Mixed-Integer Nonlinear Programming Models for Optimal Simultaneous Synthesis of Heat Exchangers Network

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Overview

In this optimization problem we develop two models for the optimal simultaneous synthesis of heat exchanger networks based on a given stage wise superstructure. The objective is to find a network design that minimizes the total annualized cost in the design, i.e. the investment cost in units and the operating cost in terms of utility consumptions. The models simultaneously determine the number of units and size of the heat exchangers, as well the heating and cooling utility consumption. Two mixed-integer nonlinear programming (MINLP) formulations of this problem are presented. All mass and heat balances are performed, and also feasibility and logical constraints. The first formulation is a general straightforward nonconvex MINLP with a nonconvex objective function and several nonconvex constraints. In addition, it involves the logarithmic mean temperature that can result in numerical difficulties when the approach temperatures of both sides of the heat exchanger are equal (it can causes division by zero). The second formulation is the specialized MINLP model by Yee and Grossmann (1990) that is obtained assuming isothermal mixing of the streams in the superstructure, which significantly simplifies the model formulation, since nonlinear heat balances can be eliminated. For each stream, only an overall heat balance must be performed within each stage. Furthermore, the heat capacity flowrates are fixed, and hence flow variables are no longer needed in the model. In addition, the logarithmic mean temperature is replaced by the Chen approximation (Chen, 1987), where no logarithmic terms are involved. Moreover, the areas are not treated explicitly as a variable and its expressions are substituted in the objective function. As a result, not only is the dimensionality of the problem is reduced, but the feasible space of the problem can be defined by a set of linear constraints. For this formulation, the nonlinearities are only involved in the objective function. When stream splits take place in the MINLP solution, an additional NLP model for fixed structure can be solved in order to remove the isothermal mixing assumption. Three examples are solved to illustrate the application of the models and compared their computational efficiency using MINLP solvers including Alpha-ECP, BARON, Bonmin, DICOPT and SBB.

Reference

1. *T. F. Yee, I. E. Grossmann, "Simultaneous Optimization Models for Heat Integration-II. Heat Exchanger Network Synthesis," Computers Chem. Eng., 1990, 14(10), 1165-1184.*