A Methodology to Model and Simulate Binary Distillation Columns with Inventory Control

N. Duro Tf: 34-91-3987169, Fax:34-91-3988663, E-mail: nduro@dia.uned.es
F. Morilla Tf: 34-91-3987156, Fax: 34-91-3988663, E-mail: fmorilla@dia.uned.es
Dpto de Informática y Automática, UNED, C/ Juan del Rosal nº16, 28040 Madrid.

Distillation is a complex process that involves large and interesting modelling and control problems (see references [1], [5], [7]). This paper describes a methodology to model and simulate binary distillation columns with inventory control, which solves some of these problems. The modelling goes further than a dynamic modelling, since it also includes the column design and the tuning of the controllers.

The proposed methodology allows modelling the ideal column for a well-known mixture, ideal or non-ideal, in several operation conditions. The resulting column can be modelled in two different modelling languages (Dymola and Simulink), taking advantage of the modular structure proposed for the model. The methodology has been tested efficiently in some mixtures (water and acetic acid, water and acetone, water and methanol, etc) [2]. Besides it has been useful to get a good benchmark of distillation columns models. These models are being used for multivariable control evaluations and will be integrated into a virtual laboratory for training students about the distillation process and its control.

The model

The selected model for the distillation column is modular and rigorous [8], therefore in this work it was selected an EMC staged structure [4], that includes a non-null dynamic balance of material, composition and energy in each equilibrium stage.

The columns are modelled combining five modules in order to get reusability and generality to the model. The first and more important module is the conventional tray. This module will be repeated so many times like trays minus one there are in the column. The other modules are the feed tray, the top group, the bottom group and the controller (one for the top group and one for the bottom group).

All modules except the controller are modelled as equilibrium stages using three groups of equations: (1) the differential equations describing the dynamic behaviour of the main variables (mass, composition and temperature), (2) the algebraic equations describing the hydraulic relations between the mass, the liquid flow and the vapour flow and (3) the liquid-vapour equilibrium equations.

The methodology

The proposed modelling methodology determines the design of the best distillation column to simulate the distillation process of a given mixture under some concrete operation conditions, selected by the user. For this, the methodology combines three different steps:

- The first step is the column design, where are calculated all necessary data to build the model. In this step the user takes active part, collecting the data and selecting the operation conditions for the distillation process.

The user fundamentally should know the equilibrium curve of the mixture and a few specifications about it and about its components. All these data can be obtained from [3] and [6].

- The second step is to build the model. In this step, the four types of sub-models (tray, feed tray, bottom and top group) and the control strategy are properly connected. The number of trays in the column is known for the first step of the methodology. The model can be built in Dymola or Simulink because all the sub-models have been developed in both languages. The modelling in Dymola is made with two text files. The first file includes a declaration for each block and the connections between them, and the second file includes the call to the other file, the call to equations ordering and the initialisation of variables. The modelling in Simulink is made graphically copying the blocks, connecting them and filling his masks. It is advisable to use Dymola when the number of the trays in the column is very high. Otherwise, when the model has only a few trays or when the user wants to test different control strategies on a given column, it is more appropriate to use Simulink.

- The third step is the tuning of the controllers. At this point the user has the ideal column to simulate the distillation process of this mixture without control. It is very usually to put an inventory control strategy upon a distillation column, to control the retained masses in the accumulator and in the bottom. In this step the controllers of the inventory control strategy are properly tuned using simulation data and a multivariable control tool [9], where the user can analyse the interactivity between the variables and obtain the appropriate control parameters.

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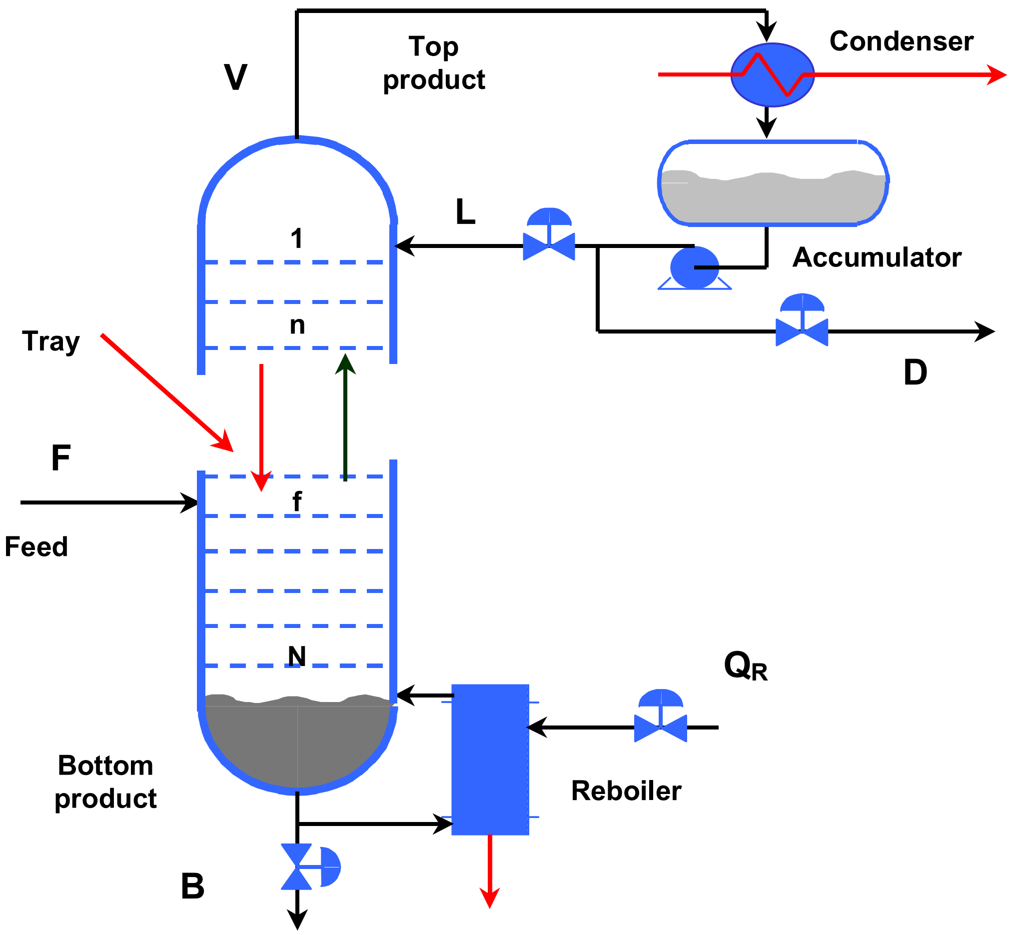

Figure Distillation column with inventory control