Optimization of Distillation Column

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Abstract: The overview of the main advances in distillation column its sequence optimization in zeotropic systems, ranging from systems, using only in conventional columns, each with a condenser and a reboiler, to fully thermally coupled systems with a single reboiler and a single condenser in the entire sequence. We also review the rigorous design of distillation columns, or column sequences. Various optimization tools along with energy aspect are also discussed.

Keywords: Distillation, Column Sequencing, Energy, Tools

I. INTRODUCTION

The Unit Operation Distillation is the most important operation for purification and separation in chemical process industries. To get an idea of the importance of distillation. Industrially, vapour and liquid phases are found to coexist most commonly, although liquid-liquid, vapor-solid, and liquid-solid systems are also found. This work deals with vapor and liquid in equilibrium with each other. Equilibrium is a static condition in which no changes occur in the macroscopic properties of a system with time. Vapor–liquid equilibrium (VLE) is a condition in which a liquid and its vapor (gas phase) are in equilibrium with each other, in other words, a condition where the rate of evaporation equals the rate of condensation [1]. Reducing the energy consumption is not as easy as it seems to be. The columns have different configurations with different objectives. [2] The schematic of the process is shown in Figure 1.

II. OPTIMIZATION TOOLS

Simulation & control studies are widely in practice for batch and continuous chemical process operations for last two decades [3,4, 5]. Optimization techniques have been applied to problems of industrial importance ever since the late 1940s. Distillation processes are most essential unit operations in chemical engineering. They are of significant importance as separation methods in chemical and petroleum industries. Chemical and petroleum industries hold a significant share in the overall world economy. Distillation processes have huge maintenance and running cost that can be greater than the overall cost of many other processes. Therefore, there should be an effective a reliable control system for efficient and safe operation of a distillation column. It presents various challenging control problems. Distillation columns are highly multivariable and shows non-linear behaviour. Therefore, their control is not a trivial task.

A. Mixed-Integer Non Linear Programming (MINLP)

The most common form of MINLP problems is the special case in which 0-1 variables are linear while the continuous variables are nonlinear, a new application of the case-based reasoning method for finding a MINLP model with superstructure and a solution of the corresponding distillation synthesis problem by suggesting an initial point for performing design and optimization of the system. When solving a new problem, the most similar case to the target is found in the case library during the retrieval process in two steps: (i) first, a set of matching cases is retrieved, using inductive retrieval;

(ii) the cases in the retrieved set then are ranked according to their similarity to the target case, using the nearest-neighborhood method [6].

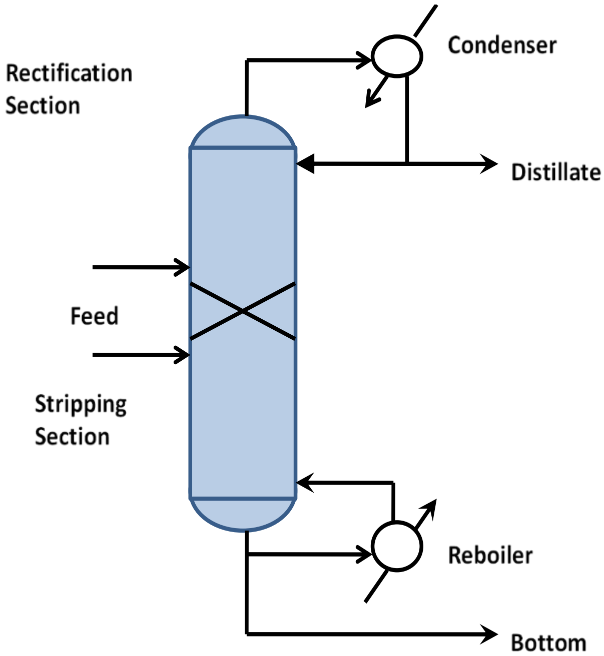

Figure 1: The schematic of the process

B. Generalized Disjunctive Programming

An alternative approach for representing discrete – continuous optimization problems is by using models consisting of algebraic constraints, logic disjunctions and logic propositions. This approach not only facilitates the development of the models by making the formulation intuitive, but it also keeps in the model the underlying logic structure of the problem that can be exploited to find the solution more efficiently the synthesis of distillation column configurations to separate non-azeotropic multicomponent mixtures containing N components. It is shown that, for sharp separations of an N-component mixture, it is possible to develop a superstructure that takes into account all of the possibilities, from thermally linked systems with only one reboiler and one condenser to sequences with only conventional columns [2(N − 1) condensers and reboilers]. All of the partially thermally linked superstructures are included. The superstructure is systematically generated using the state task network (STN) formalism, in which only the tasks that can be performed are specified, but not equipment. [7, 8].

C. The Rectification Body Method (RBM)

Proposed by Bausa et al [9] for the determination of minimum energy requirements of a specified split. For a given product, branches of the pinch point curves can be found. Rectification bodies can be constructed by joining points on the branches with straight lines. For either section of a column a rectification body can be constructed. The intersection of the rectification bodies of two sections of a column indicates its feasibility. The RBM can be used to calculate the minimum reflux ratio and minimum energy cost and to test the feasibility of a split. Because faces on rectification bodies are linearly approximated by joining branches of pinch point curves using straight lines, this method cannot guarantee accurate results. No information about column design (number of stages and operating reflux ratio) is obtained. The calculation of pinch point curves is, furthermore, computationally intensive [10].

D. Column Sequencing

Multicomponent mixtures are separated using distillation usually in a number of different sequences, which gives the same products but with different energy demand. Multicomponent mixtures are often separated into extrapure products. Column sequencing is a systematic method to find the optimal column sequence based on ease of operation and energy demand. The screening of design substitutes is carried out within a superstructure framework, which allows the breakdown of the separation sequences into unique separation array. The use of the selected array significantly reduces the work. The individual separation tasks are evaluated using shortcut methods. For the application to azeotropic mixtures, the mixture topology is obtained, and feasibility checks are performed for every split. In this context, azeotropes are treated as pseudo components [11,12]. The main aim of doing the column sequencing is to isolate the desired product with high purity. This is achieved by using distillation column in series.

E. Heat integration

In the first step, the target is to minimize the total annual cost of sequences by creating heat integration among columns. To calculate the temperatures and heat flow rates of condensers and reboilers and find the design specifications of columns such as the actual number of trays, reflux ratio, rectify vapor flow, etc., all the simple sequences are simulated by shortcut and rigorous method of commercial software. In the second step, the target is to find the possible power generation in all the sequences which can be designed and optimized. This investigation is in theory and is just a feasibility study to find the effects of power generation on the energetic efficiency of process and total annual cost [13]

III. CONCLUSION

The optimization of a distillation renders the increase in profitability at maximum possible energy consumption. The initial emphasis of the optimization work was to arrive at operational changes that could be implemented without substantial plant interruptions or modification, using existing piping and equipment. Many different variables were methodically tested to see the effects on throughput. A theoretical approach to optimization has been also accepted, to find ways to increase throughput without forgoing product quality.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities.

REFERENCES

[1] J. M.Smith, H. C.Van Ness and M. M.Abbott (2005), Chemical Engineering Thermodynamics, Tata McGraw Hill Edition, Special Indian Edition, pp.341-343.

[2] E. J. Henley and J. D. Seader (1981), Equlibrium –Stage Separation Operations in Chemical Engineering, John Wiely and Sons, (Inc. 1981).

[3] W. L. Luyben (2015) Aspen Dynamics simulation of a middle-vessel batch distillation process, Journal of Process Control. 33, pp. 49-59.

[4] W. L. Luyben (2013) Distillation design and control using Aspen simulation: John Wiley & Sons.

[5] V. D., Talnikar and Y. S Mahajan (2014) Recovery of acids from dilutestreams: A review of process technologies, Kor. J. Chem. Eng. 31, pp. 1720–1731.

[6] B. Borchers and J. E. (1994) Mitchell, An improved branch and bound algorithm for mixed integer nonlinear programs. Computers & Operations Research, 21(4): pp. 359-367.

[7] M. Turkay and I. E. Grossmann (1996) Disjunctive programming techniques for the optimization of process systems with discontinuous investment costs multiple size regions. Industrial & Engineering Chemistry Research,. 35(8), pp. 2611-2623.

[8] J. P Ruiz (2012) Generalized Disjunctive Programming: Solution Strategies Algebraic Modeling Systems , J. Kallrath, Editor, Springer Berlin.

[9] J. Bausa, R. von Watzdorf, and W. Marquardt (1998) Shortcut Methods for Nonideal Multicomponent Distillation: 1. Simple Columns. AIChE Journal, 44(10), pp. 2181-2198.

[10] L. Guilian (2004) Shortcut design for columns separating azeotropic mixtures. . Industrial & Engineering Chemistry Research, 43(14), pp. 3908-3923.

[11] A. Harwardt, S. Kossack and W. Marquardt (2008) Optimal column sequencing for multicomponent mixtures, 18th European symposium on computer Aided Process Engineering – ESCAPE -18.

[12] M. Eszter, E. Matild, K. Kornelia, N. Nandor, F. Jeno and B. Katalin (2009) Utilization of electrodialysis for galacturonic acid recovery, Desalination, 241, pp.81-85.

[13] I. E. Grossmann (2002) Review of Nonlinear Mixed-Integer and Disjunctive Programming Techniques. Optimization and Engineering, (3), pp. 227-252.

This volume is dedicated to Late Sh. Ram Singh Phanden, father of Dr. Rakesh Kumar Phanden.

