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Systematic approach for the synthesis of water and energy networks

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A B S T R A C T

In this paper a heuristic procedure for the synthesis of integrated water and thermal energy networks is presented. The procedure is based on process integration techniques and looks at design of networks that exhibit minimum water and energy consumption. The interrelations between of water and energy are analyzed and new insights are drawn that allow for the implementation of a systematic methodology. The approach starts with the use of a temperature vs. concentration diagram from which the water using structure is designed. Starting from an initial network configuration, the structure is further improved in order to minimize the external resources requirements. In addition, the use of non-isothermal mixing allows the reduction in the number of required heat exchangers. A case study from the open literature is used to show the application of the procedure.

1. Introduction

Energy and water are two major resources in process industries. To reduce their consumption, it is important to understand interactions between fresh water and primary energy requirements. As observed by Bagajewicz et al. [1], Sorin and Savulescu [12], and Martinez-Patiño [6] a simultaneous heat and mass transfer system contains three kinds of sub-networks, namely: Direct Heat Exchange Network, Indirect Heat Exchange Network and a Simultaneous Heat and Mass Transfer Network. A Direct Heat Exchange Network is a network of water streams where target temperatures are reached by their direct mixing. The Indirect Heat Exchange Network is an ordinary heat exchanger network where heat is transferred through heat exchangers. The Simultaneous Heat and Mass Transfer Network is a network of water streams coming out from the plant processes, where heat and mass are transferred simultaneously with target and constraints on temperatures and concentrations. A heat and mass transfer system is shown in Fig. 1.

Most of the recently published research on this subject is focused on simultaneous energy and water minimization design using heuristic rules [9–11] and optimization using mathematical programming [2,3].

Heuristic rules do not guarantee the reaching of the optimum design, however, it is a much faster method for producing preliminary designs. Besides, a heuristic approach brings out to light some insights that lead to deeper understanding of the interactions between energy and water consumption.

Savulescu et al. [10,11] in their work presented a heuristic methodology derived from the thermal pinch method [5]. They incorporate the concepts of water pinch methodology to determine the minimum consumption of fresh water and from this information, develop a two-dimensional diagram which includes the following variables: Temperature, concentration and stream flowrate. Out of this diagram, the required stream mixing that meets the required temperature and concentration in each operation is determined. This diagram also allows for the identification of those streams that require external heating or cooling. This information is then used to design the HEN that maximizes the energy recovery given the limitations imposed by the fresh water inlet temperature and the minimum allowed waste water discharge temperature.

In a recent paper by Polley et al. [9]; an equation to calculate the minimum external energy requirements for a water and energy network is proposed:

$$Q = \dot{m} \cdot c_p \cdot \Delta T_{min} \tag{1}$$

where Q is the external load requirements of the operations, $\dot{m}$ is the weather mass flowrate, c_p is the specific heat of water and ΔT_{min} is the minimum temperature difference between hot flows and cold flows allowed in the heat exchangers.

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