APPLICATION OF GENETIC ALGORITHMS FOR DESIGNING COST OPTIMAL HEAT EXCHANGER NETWORKS

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Abstract— **Genetic Algorithms (GA) were implemented in a synthesis design procedure for cost optimal Heat Exchanger Networks (HEN). The procedure consisted of two coupled GAs: External GA to search the optimal HEN structure, and Internal GA to search the optimal split-fractions for each evaluated HEN structure. This design procedure was tested with five HEN synthesis cases; the configurations obtained were compared with other design procedures such as Pinch Method, Mathematical Programming (LP, MILP, MINLP and NLP models) and Stochastic methods (Genetics Algorithms, Tabu Search and Particle Swarm Optimization). In the cases 1 to 4, the ΔTmin value was taken from previous papers. In case 5 the ΔTmin value was optimized using a supertargeting routine available in the design algorithm proposed in this work. User-defined forbidden/desired matches can be easily implemented as target in the HEN design.**

Keywords— **Heat-Exchanger Network (HEN); Design synthesis; Stochastic Optimization; Genetic Algorithms.**

I. INTRODUCTION

Heat Exchanger Networks (HEN) are one of the most important components in chemical processes. In most cases, the HEN design determines energy efficiency of processes. A HEN consists of a group of cold streams exchanging heat with a group of hot streams. A cold stream is defined as a stream that has to be heated from a supply temperature to a higher final target temperature at which this stream is required for further stages in the process. On the other hand, a hot stream is defined as a stream that has to be cooled from a supply temperature to lower final target temperature (Biegler *et al.*, 1997).

The synthesis design problem analyzed in this paper is determining the optimal cost HEN structure required to take all process streams from their supply temperatures to their target temperatures.

There are three different synthesis approaches to solve this problem: Mathematical programming (Soršak and Kravanja, 2004; Biegler *et al.*, 1997; Zhu, 1997), thermodynamic (Linnhoff and Hindmarsh, 1983; Gundersen and Naess, 1988) and stochastic methods (Lin and Miller, 2004; Lewin *et al.*, 1998; Lewin, 1998). In this work a stochastic approach, Genetic Algorithms, is applied to design Cost Optimal HENs.

GAs are iterative and stochastic procedures, which attempt to emulate the evolution given in nature by applying genetic principles on a group of individuals. Each individual represents a potential solution to the problem. An encoding - decoding method has to be defined for each type of problem; usually, the encoded individual is a string of characters. Each encoded individual must represent one, and only one, potential solution. The initial population of individuals (possible solutions) is created randomly; each individual is evaluated by a fitness function (related to the objective function in the classical optimization approach); the result of this evaluation is the quantitative performance used by the GA to guide the search through the application of genetic operators. As a result, individuals evolve, improving the fitness value (Goldberg, 1989).

GAs performance is not affected by the problem of existence of the objective function derivative or badly behaved objective function surface. GAs are very useful when the behavior of the objective function is very noisy because sub-optimal solutions are not difficult to overcome with this technique. Since GAs examine several points (individuals) in each iteration (generation), good regions instead of good points are found in the search space (Goldberg, 1989). GAs have been previously applied to many fields including communication network design and decoding of LDPC codes (Scandurra *et al.*, 2006).

Nowadays, when faster machines are being available in the market at low cost, the computation resources required by GAs are easily fulfilled.

II. SYNTHESIS DESIGN ALGORITHM

The synthesis procedure used in this paper for designing cost optimal HENs consisted of two coupled GAs: External GA to search the optimal HEN structure, and Internal GA to search the optimal split-fraction vector for each evaluated HEN structure.

Only one type of cold utility and one type of hot utility are considered by the synthesis design procedure used here. Each stream was allowed to split in a maximum of two branches. Pipe costs are not taken into account.

The cost law for individual installed heat exchanger is shown in Eq. 1.

$$C_{exchanger} = FC + C_A S^m , \qquad (1)$$

where $C_{exchanger}$ is the present capital cost of each installed exchanger [US$], FC is the fixed charge [US$], S is the heat exchanger area [m^2], C_A is a cost coefficient per unit area [US$·m^{-2}], and m is the power for the area.