Design optimization of shell-and-tube heat exchanger using Rao algorithms and their variants

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ABSTRACT

Shell-and-tube heat exchangers (STHEs) are widely used type of heat exchangers in the industrial applications. Due to the high usage, it is essential to design the STHEs with minimum cost possible. The traditional method for achieving minimum cost involved manual calculations and re-iterating the same by changing few parameters until obtained the minimum solution. However, this method would require lots of efforts and time but ultimately it would still not guarantee the optimum solution. In this work, the design of STHE is obtained with the help of Rao Algorithms and their variants, which would bring the best solutions for the problem with a simple approach. Rao algorithms collectively include Rao-1 algorithm, Rao-2 algorithm and Rao-3 algorithm. The salient feature of these algorithms is that they do not require any algorithm-specific parameters and hence without working on the algorithm for finding its best suitable parameters, one can immediately apply the algorithm easily. These algorithms use the best and worst solutions for finding the optimal solution in the search space with the help of random interactions between the alternative solutions. The self-adaptive multi-population Rao (SAMP Rao) algorithms are the variants of Rao algorithms, and these algorithms adapt the population size automatically based on the fitness value of the objective function, thus eliminating the tuning of population size. In this study, four different case studies have been taken into consideration and the design optimization of these four shell-and-tube heat exchangers for minimum cost is performed using Rao and SAMP Rao algorithms. The cost includes the fixed and operating costs and is calculated from the pumping power. Discrete variables are also included in the study to have the advantage of these in real-life applications. These studies were previously carried out using seven different optimization algorithms and the results obtained now by Rao Algorithms and SAMP Rao algorithms are compared with them. The results showed a significant improvement in minimizing the cost of STHE. For multi-objective optimization, total cost and effectiveness are targeted and their solutions are obtained in the form of Pareto front. It is found that the Rao algorithms and the SAMP Rao algorithms have provided improved results compared to the other optimization algorithms.

Keywords: Shell-and-tube heat exchanger, Multi-objective optimization, Bell-Delaware method, Kern's method, Rao algorithms.

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