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Supply and target based superstructure synthesis of heat and mass exchanger networks

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ABSTRACT

This paper presents new methods for the optimisation of superstructures involving heat exchanger networks (HENs) and mass exchanger networks (MENs). The techniques developed in this study explore the use of key variables (namely supply temperatures/compositions and target temperatures/compositions) in HENs and MENs to define the intervals of superstructures. Such superstructures are modeled as mixed integer non linear programmes (MINLP) with the objective of minimisation of the total annual cost (TAC) for each network. The superstructures presented in this paper are derivatives of the interval and supply based superstructures (IBMS and SBS) developed previously. Two different superstructures are developed in this paper: the first uses the supply temperature/composition of hot/rich streams and the target temperature/composition of cold/lean streams (denoted supply and target based superstructure, S&TBS), while the second superstructure uses the target temperature/composition of hot/rich streams and the supply temperature of cold/lean streams (denoted target and supply based superstructure, T&SBS). Five HEN examples and three MEN examples are presented. The results obtained compare well with those in the literature.

Keywords: Heat exchanger networks; Mass exchanger networks; Superstructure; Total annual cost

1. Introduction

The tasks of synthesizing cost effective heat exchanger networks (HENs) and mass exchanger networks (MENs) have become key aspects of process synthesis. Heat exchanger network synthesis (HENS) has received much attention over the years. For example, Lee et al. (1970) formulated HENS problems using the branch and bound technique of Lawler and Wood (1966) with the aim of optimal energy exchange to obtain a network of minimum cost. In their formulation, no stream splitting was considered. The technique of Lee et al., though helped in the reduction of combinatorial difficulty in HENS, but the highest number of streams that has been solved in the literature by this technique is ten (Pho and Lapidus, 1973). Another shortcoming of the method of Lee et al. is the difficulty in obtaining cyclic structures; as such optimality cannot be guaranteed (Rathore and Power, 1975). Nishida et al. (1977) presented an algorithmic evolutionary synthesis method that appears to be more suitable for more sizable HENS problems but the approach is sequential.

Linnhoff and Flower (1978) presented a thermodynamically based temperature interval synthesis method from which the pinch concept for HENS developed. The method is premised on the basis that a cost effective network should exhibit a high degree of energy recovery. They subdivided their approach into two stages: in the first stage, a preliminary network that gives the highest possible energy recovery was generated, in the second stage; the preliminary network generated in the first stage served as the initial point to search for the most satisfactory network from the view points of cost, safety, and control, among other considerations.

In the application of pinch technology to process synthesis, the design requirement is that there should be no heat flow across the pinch. The first step is to determine the minimum energy consumption to obtain the annual operating cost (AOC) target. The network synthesis is then decomposed into subnetworks below and above the pinch, and the problem solved independently for each subnetwork, using heuristics to evolve networks with minimum units. This may be compared with the annual capital cost (ACC) target obtained from the pinch

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