International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 04, April 2016
www.ijates.com
ijates
ISSN 2348 - 7550

EFFECTS OF PROCESS PARAMETERS ON MATERIAL REMOVAL RATE IN WEDM USING EXPERIMENTAL DESIGN

Pawan Bishnoi [1], Dinesh Sindhu [2], Naresh Panchal[3]

[1] Assistant Professor, [3]B.Tech Scholar, Department of Mechanical Engineering ,
Vedant College of Engineering & Technology ,Bundi ,Rajasthan, (India)
[2] Research Scholar, Department of Mechanical Engineering, National Institute of Technology Kurukshetra ,Haryana, (India)

ABSTRACT

*Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the conventional machining processes. The development of new advanced engineering materials and the need to meet demand for precise and flexible prototype and low-volume production of components has made wire electrical discharge machining (WEDM) an important manufacturing process. Wire Electrical Discharge Machining (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profiles. WEDM utilizes a continuously travelling wire electrode made of Cu, brass or tungsten of diameter 0.05 -0.30mm, capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire electrode, eliminating the mechanical stresses during machining. The effects of various process parameters of WEDM pulse on time (Ton), pulse off time (Toff), gap voltage (SV), peak current (IP), have been investigated to reveal their impact on material removal rate. The experimental plan is performed by a standard **RSM** design called central composite design. The experimental studies were performed on ELECTRONICA SPRINTCUT WEDM machine. It is concluded from the study that the material removal rate (MRR) increases with increase in pulse on time (Ton) and peak current (IP) while if decreases with increase in pulse off time (Toff) and servo voltage (SV).*

Keywords-Component: IP Peak Current, Mrr Material Removal Rate, Rsm Response Surface Methodology, SV Servo Voltage , Toff Pulse Off Time, Ton Pulse on Time, µm Micro Meter

I. INTRODUCTION

Wire Electric Discharge Machining (WEDM) is a non-traditional process of material removal from electrically conductive materials to produce parts with intricate shapes and profiles. This process is done by using a series of spark erosion. These sparks are produced between the work piece and a wire electrode (usually less than 0.30 mm diameter) separated by a dielectric fluid and erodes the work piece to produce complex two and three dimensional shapes according to a numerically controlled pre-programmed path. The sparks produce heating and melt work piece surface to form debris which is then flushed away by dielectric pressure. During the cutting process there is no direct contact between the work piece and the wire electrode. The wire electrical discharge machining (WEDM) has become an important non-traditional machining process because it can machine the difficult-to-machine materials like titanium alloys and zirconium which cannot be machined by conventional machining processes.

Wire electrical discharge machining (WEDM) is a specialized thermal machining process capable of accurately machining parts with varying hardness or complex shapes, which have sharp edges that are very difficult to be machined by the main stream machining processes. The development of new advanced engineering materials and the need to meet demand for precise and flexible prototype and low-volume production of components have made wire electrical discharge machining (WEDM) an important manufacturing process.The basic mechanism of metal removal in WEDM is identical to conventional EDM. Instead of moving electrode (as in EDM), the electrode in this process is a moving wire of copper or brass. A vertically oriented wire is fed into the work piece continuously travelling from a supply spool to a take up spool. For this purpose a hole is pre-drilled in the work piece, through which the wire electrode will pass. A constant gap between tool and work piece is maintained with the help of computer controlled positioning system. This system is used to cut through complicated contours especially in difficult-to-machine materials. This process gives a high degree of accuracy and a good surface finish. Wire Electrical Discharge Machining (WEDM) is a widely accepted non-traditional material removal process used to manufacture components with intricate shapes and profiles. It utilizes a continuously travelling wire electrode made of Cu, brass or tungsten of diameter 0.05 -0.3mm, capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire electrode, eliminating the mechanical stresses during machining. In addition, the WEDM process is able to machine exotic and high strength and temperature resistant materials and eliminates the geometrical changes occurring in the machining of heat-treated steels. WEDM equipment first appeared in the early 1960s, and performed simple machining utilizing the phenomenon of electrical spark. The first five-head WEDM arrived in the United States in December, 1980. In today’s WEDM it is possible to program wire to follow a complex path in two axes. Hence, it is possible to use this machine tool for making dies for stamping fine blanking and extrusion as well as 2-D through holes. It is possible to tilt the wire in position other than perpendicular to X and Y axes. It is possible to perform 3-D cutting using WEDM in which two additional axes have been introduced. The drive motors which tilt the wire towards the front or back and left or right are controlled by the programmed commands in CNC WEDM.

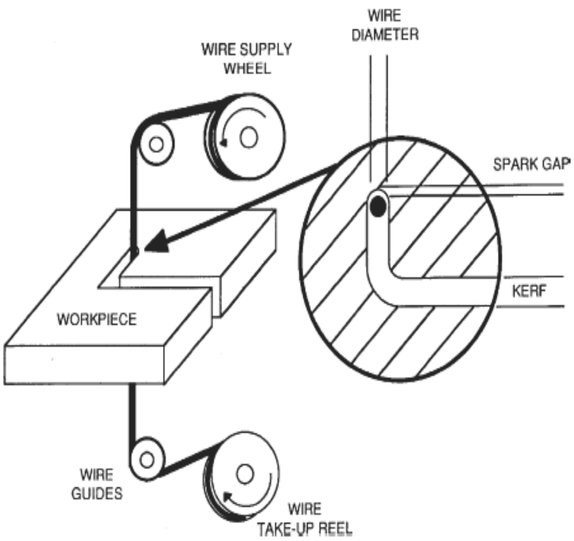

Figure 1 Schematic representation of WEDM cutting process.

II. RESPONSE SURFACE METHODOLOGY (RSM) AND CENTRAL COMPOSITE DESIGN

Response surface methodology (RSM) is defined as a collection of mathematical and statistical methods that are used to develop, improve, or optimize a product or process. The method was introduced by Box and Wilson in 1951. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. It comprises statistical experimental designs, regression modelling techniques, and optimization methods. Most applications of RSM involve experimental situations where several independent (or control) variables potentially impact one or more response variable. The independent variables are controlled by the experimenter, in a designed experiment, while the response variable is an observed output of the experiment. Fig. 2 illustrates the estimated relationship between a response variable and the two independent variables x_1 and x_2.

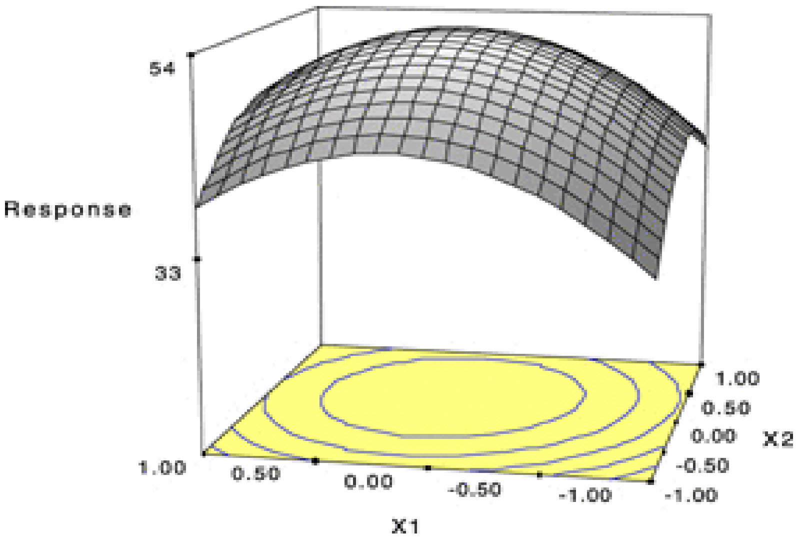

Figure 2 An example of a response surface.

2.1 Steps Involved In Rsm

The following steps are involved in RSM for developing an empirical model through a sequential program of experimentation

1. At first some ideas are generated concerning which factors or variables are likely to be important in response surface study. It is usually called a **screening experiment**. The objective of factor screening is to reduce the list of candidate variables to a relatively few so that subsequent experiments will be more efficient and require fewer runs or tests. The purpose of this phase is the identification of the important independent variables.
2. The experimenter's objective is to determine if the current settings of the independent variables result in a value of the response that is near the optimum. If the current settings or levels of the independent variables are not consistent with optimum performance, then the experimenter must determine a set of adjustments to the process variables that will move the process towards the optimum. This phase of RSM makes considerable use of the first-order model and an optimization technique called the **method of steepest ascent (descent).**

   The first step in obtaining the optimum response settings, after the important factors have been identified, is to explore the region around the current operating conditions to decide what direction needs to be taken to move towards the optimum region. Usually, a first order regression model (containing just the main effects and no interaction terms) is sufficient at the current operating conditions because the operating conditions are normally far from the optimum response settings. The experimenter needs to move from the current operating conditions to the optimum region in the most efficient way by using the minimum number of experiments. This is done using the method of steepest ascent. In this method, the contour plot of the first order model is used to decide the settings for the next experiment, in order to move towards the optimum conditions.
3. At this point the experimenter usually wants a model that will accurately approximate the true response function within a relatively small region around the optimum. Because the true response surface usually exhibits curvature near the optimum, a second-order model (or perhaps some higher-order polynomial) should be used. Once an appropriate approximating model has been obtained, this model may be analyzed to determine the optimum conditions for the process. This sequential experimental process is usually performed within some region of the independent variable space called the **operability region or experimentation region or region of interest.** It is possible that a number of responses may have to be optimized at the same time. For example, an experimenter may want to maximize strength, while keeping the number of defects to a minimum. The optimum settings for each of the responses in such cases may lead to conflicting settings for the factors. A balanced setting has to be found that gives the most appropriate values for all the responses.

2.2 Central Composite Design

The most popular response surface design is the central composite design (CCD). A CCD has three groups of design points:

(a) Factorial points (b) Axial points (c) Center points

CCD's are designed to estimate the coefficients of a quadratic model. All point descriptions are in terms of coded values of the factors.

Factorial Points

The two-level factorial part of the design consists of all possible combinations of the +1 and -1 levels of the factors. For the two factor case there are four design points: (-1, -1) (+1, -1) (-1, +1) (+1, +1).

Star or Axial Points

The star points have all of the factors set to 0, the midpoint, except one factor, which has the value +/- Alpha. For a two factor problem, the star points are (-Alpha, 0), (+Alpha, 0), (0, -Alpha), (0, +Alpha).

Centre Points

Centre points, as implied by the name, are points with all levels set to coded level 0 -- the midpoint of each factor range: (0, 0). Center points are usually repeated 4-6 times to get a good estimate of experimental error (pure error). A central composite design (CCD) is a type of response surface design that will give us very good predictions in the middle of the design space.

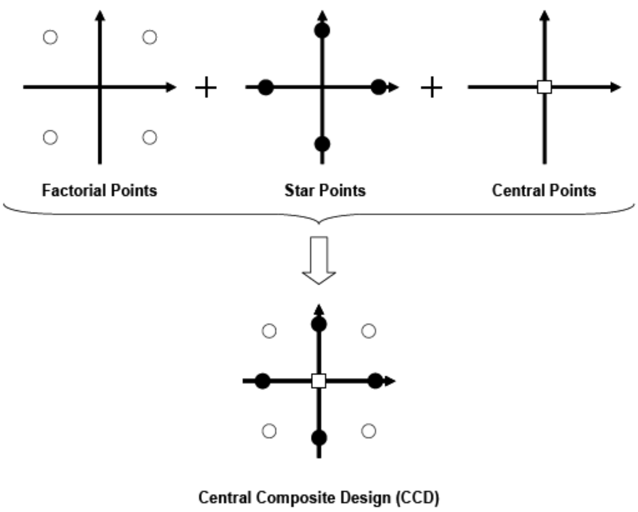

Figure 3 Schematic representation of central composite design (CCD).

III. EXPERIMENTAL PROCEDURE

RSM methodology with central composite design is selected for experimentation. In this work four factors are taken as input parameters, and the effect of these parameters on MRR is as certained. The details of RSM and central composite design are given in chapter 3.

3.1 Process Parameters For Study

There are various process parameters of WEDM affecting the machining characteristics. The work piece material is a high carbon high chromium (HCHCr) die steel with excellent wear resistance, hot toughness and

International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 04, April 2016
www.ijates.com
ijates
ISSN 2348 - 7550

good thermal shock resistance. On the basis of literature review and some pilot investigations (not reported here), the following process parameters have been selected for study in the range shown in table 1

Table 1 Process parameters with their ranges.

S.No.	Input Parameters	Range
1.	Pulse on time (Ton)	100-135 machine units
2.	Pulse off time (Toff)	30-65 machine units
3.	Peak current (IP)	70-230 Amps
4.	Servo voltage (SV)	10-70 Volts

3.2 Experimental Data

The experimental work is carried out as per the central composite design using RSM methodology. The design is prepared with the help of Design expert software version 8.0.3 which is used to create experimental designs. The design is shown in table 2 with response

Table 2 Experimental Design with Response Data.

Run	Factor 1 A: Ton Machine units	Factor 2 B: Toff Machine units	Factor 3 C: SV Volts	Factor 4 D: IP Amp	Response MRR mm^2/min
1	125	55	20	230	33.75
2	105	30	10	70	17.5
3	125	63	50	70	8.75
4	125	52	30	150	24.25
5	105	63	10	70	4
6	105	40	50	70	8.75
7	125	40	10	70	43
8	105	63	50	230	3.5
9	115	52	30	150	23.75
10	105	40	10	230	21.5
11	105	40	10	70	15.25
12	105	63	10	230	6.25
13	125	40	50	70	23.25
14	125	63	50	230	21.25
15	115	52	30	150	18.75
16	125	63	10	70	12
17	105	40	50	230	10
18	115	52	30	120	18
19	125	40	10	230	58.25
20	105	63	50	70	2.75
21	115	52	30	120	20.25
22	135	52	30	150	42
23	115	52	30	230	25.50
24	115	63	30	150	13.50
25	105	52	30	150	8

26	105	63	70	150	10
27	125	52	30	230	34
28	125	52	20	230	58
29	125	40	20	230	58.75
30	95	40	20	120	13

IV ANALYSIS OF EXPERIMENTAL RESULTS

4.1 Effect of Pulse on time on MRR

It can be seen from fig.4 that machining speed increases with increase in the pulse on-time. It means that the number of sparks in unit time increases which increase in discharge energy. As a result machining speed becomes faster with increase in pulse on time. So the pulse on time can be adjusted to get the desired material removal rate.

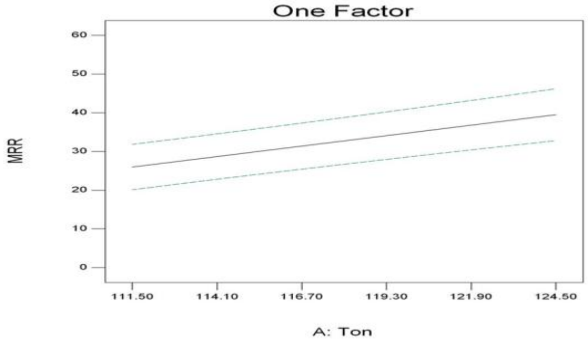

Fig 4 Effect of Ton on MRR.

4.2 Effect of Pulse off-time on MRR

It can be seen from fig.5 that as the pulse off-time increases, the number of discharges within given period of time decreases. This will lead to a lower machining speed.

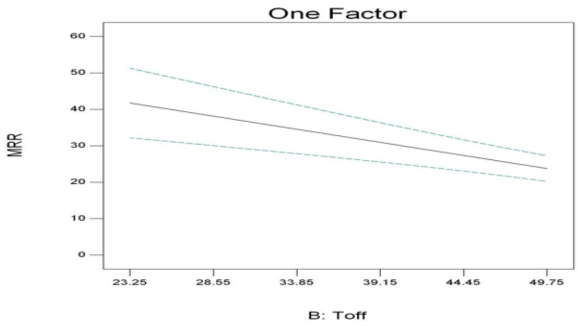

Figure 5 Effect of Toff on MRR.

4.3 Effect of SV on MRR

It can be seen from figure 6 that there is not much influence of servo voltage on MRR.

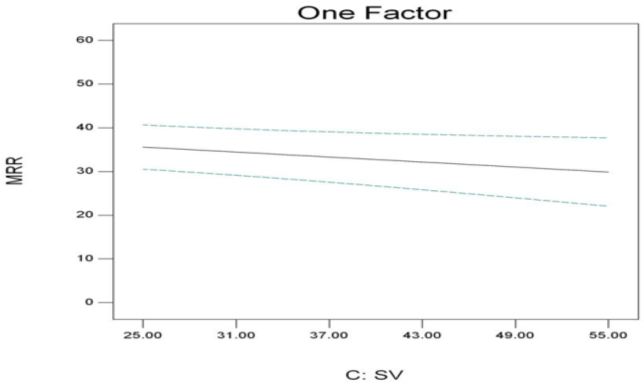

Figure 6 Effect of SV on MRR.

4.4 Effect of Peak Current on MRR

It can be seen from figure.7 that material removal rate increases very slightly with increase in peak current. So the peak current should be high to obtain higher MRR.

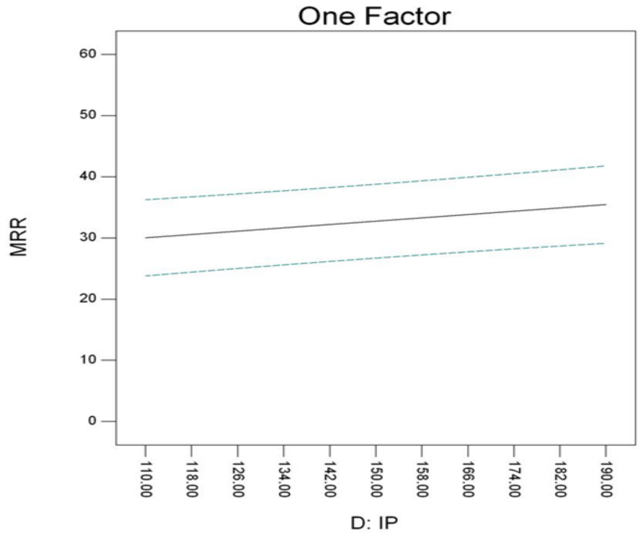

Figure 7 Effect of IP on MRR.

V CONCLUSIONS

The following conclusions are drawn from the experimental study

- When pulse on time is increased the material removal rate increases.
- When pulse off time is increased the material removal rate decreases.
- When servo voltage is increased the material removal rate decreases.
- When peak current is increased the material removal rate is increases.

REFERENCES

[1] Ahmet Hasçalyk and Ula Çayda (2004), "Experimental study of wire electrical discharge machining of AISI D5 tool steel." Journal of Materials Processing Technology Volume 148, Issue 3, Pages 362-367.

[2] D.F. Dauw and L. Albert;(1992), "About the Evolution of Wire Tool Performance in Wire EDM." CIRP Annals - Manufacturing Technology Volume 41, Issue 1, Pages 221-225.

[3] Eva Portillo, Marga Marcos, Itziar Cabanes, (2009), "Real-time monitoring and diagnosing in wire-electro discharge machining." The International Journal of Advanced Manufacturing Technology, Volume 44, Numbers 3-4.

[4] F. Klocke, D. Lung, D. Thomaidis and G. Antonoglou,(2004), " Using ultra thin electrodes to produce micro-parts with wire-EDM." Journal of Materials Processing Technology 149, pp. 579–584.

[5] Fabio N. Leao, Ian R. Pashby (2004), "A review on the use of environmentally-friendly dielectric fluids in electrical discharge machining." Journal of Materials Processing Technology Volume 149, Issues 1-3, Pages 341-346. 14th Interntaional Symposium on Electromachining (ISEM XIV).

[6] Fleischer J, Masuzawa T, Schmidt J, Knoll M. (2004) ,"New applications for micro-EDM. J. Mat. Processing Tech. 149 Pages 246 – 249.

[7] Ghosh Amitabh & Malik Ashok Kumar (1995), Manufacturing science, East-West Press Private Ltd, New Delhi.

[8] Habib *et al* (2009), "Computational fluid dynamics analysis of working fluid flow and debris movement in wire EDMed kerf." CIRP Annals - Manufacturing Technology Volume 58, Issue 1, 2009, Pages 209-212.

[9] Hassan (2009), "Study of the Surface Integrity of AISI 4140 Steel in Wire Electrical Discharge Machining." International Multi Conference of Engineers and Computer Scientists 2009 Vol. II 978-988.

[10] H. Singh, R. Garg (2009), "Effects of process parameters on material removal rate in WEDM."Journal of Achievements in Materials and Manufacturing Engineering Volume 32 Issue 1 January 2009 page no.70-74.

[11] Jain V.K (2002) Advanced Machining Processes. Allied, New Delhi.

[12] Jain R.K., Production Technology, Khanna Publications, New Delhi 15th edition, 1995.

[13] J. T. Huang, Y. S. Liao and W. J. Hsue (1999), "Determination of finish-cutting operation number and machining-parameters setting in wire electrical discharge machining". Journal of Materials Processing Technology Volume 87, Issues 1-3, Pages 69-81.

[14] J. Simao,H. G. Lee, D. K. Aspinwall, R. C. Dewes and E. M. Aspinwall (2003),"Workpiece surface modification using electrical discharge machining." International Journal of Machine Tools and Manufacture Volume 43, Issue 2, January 2003, Pages 121-128.

[15] J. A. Sanchez; S. Plaza; L. N. Lopez De Lacalle; A. Lamikiz' 2006, "Computer simulation of wire-EDM taper-cutting." International Journal of Computer Integrated Manufacturing, Volume 19, Issue 7, pages 727 – 735.