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OPTIMUM AIR COOLING COST BY T.L.B.O.

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Abstract

This paper presents the performance of the Teaching-Learning-Based Optimization (T.L.B.O.) algorithm for the optimum design of an air cooling system. The optimal cost of an air cooling system is investigated using the TLBO algorithm and compared with other optimization algorithms, including the Lagrange Multipliers (LM) method, Differential Evolution (DE) algorithm, and Particle Swarm Optimization (PSO) algorithm. TLBO is a recently proposed population-based algorithm that simulates the teaching-learning process in a classroom. This algorithm requires only the common control parameters and does not require any algorithm-specific control parameters. Computational results demonstrate that the TLBO algorithm is successfully applied to the air cooling system, exhibiting better performance compared to other optimization algorithms considered for this problem.

Keywords: *TLBO algorithm, Optimum cost, Air cooling system*

1. Introduction

Over the last decade, the interest of researchers is optimization of mechanical thermal system design in order to improve system performance using advanced optimization techniques. In the present work design optimization of air cooling system is considered. There are several published research papers on thermal system optimization using various optimization methods. Ozcan et al. [1] discussed the optimum cost of air cooling system. The authors used Differential Evolution (DE) and Particle Swarm Optimization (PSO) algorithms for optimization of the cost of an air cooling system. Lee et al. [2] employed DE to solve the optimal chiller loading problem for reducing energy consumption. Khademi et al. [3] had also been applied DE to optimize a reactor for methanol synthesis and the simulation results had shown that there are optimum values of initial molar flow rate of both of exothermic and of endothermic stream, inlet temperature of exothermic, endothermic and permeation sides, and inlet pressure of exothermic side for maximizing the objective function. Optimum cost of heat exchanger network has been determined by usind D.E. in Yerramsetty and Murty [4] and model had been applied to the case studies available in the literature. An improved DE algorithm for economic load dispatch problems solving which takes into account non-linear generator features was proposed in Coelho and Mariani [5] and resulted that DE outperforms other state of the art algorithms reported in the literature. Chang et al. [6] used Genetic Algorithms (GA) for air-conditioning applications and discussed the performance of genetic algorithms comparing Lagrangian Methods (LM). PSO had applied to optimize chiller loading by Ardakani et al. [7]. Lee et al. [8] used PSO to developed optimum optimal operating conditions of an ice storage air conditioning system. Wang et al. [9] used PSO to validate its applicability on a hybrid energy generation unit. They carried out the cost optimization of air cooling system using LM, DE and PSO. Constraints of the system are based on the energy equilibriums of including devices and energy equations of these devices were individually analyzed and constraints are created. LM, DE and PSO methods were applied to the system using MATLAB and results were comparatively discussed. There are many nature-inspired optimization algorithms, such as the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Ant Colony Optimization (ACO), Harmony Search (HS), the Grenade- Explosion Method (GEM), etc. working on the principle of different natural phenomena. These algorithms have been applied to many engineering optimization problems and proven effective in solving these problems.

Meta-heuristic applications have evolved a lot nowadays and have been used in many domains. However, their parameter setting stills, till now, a serious problem which influences their efficiency and their attitude. Many optimization methods require algorithm parameters that affect the performance of the algorithm. Rao et al. [10] introduced the Teaching Learning-Based Optimization (TLBO) algorithm, as an innovative optimization algorithm inspiring the natural phenomena, which mimics teaching-learning process in a class

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between the teacher and the students (learners). TLBO does not require algorithm parameters initial tuning, thus making the implementation of TLBO simple. TLBO algorithm requires only the common control parameters and does not require any algorithm-specific control parameters [11]. Hence in this paper the application of TLBO algorithm to design an air cooling system is considered. Next section gives brief description about the TLBO algorithm.

2. Teaching Learning Based Optimization

TLBO algorithm is a teaching-learning process inspired algorithm proposed by Rao et al. [10,11] based on the effect of influence of a teacher on the output of learners in a class. The algorithm describes two basic modes of the learning: (i) through teacher (known as teacher phase) and (ii) interacting with the other learners (known as learner phase). In this optimization algorithm a group of learners is considered as population and different subjects offered to the learners are considered as different design variables of the optimization problem and a learner's result is analogous to the 'fitness' value of the optimization problem. The best solution in the entire population is considered as the teacher. The design variables are actually the parameters involved in the objective function of the given optimization problem and the best solution is the best value of the objective function. The working of TLBO is divided into two parts, 'Teacher phase' and 'Learner phase'. The next section explains the details of the experiments on design optimization of air cooling system.

3. Experiments on Design Optimization

This section presents the optimization of optimum cost of an air cooling system using the TLBO algorithm. The problem formulation of cost optimization of air cooling system is explained as follows in [1]. The schematic representation of an air cooling system is shown in Fig. 1. Between two stages of air compression, air is cooled from an input temperature to the desired value using a pre-cooler and a refrigeration unit. The heat provided by air is rejected to a water circuit by both pre-cooler and refrigeration unit and heated water is cooled in a cooling tower. The power input to the water cycle is provided by a pump. Constraints for optimization of the air cooling system are created by the energy transformation of the system. The elements of the mathematical statement of optimization include specification of the function and the constraints. As the cost of the system depends strongly on the energy transfer of the system, energy equations for the whole system should be created. The system is to be designed for minimum first cost, where the first cost of the refrigeration unit, pre-cooler and cooling tower, designated as x_1, x_2, and x_3 respectively in dollars. Since the pre-cooler is a simple heat exchanger, under most operating condition it is less costly for a given heat transfer rate than the refrigeration unit. It would appear preferably, then, to do, as much cooling of the air as possible with the pre-cooler. However, as the temperature t_3 approaches to the value of t_1, the size of the pre-cooler becomes very large. Some capacity is required of the refrigeration unit in order to cool the air below a desired temperature. The cooling tower must reject all the heat from the system, which includes the heat from the air as well as the compression power to drive the refrigeration unit. Shifting more cooling load refrigeration unit increases the size and cost of the cooling tower moderately. The first assignment is to develop expression for the objective function for the system and setting up constraints. After setting up energy and mass balances, a choice must be made of all variables of the system and all constraints should be eliminated in to independent variables since these variables are a part of objective function. The most straightforward choice is to use the component costs. If heat fluxes or temperature are used as optimization variables, it is necessary to express all terms related to each other.

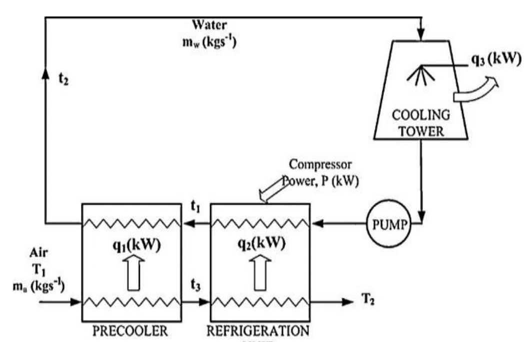

Fig. 1. Schematic representation of air cooling unit

The energy mass balances set up for each balances is as follows [1].

Refrigeration unit :

$$q_1 + P = m_w C_{p.w}(t_1 - T_{CT}) \quad (1)$$

Precooler :

$$m_a C_{p.a}(T_1 - t_3) = m_w C_{p.w}(t_2 - t_1) \quad (2)$$

Cooling tower :

$$q_3 = m_w C_{p.w}(t_2 - T_{CT}) \quad (3)$$

The complete set of constraints is as follows :

$$q_1 = m_a C_{p.a}(t_3 - T_2) \quad (4)$$

$$q_2 = m_a C_{p.a}(T_1 - t_3) \quad (5)$$

$$P = 0.25 q_1 \quad (6)$$

$$x_1 = 48 q_1 \quad (7)$$

$$x_2 = \frac{50 q_2}{t_3 - t_1} \quad (8)$$

$$x_3 = 25 q_3 \quad (9)$$

$$q_1 + P = m_w C_{p.w}(t_1 - T_{CT}) \quad (10)$$

$$m_a C_{p.a}(T_1 - t_3) = m_w C_{p.w}(t_2 - t_1) \quad (11)$$

$$q_3 = m_w C_{p.w}(t_2 - T_{CT}) \quad (12)$$

There are nine equations in the set and ten unknowns. q_1, q_2, q_3, x_1, x_2, x_3, t_1, t_2, t_3, P. The next operations will be elimination and setting up constraints as functions of independent variables. As the elimination of variables and equations proceeds, there will always be one more unknown than the number of equations, so when all but three *x's* are eliminated, there should be two equations remaining. Hence, the complete mathematical statement of this optimization is as follows:

Minimize :

$$y = \sum_{i=1}^{n} x_i \quad (13)$$

Subject to

$$0.01466 x_1 x_2 - 14 x_2 + 1.042 x_1 = 5100 \quad (14)$$

$$7.69 x_3 - x_1 = 19615 \quad (15)$$

4. Experimental Results and Discussion

To check the effectiveness of the TLBO algorithm extensive experiments are conducted on an air cooling system from the literature and results are compared with the other optimization algorithms. Like other optimization algorithms, TLBO algorithm also has not any special mechanism to handle the constraints. So, for the constrained optimization problems it is necessary to incorporate any constraint handling techniques with the TLBO algorithm.

In the present experiments, Deb's heuristic method is used to handle the constraints with the TLBO algorithm. Deb's method uses a tournament selection operator in which the two solutions are selected and compared with each other. The TLBO code is written in MATLAB and implemented on a laptop having Intel core i3 2.53 GHz processor with 1.85 GB RAM.Table 1 gives the set of values five values taken for different experiments. A set of values at an interval of are considered. The obtained result values for Lagrange Multipliers (LM), Differential Evolution (DE) algorithm, Particle Swarm Optimization (PSO) and TLBO algorithm with number of iterations (It.) of 50, 100 and 200 are given in the following Table2 , Table 3, Table 4 and Table 5. DE & PSO do not yield optimum value in 50 iterations in some of the instances. While TLBO algorithm gives optimum values in all the instances of 50 iterations. Thus TLBO algorithm had ability to provide optimum value in any such instances.

5. Conclusions

In this paper, performance of TLBO algorithm for the design optimization of air cooling system is investigated. Total cost of the system is dependent strongly on varying temperatures and mass flow rates of the system. Best cost values are obtained when air mass flow rates, input and output air temperature difference and cooling tower exit temperatures are lower and water mass flow rate is higher. The results have satisfactory performance of the TLBO algorithm for the design optimization of air cooling system. Therefore, it can be stated that the TLBO algorithm is an effective algorithm and has a great potential for solving the design optimization of air cooling system. The TLBO is proven algorithm and can be tried on more complex problems in future.

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Table 1 - Thermodynamic data for constrainted setup

ΔT	**m_w**	**m_a**	**T_{CT}**
70	1.7	0.6	18
75	1.9	0.8	20
80	2.1	1.0	22
85	2.3	1.2	24
90	2.5	1.4	26
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85	2.3	1.2	24
90	2.5	1.4	26

Table 2 - Comparion of optimization methods *ΔT* values

ΔT	LM	DE		PSO		TLBO		
It.		50	100	50	200	50	100	200
70	4102	4102	4102	12357	4102	4102	4102	4102
75	4298	5301	4298	17426	4298	4871	4298	4298
80	4491	6032	4491	11240	4491	4989	4491	4491
85	4683	5741	4683	17251	4683	4887	4683	4683
90	4873	4657	4873	12325	4873	4873	4873	4873

Table 3:Comparion of optimization methods m_a values

m_a	LM	DE		PSO		TLBO		
It.		50	100	50	200	50	100	200
0.6	2281	2876	2281	33215	2281	2398	2281	2281
0.8	3067	3067	3067	31121	3067	3067	3067	3067
1.0	3867	3867	3867	27541	3867	3867	3867	3867
1.2	4683	4683	4683	18895	4683	4683	4683	4683
1.4	5517	6670	5517	24156	5517	5517	5517	5517

Table 4:Comparion of optimization methods m_w values

m_w	LM	DE		PSO		TLBO		
It.		50	100	50	200	50	100	200
1.7	4798	4798	4798	8924	4798	4798	4798	4798
1.9	4742	4742	4742	9213	4742	4742	4742	4742
2.1	4709	4709	4709	11254	4709	4709	4709	4709
2.3	4683	4683	4683	7542	4683	4683	4683	4683
2.5	4663	4663	4663	10201	4663	4663	4663	4663

Table 5:Comparion of optimization methods T_{CT} values

T_{CT}	LM	DE		PSO		TLBO		
It.		50	100	50	200	50	100	200
18	4277	4277	4277	14218	4277	4277	4277	4277
20	4413	4413	4413	9857	4413	4413	4413	4413
22	4548	4548	4548	11124	4548	4548	4548	4548
24	4683	4683	4683	21563	4683	4683	4683	4683
26	4819	4683	4683	7523	4819	4819	4819	4819

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