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Various Aspects of Distillation with Emphasis on Modeling, Optimization and Simulations - a Review

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ABSTRACT

Various distillation operations such as reactive distillation, azeotropic distillation, steam distillation, extractive distillation are used according to the need. Modeling of distillation columns helps in predicting various parameters for given separation. Optimal reflux ratio largely depends on the feed mole fraction, feed quality, relative volatility, and a separation factor. Studies reveal that very narrow range of reflux ratios which can produce high conversions and high purity methyl acetate. Optimal reflux ratio largely depends on the feed mole fraction, feed quality, relative volatility, and a separation factor. Extensive work is reported on various aspects of reactive, azeotropic, divided wall columns. Current review summarizes various aspects like modeling and simulation of these distillation operations.

Keywords: Reflux Ratio, Simulation, Distillation Column, Relative Volatility, Control System.

I. INTRODUCTION

Distillation is separation of components from liquid feed by virtue of volatility difference. Fractional distillation is very major and important operation in petroleum sector. Various distillation operations such as reactive distillation, azeotropic distillation, steam distillation, extractive distillation are used according to the need. Modeling of distillation columns helps in predicting various parameters for given separation. Optimal reflux ratio largely depends on the feed mole fraction, feed quality, relative volatility, and a separation factor. The location of feed plate and number of trays along with reflux ratio are important factors in design of distillation columns. Extensive work is reported on various aspects of reactive, azeotropic, divided wall columns. Current review summarizes various aspects like modeling and simulation of these distillation operations.

II. VARIOUS OF DISTILLATION- MODELING, OPTIMIZATION AND SIMULATIONS

Sarma et.al. used ASPEN PLUS simulation software to control a reactive distillation column for maintaining the product purity at the desired level[1]. They introduced tray temperature control. This solved the problem of nonlinearity to a great extent. There was no direct control for purity. They suggested more study for more advanced model predictive control to reduce the complexity of the system.

An investigation was carried by Chen and Lin to study optimum reflux ratio of distillation towers[2].They observed that reflux ratio was highly sensitive parameter in distillation columns. They also observed that optimal reflux ratio largely depends on the feed mole fraction, feed quality, relative volatility, and a separation factor. By evaluating annualized and operating costs, they evaluated optimum reflux ratio. Zhu et.al. carried out investigation on low-order dynamic model based on nonlinear wave theory[3].They tracked wave front propagating through the column. They carried out rigorous mass and energy balances for modeling reboiler/condenser system. They proposed on-line model adaptation. Sharmila and Mangaiyarkarasi carried out an investigation on modelling and control of binary distillation column[4].They developed a model for composition control. The model developed was useful for initial steps of a petroleum project feasibility study and design. Shehata et.al. carried out studies on simulation of natural gas liquids (NGL) separation using series of distillation columns[5]. They studied various factors which enhance the separation process efficiency.

The important parameters they considered were the number of trays, reflux ratio and the feed tray location. They obtained the lowest heat duties and the highest composition for top products at highest number of trays. Thirumalesh and Ramesh carried out investigation on design a multi-component distillation column for the given organic mixture[6]. They also investigated sequencing of a multi-component distillation column. They calculated relative volatility using Antonie equation. Also they considered component with lowest relative volatility at the top above the feed tray as light key component (LK) and the highest volatility at the bottom, below the feed plate are designated as the heavy key component (HK). Study was reported by Manzo, Tzouanas and Barbieri on heat integrated distillation columns[7].They presented case study on the said topic.in the chemical and refining industries, according to their estimates, nearly 40% of the energy is consumed.They carried out a case study on separation of benzene, toluene, and m-xylene.

Kumar studied dynamic behaviour of ethyl acetate reactive distillation[8]. They used ASPEN PLUS. Mustapha et.al.carried out analysis of high pressure distillation columns[9]. They carried out analysis based on based on the bubble point method. By using Gibb's rule they determined degree of freedom. They found that increasing the feed rate from 100 to 140% had negligible effect on the liquid and vapour flow rates distribution. They expressed the need for model sensitivity analysis as interactions between the different parameters were very strong. Chwukuma and Faniran investigated operating conditions of straight run gasoline (SRG) stabilizer column[10]. They explored various product recovery and energy savings options. They felt the need to reduce operating cost of the process by optimization of the operating conditions. They used the Hysys simulator to simulate the Straight Run Gasoline (SRG) stabilizer column. The number of trays, feed tray location, feed pressure and temperature were important operating parameters. They conducted parametric studies by varying the operating parameters. The optimization was trade-off between energy usage and product purity. Ghaee et.al. carried out investigation on dynamic optimization of the benzene extractive distillation unit[11]. They developed a mathematical model for describing the dynamic operation of the Nformylmorpholine extractive distillation column. They calculated the equilibrium and thermodynamic properties of the mixtures by NRTL equation. During unsteady-state operation they used Nelder-Mead algorithm for optimum values of the constants of the controllers. An investigation was carried out by Popoola et.al., on optimization models of crude oil distillation column[12]. In their studies, they proposed optimization models of crude oil distillation column for both limited and unlimited feed stock. The loading of feed was limited due to capacity of reboiler. Udeye et.al. carried out an investigation on the design and installation of a continuous ethanol distillation unit[13]. They studied azeotropic distillation. In dehydrating column, they used reboiler with an electric heater. According to investigations carried out by Bakar, batch distillation still remains important for the distillation because of its flexibility and capability to produce high purity product [14]. They performed simulation of batch distillation using computer aided software. They validated their results using MATLAB software. **Demirel discussed** sustainable operations for distillation columns [15].For sustainable operation, it is very important to ensure responsible use of energy and reduction of harmful emission such as CO2. They discussed the use of aspen plus targeting and carbon tracking tools for effective use of energy resources. Khalili-Garakani et.al. investigated distillation columns sequencing[16]. Their studies included divided wall column. In their investigation, they carried out the exergy analysis and economic study of 3 different samples of three-component mixtures.

Studies were carried out by Mair and Willingham on efficiency of a rotary distillation column[17]. Taylor and Krishna investigated modeling of reactive distillation [18].In their work; they introduced an in situ separation function within the reaction zone. They verified in experimental laboratory and pilot plant units, complex interactions between vapor}liquid equilibrium, vapor}liquid mass transfer, intra-catalyst diffusion lead to phenomenon of multiple steady-states and complex dynamics. Sadeghi and Ahangar studied methanol separation [19].They simulated a methanol distillation unit with three columns to separate methanol from its impurities and water in steady and dynamic states. Also they carried out investigation to study the effect of variable changes on purity rate of the product methanol and water flow. They found that the increase and reduction of the feed stage position of the first column had negligible effect on product purity.

An investigation was carried out by Adogbo and Ayodele on plastic packed distillation column for ethanol-water separation[20]. They studied water ethanol system. They found that the fluid dynamics and mass transfer were affected by geometry and structure of materials in the column. Hammad et.al. proposed approach for distillation column malfunction identification [21]. They proposed use of higher order statistical method. Huss et.al. studied reactive distillation for production of methyl acetate[22].For design of these columns, they described a hierarchy of methods, models, and calculation techniques. They observed that there is very narrow range of reflux ratios which can produce high conversions and high purity methyl acetate. Also there were multiple steady states.

III. CONCLUSION

Modelling of distillation columns helps in predicting various parameters for given separation. Optimal reflux ratio largely depends on the feed mole fraction, feed quality, relative volatility, and a separation factor. Studies reveal that very narrow range of reflux ratios which can produce high conversions and high purity methyl acetate. Optimal reflux ratio largely depends on the feed mole fraction, feed quality, relative volatility, and a separation factor. Extensive work is reported on various aspects of reactive, azeotropic, divided wall columns.

IV. REFERENCES

[1] Satirtha Kumar Sarma, Kailash Singh And Rajeev Kumar Dohare(2017). Control Of A Reactive Distillation Column For Methyl Acetate System Using Aspen Plus. International Journal Of Advanced Technology And Engineering Exploration, 4(26), pp.12-16.

[2] Hsi-Jen Chen And Yeh-Chin Lin(2001), Case Studies On Optimum Reflux Ratio Of Distillation Towers In Petroleum Refining Processes. Tamkang Journal Of Science And Engineering. 4(2), 105-110.

[3] Guang-Yan Zhu A, Michel A. Henson A, Lawrence Megan(2001). Low-Order Dynamic Modeling Of Cryogenic Distillation Columns Based On Nonlinear Wave Phenomenon. Separation And Purification Technology, 24, pp.467–487.

[4] M.Sharmila,Ms.V.Mangaiyarkarasi(2014).Modeling And Control Of Binary Distillation Column. International Journal Of Advanced Research In Electrical, Electronics And Instrumentation Engineering. 3(4), pp.105-111.

[5] Ali I. Shehata, Mohamed A. Teamah,Ahamed A. Hanfy, Ahmed A. Ali(2015). The Simulation Of Natural Gas Liquids (NGL) Separation Using Series Of Distillation Columns. International Journal Of Advanced Scientific And Technical Research, 5(7), pp. 154-161.

[6] Thirumalesh. B.S, Ramesh.V(2015). Case Study On Multicomponent Distillation And Distillation Column Sequencing, International Journal Of Engineering Sciences & Research Technology. 4(8), pp.609-623.

[7] Ing. Fabiana Manzo Dr. Vassilios Tzouanas, Dr. Enrique Barbieri(2012). Modeling, Simulation And Control Of Heat Integrated Distillation Columns: A Case Study. American Society For Engineering Education, 1, pp.1-6.

[8] J Susheel Kumar(2008).Under The Guidance Of Prof.B. Munshi, Study Of Dynamic Behavior Of Ethyl Acetate Reactive Distillation Column Using Aspen Plus, Department Of Chemical Engineering National Institute Of Technology, Rourkela,1,pp.1-35.

[9] Douani Mustapha, Ouadjenia Fatima And Terkhi Sabria(2007). Distillation Of A Complex Mixture. Part I: High Pressure Distillation Column Analysis: Modeling And Simulation, Entropy, 9, pp.58-72.

[10] F.O. Chwukuma And K.K. Faniran(2013). A Simulation Study Of Operating Conditions Of Straight Run Gasoline (Srg) Stabilizer Column: A Consideration Of Product Recovery And Energy Saving Options. Journal Of Emerging Trends In Engineering And Applied Sciences, 4(5), pp.731-736.

[11] A. Ghaee, R. Sotudeh-Gharebagh And N. Mostoufi(2008). Dynamic Optimization Of The Benzene Extractive Distillation Unit, Brazilian Journal Of Chemical Engineering, 25(4), pp.765 – 776.

[12] Lekan T. Popoola, Jamiu A. Adeniran, Solomon O. Akinola(212). Investigations Into Optimization Models Of Crude Oil Distillation Column In The Context Of Feed Stock And Market Value.

Advances In Chemical Engineering And Science, 2, pp.474-480.

[13] V. Udeye, S. Mopoung, A. Vorasingha And P. Amornsakchai(2009).Ethanol Heterogeneous Azeotropic Distillation Design And Construction. International Journal Of Physical Sciences, 4 (3), pp. 101-106.

[14] Faezah Bt Bakar (2013). Modeling And Simulation Of Fermentation Product Purification Using Batch. Thesis Submitted In Fulfillment Of The Requirement For The Award Of The Degree Of Bachelor Of Chemical Engineering, Faculty Of Chemical & Natural Resources Engineering University Malaysia Pahang, 1, pp.1-24.

[15] Yaşar Demirel (2013). Sustainable Operations for Distillation Columns. Chemical Engineering & Process Techniques, 1, pp.1-15.

[16] Amirhossein Khalili-Garakani, Javad Ivakpour, and Norollah Kasiri (2016). Three-Component Distillation Columns Sequencing: Including Configurations with Divided-Wall Columns. Iranian Journal Of Oil & Gas Science And Technology, 5(2), pp. 66-83.

[17] Beveridge J. Mair and Charles B. Willingham (1939). Efficiency of a Rotary Distillation Column. Research Paper Rpl201, Part Of Journal Of Research Of The National Bureau Of Standards, 22, pp.519-527.

[18] R. Taylor, R. Krishna(2000). Modeling Reactive Distillation, Chemical Engineering Science, 55,5183-5229.

[19] Jafar Sadeghi And Mansureh Ahangar(2012).The Study Of Methanol Separation Columns Control.Oriental Journal Of Chemistry, 28(1), pp.229-235.

[20] Gideon Majiyebo Adogbo, Ayobiyi Joy Ayodele(2013). Performance Of A Plastic Packed Distillation Column For Ethanol-Water Separation. International Journal Of Scientific & Engineering Research, 4(4), pp.1330-1335.

[21] M. E. Hammad, H. Kasban, Sayed M. Elaraby, Moawad I. Dessouky, O. Zahran, Fathi E. Abd El-Samie(2014). Distillation Column Malfunctions Identification Using Higher Order Statistics. International Journal Of Computer Applications, 108(1), pp.7-13.

[22] Robert S. Huss, Fengrong Chen, Michael F. Malone, Michael F. Doherty (2003). Reactive Distillation for Methyl Acetate Production. Computers and Chemical Engineering, 27, 1855-1866.