A Brief Study on TLBO Algorithm and Its Applications on Mechanical Engineering Field: A Review

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Abstract

Different processes subjected to mechanical engineering field optimized by the Teaching-learning-based optimization (TLBO) algorithm are presented in this review paper. The main focus is on the optimization of the various processes subjected to mechanical engineering by TLBO algorithm. The review work on mechanical engineering process, on such a large scale was not performed earlier by considering different processes at a time on TLBO algorithm, and hence, this review work may be prepare for the future information at one place for the subsequent researchers, in order to determine their way of research on TLBO algorithm. The machining processes that have been considered in this work are Optimization of two stage thermoelectric cooler, Laser Cutting, Disassembly Sequence Planning, Job Shop Scheduling Problems, Machining, Four-Bar Linkage Path Generation, fused deposition modeling process, assembly line balancing, End milling, Face Milling, Drilling, Turning, Grinding, Electric Discharge Machining.

Keywords: *TLBO algorithm, Laser cutting, Scheduling, Path generation, End milling, Face Milling, Drilling, Turning, Grinding, Electric Discharge Machining.*

1. Introduction

Optimization of any process can be defined as “the discipline of adjusting a process so as to optimize some specified set of parameters without violating some constraint.” And also in other word “The action of making the best or most effective use of a situation or resource.” Most common goals of optimization techniques are to minimizing cost and maximizing throughput and/or efficiency. This is one of the major quantitative tools in industrial decision making.

Some of the recognized revolutionary algorithms are: Genetic Algorithm (GA), Evolution Programming (EP), Bacteria Foraging Optimization (BFO), Artificial Immune Algorithm (AIA), Evolution Strategy (ES), Differential Evolution (DE), etc. Some of the well-admitted swarm intelligence based algorithms are: Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Shuffled Frog Leaping (SFL), Fire Fly (FF) algorithm, Artificial Bee Colony (ABC), etc. Besides the swarm intelligence based and revolutionary algorithms, there are some algorithms which works on the principles of different natural phenomena are: Grenade Explosion Method (GEM), Gravitational Search algorithm (GSA), Biogeography-Based Optimization (BBO), Harmony Search algorithm (HSA), etc.

The TLBO algorithm is also a popularly used algorithm for optimization of any process. This review paper is based only on the brief study of TLBO algorithm and its applications in mechanical engineering field. Mechanical engineering is divided into different sub stream viz. Production engineering, Design engineering, thermal engineering, industrial engineering etc. Production and Manufacturing engineering operation transforms bulk material into finished goods. This transformation process can be done by place the material together, by movement of material from one workstation to another and subtracting unwanted or scrap material, advancements have taken place in all of methods. Of the above methods, traditional/conventional processes are being followed to process materials that are within some level of condition of hardness. Researchers gave a major emphasis in conventional/traditional and non-traditional/unconventional optimization techniques in process optimization. They researched on both single pass and multi-pass problems. In modern production, to determine optimum cutting parameters is one of the importances to improve the quality of goods, to maximize the profit rate and to reduce the machining costs.

Also in thermal engineering with the help of TLBO algorithm parameters of cooling process, heat engines and performance of rotary regenerator can also be optimized. In design engineering design can be differentiate as a goal-oriented, constrained, decision making process to create goods that satisfy human needs. Design optimization consists of certain goals called objective functions, a search space called feasible solutions and a search process called optimization methods. The feasible solutions are set of all designs characterized by all possible solutions of the design parameters called design variables. The optimization searches for the optimum design from all available feasible designs. Mechanical design comprise an optimization process in which designers always study certain objectives such as weight, strength, deflection, corrosion, wear etc. depending on the requirements. However, design optimization for a mechanical assembly leads to a puzzled objective function with a more number of design variables. So it is good to apply optimization techniques for intermediate assemblies rather than a complete assembly.

2. Teaching-learning-based optimization algorithm (TLBO) –

TLBO is effective than other met heuristics according to its characteristics viz. less computation effort, Parameter less, and high consistency. It outperforms some of the known met heuristics concerning continuous non-linear numerical optimization problems, constrained benchmark functions, constrained mechanical design. It is being utilized by various researchers as a replacement for the other techniques available. Such a breakthrough has governed Crepinšek et al [19], towards investigating the puzzle of TLBO‘s dominance. They examined some mistakes regarding TLBO by experiments and code-reviews respectively. However, Waghmare [1] in commented on the work performed by Crepinšek et al. He not only addressed the queries erected by Crepinšek et al, But also re-examined the results obtained by experiment, which demonstrates that the TLBO performs well on the issues where the fitness-distance correlations are low by proper adjustments of the common control parameters of the algorithm. TLBO has been used by a many researchers to resolve their problems and found it more effective than other. Krishnan et al [5] have applied a multi-objective teaching-learning-based optimization algorithm with application in electric power dispatch. Rao and Patel [4] in explored the use of ABC algorithms and TLBO for determining the optimal operating conditions of combined Brayton and also in inverse Brayton cycles. Rao et al [3] in proposed the optimization of design problems using TLBO and examined it on five different constrained benchmark test functions with different characteristics, six mechanical design

optimization problems and four different benchmark mechanical design problems. González-Álvarezetat al. [14] in proposed Multi-objective TLBO for examining Motif Discovery Problem and solved a set of 12 biological instances subjected to different organisms. Rao and Patel [23] established and investigated the influence of elitism on the performance of a teaching-learning -based algorithm while solving unconstrained benchmark problems and complex constrained optimization problems. Population size and Number of generations, these two parameters affect the performance of TLBO are also examined. Rajasekharet al.[2] in introduced a new variant of TLBO, termed as Elitist Teaching-Learning Opposition based Algorithm for numerical function optimization, which is empowered with 2 mechanisms, one is Opposition method (helps to improve the capability of searching) and second is elitism, to reach the accurate global optimal with less time complexity. Rao and Patel [2] in proposed a modified version of the TLBO algorithm and applied this for the multi-objective optimization of heat exchangers. Pawar and Rao [7] presented TLBO to find the optimal process parameters of the milling, abrasive water jet, and grinding machining processes. Rao and Kalyankar [9] are applied TLBO for optimization of the process parameter of electrochemical discharge machining (ECDM) and electrochemical machining (ECM) process. Rao et al. [12] in proposed TLBO to solve continuous constrained and unconstrained constrained optimization problems.Niknam et al. [13] in introduced a θ-multi-objective-TLBO algorithm to examine the dynamic economic emission dispatch problem.

2.1. Algorithm

In teaching-learning-based (TLBO) Algorithm teacher and learners are the two significant components. This describes two basic techniques of the learning, through teacher, known as teacher phase and interacting with the other learners, known as learner phase. Teacher is usually considered as an eminently learned person who trains learners so they can have best results in terms of their grades and marks. Moreover, learners also learn from the cooperation among themselves, which also helps in enhancing their results. TLBO is population based method. In this algorithm a group of learners is taken as population and different design variables are taken as different subjects offered to the learners and learners' result is synonymous to the fitness value of optimization problem. In the population the best solution or result is considered as the teacher. TLBO mainly working of two phases, namely:

1. Teacher phase.
2. Learner phase.

TLBO Algorithm is presented in figure.1.

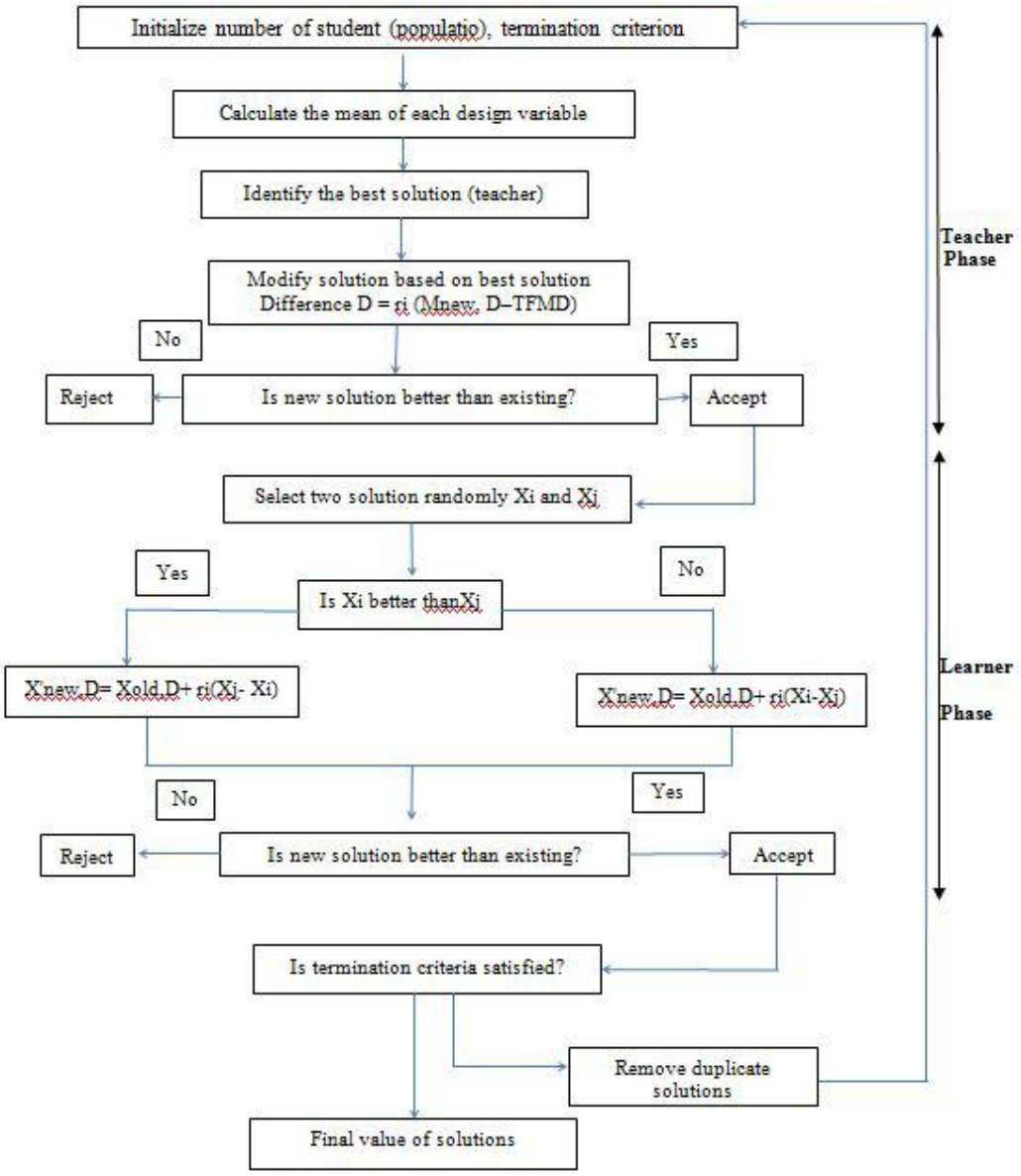

Figure 1: Flow Chart for Teaching-Learning-Based Optimization (TLBO).

2.2. Teacher Phase

Teacher phase is the 1st phase of TLBO algorithm. In this teacher will try to improve or refine mean of class .A best teacher is one who brings his/ her learners up to his or her level in terms of all kind knowledge. But in practice this is difficult to possible and a teacher can only improve the mean of a learner or class up to some extent depending on the ability of the learners or class. This follows a random process depending on factors. Generate the random population according to the population size and number of generations [6]. Calculate the mean of the population, which will give the mean for the particular subject as

M,D = [m1, m2, …….mD]. The best solution will act as a teacher for that iteration teacher = Xf(X) =min .The teacher will try to shift the mean from MD towards X teacher which will act as a new mean for the iteration. So,

Mnew, D =X teacher D. (1)

The difference between two means is expressed as
Difference D = ri (Mnew, D–TFMD) (2)

Where, ri is the random number in the range [0, 1], the value of Teaching Factor (TF) is considered 1 or 2. The obtained difference is added to the current solution to update its values using

X new, D = Xold, D + Difference D (3)
Accept Xnew if it gives better function value.

2.3. Learner Phase

A learner interacts randomly with other learners for strengthen his or her knowledge [4]. Randomly select two learners Xi and Xj.

X'new,D= Xold,D+ ri(Xi-Xj) if f (Xi) <f (Xj) (4)
X'new,D=Xold,D+ ri(Xj-Xi)if f(Xi)>f(Xj) (5)

Termination criterion: Stop if the maximum generation number is achieved otherwise repeat from Step Teacher phase Implementation steps of the TLBO are summarized below:
Step 1: Initialized the population (i.e. learners') and design variables of the optimization problem (i.e. number of subjects offered to the learner) with random generation and evaluate them.
Step 2: Select the best learner of each subject as a teacher for that subject and calculate mean result of learners in each subject.
Step 3: Evaluate the difference between current mean result and best mean result according to equation (1) by utilizing the teaching factor (TF).
Step 4: Update learner's knowledge with the help of teacher's knowledge according to equation (3)
Step 5: Update the learner's knowledge by utilizing the knowledge of some other learner according to equations (4) and (5).
Step 6: Repeat the procedure from step 2 to 5 till the termination criterion is met.

3. Applications of Teaching-learning-based optimization algorithm (TLBO) – Literature Review

TLBO algorithm can be used in many problems for optimize the result and improve the process. In mechanical engineering field the TLBO algorithm used in different sub areas or sub streams, viz. thermal engineering, manufacturing engineering, design engineering, industrial engineering etc. Some of those are listed below-

Table 1: Application of TLBO algorithm

S. No.	Author(s)/ year	Process	Inputs parameter	Output parameters	Another algorithm	Remark
1	Ravipudivenkata Rao and Vivek D. Kalyankar 2012 [23]	Continuous Casting Process	Stroke, casting speed, frequency and deviation from sinusoid(fitness)	Minimization of peak friction, oscillation marks maximization of lubrication index,	DE, GA	TLBO algorithm has taken very fewer number of generations for convergence when compared to that taken by DE and GA
2	R. Venkata Rao, V.D. Kalyankar, G. Waghmare 2014	Die casting	Die temperature, Holding furnace temperature, Plunger velocity in the second stage, Plunger velocity in the first stage, Multiplied pressure	Porosity	GA	TLBO algorithm is negligible compared to GA and proved its capabilities in the field of parameters optimization of die casting.
3	R. Venkata Rao n, V.D. Kalyankar 2013	AJM	Mean radius of abrasive particles, mass flow rate of abrasive particles, velocity of abrasive particles	Material removal rate	SA GA	Considered both brittle and ductile materials MRR is batter then both SA and GA algorithm.
4	R V Rao, V D Kalyankar [18] 2011	ECM	Electrolyte flow rate, electrolyte concentration, applied voltage, inter-electrode gap	Radial overcut, material removal rate.	ABC	Can perform on both Single and multiobjective optimization problem. Require a minimum number of iteration than ABC. also require low number of population to ABC for similar result
5	R. Venkata Rao n, V.D. Kalyankar [19] 2013	USM	Frequency of vibration, amplitude of vibration, , volumetric concentration of abrasive particles in slurry, mean diameter of abrasive grains static feed force	MRR	GA, PSO, ABC, HSSFL	TLBO algorithm requires comparatively less number of function evaluations then other.
6	Ranjan Kumar Hasda [17] 2013	EDM	Average gap voltage, Pulse-on time, Peak	Material removal rate, surface finish	ABC, GA, ACO,	Can perform on both single and multiobjective

			current, Percent volume fraction of sic	tool wear rate gap size,	BBO	optimization problems. TLBO gives better results in all 4 variables then other algorithm
7	R. V. Rao1 & V. D. Kalyankar [14] 2011	Grinding	Wheel speed, lead of dressing, work piece speed, depth of dressing.	Production cost, surface roughness, production rate.	SA, HA, ABC	TLBO gives improvement over the traditional optimization technique like quadratic programming, and in advanced optimization techniques like SA, HS and ABC
8	*Kai Xia, Liang Gao, Lihui Wang, Weidong Li, Kuo-Ming Chao 2013*	Disassembly Sequence Planning	Joints, components	Order in which these joints are to Be broken and the components removed		Modified TLBO, STLBO was used
9	Linna Li, Wei Weng, Shigeru Fujimura	Job Shop Scheduling Problems	Job ,machine	Completion time	ITLBO	Improve TLBO gives better result compare to basic TLBO and other algorithm
10	Vivek Patel, Vimal Savsani 2015	Optimization of a Stirling heat engine	Temperature pressure etc	Maximization of Thermal efficiency, output power and minimization of total pressure drop of the engine		Multi-objective TS-TLBO algorithm has Been used to solve the multi-objective optimization problem of Stirling heat engine.
11	S. Radhika, Ch. Srinivasa Rao, D. Swapna, B. Purna Chandra Sekhar	Effective Master Production Schedule	Available capacity, Average inventory level, Standard lot size etc.	FITNESS, EI, RNM, BSS Etc	MPS GA	Improvement in performance by using MOTLBO
12	R. Venkata Rao, V.D. Kalyankar, G. Waghmare 2014	Continuous casting process	Stroke, Viscosity, frequency, temperature, flux solidus drain rate, mould length ,flux density,	Total loss function	SA	TLBO give better result compare than SA method
13	R. Venkata Rao, V.D. Kalyankar, G. Waghmare 2014 [22]	Squeeze casting process	Die preheating temperature, Squeeze pressure, and compression holding time. Melt temperature,	Maximum hardness , ultimate tensile strength.	Taguchi method	Taguchi's orthogonal array was used to conduct the number of experiments

14	R. Venkata Rao, V.D. Kalyankar [15] 2013	Multi-pass turning	Speed feed, cutting force, cutting depth of cut, cutting power,	Production time, used tool life		Dark portion are constraints Light portion are variable
15	R. Venkata Rao n, V.D. Kalyankar 2013	WEDM	Surface roughness, pulse on time, pulse off time, servo feed setting, and peak current.	Cutting speed	PSO HSM ,SA SFL, ABC ,	Dark portion are constraints Light portion are variable less iteration &better result than other
16	Zhibozhai, Shujuan Li, Yong Liu [20] 2015	Milling Process	Feed per tooth, cutting velocity.	Profit rate.	NTLB O	Pocket milling, Slot milling, Face milling, Corner milling,

4. Discussion –

Rao et al. (2011, 2012, 2013, and 2014) demonstrated that TLBO requires a few number of function evaluations compared to other algorithms. It can be seen from the review of applications of teaching-learning-based algorithm that the algorithm has been effectively applied by many researchers in different mechanical engineering fields such as Electric Discharge Machining, Grinding, Milling, Drilling, Turning, Abrasive Jet Machining, Ultrasonic Machining, Laser Beam Machining, MPS, Micro Machining Electrochemical Machining, job scheduling laser cutting balancing etc. The number of applications of TLBO algorithm including basic and modified versions of TLBO is increasing at a faster rate and it clearly shows the potential of the TLBO algorithm. The TLBO algorithm gave better performance result with less computational effort for large scale problems, i.e. It may be specified here that, in general, algorithm which requires less number of function evaluations to get the same and best solution or result may be taken as a better algorithm compared to the other algorithms.

The solution obtained by using TLBO techniques were compared with the other optimization algorithms available in literature such as ABC, EP PSO, DE, etc. for the benchmark problems considered. Solution had shown the acceptable performance of TLBO algorithm for constrained optimization problems. Computational experiments were conducted for same number of function evaluations applied by the other algorithms. The Teaching-learning-based algorithm has never claimed for it is a parameter-less algorithm. What it has claimed for that it requires only common parameters: like population size and number of generations to tune and it do not need algorithm-specific parameters unlike other algorithms. The common control parameters are needed by all the algorithms and no algorithm is exceptional in this issue (and how parameters are tuned is another issue),and it is to be understood by Črepinšek et al. (2014) that the GA algorithm needs algorithm-specific parameter(s) in addition to the common parameters and TLBO needs only the common parameters. More details about the TLBO algorithm can be obtained from https://sites.google.com/site/tlborao/

Some advancement is also performed in basic TLBO algorithm which are:

1. Elitist TLBO algorithm.
2. Improved TLBO (I-TLBO) algorithm.
3. Modified TLBO algorithm
4. Multi-objective TS-TLBO algorithm, etc.

TLBO algorithm is also used in other engineering fields like computer science engineering, electrical engineering, civil engineering etc

5. Conclusion -

In this review paper, TLBO algorithm is one of the techniques that can be used to optimize mechanical engineering processes. This method has proved to generate better results compared to other similar optimization technique like GA, ABC, PSO, SA, and Taguchi Method. It requires a lesser number of iterations and produce higher specific results, which is better when compared to other algorithms. Some new advanced optimization technique TLBO has also developed, which is based on the influence of the influence of a teacher on the output of learners in a group or class. This algorithm also confirmed to be best in electronics engineering, chemical engineering, thermal engineering, civil engineering production engineering. Besides engineering field, it techniques gives its best in the Process Planning, biomedical field, maintenance field. This can also be used in more number of constraints and multi-objective functions. Concept of duplicate solution removal and elitism can also be implemented in the TLBO algorithm techniques. TLBO techniques are an algorithm-specific parameter which needs only common control parameters, such as number of generations, population size and elite size.

References

[1.]Rao, R. Venkata, and G. G. Waghmare. Journal of King Saud University-Computer and Information Sciences 26.3 (2014): 332-346.
[2.]Rao, R. Venkata, and Vivek Patel. Applied Mathematical Modelling 37.3 (2013): 1147-1162.
[3.]Rao, R., and Vivek Patel. International Journal of Industrial Engineering Computations 3.4 (2012): 535-560.
[4.]Venkata Rao, R., and Vivek Patel. Engineering Optimization 44.8 (2012): 965-983.
[5.]Ramanand, K. R., et al. Swarm, evolutionary, and memetic computing.Springer Berlin Heidelberg, 2012.476-483.
[6.]Rao, R. V., and V. D. Kalyankar.-"Grinding parameters selection using TLBO method."
[7.]Pawar, P. J., and R. Venkata Rao. The International Journal of Advanced Manufacturing Technology 67.5-8 (2013): 995-1006.
[8.]Rajasekhar, Anguluri, et al. Systems, Man, and Cybernetics (SMC), 2012 IEEE International Conference on IEEE, 2012.
[9.]Rao, R. Venkata, and V. D. Kalyankar. Engineering Applications of Artificial Intelligence 26.1 (2013): 524-531.
[10.]Rao,RavipudiVenkata&Vivek D. Kalyankar.-Swarm, Evolutionary, and Memetic Computing.,Springer Berlin Heidelberg 2012.540.
[11.]Rao, R. Venkata, and V. D. Kalyankar. Engineering Applications of Artificial Intelligence 26.1 (2013): 524-531.
[12.]Rao, R. V., V. J. Savsani, and D. P. Vakharia. Information Sciences 183.1 (2012): 1-15.
[13.]Azizipanah-Abarghooee, Rasoul, et al. Energy 37.1 (2012): 322-335.
[14.] Gonzalez-Alvarez, David L., et al. Computational Intelligence and Informatics , 2012 IEEE 13th International Symposium on.IEEE, 2012.
[15.] Dewangan, Shailesh, C. K. Biswas, and RitanjaliSethy.- "Multiple Response Optimisation of EDM Process Using Grey-Fuzzy Logic."
[16.]Rakesh Kumar Sahu,SaurabhVerma,Santosh Kumar Mishra 2394-6210.
[17.] Sarah, P.,S. Rajendar, and K. Venkateshwarlu,Vardhaman College of Engineering. (2014).
[18.]Rao, R. V., and V. D. Kalyankar EPPM, Singapore 20 (2011): 21-31.
[19.] Črepinšek, Matej, Shih-Hsi Liu, and Luka Mernik. Information Sciences 212 (2012): 79-93.
[20.]Zhai, Zhibo, Shujuan Li, and Yong Liu. Mathematical Problems in Engineering,2015.
[21.] Hasda, Ranjan Kumar. Optimization of EDM Process Parameters through Teaching Learning Based Optimization Algorithm. Diss. National Institute of Technology, Rourkela, India, 2013.
[22.]Rao, R. Venkata, V. D. Kalyankar, and G. Waghmare. Applied Mathematical Modelling 38.23 (2014): 5592-5608.

[23.]. 547Rao, R., and Vivek Patel. International Journal of Industrial Engineering Computations 4.1 (2013): 29-50.
[24.] Rao, R. Venkata, and V. D. Kalyankar. Scientia Iranica 20.3 (2013): 967-974.
[25.]Priyadarshini, M., et al. Materials Today: Proceedings 2.4 (2015): 1518-1532.
[26] G.D. Gautam, A.K. Pandey, Teaching Learning Algorithm based Optimization of Kerf Deviations in Pulsed Nd:YAG Laser Cutting of Kevlar-29 Composite Laminates, Infrared Physics & Technology (2017).
[27] Kai Xia, Liang Gao, Lihui Wang, Weidong Li, Kuo-Ming Chao, A Simplified Teaching-Learning-Based Optimization Algorithm for Disassembly Sequence Planning, 2013 IEEE
[28] Linna Li, Wei Weng, Shigeru Fujimura, An Improved Teaching-Learning-Based Optimization Algorithm to Solve Job Shop Scheduling Problems, 2017 IEEE
[29] S. Sleesongsom , S. Bureerat , Four-Bar Linkage Path Generation through Self-Adaptive Population Size Teaching-Learning Based Optimization, Knowledge-Based Systems (2017).
[30] A. Baykasog˘lu et al., Testing the performance of teaching–learning based optimization (TLBO) algorithm on combinatorial problems: Flow shop and job shop scheduling cases, Inform. Sci. (2014)
[31 Shubham V. Kothavade and S.P. Deshpande,to Solve Assembly line balancing problem 2016, E-ISSN 2277 – 4106
[32] Bansi D. Raja, R.L. Jhala, Vivek Patel, Multi-objective optimization of a rotary regenerator using tutorial training and self-learning inspired teaching-learning based optimization algorithm (TS-TLBO), Applied Thermal Engineering (2015)
[33] S. Radhika, Ch. Srinivasa Rao, D. Swapna, B. Purna Chandra Sekhar,Teaching Learning Based Optimization Approach for the Development of an Effective Master Production Schedule, 2017 ISSN: 2277 128X