INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING
WWW.IJRAME.COM
ISSN (ONLINE): 2321-3051

Vol.5 Issue.11,
November 2017
Pg: -16-24

PARAMETRIC ANALYSIS AND OPTIMIZATION OF POWER CONSUMPTION IN CNC-WIRE EDM USING GENETIC ALGORITHM

Rachayya. R. Arakerimath
Professor and Head Mechanical Department
G.H.Raisoni College of Engineering and Management, Pune,India.
Email:rrarakerimath@gmail.com

Abstract

The purpose of this paper is to optimize process variables of CNC-WEDM to obtain maximum MRR and minimum Power consumption in rough cutting. This paper explains Wire electrical discharge machining (WEDM) and design of experiment. The material used in this project is D3. Standard Roughing Intensity power and others factor (pulse on time, pulse off time and servo speed) have been studied. The material was cut using brass wire of diameter 0.25mm using dielectric media for various operating conditions. The design of experiment (DOE) method was utilized to find the best combination of the parameters setting to achieve the maximum Material Removal Rate (MRR) and minimum Power consumption to study the interaction between factors that can affect the response. With the result of analysis using DOE the confirmation process on the material have been done. The mathematical models are developed using regression analysis. The GA is used as optimization process to study the optimum settings for minimum power consumed and maximum MRR. The optimum parameters on the material removal rate and Power consumed have been discussed. The most importance of this work is the information about the optimum selection of parameter setting in machining of alloy steel. This information is useful for industries to produce many kinds of components using alloy steel material by saving time and cost while maintaining the accuracy and efficiency machining by CNC-WEDM.

Key words:
CNC-WEDM, MRR, Power consumption, Regression analysis, Genetic Algorithm and Optimum objectives.

1.Introduction to WEDM:

Electrical Discharge Machining (EDM) is a well-known nontraditional machining process among manufacturers especially in precision die and tool industries who always to emphasize for good desired accuracy and surface finish products. EDM is a specialized thermal machining process that utilizing non-contact technique by generating electrical spark at the wire and work piece gap. There are two type principles of EDM; die-sinking EDM and Wire EDM (WEDM). Die-sinking EDM is traditionally performed vertically and may also be conducted horizontally by a tool (electrode) but for WEDM, the

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electrode is a continuously moving conductive wire. In this study, we are focus on the application of wire EDM (WEDM). Figure-1, shows about the general application of WEDM cutting process.

WEDM is an extremely accurate machining process. It is a finish-cutting process that a process of one-side cutting with a smaller offset value and just needs smaller electrical discharge energy. It can produce a smooth surface finish because the wire is able to go through at entire part and the accuracy can be achieved until ±0.0001 inches . Wire EDM is also very effectively to machine small holes, blind holes, inclined holes, irregular holes and deep holes and a micro-hole with a diameter 5 micrometers diameter has been machined [2]. With a very accurate and good surface finish machining, it is able to prevent micro-crack at the machined area and produce products with longer reliability [3]. That’s why WEDM is very popular among manufacturers to obtain higher quality goods and increasing demands in marketing. Generally, WEDM is a cutting process that similar with the mechanisms of hand sawing. But in WEDM case, the ‘saw’ used is wire electrode with small diameter. The mechanism occurs while the electrical current flow on the wire that enough to melt the work piece. The current generate discharge spark between work piece and the wire. Then, the spark will produce crates on the material surface and causing debris (chip) which will be flushed away by dielectric fluid such as mineral oils or deionized water after eroded by the wire. Figure 2, shows the mechanism on WEDM process.

Figure-1,Block diagram of Wire EDM.

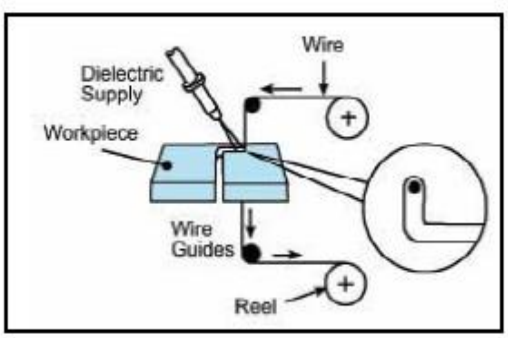
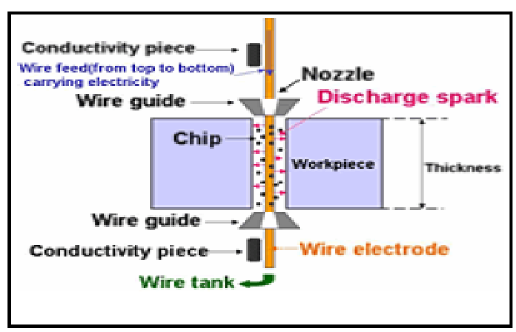


Figure-2, Principle of Wire EDM



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1.1 Importance of the Study

The most important contribution of this work is the information about the selected parameters in machining of alloy steel using WEDM. This information is useful for industries to produce many kind of components using alloy steel material by saving time and cost while maintaining the accuracy and efficiency machining by WEDM. The process of WEDM is complex process[1] including multi-parameter. It is difficult to describe the variation of output parameter with number of control variables precisely.

1.2 Objective of the Study

1. To determine the effect of machining parameter setting over WEDM performance for machining alloy steel (D3).
2. To obtain the best combination of WEDM parameters for optimization of:
i. Highest material removal rate (MRR)
ii. Minimum power consumption (P)

2. Experimental work and Mathematical modeling:

The experiment is conducted on CNC Wire EDM machine for D3 work material with Brass wire of diameter 0.25mm as per DoE table. There were six parameters (table-1) at three ranges to perform linear cutting operation using dielectric medium.

Table-1,Ranges of WEDM parameters and their units.

	ON	Off	MA	SF	WS	WT
High	4	17	17	9	5	8
Low	1	10	15	6	3.5	6
Mid	3	13	16	7	4.5	7

Table-2, The machining settings and parameters used

	Control parameters		Fixed parameters	
1	ON	Pulse duration	Wire type	Brass of dia 0.25mm
2	OFF		Shape of job	Rectangular
3	MA		Job location	Centre of machine table
4	SF		Type of cut	Vertical
5	WS	Wire speed	Job thickness	20mm
6	WT	Wire tension	Dielectric fluid type and flow rate	

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2.1 Mathematical modeling

Table-3, Regression statistics and model development:

Type of objective	Regression o/p		Model obtained
Power consumed (P)	Multiple R	0.9821	$P = 0.2438\,(x1)^{0.0457}(x2)^{-0.0298}(x3)^{-0.1536}(x4)^{-0.01245.}(x5)^{0.1143}(x6)^{0.05814}$
	R Square	0.9645	
	Adjusted R Square	0.8936	
	Standard Error	0.00689	
	Observations	10	
Metal removal rate (MRR)	Multiple R	0.9657	$MRR = 0.5951\,(x1)^{1.565}(x2)^{-0.20755}(x3)^{-1..262}(x4)^{0.0873.}(x5)^{0.391}(x6)^{0.1901}$
	R Square	0.9326	
	Adjusted R Square	0.7979	
	Standard Error	0.04708	
	Observations	10	

Based on Multiple regression for higher Co-efficient of 'R' the model developed are:

$P = 0.2438\,(x1)^{0.0457}(x2)^{-0.0298}(x3)^{-0.1536}(x4)^{-0.01245.}(x5)^{0.1143}(x6)^{0.05814}$

$MRR = 0.5951\,(x1)^{1.565}(x2)^{-0.20755}(x3)^{-1..262}(x4)^{0.0873.}(x5)^{0.391}(x6)^{0.1901}$

3. Genetic Algorithm (GA) based optimization

GA is based on mechanics of natural selection and natural genetics, which are more robust and more likely to locate global optimum. It is because of this feature that GA goes through solution space starting from a group of points and not from a single point. The cutting conditions are encoded as genes by binary encoding to apply GA in optimization[2] of machining parameters. A set of genes is combined together to form chromosomes, used to perform the basic mechanisms in GA, such as crossover and mutation. Crossover is the operation to exchange some part of two chromosomes to generate new offspring, which is important when exploring the whole search space rapidly. Mutation is applied after crossover to provide a small randomness to the new chromosomes. To evaluate each individual or chromosome, the encoded cutting conditions are decoded from the chromosomes and are used to predict machining performance measures. Fitness or objective function is a function needed in the optimization process and selection of next generation in genetic algorithm. Optimum results of cutting conditions are obtained by comparison of values of objective functions among all individuals after a number of iterations. Besides weighting factors and constraints, suitable parameters of GA are required to operate efficiently. GA optimization methodology is based on machining performance[13] predictions models developed from a comprehensive system of theoretical analysis, experimental database and numerical methods. The GA parameters along with relevant objective functions and set of machining performance constraints are imposed on GA optimization methodology to provide optimum cutting conditions.

3.1 Implementation of GA

First of all, the variables are encoded as *n*-bit binary numbers assigned in a row as chromosome strings. To implement constraints in GA, penalties are given to individuals out of constraint. If an individual is out of constraint, its fitness will be assigned as zero. Because individuals are selected to mate according to fitness value, zero fitness individuals will not become parents. Thus most individuals in the next generation are ensured in feasible regions bounded by constraints. The GA is initialized by randomly selecting individuals in the full range of variables. Individuals are selected to be parents of the next generation according to their fitness value. The larger the fitness value, the greater their possibility of being selected as parents. Wang and Jawahir[12] have used this technique for optimization of milling machine parameters.

3.2 Principle steps used in GA

1.Define the bit string with the necessary length (see explanation of the coding above)
2.Make random initial - population
3.Start genetic algorithm as shown in algorithm.
4.After the mutation step: transform the bit string of each individual back to the model-variables
5.Test the quality of fit for each parameter set (= individual) (e.g. using the sum of squared residuals; as the quality of fit has to be increasing with better quality, take 1 / LS as value for the fitness)
6.Check if quality of the best individual is good enough, if so: stop iteration, otherwise restart algorithm: do selection, mating, crossover, and mutation, calculate fitness.

3.3 Genetic algorithm parameters

Population type = Double vector type, Population size =50
Maximum number of generation =100, Number of problem variables =6
Probability of crossover =80% Probability of mutation= 1%

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Selection function = Roulette
Selection type = Double point
Mutation function = Uniform.

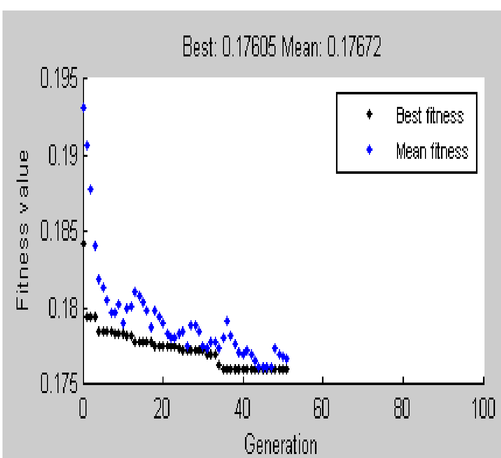
4. Results and discussion

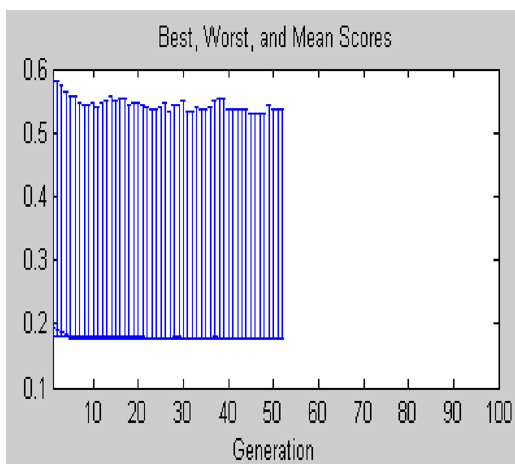
From the developed models it is found that Power consumed is directly dependent on Pulse current, wire speed and wire tension. Where as MRR is directly dependent on Pulse current, SF, wire speed and wire tension. The optimum values obtained for Power consumed and MRR by GA method are shown in table- 4.

Table- 4, Optimum results obtained by GA and comparison

Parameters	ON	Off	MA	SF	WS	WT	Power	MRR
Optimum Values for Power	1	16.55	17	8.997	3	5	0.1758	-----
For MRR	1	17	17	6	3	5	-------	0.0226
Theoratical Range	1-4	10-17	15-17	6-9	3.5-5	6-8		

Graph 1,GA output plot of fitness v/s generations for Power consumed





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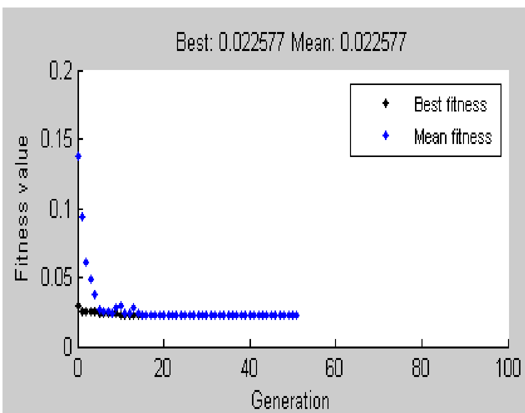
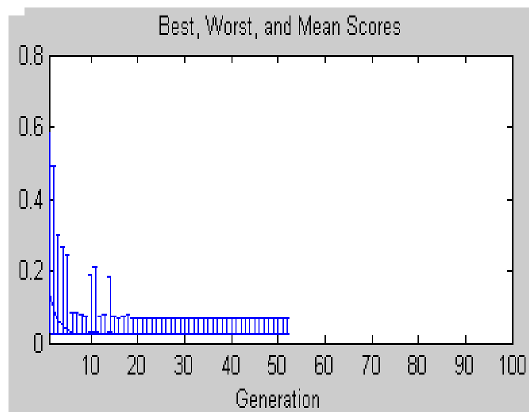
Graph 2,GA output plot of fitness v/s generations for MRR





Graph 1 and 2 explains the variation of fitness v/s number of generations in optimization of P and MRR using GA. It is found that as no of generations increases the fitness value is constant, this means that the obtained objectives are optimum at nth generations.

5.Conclusion

This work is an attempt to determine the important machining parameters for performance measures like Power consumption and MRR separately in the CNC WEDM process. Factors like discharge current, pulse duration, and dielectric flow rate and their interactions have been found to play a significant role in rough cutting operations for maximizations of MRR, minimization of Power consumption. Based DoE experimental observations are made to obtain the mathematical modell, and optimum parameter combination for maximization of MRR and minimization of Power consumption. Interestingly, the optimal levels of the factors for all the objectives differ widely. In order to optimize for both the objectives, mathematical models are developed using the non-linear regression method. It is found that Power consumed is directly dependent on Pulse current, wire speed and wire tension. Where as MRR is directly dependent on Pulse current, SF, wire speed and wire tension. The optimum values obtained for Power consumed and MRR by GA method are listed in table-4

6. Acknowledgement

We acknowledge the support given by Mr P Dehedkar of M/s solis engineering Pune throught the work.

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