Analysis, Synthesis and Optimization of Multiple-Effect Evaporation Systems using Mathematical Programming

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Evaporation processes are used within the process industries in order to produce concentrated products by evaporating part of water from different feeds-diluted water solutions. Concentrated products can represent final products (fruit and vegetable juices) or intermediate products in cases that crystalized (salt, sugar) or dried (milk powder) final products should be produced. Large amounts of steam and cooling water are consumed in these processes. In order to reduce energy and water consumption within evaporation processes different systems can be applied, namely, multiple-effect evaporation, vapor recompression (thermal and mechanical) or their combinations. Additionally, these processes can be integrated with other process subsystems in order to achieve improved energy and water integration.

To address these issues different computer-aided tools have been proposed. However, most studies have focused on analysis and simulation of evaporation processes. Some of the initial studies [1, 2] considered the synthesis of evaporation processes in order to develop tools for computing the minimum utility use for a multiple-effect evaporation system, which was heat-integrated with process hot and cold streams. These studies were based on a modified grand composite curve and heat-path diagram. Also, the focus of the recent works have been on multiple-effect evaporation systems [3] and their energy integration with the background processes in order to minimize the energy consumption within the overall system [4]. These studies have motivated us to further expand research in this direction, by applying mathematical programming approach for the analysis of existing and the design of new evaporation systems as well as their heat integration with other process subsystems or process streams.

The main goal of this paper is to develop models based on mathematical programming that can be applied for the analysis, synthesis and optimization of multiple-effect evaporation systems. The proposed models will be developed in General Algebraic Modeling System (GAMS). The developed models will enable examination of different scenarios of multiple-effect evaporation in order to address the analysis of existing, retrofit and/or design new evaporation process. Within the proposed framework, a network consisting of a multiple-effect evaporation system and heat exchanger network will be investigated in order to achieve the improved heat integration within the overall system. Two strategies will be considered to achieve this task, namely, sequential and simultaneous. The developed models will be tested on several examples, and also applied to different feed streams. New results are expected to be obtained within this field.

Keywords: multiple-effect evaporation, analysis, synthesis, optimization, mathematical programming.

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