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Optimization techniques for heat exchanger networks using the minimum rule (MR)

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A B S T R A C T

Two aspects of the existing minimum rule (MR) are used in the optimization of heat exchange networks (HENs). One aspect is to use the minimum of the algebraic quantities Ω^1 and Ω^2 or the minimum of cold and hot stream heat capacity flowrates of each heat exchanger (HEX) in HEN optimization. The other aspect is the dependency (or relationship) between the input and output temperature differentials of each HEX in HEN. As a consequence of the first aspect, the number of constraints of the HEN optimization problems of HEN synthesis is reduced. The second aspect is used to reduce the calculations of the HEN HEXs' areas. The results obtained are demonstrated using no stream splitting and stream splitting synthesis formulations. In stream splitting formulation, HENs are composed of superstructures.

1. Introduction

Recently, in response to strict environmental regulations the petrochemical and chemical industries have adopted more efficient operations and implemented heat and process integration. One of these regulations is to make deep cuts in green house gases (GHGS) emissions in their operations. GHGS are responsible for global warming. In plant heat integration, the aim is to use hot streams to heat cold streams, i.e., to recover heat that would otherwise be lost. The use of heat integration schemes results in conservation of heat energy and reductions in utility requirements, energy consumption, and cost per unit of production. Efficient heat integration can be achieved by synthesizing optimal and practical heat exchanger networks (HENs).

HEN synthesis approaches can be broadly classified as mathematical optimization methods [19] and pinch technology [17]. The mathematical optimization methods involve the formulation of constrained optimization problem and the pinch technology is based on insights from the first and second laws of thermodynamics. While the HEN synthesis approaches using mathematical optimization methods such as the MINLP is sound and effective. However, in the proposed approach two ideas are introduced, one on reducing the number of constraints in the associated optimization problem and the other one is the use of one temperature differential at each HEX for calculating the HEX area. Applying these ideas, the proposed approach provides a simple-to-apply tool for HEN model optimization.

Gundersen and Naess [9], Jezowski [10,11], and Shenoy [23] presented excellent reviews of the developments in these areas. Another article by Furman and Sahinidis [8] provides an excellent review of HEN synthesis approaches. Recent work has incorporated techniques such as fuzzy logic [3], graph theory [24], and randomized algorithms [20]. The present author has developed synthesis technique based on minimum rule (MR) and its variations [21]. A recent article on process integration for energy and water minimization, and reduction of environmental impacts is given by Klemes et al. [12] Furthermore, an interesting article on sequential framework for HEX synthesis is proposed by Anantharaman et al. [1].

Salama [21] has proposed an algebraic HEN synthesis technique where four algebraic quantities Ω^1, Ω^2, Ω^3, and Ω^4 are introduced at each HEX. The HEX heat load Q is the minimum of Ω^1, Ω^2, Ω^3, and Ω^4 (or minimum rule MR). This process starts from the HEX which has no preceding HEXs and then proceeds in a sequential manner to synthesize a sub maximum energy recovery (MER) HENs. Once the heat load of the first HEX is determined the technique proceeds to the adjacent HEXs. This process is repeated to complete all the HEXs heat loads. Further, in the same paper, HEX Qs were allowed to vary within the bounds Ω^1, Ω^2, Ω^3, and Ω^4 of each HEX to optimize the HEN economics. Note that Ω^1 and Ω^2 are derived based on the input and output temperature differentials of each HEX and Ω^3 and Ω^4 are derived based on the availability of heat load to each HEX. The details

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