Process Parameter Optimization for EDM Machined Stainless Steel

Dr. Rahul O. Vaishya[1] Chand[2]
[1,2]Department of Production and Industrial Engineering
[1,2]PEC University of Technology, Chandigarh, India

Abstract— Electro Discharge Machining (EDM) has become an important and cost-effective method of machining extremely tough and brittle electrically conductive materials. It is widely used in the process of making moulds, dies, sections of complex geometry and intricate shapes. The work piece material selected for this study is AISI 304L Stainless steel. In the present work the effect and percentage contribution of various machining parameters on output parameters is studied using Taguchi's method and ANOVA analysis. A hybrid Taguchi based grey relational analysis is proposed for multi objective optimization of performance variables i.e. high material removal rate, low tool wear rate, better surface finish with lower dimensional tolerance. Further a regression analysis can be used for finding the model equations for various performance parameters. The input parameters considered in this study are dielectric flow rate, discharge current, Pulse on time (Ton) and Pulse off time (TOff). The tool material used is copper. Analysis of variance is used to study the significance of process variables on Material Removal Rate (MRR), Tool Wear Rate (TWR), Surface Roughness (Ra), Dimensional Tolerance (DT). The analysis using Taguchi method reveals that discharge current significantly affects MRR, Dimensional Tolerance and Ra whereas TWR is mostly affected by flow rate of the dielectric used. A comparison of the hybrid approach and Taguchi analysis is presented in this study. The confirmation test supports the result of the proposed hybrid Grey-Taguchi analysis.

Key words: Electro Discharge Machining (EDM), Stainless Steel

I. INTRODUCTION

Electrical Discharge Machining is a most basic non-traditional machining process, where material is removed by thermal energy of spark occurring by means of repeated sequences of electrical ejections between the small gap of an electrode and a work piece. EDM is commonly used for machining of electrically conductive hard metals and alloys in automotive, aerospace and die making industries. EDM process is removing undesirable material in the form of debris and produce shape of the tool surface as of a metal portion by means of a recurring electrical ejection stuck between tool i.e. cathode and the work piece i.e. anode material in the existence of dielectric liquid. In this machining process work piece is called the anode because it is connected with positive terminal and electrode is connected with negative terminal i.e. called cathode. Dielectric fluid may be kerosene, transformer oil, distilled water, etc.

II. LITERATURE SURVEY

Some survey on research papers require to deliberate in this chapter connected towards Electrical Discharge Machining. From the readings out in these papers and thesis is mostly concerned through the EDM settings such as the discharge current, applied voltage, pulse on time, pulse off time, duty cycle, etc. and in what way these parameters will affect the machining outputs like MRR, Ra, TWR etc.

AKM Asif Iqbal and Ahsan Ali Khan [1] optimized the machining process parameters for the EDM milling operation of a stainless-steel work piece with copper tools. Input parameters are RPM of tool, feed rate and voltage while the outputs are MRR, TWR and Ra. Central composite design is utilized for optimization to get higher MRR, TWR and Ra. From the results the machining settings for optimal condition are done at 1200 RPM, voltage 120V and feed rate 4µm/Sec.

B. Sidda Reddy et al. [2] studied that influence by design four factors such as current, servo control, duty cycle and open circuit voltage over the outputs on MRR, TWR, SR and hardness on the die-sinker EDM of machining AISI 304 SS. They had been employed DOE technique with mixed level design and analyze for performing a minimum number of runs. They achieved that for higher MRR, the current, servo and duty cycle should be fixed as high levels and 95% confidence level with descending order in case of TWR with same factors.

B. Bhattacharyya et al. [3] Experimented on EDM using the development of a mathematical model based on RSM for correlating the interactive and higher order effect on machining parameter such as peak current and pulse on time of surface integrity of M2 Die steel machined through analysis of EDM parameters on surface roughness, white layer thickness and surface crack density. With the developed model the optimal combination evaluated for minimizing the surface integrity.

Dhar et al [4] developed a second order nonlinear mathematical model to establish the relationship between machining settings. And ANOVA has been performed to verify the fit and adequacy of the model. Process parameters on EDM are current, pulse on time and gap voltage over the responses of MRR, TWR and ROC of a composite material with brass tool having 30 mm cylindrical diameter.

I. Puertas et al. [5] Investigated the attention on the die-sinking EDM with an adequate selection of machining condition is the most important aspects of the machine. They were found that the impact of the features of intensity, pulse on period and duty cycle over cemented carbide or hard material such as 94WC-6Co. They determine characteristics: TWR, MRR and Ra by mathematical simulations will be achieved with the DOE method combined with multiple regressions has been effectively applied to modelling for optimal machining condition. When intensity or pulse times were increased, the roughness value also increased. With tungsten carbide low values should be used for both intensity and pulse time.

J. Simao et al [6] investigated work on the surface alloying of the different work piece on machining over EDM. In experiments powder metallurgy made tools and use of powders suspended in dielectric liquid. Based on

experimental results the use of primary sintered electrodes made from tungsten carbide resulted in the formation of a uniform modified surface layer with some micro cracks and an average thickness of up to 30 µm.

M. M. Rahman et al. [7] experimentally found out the machining characteristic of austenitic stainless steel 304 through electric discharge machining. The investigation shows that with increasing current increases the MRR and surface roughness. The TWR increases with peak current until 150 µsec pulse on time. And from the results they were found for copper electrode al long pulse on time no tool wear with reverse polarity.

Norliana Mohd Abbas et al. [8] reviewed the trends of various research on EDM such as ultrasonic vibration assisted EDM, dry EDM, powder mixed EDM, water based EDM and various modeling techniques of EDM to precise and accurately EDM performance. They found that ultrasonic vibration assisted EDM is suited for micro machining, dry EDM is cost effective, water based EDM provides safe and conductive working environment, powder mixed EDM provides increasing surface quality, MRR and TWR.

S. H. Tomadi et al. [9] analyzed that effect of machining settings of tungsten carbide on the outputs such as TWR, MRR and Surface finish. Confirmation test performed to evaluate error between predicted values and by experimental runs in terms of machining characteristics. They were found out copper tungsten tool use for better surface finishing of the work piece. They were using full factorial DOE for optimization and found out with greater pulse off time lesser tool wear of tungsten carbide and with current, voltage and pulse on time increment tool wear increased.

S. Jai Hindus et al [10] done experimentations by way of the Box Behniken design. The effects show that TWR and MRR are deeply affected using Pulse on time and current (A). Cylinder-shaped copper tool ensuring a dimension of diameter of 13 mm is castoff to machining of stainless steel 316 L work piece. On MRR the greatest weighty cause was found to be Pulse on time trailed by peak current (A) and the smallest significant was gap voltage. The MRR increased linearly with the increase in current (A). For tool wear the most significant factor was current (A) followed by Pulse on time (tw) and also laterally with the increase in voltage.

S. K. Dewangan [11] investigated the effect of machining parameter settings like pulse on time, discharge current and diameter of tool of AISI P20 tool steel material using U-shaped copper electrode with interior flushing technique. Experiments were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by which factor is most affected by the Responses of Material Removal Rate (MRR), overcut (OC) and Tool Wear Rate (TWR).

Sanjeev Kumar et al [12] reviewed on the new uses of electrical discharge machining (EDM) process, with certain prominence on the prospective of this process for surface alteration. Above and beyond removal of work material during machining, the fundamental nature of the process results in erosion of tool material also. Creation of the plasma passage containing of material vapors from the eroding work material and tool electrode; and pyrolysis of the dielectric affect the surface composition after machining and hence, its properties. Deliberate material transfer may be carried out under specific machining conditions by using either composite electrodes or by a break up metallic powders in the dielectric or both. In this review on the wonder of surface modification by electric discharge machining and upcoming leanings of its applications.

Singh et al [13] investigated the influence of machining settings such as peak current on MRR, overcut, TWR and Ra in EDM of E31 tool steel heat treated with different tools such as copper, brass, aluminum and copper tungsten. From results copper and aluminum electrode gives higher MRR, Overcut in diameter is minimum with this tools.

T. M. Chenthil Jegan et al [14] determines the assortment of machining settings like peak Current, Pulse on time, Pulse off time in EDM intended for the machining of AISI202 stainless steel metal. They were using of grey relational analysis technique to optimizing the machining parameters MRR and SR is introduced. The greatest nominal influence in addition to the order of significance of the manageable influences to the multi performance physical characteristics on EDM machining procedure stayed determined. The results show that Discharge current was the main parameter affecting the MRR.

III. Objective of the Study

1) The objective of the present study is to investigate the effect of the machining variables viz. discharge current, pulse on time and voltage on output performances such as MRR, SR during machining of AISI 304 stainless steel work piece by using Tungsten Carbide tool material.
2) Based on experimental results, an optimization of machining variables can be perform and analyse by STATISTICA 9.0.

IV. Methodology

A. Selection of Work Piece

In this experiment AISI 304 stainless steel of size 80×50×5 mm3 plate is chosen for conducting the experiment. Grade 304 is the commonly used stainless steel; it is the utmost versatile applications and greatest use of stainless steel, offered in an extensive variety of good products, practices and qualities than any other. It has wonderful welding and forming characteristics. Grade 304 is freely brake or spool moulded into a variability of work uses in the manufacturing, construction as well as automobile fields. The austenitic configuration provides these grades brilliant toughness, straight down to lower hotness.

It has excellent oxidization prevention in a numerous range of full of atmosphere environments as well as lots of corrosive medium. It has good corrosion resistance in intermittent service and brilliant weld ability property in entirely available standard fusion methods, both with and without filler methods. Therefore it is applicable to make kitchen appliances, sinks, benches, architectural panelling,

railings, heat exchangers, threaded fasteners, spring, chemical containers including for transport etc.

B. Selection of Tool Material

In this experiment Tungsten carbide rod of 10×100 mm2 used. Tungsten carbide products are famous for their heat resistance, toughness and good machinability. One of the products of tungsten carbide are the solid tungsten carbide rods that are used for cutting dissimilar alloys, cast iron, stainless steel, refractory alloy steel, nickel based alloy, titanium alloy and other nonferrous metals.

The solid tungsten carbide rods are offered as a ground and unground with metric or inch standards. These rods possess the features of good wear resistance and corrosion resistance. The other uses of these rods are as HSS cutting tool, carbide end mills, aerospace cutting tool, carbide drills, milling cutter, electronic cutter, gun barrel, metal cutting saw and several other applications. Tungsten carbide (WC), alternatively, is a composite of W and C. Subsequently most of the commercially essential cemented carbides are constructed on WC as per the rigid part, the terms "tungsten carbide" as well as "cemented carbide" are every so often used interchangeably. Tungsten carbide as a metal composite is significant for its robustness with highest melting point of all the elements.

V. RESULTS

Run no.	I_P (A)	T_{ON} (µs)	Voltage (V)	MRR (mm^3/min)	R_a (µm)
1	5	50	45	2.9500	5.9333
2	5	150	55	4.0750	7.1333
3	5	200	65	3.4000	8.4000
4	7	50	55	4.8375	5.2667
5	7	150	65	6.0625	7.8000
6	7	200	45	6.6000	7.1333
7	9	50	65	5.9375	8.4000
8	9	150	45	9.2250	4.2000

Table 1: Shows the Response and Calculation for MRR and Ra Along With the Input Parameters or Factors

VI. CONCLUSION

In this investigational experiment on EDM to know the effect of machining outputs taken for consideration are material removal rate and surface roughness of the AISI 304 SS work piece using the solid tungsten carbide tool with side flushing method have been investigated. Both these outputs are important in industrial applications. The conduction of experiment depends upon various parameters settings such as discharge current (Ip), pulse on time (Ton) and voltage (v) have been selected. Based on L9 orthogonal array by taguchi design was conducted and STATISTICA 9.0 software package was used for analysis of the experiment. The results on outputs are to some extent be authenticated. The following points conclude the experiments are:

1) From the results of MRR we conclude that the discharge current is most significant or influencing factor then pulse on time and at last is voltage on the given input. MRR increased linearly with some extent of current and increases and decreases slightly with pulse on time.
2) In case of surface roughness, the voltage is the effective parameter after that current and voltage are less effective on machined work piece.

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