Optimization of WEDM machining process parameters with Modified TLBO method

O.Y. VENKATA SUBBA REDDY
Department of Mechanical Engineering, MRCET, Hyderabad, India

S. VIVEKANANADA
Department of Mechanical Engineering, MRCET, Hyderabad, India

V.GOPALA KRISHNA
Department of Mechanical Engineering, MRCET, Hyderabad, India

ABSTRACT

Wire Electrical Discharge Machining (WEDM) is a non-traditional machining process where intricate and complex shapes can be machined. Conductive materials can be machined and it is one of the important machining processes for machining high strength temperature-resistant (HSTR) alloys. For achieving the best performance of the WEDM process, it is crucial to carry out parametric design responses such as Material Removal Rate, Tool Wear Rate, and surface roughness etc. It is essential to consider the important process parameters in order to find the optimal result.

In the present work Modified Teaching-Learning-Based optimization (TLBO) algorithm has been applied for optimization of the responses of WEDM process. The optimization performance of the modified TLBO algorithm is compared with that of other population-based algorithms, e.g., TLBO, genetic algorithm (GA), ant colony optimization (ACO), and artificial bee colony (ABC) algorithm. It is observed that the modified TLBO method provides the better results rather than the others with respect to the optimal process response values.

Keywords: Modified Teaching-Learning-Based optimization, Genetic Algorithm, Wire Electrical Discharge.

1. INTRODUCTION

Wire Electrical discharge machining is one of the most important non-convectional machining processes. it is widely used for pattern and die preparing industries, it is also used for refining intricate shapes in components used for the electric and aerospace industries. By the principle of electro thermal mechanism material is removed from the work piece with the help of the tool which is moved in a desire path. By a series of discrete discharges between electrode and work piece takes for material removal. Due to series of discrete discharge creates sparks and result in high temperatures instantaneously, up to about 10000° C. In order these temperatures are huge enough to melt and vaporize the work piece metal and the eroded debris cools down swiftly in working liquid and flushed away.

Jaganjeet Singh and Sanjeev Sharma Vol.3, No.5 (December 2013) evaluate the effects of process parameters of WEDM like pulse on time (TON), pulse off time (TOFF), gap voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT) have been investigated to reveal their impact on material removal rate and surface roughness of aluminum H-13. The optimal set of process parameters has also been predicted to maximize the material removal rate and minimize the surface roughness & finally concluded that the Parameters Wire Tension, Wire Feed not highly contribute in MRR whereas by increasing the value of parameter Pulse ON Time the MRR also increases & by increasing the value of parameter Pulse Off Time & Servo Voltage the MRR decreases. By increasing the parameters wire Tension, Pulse off time & Servo voltage the value of Ra also increases whereas by increasing the Value of Parameters Wire Feed, Pulse ON Time the value of Ra decreases & for parameter Peak current the value of Ra first decreases and then there is some increase in the value

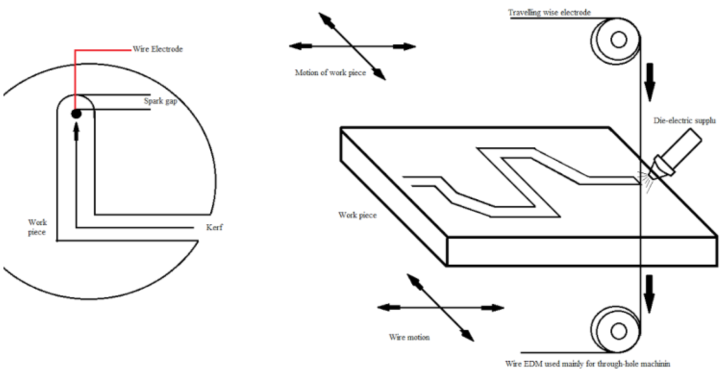

Figure 1. Working principle of WEDM

Jaganjeet Singh and Sanjeev Sharma Vol.3, No.5 (December 2013) evaluate the effects of process parameters of WEDM like pulse on time (TON), pulse off time (TOFF), gap voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT) have been investigated to reveal their impact on material removal rate and surface roughness of aluminum H-13. The optimal set of process parameters has also been predicted to maximize the material removal rate and minimize the surface roughness & finally concluded that the Parameters Wire Tension, Wire Feed not highly contribute in MRR whereas by increasing the value of parameter Pulse ON Time the MRR also increases & by increasing the value of parameter Pulse Off Time & Servo Voltage the MRR decreases. By increasing the parameters wire Tension, Pulse off time & Servo voltage the value of Ra also increases whereas by increasing the Value of Parameters Wire Feed, Pulse ON Time the value of Ra decreases & for parameter Peak current the value of Ra first decreases and then there is some increase in the value.

Rao et al. (2011) proposed a teaching–learning based optimization (TLBO) algorithm based on the natural phenomenon of teaching and learning. TLBO is an algorithm-specific parameter-less algorithm. The implementation of TLBO does not require the determination of any controlling parameters which makes the algorithm robust and powerful. In this work, some modifications to the standard TLBO algorithm are introduced and the performance of the modified TLBO algorithm is investigated for multi-objective optimization of a two stage TEC considering two conflicting objectives cooling capacity and COP. Two different configurations of TECs, electrically separated and electrically connected in series are investigated for the optimization. Moreover, the contact and spreading resistance of TEC are also considered. The ability of the proposed algorithm is demonstrated by using an example and the performance of the modified TLBO algorithm is compared with the performance of basic TLBO and GA. Improvements in the results are observed using the basic TLBO and modified TLBO algorithms as compared to the GA approach showing the improvement potential of the proposed algorithm for such thermodynamic optimization.

H. Singh and R. Garg et .al, 2009 evaluates the effects of various process parameters of WEDM like pulse on time (TON), pulse off time (TOFF), gap voltage (SV), peak current (IP), wire feed (WF) and wire tension (WT) have been investigated to reveal their impact on material removal rate of Hot die steel (H-11) using one variable at a time approach. The optimal set of process parameters has also been predicted to maximize the material removal rate & finally concluded that the wire feed and wire tension are neutral input parameters. The material removal rate (MRR) directly increases with increase in pulse on time (TON) and peak current (IP) while decreases with increase in pulse off time (TOFF) and servo voltage (SV).

S. B. Prajapati and N. S. Patel et .al, 2013 evaluates the effect of process parameter like Pulse ON time, Pulse OFF time, Voltage, Wire Feed and Wire Tension on MRR, SR, Kerf and Gap current is studied by conducting an experiment. Response surface methodology is used to analyze the data for optimization and performance. The AISI A2 tool steel is used as work piece material in the form of square bar. & finally concluded that for cutting rate and surface roughness, the pulse ON and pulse OFF time is most significant. The spark gape set voltage is significant for kerf. Lokesh Goyat, Rajesh Dudi and Neeraj Sharma et .al, 2013 have discuss and investigate the significant process parameters along with the percentage contribution of each parameter. ANOVA is used to find the percentage contribution of significant process parameters. Response surface methodology is used for the planning of experiments and D-2 tool steel is used as a work-piece. D2 tool steel used in tools, punches and die industries. The analysis of results indicates that pulse on servo voltage have the maximum effect in single parameter compared to pulse off time and peak current during the investigation of cutting rate on WEDM for D-2 tool steel.

Kuriachen Basil, Dr. Josephkunju Paul and Dr. Jeoju M.Issac et .al, 2013 evaluates the effect of voltage, dielectric pressure, pulse on-time and pulse off-time on spark gap of Ti6AL4V alloy. It is found that the pulse on time, pulse off time, the interaction of dielectric pressure and pulse off time, and interaction of pulse on time and pulse off time are significant parameters which affect the spark gap of WEDM. Minimum spark gap can be obtained by adopting a low value of pulse on time (20 μs), a high value of dielectric pressure (15 kgf/cm2), high value of pulse off time (50 μs) and voltage of 50V.

From the above literature review it is concluded that the following are the most important process parameter which effects the efficacy and efficiency of the machine

Input parameters of WEDM

1. Electrical parameters
    - Pulse Duration
    - Pulse Interval
    - Servo Voltage
    - Peak current
    - Gap Voltage
2. Electrode wire
    - Wire Material
    - Wire Size
    - Wire Tension
    - Wire Feed
3. Dielectric Fluid
    - Dielectric Flow Rate
    - Dielectric Conductivity
4. Work Piece Related Parameters
    - Work Piece Material
    - Work Piece Size

2. METHODOLOGY

A. Design of experiments:

Most important parameters in WEDM like polarity, voltage, pulse on/off time, ignition pulse current, injection pressure, electric temperature, pulse width, pulse duration, wire tension and wire feed speed which can be changed during the machining process. Selection of process parameters and experimental design is considered for optimization tasks in machining process. In this research experimental design is done by using Taguchi Method which is explained. In this research work the performance of the WEDM process on H13 material has been studied by considering the various performance measures (material removal rate, surface flatness) by taking different input parameters (pulse on time, pulse off time, voltage and wire feed). After literature review and based on the experienced persons review the range of input parameters has been decided, which is given in the Table 1

Table (1): Parameters with Range

S. No	Machining parameter	Range	
		Lower	Upper
1	Pulse on time	115	125
2	Pulse off time	50	60
3	Voltage	100	180
4	Wire feed	3	7

Based on the above information we create a taguchi design with three levels of each factor have been selected and L9 orthogonal array has been prepared as suggested by Taguchi, which is given in Table 2.

Table (2): Parameters with different levels

S. No	Machining parameter	Levels		
		Level 1	Level 2	Level 3
1	Pulse on time	115	120	125
2	Pulse off time	50	55	60
3	Voltage	100	140	180
4	Wire feed	3	5	7

Table (3): Design of experiments

S. No	Pulse on time	Pulse off time	Voltage	Wire feed
1	115	60	100	3
2	115	55	140	5
3	115	50	180	7
4	120	60	180	7
5	120	55	140	3
6	120	50	100	5
7	125	60	180	5
8	125	55	100	7
9	125	50	140	3

By using the above design experiments done on the work piece in WEDM machine. After completion of the experiments the output parameter MRR are calculated by using the formulae and surface roughness of the work piece was measured with the help of Tally surf meter equipment.

Material removal rate is calculated by using the formula

MRR = Wire feed*Thickness*Speed

Where wire feed and speed are collected will doing each experiment on work piece and thickness of the tool is constant i.e. 19 mm.

Table (4): Design of experiments with MRR & Ra values

S. No	Input parameters				Output parameters	
	Pulse on time	Pulse off time	Voltage	Wire feed	MRR	Ra
1	115	60	100	3	4.28196	370.500
2	115	55	140	5	4.20100	490.865
3	115	50	180	7	4.49271	653.961
4	120	60	180	7	4.66329	609.539
5	120	55	140	3	4.90687	232.731
6	120	50	100	5	4.86654	278.635
7	125	60	180	5	5.13371	368.885
8	125	55	100	7	4.90617	469.889
9	125	50	140	3	4.85829	169.119

By using the above values, we are going to generate the regression equation for material removal rate and surface roughness using regression technique in MINITAB17 software. These regression equations will relate the output parameters with the input parameters.

Developed equation from the MINITAB software is shown in below

MRR = 1501-16.9*x1+8.24*x2+0.569*x3+80.1*x4

Ra = -3.02 + 0.0641*x1 + 0.0046*x2 + 0.00199*x3 + 0.0013*x4

These multi objective functions are converted into single objective function by using operation research techniques. One of the techniques is by using the formula

Objective function = Min (Max (MRR)-Min (Ra))

That is single objective function is given as

Objective function = Min (1501-16.9*x1 + 8.24*x2 + 0.569*x3+80.1*x4)

– (-3.02+0.0641*x1- 0.0046*x2 +0.00199*x3+0.0013*x4)

Taking this as input to the MATLAB code we are going to get the optimized values.

3. EXPERIMENTAL RESULTS

A. Modified TLBO:

The modified TLBO algorithm presented for Wire electric discharge machining process is coded in MATLAB. So that when the inputs are given to the wire EDM process then the program executes and results will be displayed on the command window.

Inputs given to the code are:

- Number of design variables
- Ranges for each design variable
- Population size
- No of iterations

Outputs are:

- Material removal rate
- Surface roughness

B. Experiment by using modified TLBO technique:

After generating the code in M-File we are going to execute this by using the run button. Then the program start executing from generation of population to the display of outputs i.e., MRR and Ra

Input:

Number of design variables	= 4		
Population size	= 50		
Number of iterations	= 100		
Ranges for each design variable			
Pulse on time	115	to	125
Pulse off time	50	to	60
Voltage	100	to	180
Wire feed	3	to	7

Based upon this factors program generates its initial population and then fitness values are calculated by using the regression equation

Fitness = (1501-16.9*x1+8.24*x2+0.569*x3+80.1*x4)
- (-3.02+0.0641*x1- 0.0046*x2+0.00199*x3+0.0013*x4)

Among those all values one value is displayed based on the objective function. The value is shown below.

OUTPUT:

OPT_VAL =125.0000 50.0000 100.0001 3.0000
Fitness = 92.7356

By using this input design factor values it calculates the output parameter values i.e., MRR & Ra. Those values are

Surface roughness, Ra = 4.9654
Material removal rate, MRR = 97.7010

C. Genetic Algorithm

This output values are then compared with the results obtained from Genetic Algorithm technique. In MATLAB there is an inbuilt tool for genetic algorithm i.e., OPTIMTOOL by using this tool we are going obtain the results. The input parameters for GA also same as modified TLBO but the way to link up with tool is different.

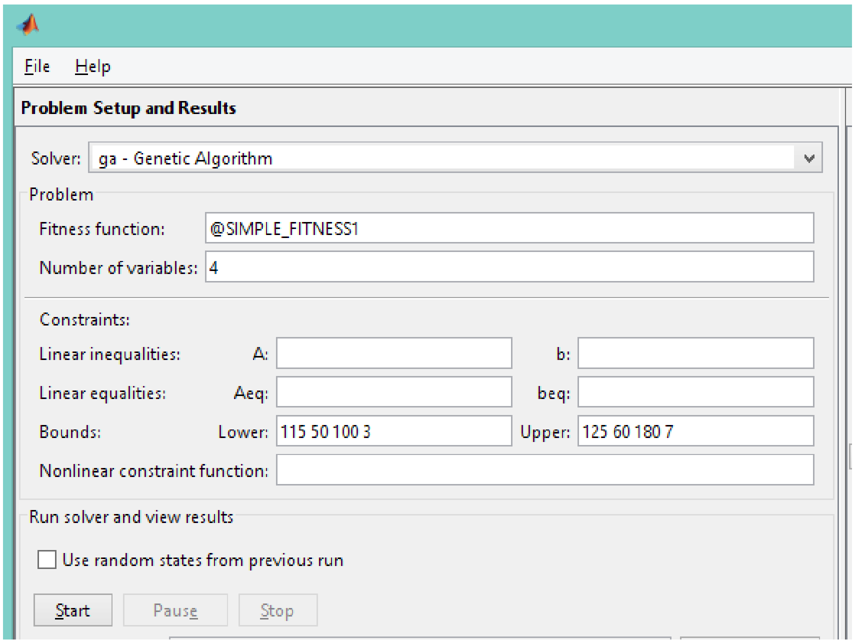

Figure 2. Input to Genetic Algorithm.

After completion of link up we are required to start execution by using start button. Then the process runs according to the GA tool algorithm. Finally, we can get the optimized results in the same screen itself. Along with this one more information is displayed i.e., graphical analysis of best and mean results at that iteration.

These are the output's which we got from GA algorithm. By taking this as the optimized output we can calculate the individual outputs (MRR & Ra) by using the formulae

MRR = 1501-16.9*x1+8.24*x2+0.569*x3+80.1*x4

Ra = -3.02+0.0641*x1-0.0046*x2+0.00199*x3+0.0013*x4

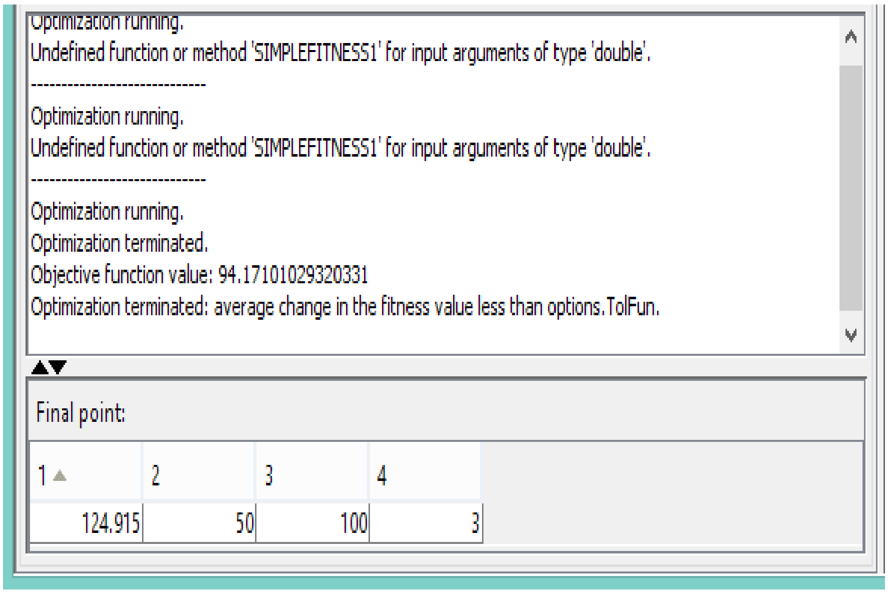

Figure 3 : Result from genetic algorithm

4. RESULTS COMPARISON

The obtained results are compared in order decide which technique is better to use for the optimization of Wire EDM

Table (5): Comparison of Modified TLBO & Genetic Algorithm

OPTIMIZATION TECHNIQUE	FITNESS VALUE	PULSE ON TIME	PULSE OFF TIME	VOLTAGE	WIRE FEED
MODIFIED TLBO	92.7356	125.0000	50.0000	100.0001	3.0000
GENETIC ALGORITHM	94.1710	124.9150	50.0000	100.0000	3.0000

By comparing the above values of Modified TLBO and genetic algorithm we can say that modified TLBO technique is better than genetic algorithm technique.

5. CONCLUSION

In this present work, the Modified TLBO algorithm is applied to determine the optimum process parameters for Wire EDM process for achieving better machining performance. Modified TLBO can also be successfully applied for optimizing other nontraditional machining processes. The fitness values after doing optimization by using modified TLBO and genetic algorithm are 92.7356 and 94.1710 respectively. When comparison is done with genetic algorithm (GA) it is observed that the modified TLBO algorithm gives better results. By using the corresponding population values as design factors, we can get good surface finish and increased material removal rate. Finally, conclude that by using this algorithm we can get optimized process parameters.

REFERENCES

1. Jaganjeet Singh and Sanjeev Sharma, EFFECTS OF PROCESS PARAMETERS ON MATERIAL REMOVAL RATE AND SURFACE ROUGHNESS IN WEDM --- Accepted 10 November 2013. (International Journal of Current Engineering and Technology)
2. R. Venkat Rao and Vivek patel --- MULTI-OBJECTIVE OPTIMIZATION OF TWO STAGE THERMOELECTRIC COOLER USING MODIFIED TLBO TECHNIQUE --- accepted 21 February 2012. (ELSEVER)
3. H. Singh and R. Garg (2009), Effects of process parameters on material removal rate in WEDM Journal of Achievements in Materials and Manufacturing Engineering, 32,70-74.
4. B. Prajapati and N. S. Patel (2013), Effect of Process Parameters on Performance Measures of Wire EDM for AISI A2 Tool Steel, International Journal of Computational Engineering Research,03,274-278.
5. Kuriachen Basil, Josephkunju Paul and Jeoju M.Issac (2013), Spark Gap Optimization of WEDM Process on Ti6Al4V,International Journal of Engineering Science and Innovative Technology (IJESIT) 2(1),364-369.
6. Lokesh Goyat , Rajesh Dudi and Neeraj Sharma(2013),Investigation of Process Parameters Contribution and their Modeling in WEDM for D-2 Tool Steel Using ANOVA.,Global Journal of Engineering, Design andTechnology,2(3),41-46.
7. Swati.D.Lahane , Manik.K.Rodge and Sunil.B. Sharma (2012), Multi-response optimization of Wire-EDM process using principal component analysis, IOSR Journal of Engineering (IOSRJEN), 2(8) , 38-47.