow and the liquid levels of condenser and reboiler are fluxed at the startup of the operation. This is due to the dynamic responsiveness of reboiler heat input to the liquid level controller.



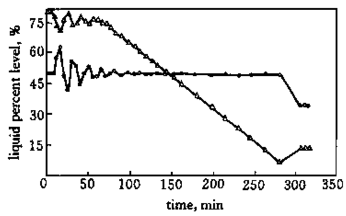
(a) Product composition



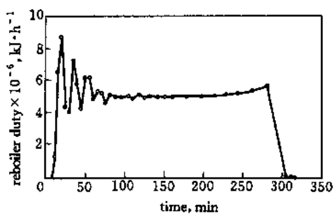
(b) Temperature
○ condenser; △ No. 7 tray; ▽ reboiler



(c) Mass flow
○ boilup; △ reflux; ▽ bottoms



(d) Holdup
○ reboiler; △ condenser;



(e) Reboiler heat duty

Figure 5 Reboiler liquid level control by reboiler heat input

3.3 Control reboiler liquid level by bottom product flow

The reboiler liquid level is controlled by bottom product flow in this control scheme [Fig. 1(c)]. This scheme is similar to the third control mode for a rectifier, in which the reboil ratio is variable. In order to get the bottom product specification, a total reboil process should be established at the beginning of the operation. The action of the reboiler liquid level controller is direct, which means that the higher the liquid level, the more the bottom product flow and *vice versa*.

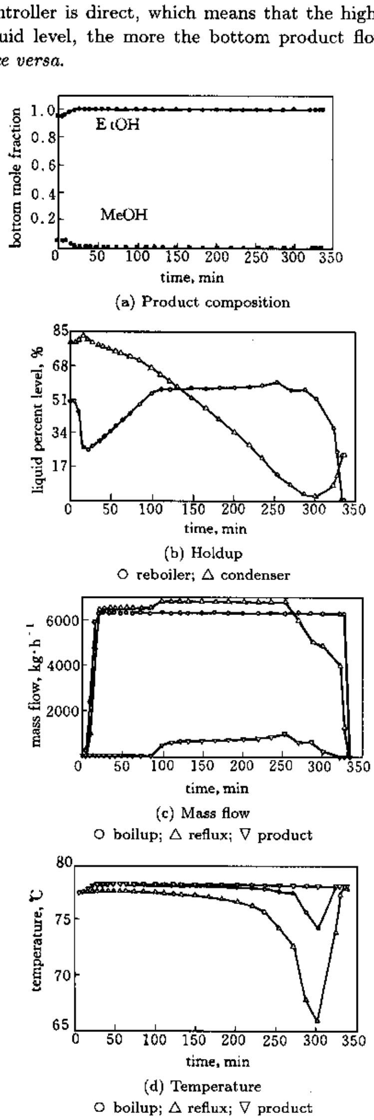


Figure 6 Reboiler liquid level control by bottom product flow

Figure 6(b) shows that at the startup of this operation, the liquid levels in both reboiler and condenser are oscillated, since it is difficult to meet the requirement for the total reboil at the beginning of the operation, for the reflux flow and reboiler heat input are operated manually.

4 CONCLUSIONS

The dynamic simulation with Hysys for the operation of a batch stripping distillation column indicates the main characterics of this kind of column, in which three different control schemes are employed. In the first scheme, reboil ratio is constant with variable bottom product composition; in the second scheme, reboil ratio is variable and the heavy key component composition in the bottom product is nearly constant, and the third is an optimal operation which could obtain more profit. Among these three control modes, the third is the most difficult to operate, since both controllers for reflux flow and reboiler heat input are operated manually.

This work demonstrates the operation of a batch stripping column, provides some practical guidlines for the startup and operation of the column, shows how the column can be run under different operating modes, and clarifies the effect of some key control tuning on the column performance. However, this work is a dynamic simulation. The practical operation of a batch stripping distillation column still needs to be investigated in detail.

REFERENCES

1 Salomone, H. E., Chiotti, O. J., Iribarren, O. A., "Short-cut design procedure for batch distillation", *Ind. Eng. Chem. Res.*, **36** (1), 130—136 (1997).

2 Sundaram, S., Evans, L. B., "Shortcut procedure for simulating batch distillation operations", *Ind. Eng. Chem. Res.*, **32** (3), 511—518 (1993).

3 Yang, Zh. C., Yu, G. C. (K. T. Yu), Mo, Zh. M., *et al.*, "Study on optimal strategies and microcomputer control of batch distillation (II) Batch distillation column and its microcomputer control", *J. Chem. Ind. Eng. (China)*, **40** (3), 280—286 (1989). (in Chinese)

4 Lotter, S. P., Diwekar, U. M., "Shortcut models and feasibility consideration for emerging batch distillation columns", *Ind. Eng. Chem. Res.*, **36** (4), 760—767 (1997).

5 Sørensen, E., Skogestad, S., "Comparison of regular and inverted batch distillation", *Chem. Eng. Sci.*, **51** (22), 4949—4962 (1996).