Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

APPLICATION OF METAHEURISTIC TECHNIQUES FOR THE OPTIMIZATION OF HEAT EXCHANGERS: A REVIEW

B.D. Raja[1], P.H. Darji[2], R.L. Jhala[3*]

[1] Mechanical Engineering Department, Indus University, Gujarat, India
[2] Mechanical Engineering Department, C.U.Shah University, Gujarat, India
[3] Mechanical Engineering Department, Marwadi University, Gujarat, India

Abstract- *Heat exchangers are used in industrial process to recover heat between two process fluids. Heat exchangers design includes an optimization process in which designers always consider certain objectives such as effectiveness, heat transfer amount, pressure drop, etc. depending on the requirements. While achieving these objectives, it is also desirable to minimize the total cost of the heat exchangers. Further, design optimization of a heat exchangers leads to a complicated objective function with a large number of design variables. Hence, it is necessary to apply advanced metaheuristic techniques for the optimization of heat exchangers. This paper presents the review of application of different advanced metaheuristic techniques for the optimization of various heat exchangers.*

***Keyword**: heat exchanger, optimization, metaheuristic algorithm*

I. INTRODUCTION:

Heat exchangers are used in industrial process to recover heat between two process fluids. Depending upon the application different types of heat exchanger are used in different processes [1]. The design of heat exchanger involves a large number of geometric and operating variables as a part of the search for an exchanger geometry that meets the heat duty requirement and a given set of design constrains. The conventional design method for heat exchanger applies an iterative procedure based on the design specification and assuming design variables for several configurations until one is found that meets the system heat duty and calculated pressure drops are below the maximum allowable values [2]. The final design which meets the design specifications has reasonable compromise between pressure drop and thermal exchanger performance. Typically, the use of this approach results in oversize equipment and complex design procedure. Considering the drawbacks of traditional optimization techniques, attempts are being made to optimize the heat exchangers by using advanced metaheuristic techniques. The remaining paper discussed the optimization of various heat exchangers through different metaheuristic techniques.

II. SHELL AND TUBE HEAT EXCHANGER OPTIMIZATION:

Shell and tube heat exchanger (STHE) are widely used in refineries and petrochemical industries, power generation, refrigeration, heating and air conditioning applications. Previously, several investigators had used different optimization techniques with different methodologies and objective to optimize STHE. Mohanty [3] carried out the work for economic optimization of STHE. He used gravitational search algorithm as an optimization tool and focus on optimization of total annual cost of STHE. Wong et al. [4] used NSGA-II for the simultaneous optimization of capital cost and operating cost of STHE. Amin and Bazargan [5] considered increment in heat transfer rate and decrement in total cost of the heat exchange as objective functions for multi-objective optimization of STHE. They employ eleven decision variables and pressure drop constraint in their investigation with genetic algorithm. Hadidi and Nazari [6] employed biogeography-based optimization (BBO) algorithm for cost minimization of STHE. The authors solved three test case of STHE to demonstrate the effectiveness of BBO approach.

Rao and patel [7] perform the multi-objective optimization of STHE with heat transfer rate and total cost of the heat exchanger as objective functions. The authors used modified version of teaching learning based optimization (TLBO) algorithm as an optimization tool. Wen et al. [8] obtained a Pareto front between heat transfer rate and total cost of the helical baffle STHE. The authors had demonstrate the comparison between optimized and conventional STHE design. Guo et al. [9] applied field synergy principle to optimized STHE design. The authors had considered field synergy number maximization as an objective function and employed genetic algorithm to solve optimization problem. Caputo et al. [10] presented a new mathematical model for manufacturing cost estimation of STHE. The authors had carried out the parametric analysis to obtain the optimum length to diameter ratio of STHE. Hajabdollahi et al. [11] perform economic optimization of STHE with nine decision variables and genetic algorithm as an optimization tool.

Khosravi et al. [12] investigates the performance of three different evolutionary algorithms for economic optimization of STHE. Sadeghzadeh et al. [13] demonstrate techno-economical optimization of STHE design with genetic and Particle swarm optimization algorithm. Yousefi et al. [14] implemented NSGA-II to for the optimization of STHE used for exhaust heat recovery in hybrid PV-diesel power systems. Hajabdollahi and Hajabdollahi [15] investigate the effect of nanoparticles in the thermo-economic optimization of STHE. Yousefi et al. [16] perform thermo-economic optimization of STHE for nanofluid based heat recovery systems. Raja et al. [17] performed the many objective optimization of STHE using multi-objective heat transfer search algorithm.

III. PLATE FIN HEAT EXCHANGER OPTIMIZATION:

Plate-fin heat exchanger (PFHE) belongs to the category of compact heat exchanger due to its large heat transfer surface area per unit volume. PFH are widely used in air separation plants, liquefaction plants, aerospace, and cryogenics applications. Earlier, several investigators used various optimization techniques to optimize PFHE. Wen et al. [18] carried out a thermodynamic optimization of PFHE. The authors considered two conflicting objectives namely, Colburn factor and friction factor for optimization and used Genetic algorithm (GA) as an optimization tool. Du et al. [19] focused on a double flow plate-fin heat exchanger for improving its thermal and hydraulic behaviour using GA. Turgut [20] investigated Hybrid Chaotic Quantum behaved Particle Swarm Optimization algorithm for minimizing the heat transfer area and total pressure drop of PFHE. Sanaye and Hajabdollahi [21] performed a simultaneous optimization of total cost and effectiveness using a design which featured NSGA-II and PFHE. Rao and patel [22] performed a multi-objective optimization of PFHE with effectiveness and total cost of heat exchanger as objective functions. The authors used modified version of teaching learning based optimization algorithm as optimization tool.

Wang and Li [23] introduced and applied an improved multi-objective cuckoo search algorithm for optimization of PFHE. The authors considered conflicting thermo-economic objectives for optimization. Hajabdollahi [24] investigated the effect of non-similar fins in thermo-economic optimization of plate fin heat exchanger. They considered total annual cost and effectiveness of heat exchanger as objective functions and utilized NSGA-II for optimization. Hadidi [25] employed biogeography-based optimization algorithm for optimization of heat transfer area and total pressure drop of the PFHE. Patel and Savsani [26] obtained a Pareto front between conflicting thermodynamic and economic objectives of PFHE by implementing multi-objective improved TLBO algorithm.

Wang et al. [27] presented few layer pattern criterion models to determine optimal stacking pattern of multi-stream plate-fin heat exchanger. Authors had developed these models by employing genetic algorithm and observed that the performance of MPFHE in relation to heat transfer and fluid flow was effectively improved by the optimization design of layer pattern. Zaho and Li [28] developed an effective layer pattern optimization model for multi-stream plate-fin heat exchanger using genetic algorithm. Zhou et al. [29] presented an optimization model for PFHE based on entropy generation minimization method. They considered specific entropy generation rate as an objective function and total heat transfer area of PFHE as a constraint. Yousefi et al. [30] presented a learning automata based particle swarm optimization employed to multi-stage thermo-economical optimization of compact heat exchangers. Raja et al. [31] adopted heat transfer search algorithm for the many objective optimization of PFHE.

IV. FIN AND TUBE HEAT EXCHANGER OPTIMIZATION:

A fin and tube type heat exchanger (FTHE) are widely used in power engineering, and automobiles such as compressors, intercoolers, air coolers and fan coils. Earlier, few works has been reported related to optimization of FTHE using various optimization algorithms. Xie et al. [32] used mathematical based traditional optimization technique to carry out the optimum design of fin and tube heat exchanger. The authors had considered minimization of total annual cost of FTHE as an objective function. Xie et al. [33] used GA for minimization of a total annual cost and a total weight of FTHE. Tang et al. [34] applied GA for optimization of heat transfer performance of FTHE. The authors investigated various fin patterns to reach at optimized design. Pacheco-Vega et al. [35, 36] used SA and GA for the prediction of fin-tube heat exchanger performance. Raja et al. [37] adopted heat transfer search algorithm to identify the minimum weight and minimum total cost design of FTHE. The authors also performed the sensitivity analysis to identify the feasible design space of the FTHE.

V. PLATE HEAT EXCHANGER OPTIMIZATION:

Plate heat exchanger (PHE) is belonging to compact heat exchanger. PHEs are widely used in Petroleum, chemical processing, food & beverages, cryogenics, and pharmaceutical industries.

Earlier, researchers had carried out different types of numerical works to optimize PHEs design with different methodologies. Hajabdollahi et al. [38] obtained optimized geometric parameters of gasket plate heat exchanger for maximum effectiveness and minimum total cost by adapting NSGA-II. Hajabdollahi et al. [39] presented the comparative study of gasket plate and shell and tube heat exchangers from the economic point of view by using a GA. Najafi and Najafi [40] performed a multi-objective optimization of PHE with pressure drop and heat transfer coefficient of a heat exchanger as objective functions. The authors used NSGA-II as an optimization tool. Lee and Lee [41] carried out a thermodynamic optimization of PHE using GA. The authors considered two conflicting objectives namely, Colburn factor and friction factor for optimization.

Arsenyeva et al. [42] proposed mathematical model based area optimization of a multi-pass plate-and-frame heat exchanger. Gut and Pinto [8, 9] presented a mathematical model of plate heat exchanger [43] and perform shape optimization [44] of that model. Further, authors presented a screening method for selection of optimal configurations of plate heat exchangers. Wang and Sunden [45] used derivative-based optimization method for the economic optimization of plate heat exchanger. Durmus et al. [46] carried out an experimental investigation of plate heat exchanger having different surface geometry. They proposed heat transfer, and friction factor correlations for plate heat exchanger. Zhu and Zhang [47] perform area optimization of plate heat exchanger used for the geothermal application. Raja et al. [48] performed the thermal-hydraulic optimization of plate heat exchanger using heat transfer search algorithm.

VI. CONCLUSION:

Researchers had applied different advanced metaheuristic techniques for the optimization investigation of various heat exchangers. Researchers carried out the optimization of heat exchangers for single objective, multi-objective and many-objective considerations. The objective considered for the optimization of heat exchangers are thermodynamics or economics e.g. effectiveness maximization, cost minimization, pressure drop minimization, overall heat transfer co-efficient maximization, entropy generation minimization, weight minimization etc. Further it can be observed from the literature that advanced metaheuristic techniques results in better design of heat exchanger as compared to traditional approach.

REFERENCES

[1] R.K. Shah, P. Sekulic, Fundamental of Heat Exchanger Design, Wiley, 2003
[2] R. Selbas, O. Kızılkan, M. Reppich, A new design approach for shell-and-tube heat exchangers using genetic algorithms from economic point of view, Chem. Eng. Process. 45 (2006) 268–75
[3] D.K. Mohanty, Gravitational search algorithm for economic optimization design of a shell and tube heat exchanger, Appl Therm Eng 107 (2016) 184-193
[4] J.Y.Q. Wong, S. Sharma, G.P. Rangaiah, Design of shell-and-tube heat exchangers for multiple objectives using elitist non-dominated sorting genetic algorithm, Appl Therm Eng 93 (2016) 888-899
[5] M. Amini, M. Bazargan, Two objective optimization in shell-and-tube heat exchangers using genetic algorithm, Appl Therm Eng 69 (2014) 278-285
[6] A. Hadidi, A. Nazari, Design and economic optimization of shell-and-tube heat exchangers using biogeography-based (BBO) algorithm, Appl Therm Eng 51 (2013) 1263-1272
[7] R.V. Rao, V.K. Patel, Multi-objective optimization of heat exchangers using a modified teaching learning based optimization algorithm, Appl Math Model 37 (2013) 1147–1162
[8] J. Wen, H. Yang, G. Jian, X. Tong, K. Li, S. Wang, Energy and cost optimization of shell and tube heat exchanger with helical baffles using, Int J Heat Mass Tran 98 (2016) 29–39
[9] J. Guo, M. Xu, L. Cheng, The application of field synergy number in shell-and-tube heat exchanger optimization design, Appl Energ 86 (2009) 2079–2087
[10] A.C. Caputo, P.M. Pelagagge, P. Salini, Manufacturing cost model for heat exchangers optimization, Appl Therm Eng 94 (2016) 513–533
[11] H. Hajabdollahi, M. Naderi, S. Adimi, A comparative study on the shell and tube and gasket-plate heat exchangers: The economic viewpoint, Appl Therm Eng 92 (2016) 271-282
[12] R. Khosravi, A. Khosravi, S. Nahavandi, H. Hajabdollahi, Effectiveness of evolutionary algorithms for optimization of heat exchangers, Energ Convers Manage 89 (2015) 281–288
[13] H. Sadeghzadeha, M.A. Ehyaeib, M.A. Rosen, Techno-economic optimization of a shell and tube heat exchanger by genetic and particle swarm algorithms, Energ Convers Manage 93 (2015) 84–91
[14] M. Yousefi, J.H. Kim, D. Hooshyar, M. Yousefi, K.S.M. Sahari, R.B. Ahmad, A practical multi-objective design approach for optimum exhaust heat recovery from hybrid stand-alone PV-diesel power systems, Energ Convers Manage 142 (2017) 559-573
[15] H. Hajabdollahi, Z. Hajabdollahi, Assessment of nano particles in thermo-economic improvement of shell and tube heat exchanger, Appl Therm Eng 106 (2016) 827–837
[16] M. Yousefi, D. Hooshyar, J.H. Kim, H. Lim, Modeling and thermo-economic optimization of a biomass heat recovery exchanger operating on nanofluid, Int Commun Heat Mass 82 (2017) 63-73
[17] B.D Raja R.L. Jhala, V.K. Patel, Many objective optimization of shell and tube heat exchanger, Thermal Science and Engineering Progress 2 (2017) 87–101
[18] J. Wen, H. Yang, X. Tong, K. Li, S. Wang, Y. Li, Optimization investigation on configuration parameters of serrated fin in plate-fin heat exchanger using GA, Int J Therm Sci 101 (2016) 116-125
[19] J. Du, Y.M. Ni, Y.S. Fang, Correlations and optimization of a heat exchanger with offset fins by genetic algorithm combining orthogonal design, Appl Therm Eng 107 (2016) 1091-1103.

[20] O.E. Turgut, Hybrid Chaotic Quantum behaved Particle Swarm Optimization algorithm for thermal design of plate fin heat exchangers, Appl Math Model 40 (2016) 50-69.
[21] S. Sanaye, H. Hajabdollahi, Thermal-economic multi-objective optimization of plate fin heat exchanger using genetic algorithm, Appl Energ 87 (2010) 1893-1902
[22] R.V. Rao, V.K. Patel, Multi-objective optimization of heat exchangers using a modified teaching-learning based optimization algorithm, Appl Math Model 37 (2013) 1147-1162.
[23] Z. Wang, Y. Li, Irreversibility analysis for optimization design of plate fin heat exchangers using a multi-objective cuckoo search algorithm, Energ Convers Manage 101 (2015) 126-135.
[24] H. Hajabdollahi, Investigate the effect of non-similar fins in thermo-economic optimization of plate fin heat exchanger, Appl Therm Eng 82 (2015) 152-161.
[25] A. Hadidi, A robust approach for optimal design of plate fin heat exchangers using biogeography based optimization algorithm, Appl Energ 150 (2015) 196-210.
[26] V.K. Patel, V.J. Savsani, Optimization of a plate-fin heat exchanger design through an MO-ITLBO algorithm. Chem Eng Res Des 92 (2014) 2371-2382.
[27] Z. Wang, Y. Li, M. Zhao, Experimental investigation on the thermal performance of multi-stream plate-fin heat exchanger based on genetic algorithm layer pattern design, Int J Heat Mass Tran 82 (2015) 510-520.
[28] M. Zhao, Y. Li, An effective layer pattern optimization model for multi-stream plate-fin heat exchanger, Int J Heat Mass Tran 60 (2013) 480-489.
[29] Y. Zhou, L. Zhu, J. Yu, Y. Li, Optimization of plate-fin heat exchangers by minimizing specific entropy generation rate, Int J Heat Mass Tran 78 (2014) 942-946.
[30] M. Yousefi, A.N. Darus, D. Hooshyar, Thermal-economical optimization of compact heat exchangers: a new evolutionary-based design approach, Appl Therm Eng 83 (2015) 71-80.
[31] B.D. Raja, R.L. Jhala, V.K. Patel, Many-objective optimization of cross flow plate fin heat exchanger, Int J Therm Sci 118 (2017) 320-339
[32] Xie GN, Chen QY, Tang LH, Zeng M, Wang QW. Thermal design and comparison of two FTHE. In: Proceedings of Heat Transfer Technology. China; 2005. pp. 8-11
[33] Xie GN, Wang WQ, Sunden B. Application of a genetic algorithm for thermal design of fin-and-tube heat exchangers. Heat Transfer Eng 2008; 29(7):597-607.
[34] Tang LH, Zeng M, Wang QW. Experimental and numerical investigation on air-side performance of fin-and-tube heat exchangers with various fin patterns, Exp Therm Fluid Sci 2009; 33:818-827
[35] A Pacheco-Vega, M Sen, K.T. Yang. Correlations of fin-tube heat exchanger performance data using genetic algorithm, In: Proceedings of ASME heat transfer, vol. 369. USA; 2001, pp. 143-151
[36] A Pacheco-Vega, M Sen, K.T. Yang. Simultaneous determination of in-and-over-tube heat transfer correlations in heat exchangers by global regression. Int J Heat Mass Tran 2003; 46(6):1029-1040.
[37] B.D. Raja, R.L. Jhala, V.K. Patel, Thermal design and optimization of fin-and-tube heat exchanger using heat transfer search algorithm', Thermal Science and Engineering Progress 4 (2017) 45–57
[38] F. Hajabdollahi, Z. Hajabdollahi. Optimum design of plate heat exchanger using multimodal genetic algorithm, Heat Transfer Research 44 (2013) 1–19
[39] Hajabdollahi H, Naderi M, Adimi S. A comparative study on the shell and tube and plate heat exchangers: Appl Therm Eng 92 (2016) 271–282
[40] Najafi H, Najafi B. Multi-objective optimization of a plate and frame heat exchanger via genetic algorithm, Heat Mass Transfer 46 (2010) 639–647
[41] Lee J, Lee KS. Friction and Colburn factor correlations and shape optimization of chevron-type plate heat exchangers, Appl Therm Eng 89 (2015) 62-69.
[42] Arsenyeva OP, Tovazhnyansky LL. Optimal design of plate and frame heat exchangers for efficient heat recovery, Energy 36 (2011) 4588–4598
[43] Gut JAW, Pinto JM. Optimal configuration design for plate heat exchangers, Int J Heat Mass Transf 47 (2004) 4833–4848
[44] Gut JAW, Pinto JM. Modeling of plate heat exchangers with generalized configurations, Int. J Heat Mass Transf 46 (2003) 2571–2585
[45] Wang L, Sunden B. Optimal design of plate heat exchangers with and without pressure drop specifications, Appl Therm Eng 23 (2003) 295–311
[46] Durmus A, Benil B, Kurtbas I, Gul H. Investigation of heat transfer and pressure drop in plate heat exchangers, Int J Heat Mass Transf 52 (2009) 1451–1457
[47] Zhua J, Zhang W. Optimization design of plate heat exchangers for geothermal heating systems. Geothermics 33 (2004) 337–347
[48] B.D. Raja, R.L. Jhala, V.K. Patel, Thermal-hydraulic optimization of plate heat exchanger: A multi-objective approach. Int J Therm Sci. 124 (2018) 522–535

