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Review Article

Mass Transfer with Tray Tower and Its Modeling: A Review

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ABSTRACT

Mass transfer operations for gas liquid separation can be carried out in two modes. One is gas dispersed in continuous liquid and Liquid dispersed in continuous gas flow. Tray columns and packed beds are examples of these two types of mass transfer equipments respectively. For fluids containing suspended solids, other equipments such as agitated vessels, spray chambers venture scrubbers and sparged vessels can be used according to the requirements. Tray columns are the most important contact mechanisms along with packed columns. Easy cleaning, high liquid hold up, side stream flexibility are some advantages of tray towers over packed columns. Current review summarizes studies, research work and reviews carried out on tray columns.

Keywords: Tray efficiency, modeling, inters phase mass transfer, computational fluid dynamics (CFD).

INTRODUCTION

Mass transfer operations are classified based on phases involved. Liquid separation includes extraction, which is most important operation in this category. Distillation separates liquids based on volatility. Extractive distillation combines these two mass transfer operations. [1-5] Molecular distillation is low pressure operation carried for separation of heat sensitive materials. [6-10] Adsorption is used to separate solids from fluids by using adsorbents. Adsorption also finds application in catalysis. [11-15] Also adsorption is one of the major techniques used selectively for selective removal of pollutants from gaseous and liquid effluent. [16-20] These units operations can be combined with reactions to give process intensive solutions such as reactive chromatography, reactive adsorption, reactive distillation, membrane bioreactors etc. [21-25] Packed beds are used for gas liquid and liquid- solid separations. [26-29] Use of catalyst packed or fluidized bed is common for solid catalyzed reactions. [30-35] Tray columns are used for gas absorption and stripping along with few other applications. Easy cleaning, high liquid hold up, side stream flexibility are some advantages over packed columns. Current review summarizes studies, research work and reviews carried out on tray columns.

MASS TRANSFER WITH TRAY TOWER AND ITS MODELING

Rahimi et.al used computational fluid mechanics to predict the temperature and concentration distributions of distillation sieve trays. [36] They developed a three-dimensional two-fluid computational fluid dynamics (CFD) model. They modeled dispersed gas phase and continuous liquid phase using Eulerian framework. They used interphase mass transfer concept for developing closure models. They analyzed the extent to which CFD can be used as a prediction tool for real behavior. According to them, CFD was the best and surest method of tray efficiency calculation. For development of new approaches for calculation of point and Murphree tray efficiencies by CFD, their studies can work as basis. Rahimi and Karimi studied mass transfer efficiency for distillation. [37] They used computational fluid dynamic based artificial neural network model for developing mass transfer efficiency model. They validated the CFD model for hydrodynamics and mass transfer characteristics of distillation column. Their results indicated that the CFD model predicted point efficiency close to the experimentally measurements. They combined artificial neural network tool with CFD and developed CFD-ANN model.

Justi et.al carried out momentum and heat transfer analysis for sieve tray. [38] They carried out studies on ethanol water distillation. They also carried out computational fluid dynamic analysis of the process. The distillation using tray towers faces problems like recirculation, stagnation zones and chaotic hydrodynamic behavior. The velocity profiles for upstream and downstream regions were in good agreement with experimental data. They also observed that temperature fields presented an expected behavior.

Teleken et.al carried out studies on multiphase flow in a sieve tray of a distillation column. [39] They investigated complex hydrodynamics of sieve trays in pilot plant distillation columns. They employed distributed control system with heating action at intermediate points, through electrical resistance heaters. Also they evaluated the influence of these electrical resistance heaters on the hydrodynamics. They observed that the flow patterns were influenced by electrical resistance heaters placed on the surfaces of the sieve trays. One of their key conclusions in these studies was that, understanding the inter-phase transfer is key to predicting gas-liquid flow in a distillation tray. They also found that the electrical resistance the homogenizes the phase mixture in the active bubbling region. Sovilj carried out studies on hydrodynamics of gas-agitated liquid-liquid extraction columns. [40] They reported the studies on hydrodynamics in the non-agitated extraction columns. According to them, the non-agitated contacting equipments like spray column, packed column, perforated plate column, sieve plate column, etc. have limited application because of back mixing issues. They noticed that spray column when operated with dense packing of drops exhibits low back mixing. Also introduction of inert gas can increase the efficiency of a non-agitated extraction column.

Belincanta et.al carried out investigation on parastillation column. [41] In parastillation process, the vapor stream is divided into two equal parts. In this process, the falling liquid is alternately contacted with both vapor parts on a stage-by-stage basis. They used laboratory scale apparatus to study this process. For ethanol water system, they carried out experiments under total and partial reflux conditions. They analyzed the effects of initial concentration on the hydrodynamic conditions. The effect of vapour flow rate on the hydrodynamics was also studied by them. They observed that the foam (cellular and homogeneous) regime occurred more often in parastillation than conventional column. According to these studies, higher dispersion heights were observed on the upper trays. This was due to increase in vapor velocity. They also observed that the Murphree tray efficiency was strongly affected by system properties. Also composition affects the Murphree tray efficiency to a considerable extent.

Wijn et.al investigated mechanisms for the flow of liquid over outlet weirs of distillation and absorption trays. [42] They used Francis' weir equation for estimating the height required by clear liquid flowing over a weir. They found that because of a splashing mechanism, a non-gassed zone (calming zone) next to the down comer has a large effect. By using stochastic model, they related the weir flow to the flow mechanisms upstream of the tray outlet. By using upstream mechanisms they were able to provide the input needed for a new weir crest equation. Brahem et.al carried out experimental studies on valve tray columns.[43] They studied experimentally, effect of path length on valve tray columns. They carried out experiments with two different path length columns to provide a wide data base. They proposed correlations for liquid fraction, emulsion heights and interfacial area. The effect of scaling could not be considered in these studies. There was need to improve the correlation to account for this and other aspects such as physicochemical parameters.

Malvin et.al investigated the hydrodynamics and hydraulics of industrial-scale distillation sieve tray. [44] They modeled interactions between three-dimensional two-phase flow of gas and liquid. They made an attempt o improve Reynolds-Averaged Navier-Stokes (RANS). Volume of fluid (VOF) multiphase model through large eddy simulation (LES) was employed by them in the studies. They noted very good agreement with experimental data of the model results. Attarakih et.al carried out dynamic analysis and control of sieve tray gas absorption column. [45] They used MATALB and SIMULINK software for this purpose. These studies highlighted powerful combination of SIMULINK/ MATLAB software as an effective flow sheeting tool. As a case study, they analyzed ethanol absorption from CO_2 stream in a fermentation process. They found that the number of iterations needed to achieve a given tolerance was function of the Murphree tray efficiency. They found that with respect to inlet gas composition, gas composition response was linear. It was non linear with respect to inlet gas flow rate.

CONCLUSION

Tray columns are the most important contact mechanisms along with packed columns. Easy cleaning, high liquid hold up, side stream flexibility are some advantages over packed columns. CFD was the best and surest method of tray efficiency calculation. Understanding the inter-phase transfer is key to predicting gas-liquid flow in a distillation tray. The non-agitated contacting equipments like spray column, packed column, perforated plate column, sieve plate column, etc. have limited application because of back mixing issues.

REFERENCES

1. Sunil Jayant Kulkarni, a Review on Research and Advancements in Extractive Distillation, International Journal of Research (IJR), 2015, 2(1), 306-309.
2. H. Demiral and M. Ercengiz Yildirim, “Recovery of acetic acid from waste streams by extractive distillation”, Water Science & Technology, IWA Publishing, 2003, 47(10), 183-188.
3. V. Varga, E. Rev, V. Gerbaud, Z. Lelkes, Z. Fonyo, and X.Joulia,“Batch Extractive Distillation with Light Entrainer”, Chem. Biochem. Eng. Q., 2006, 20(1), 1-23.
4. Guangzhong Li, Yang Yu, Peng Bai, “Batch extractive distillation of mixture methanol-acetonitrile using aniline as a solvent”, Polish Journal of Chemical Technology, 2012, 14(3), 48-53.
5. M.A. Marttinello, I. Leone And M. Pramparo, “Simulation of Deacidification Process By Molecular Distillation of Deodorizer Distillate”, Latin American Applied Research, 2008, 38, 299-304.
6. Sunil Jayant Kulkarni, “Molecular Distillation: A Review on Applications and Affecting Parameters”, International Journal of Research (IJR), 2015, 2(1), 310-313.
7. Tian Lye Ooi, Augustine Soon Hock Ong, Hideo Mamuro, Yasuhiko Kubota, Hisako Shiina, And Satoshi Nakasato, “Extraction of Carotenes from Palm Oil. I. Molecular Distillation Method”, 1986, 35(7), 543-548.
8. Bhat, S. G. ; Kane, J. G. ; Sreenivasan A., “Molecular distillation of some Indian vegetable oils Journal of the American Oil Chemists' Society, 1956, 33(5), 197-199.
9. Keping Liu, 2Tianfang Sun, Binglin Li, Changhong Jiang, “Study on Mathematic Model of Wiped Film Molecular Distillation Evaporator”, Advances in information Sciences and Service Sciences (AISS), 2013, 5(40, 465-473.
10. Zuogang Guo, Shurong Wang, Guohui Xu, Qinjie CAi, “Up gradation of Bio oil Moleculer Disillation Fraction with Solid Catalyst”, Bio resources, 2011, 6(3), 2539-2550.

11. Sunil Jayant Kulkarni, "A Review on Petroleum Refining and Petrochemical Processes with Special Emphasis on Catalysts and Flue Gas Treatment Technology", International Journal of Petroleum and Petrochemical Engineering (IJPPE), 2016, 2(10), 1-5.
12. Sunil Jayant Kulkarni, "Research on Biocatalysts: A Review", International Journal of Research, 2015, 2(4), PP.784-789.
13. Sunil J. Kulkarni, "A Review on Studies and Research on Catalysts with Emphasis on Catalyst Deactivation", International Journal of Research and Review, 2015, 2(10), 610-614.
14. Majid Saidi, Navid Mostoufi, Rahmat Sotudehgharebagh, "Modeling And Simulation Of Continuous Catalytic Regeneration (CCR) Process", International Journal Of Applied Engineering Research, Dindigul, 2011, 2(1), 115-124.
15. Mu Xuhong, Wang Dianzhong, Wang Wengrui, Lin Min, Cheng Shibiao, Shu Zigtian, 2013, "Nanosized Moleculer Sieves As Petrolium Refining And Petrochemical Catalyst", Chinese Journal Of Catalysis, 201, 34, 69-79.
16. Sunil J. Kulkarni, "Removal of Organic Matter from Domestic Waste Water by Adsorption", International Journal of Science, Engineering and Technology Research, 2013, 2(10), 1836-18840.
17. Sunil Jayant Kulkarni, "Removal of Zinc from Effluent: A Review", International Journal of Advanced Research in Science, Engineering and Technology, 2015, 2(1), 338-341.
18. Sunil J. Kulkarni, Dr. Jayant P. Kaware, "A Review on Research for Cadmium Removal from Effluent", International Journal of Engineering Science and Innovative Technology, 2013, 2(4), 465-469.
19. Sunil Jayant Kulkarni, "Solute Uptake, Kinetic and Isotherm Studies for Copper Removal: A Review", International Journal of Research, 2015, 2(1), 718-723.
20. Pallavi Amale, Sunil Kulkarni, Kavita Kulkarni, "A Review on Research for Industrial Wastewater Treatment with Special Emphasis on Distillery Effluent", International Journal of Ethics in Engineering & Management Education, 2014, 1(9), 1-4.
21. Sunil Jayant Kulkarni, "Advancements, Research and Challenges in Reactive Adsorption: A Review", International Journal of Research, 2015, 2(1), 310-313.
22. Kulkarni S.J., "Research and studies on membrane reactors", International Journal of Research and Review. 2016; 3(6), 59-62.
23. Rashmi Vinod Dahake, A.K.Goswami, Dr. V. Kalyanraman, S.J. Kulkarni, "Performance Evaluation of Hybrid Membrane Bioreactor for Low Strength Wastewater Treatment", International Journal of Science, Engineering and Technology Research, 2013, 2(12), 2167-2169.
24. Kulkarni S.J., "Research and studies on coal desulphurization", International Journal of Research and Review., 2016; 3(6), 56-58.
25. Sunil J. Kulkarni, Nilesh L. Shinde, "A Review on Hydrogen Sulphide Removal from Waste Gases", International Journal of Advanced Research in Science, Engineering and Technology, 2014, 1(4), 187-189.
26. Sunil J. Kulkarni, "Modeling for Adsorption Columns for Wastewater Treatment: a Review", International Journal of Innovative Research in Engineering & Multidisciplinary Physical Sciences (IJIRMPS), 2014, 2 (2), 7-11.
27. Sunil J. Kulkarni, Ajaygiri K. Goswami, "Adsorption Studies for Organic Matter Removal from Wastewater by Using Bagasse Flyash in Batch and Column Operations", International Journal of Science and Research, 2013, 2(1), 180-183.
28. Sunil J. Kulkarni and Dr. Jayant P. Kaware, "Removal of Cadmium from Wastewater by Groundnut Shell Adsorbent-Batch and Column Studies", International Journal of Chemical Engineering Research, 2014, 6(1), 27-37.
29. Sunil J. Kulkarni, "Removal of phenol from Effluent in Fixed Bed: A Review", International Journal of Engineering Research and General Science, 2014, 2(4), 35-39.
30. Sunil Jayant Kulkarni, "Role of Adsorption in Petroleum Industries and Refineries", International Journal of Petroleum and Petrochemical Engineering (IJPPE), 2016, 2(1), 1-4
31. Sunil Jayant Kulkarni, Ajaygiri Kamalgiri Goswami & Nilesh Shinde, "Treatment and Recovery for Flue Gases: a Review", International Journal of Research, 2015, 2(6), 515-519.
32. Sunil Jayant Kulkarni, "Advancements, Research and Challenges in Reactive Adsorption: A Review", International Journal of Research, 2015, 2(1), 477-480.
33. Igor Bezverkhyy, Andrey Ryzhikov, Geoffroy Gadacz, Jean-Pierre Bellat, "Kinetics of thiophene reactive adsorption

on Ni/SiO2and Ni/ZnO", Catalysis Today, 2008, 130,199-205.
34. Kulkarni S.J., "Fluidized bed contactors: a review on studies and research", Int J Res Rev., 2015, 2(12), 754-757.
35. Sunil J. Kulkarni, Ravi W. Tapre, "Mass Transfer Studies on Fluidized Bed Adsorption Column for Phenol Adsorption", International Journal of Science and Research (IJSR), 2013, 2(12), 1-4.
36. Mahmood-Reza Rahimi, Rahbar Rahimi, Farhad Shahraki and Morteza Zivdar, "Prediction of Temperature and Concentration Distributions of Distillation Sieve Trays by CFD", Tamkang Journal of Science and Engineering, 2006, 9(3), 265-278.
37. Mahmood Reza Rahimi and Hajir Karimi, "Modeling distillation mass transfer efficiency", International Journal of Chemical and Environmental Engineering, June 2011, 2(3), 1-3.
38. Gabriel Henrique Justi, Gladson Cintra De Oliveira, Prof. Dr. José Antônio Silveira Gonçalves, "Energy And Momentum Transfer Analysis Of A Distillation Collumn Sieve Tray For An Ethanol-Water System Using Cfd Techniques", 2013, ESSS Conference and Ansys Users Meeting, Bourbon Atibaia Spa Resort, Atibaia, P Brazil, 23-25 April,2013, 1-16.
39. Joel G. Teleken, Leandro O. Werle, Iaçanã G. B. Parisotto, Cintia Marangoni, Ana Paula Meneguelo, Ricardo, A. F. Machado., "Fluid-Dynamics Study of Multiphase Flow in a Sieve Tray of a Distillation Column", 20th European Symposium on Computer Aided Process Engineering-ESCAPE20, 2010,1-6.
40. Milan N. Sovilj, "Hydrodynamics of Gas-Agitated Liquid-Liquid Extraction Columns", BIBLID, 43, 199-216.
41. J. Belincanta, T. M. Kakuta Ravagnani and J. A. F. Pereira, "Hydrodynamic and Tray Efficiency Behavior In Parastillation Column", Brazilian Journal of Chemical Engineering, 2006, 23(1), 135-146.
42. E.F. Wijn, "Weir flow and liquid height on sieve and valve trays", Chemical Engineering Journal, 1999, 73, 191-204.
43. Rim Brahem, "Aude Royon-Lebeaud, Dominique Legendre. Effect of path length on valve tray columns: experimental study", Chemical Engineering Science, Elsevier, 2015, 126, 517-528.
44. A.Malvin, A. Chan, and P. L. Lau, "Large Eddy Simulation of Distillation Sieve Tray Hydrodynamics using Volume-of-Fluid (VOF)Multiphase Model", Proceedings of the World Congress on Engineering and Computer Science 2010 Vol II,WCECS 2010, October 20-22, 2010, San Francisco, USA,-6.
45. Menwer Attarakih, Mazen Abu-Khader, Hans-Jörg Bart, "Dynamic analysis and control of sieve tray gas absorption column using MATALB and SIMULINK", Applied Soft Computing, 2013, 13, 1152-1169.

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