A RECURSIVE DESIGN METHOD FOR HEAT EXCHANGER NETWORKS

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Thesis submitted for the degree of

Doctor of Philosophy

March 2000

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ABSTRACT

Over the past two decades, considerable progress has been achieved in the energy integration problem. In spite of these efforts, limitations and drawbacks still exist in the current methods.

Mathematical programming methods, which formulate the heat exchanger network problem as a non-linear optimisation problem, are limited by available solvers such as GAMS. Sometimes it is difficult to achieve a global solution, particularly when the HEN problem size exceeds 10 streams. By contrast, a typical industrial problem normally consists of about 30-80 streams. This severely limits the application of mathematical programming methods in many instances.

Evolutionary methods such as Pinch Design Method have been successfully applied to industrial-scale heat exchanger network synthesis. However, the methods are more concerned with targeting rather than detailed design. These methods still encounter problems. For example, commencing a design from a MER design may lead to a very complex system which is sometimes difficult to evolve to the cost optimal design. As well, heuristic rules, which guide the match selection, may not achieve the desired objective and many alternatives may have to be explored. For a large problem, such an exhaustive search may be quite cumbersome. Finally, the cost laws associated with the problem are not incorporated into the match selection procedure until the final stages. The objectives of the design optimisation are the physical parameters: area, number of units and utility, rather than the cost. Consequently the trade-off between operating and capital investment is sometimes poorly addressed. These disadvantages may make it difficult to achieve a high quality design, especially for a large industrial scale problem.

In this study, a novel and reliable method for heat exchanger network synthesis is proposed. The prime objective of this work has been the elimination or reduction of drawbacks inherent in both evolutionary methods and mathematical programming methods whilst retaining the advantages of both methods.

This method is based on a new decomposition strategy coupled with a new match selection model and procedure for detailed design.

In this new method, decomposition for the problem is represented by a binary tree. First, the problem is treated as a root or parent entity. An index called the dominant cost component of the total annual cost is proposed and used to determine if further decomposition of the node is required (including the root node). If decomposition for the node is required, the node will be decomposed into two sub-nodes or child nodes. Each child node may be further subdivided until the solution is reduced.

Using the proposed binary tree decomposition strategy, the algorithm readily handles problems with considerably different film heat-transfer coefficients as well as problems with equal transfer coefficients whilst applying a consistent set of rules.

During the detailed design' stage, a new match selection method is used. It is based on a match selection model, derived from a simplified superstructure involving no interaction between individual matches. This match selection procedure builds the backbone of the design by finding an initial design. This method also provides a systematic design method for the parts of the streams distant from the pinch or partition temperatures.

The proposed match selection method significantly reduces the difficulties inherent in the heuristic rules proposed for match selection in the Pinch Design Method. The final design depends on the method itself rather than on the designer's bias as the rules are consistently applied.

To overcome the inaccuracies in trade-off between utility cost and capital cost in the evolutionary method, two optimisations, individual match cost optimisation and partition temperature optimisation, are undertaken at various steps in the design. Fortunately, these trade-offs do not require complex programming.

The new method is not sensitive to the size of the problem. It easily handles a variety of difficult situations, such as forbidden matches or imposed matches. Hence, safety consideration and layout constraints may be easily incorporated into the design.

The design method can also easily be extended into more detailed design. For example, if the costs and layout of the units are available, piping cost, power cost for pumping and cost for valves may be incorporated into the cost for an individual match right from the start.

An application of the new method to practical problem is demonstrated by case studies. One of the case studies is the well-known industrial scale Aromatics Plant. Designs from the new method are compared to the designs proposed by other researchers. The case studies confirm that the proposed method can achieve similar or better design quality. However, the design effort is significantly reduced.

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