Project Proposal – Process Systems Modeling

Optimizing Tray-Layout design for preventing mal-distribution

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Relevant Module: NLP

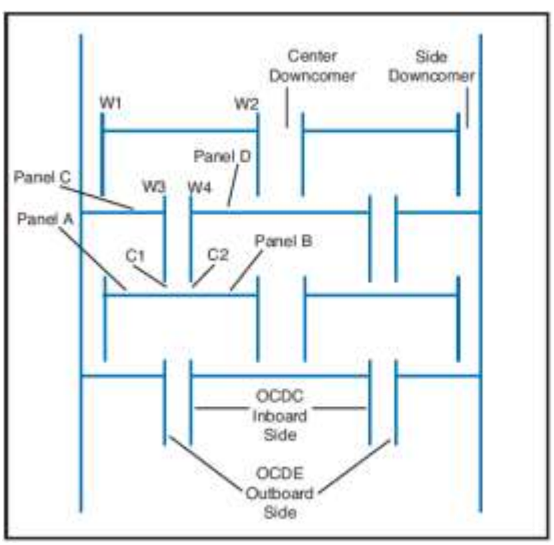
Motivation and explanation of the problem:

The topic I am planning to work on is multi-pass tray layout optimization. We focus on 4 pass trays since 4 pass trays are by far the most common multi-pass trays with the objective being minimizing the mal-distribution of liquid and vapor flows in the column arising as a result of the tray layout.

The main motivation behind optimizing the tray layout for better vapor/liquid distribution is that mal-distribution causes variation in the liquid and vapor commonly referred to as the L/V ratio from pass to pass. Pinching and low separation would occur in the low- L/V regions and overall separation suffers and efficiency would diminish greatly [1]. This variation would also affect tray capacity. Regions with excessive liquid and vapor loads would be prone to be closer to flooding and other regions would have surplus capacity. This would result in the column not being utilized efficiently and would require a more conservative design and hence higher costs.

Bolles [2] has defined a distribution ratio as the ratio of the maximum pass L/V to the minimum pass L/V on a particular tray. He has recommended keeping the distribution ratio below 1.2 to achieve good tray efficiency. Summers[3] has proposed a tighter criterion of 1.1.

This minimizing of the mal-distribution would hence quantitatively imply the optimization of this distribution ratio. A distribution ratio of 1 would imply perfect liquid-vapour distribution in the column which is the desired objective.



The essential variables in tray layout design (see figure) would be the cord width of the side downcomer, the center downcomer, the off-center downcomer (OCDC), the position of the off-center downcomer (OCDC), the clearances (C1, C2). If the downcomers are slant downcomers in order to help reducing the flooding in the column, it would make the design process even more challenging and would add more variables, which are the bottom cord widths of all the downcomers.

Fixing any one of the major tray layout parameters should in effect decide what the values of the other variables should be in order to achieve optimum distribution ratio.

Information required

The information that would be required in order to solve this optimization problem would be the knowledge of all the factors that affect this distribution ratio.

Plan for obtaining necessary data

Summers[3] and Pilling[4] have both exhaustively discussed the various factors affecting the mal-distribution and hence the distribution ratio.

Proposed solution method

1. Identify all the factors involved in deciding the distribution ratio
2. Develop equations based on the known factors
3. Develop an algorithm to optimize the distribution ratio
4. Use the algorithm and equations to solve the NLP optimization problem

Expected conclusion

There would be just one degree of freedom for optimizing the distribution ratio for the straight downcomer trays and two degree of freedoms for slant downcomer trays. The values of the other parameters would be decided after the layout has been completely optimized in order to obtain a distribution ratio as close as possible to 1.0.

Additional work

I shall try to extend this even further and solve this optimization problem for 3 and 6 pass trays respectively; if time permits.

References

[1] Kister, H. Z., R. Dionne, W. J. Stupin, and M, Olsson, "Preventing Maldistribution in Multi-Pass Trays," in "Distillation 2009: Improved Design and Operation to Meet Economic and Energy Challenges." Topical Conference Proceedings, AIChE Spring Meeting, Tampa, FL (Apr. 26-30, 2009)

[2] Bolles, W., *AIChE J*, 22 (1), 153, (1976)

[3] Pilling, M., "Ensure Proper Design and Operation of Multi-pass Trays," Chem. Eng. Progress. 101 (6), pp. 22-27 (June 2005)

[4] Summers, D. R., "Designing Four-Pass Trays," Chem. Eng. Progress, 1 06 (4), pp. 26-31 (Apr.2010)