Investigation on Electric Discharge Machine for optimization of Surface Roughness using Response Surface Methodology approach

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by

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Dedicated to

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Certificate

This is to certify that the project entitled, '**Investigation on EDM for optimization of surface roughness using RSM approach**' submitted by **Vishal Kesarwani** is an authentic work carried out by him under my supervision and guidance for the partial fulfillment of the requirements for the award of **Bachelor of Technology Degree** in **Mechanical Engineering** at **National Institute of Technology, Rourkela**.

To the best of my knowledge, the matter embodied in the project has not been submitted to any other University / Institute for the award of any Degree or Diploma.

Date - 10/5/2011
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Abstract

In this project, Response Surface Methodology (RSM) is used to investigate the effect of three important EDM parameters those are namely: discharge current(Ip), pulse-on-time(Ton) and gap voltage(V) on Surface Roughness (Ra) of on Electrical Discharge Machined surface. In this study a second-order polynomial model is used and taken help of and using the central composite design (CCD) which estimates the model coefficients of the three factors that influences surface roughness of work-piece in EDM process.A experiment was well designed and it was used to reduce the total number of experiments.Experiment was done on mild steel and copper was used as tool.The response is modeled using RSM on experimental values obtained.It was found that discharge current(Ip) and pulse-on-time(Ton) have significant effect on surface roughness whereas gap voltage(V) is less significant.

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Chapter 1

Introduction

1.1 Problem Statement

Optimizing the value of EDM parameters to get the best surface finish in mild steel in EDM using RSM approach.

1.2 Background of Electric discharge Machine

The EDM Machining Methods was discovered in 1770s when it was studied by by an English Scientist. However, Electrical Discharge Machining was not started universally until 1943 when Russian scientists learned how the erosive effects of this technique could be controlled and used for machining purposes. An Electro Discharge Machine (EDM) consists of an electrode as cutting tool and the workpiece and both are immersed in in a dielectric medium. The tool is given a positive or negative potential when a potential difference is applied, a spark is developed between the the tool and workpiece. This results in great amount of heat energy being released. EDM is an important machining process which is extensively and effectively used for the machining of such materials, precisely and cost-effectively in the said advance industry [3].

1.3 Principle of Electric Discharge Machine

In this procedure the metal is removed from the work-piece due to erosion caused by by rapidly formed spark discharge taking place betwen tool and work-piece. A thin gap about 0.025 mm is preserved between the tool and the work piece. Both the tool and the work-piece are submerged in a dielectric fluid i.e. EDM oil . The spark is continued to be formed with pulse width Ton = 2-2000 micro second and during the spark-off-time (Toff), and the discharge happens during pulse on time (Ton). This cycle goes on for working time Tw and then the electrode is raised up for efficient flushing for uplift time T . The main parameters to be controlled are the voltage (V), current(Ip), pulse duration and and percentage duty period.

1.4 Surface Roughness

Roughness of a surface is a measure of the the texture of a surface. It is counted by the vertical nonconformities of the real surface from the perfect surface. If these deviationn is large, the surface is said to be rough and if they are minor, the surface is smooth. During EDM machining, the melted material is not flushed away completely and the remaining material resolidifies to form discharge craters. As a result, machined surfce has micro-cracks and pores caused by which results n Surface Roughness of that work-piece. Roughness measurement is completed using a portable style type profilometer, Talysurf (Taylor Hobson, Surtronic 3+).

Surface roughness measuring device i.e. Profilometer or Talysurf is an electronic device that s used to calculate the surface roughness. Prior using the device it has to be calibrated. For calibrating the device we use a standard surface which has the surface roughness of 6 micro m. The instrument has a probe and thre is a very tiny tip made up of ruby. The tip should touch the work-piece machining surface when it moves up and down w.r.t. minute difference of voltage is amplified and the roughness is calculated. The measurement is taken during the forward motion of the stylus. Profilemeter is a very delicate instrument and it should be used very carefully.

1.5 Workpiece

Mild steel is taken as the workpiece for my project. 10 pieces of mild steel was prepared using hack-saw and finishing was done by grinding machine.Each workpiece have two surfaces each so total 20 experiments were conducted.

Chapter 2

Literature survey

In this chapter search few selected research paper related to EDM with effect of metal MRR, TWR, OC, surface roughness (SR) workpiece material. Each of these is explained below.

2.1 Workpiece and tool material

A. Soveja et al [4] have defined the experimental study of the surface laser texturing of TA6V alloy. The effect of the operating factors on the laser texturing technique has been studied using 2 experimental approaches: Taguchi methodology and RSM.

Biing Hwa et al. [5] has discussed the investigates the feasibility and optimization of a rotary EDM with ball burnishing for checking the the machinability of Al2O3/6061Al composite using the Taguchi method. 3 ZrO2 balls attached as additional components behind the electrode tool offer immediate burnishing following EDM. Three observed values machining rate, surface roughness and improving of surface roughness are accepted to verify the optimization of the machining process.

2.2 EDM with tubular electrode

Saha and Choudhury [6] Study the process of dry EDM with tubular copper tool electrode and mild steel work-piece. Experiments have been performed using air and study the effect of gap voltage(V) discharge current(Ip), pulse-on time(Ton), duty factor and air pressure on MRR, surface roughness (Ra) and Tool Wear Rate(TWR). Empirical models for MRR, Ra and TWR have then is produced by conducting a designed experiment based on the central composite design(CCD) of experiments. Response surface analysis is done using the developed models. ANOVA tests were performed to identify the significant parameters.

Lin and Han [7] discussed the study about tube electrode for an EDM drilling includes a stabilizer block and a mover. The stabilizer block has a concaved in shaped supporting wall that parallels to the traveling path of a tube electrode, and has a plurality of apertures interconnected air vacuuming connections to suck air.

2.3 EDM tool design

Sohani et al. [8] presented about sink EDM process effect of tool shape and size factor are to be considered in technique using RSM process parameters like discharge current(Ip), pulse on-time(Ton), pulse off-time(Toff), and tool area. The RSM-based mathematical models of Metal Removing Rate(MRR) and Tool Wear Rate have been produced using the data got through central composite design(CCD). The analysis of variance is applied to check the lack of fit and adequacy of the developed models. The investigations showed that the best tool shape for higher MRR and lower TWR is circular, then triangular,, then rectangular, and lastly square cross sections.

2.4 Effect of multiple discharges of EDM

The work-piece is machined, produced by the superposition of multiple discharges, as it happens while a actual EDM operation, by Izquierdo et al. [9] diameter of the discharge channel and MRE can be calculated using inverse identification from the results of the numerical model. An original numerical model for simulation of the EDM technique has been presented. The model generates EDM surfaces by calculating temperature fields inside the work-piece using a finite difference-based approach, and taking into account the effect of successive discharges.

Wei Bin et al. [10] has studied about electrical discharge machining with many holes in an electrically conductive work-piece, includes an electrical discharge machine for rotatable mounting a first electrode, and at least one electrical discharge unit for rotatable mounting at least one second electrode.

2.5 CNC Electric discharge machining

Study on reducing contour errors for CNC EDM was provided by Shieh and lee [11] they are proposed contrl, scheme consists of 3 portions. First, the step control conducts position loop controller for each individual axis. Second, control error calculations suiting for control system analysis and design are used, and third, cross-coupling control is used to contrl contour error. Under the control of the proposed scheme, the stability of the system is studied for both linear and circular trajectories. The experimental results of a CNC EDM reveal that the proposed scheme is effective to modify contouring performance and ready for practical implementation.

2.6 Objective of the present work

From the research papers in this classification, it is observed that few works has been reported on EDM on the material Al-Sic, EN-19, SKH 57, AISI H13, AISI D2 tool steel, and various composite materials. Study on EDM of different material and different mathematical model can be used to validated the experimental results.

The objective of the present work is to optimize the surface roughness in mild steel with EDM parameters using RSM approach.

Chapter 3

Experimental work

Under this topic we are going to discuss experimantal work i.e. experimental setup, workpiece, calculations, tool material, RSM approach and many other things.

3.1 Experimental setup

In my project I have worked on Electric Discharge Machine, model ELECTRONICA-ELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap) and positive polarity for electrode was used to conduct the experiments.Mild steel is selected as my the workpiece for my experiment. 10 pieces of mild steel was prepared with the help of Hack-saw available in production lab. Finishing of the workpiece was done by grinding machine. The diameter of the workpiece is approx 25mm n width 6-7mm. The total number of experiments conducted is 20. Both side of mild steel was machined Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94C) was used as dielectric fluid. With internal flushing of Copper tool with a pressure of 0.2 kgf/cm2 .Experiments were conducted with positive polarity of electrode. The pulsed discharge current was applied in various steps in positive mode. The test conditions are presented in the table 3.1.

3.2 Response Surface Methodology

The RSM is an empirical modeling approach for determining the relationship between various process parameters and responses with the various desired criteria and

Figure 3.1: EDM Machine

Fixed Parameter			Control Parameter					
Parameter with symbol	Value	Unit	Parameter	Symbol	Level 1	Level 2	Level 3	Unit
Duty Cycle(τ)	90	%	Dis. Curr.	IP	2	5	8	Amp
Flashing Pressure(f)	0.2	Kgf/cm2	Pulse on Time	Ton	50	175	300	μs
Work Time(tw)	0.5	Sec.	Voltage	V	40	45	50	Volt
Lift Time(T↑)	0.3	Sec.						

Table 3.1: for fixed and controlled parameter

Figure 3.2: Workpiece

searching the significance of these process parameters on the responses [12]. RSM is a collection of mathematical and statistical techniques that are useful for modelling and analysis of problems in which output or response is influenced by several input variables and the objective is to find the correlation between the response and the variables investigated [13].By using the design of experiments and applying regression analysis, the modeling of the desiring response to several independent input variables can be obtained. In the RSM, the quantitative form of relationship between desired response and independent input variables could be represented as: y = f (x1, x2, x3, . . . xn) $\pm$ a_0 where y is the desired response i.e. in our case it is Surface rough-

Run	Ip	Ton	Voltage	Surface Roughness(Ra)
1	2	3	2	8.693
2	2	2	1	8.453
3	2	2	2	7.830
4	2	2	2	7.840
5	2	1	2	5.640
6	1	2	2	5.940
7	2	2	3	7.660
8	3	2	2	10.860
9	2	2	2	9.201
10	1	4	1	3.600
11	2	2	2	8.930
12	3	1	1	6.460
13	3	3	3	11.860
14	1	1	3	4.550
15	3	1	3	5.660
16	2	2	2	8.800
17	1	3	3	4.530
18	2	2	2	9.060
19	3	3	1	11.600
20	1	1	1	5.130

Table 3.2: Analysis of Variance for SR, using Adjusted SS for Test

Term	Coefficient
Constant	8.57074
Ip	2.26900
Ton	1.28430
V	-0.09830
Ip*Ip	-0.11159
Ton*Ton	-1.34509
V*V	-0.45509
Ip*Ton	1.61125
Ip*V	-0.11125
Ton*V	0.32125

Table 3.3: Table of coefficients

ness(Ra), f the response function (or response surface), x1, x2, x3, . . ., xn are the independent input variables i.e. in our experiment these factors are discharge current, gap voltage and pulse on time, and a_0 is the fitting error[12]. The appearance of response function is a surface as plotting the expected response of f. The identification of suitable approximation of f will find out whethr the application of RSM is succesful or not. In ths study, the approximation of f will be proposed using the fitted 2nd order polynomial regression model, which called the quadratic model. The quadratic model of f can be written as below:

$$f = a_0 + \sum_{i=1}^{n} a_i x_i + \sum_{i=1}^{n} a_{ii} {x_i}^2 + \sum_{i<j}^{n} a_{ij} x_i x_j + \epsilon, \quad (3.1)$$

where a_i represents the linear effect of x_i, a_{ii} represents the quadratic effect of x_i and a_{ij} reveals the linear-by-linear interaction betwen x_i and x_j.Since Central Composite Design (CCD) predicts performance characteristics with a high degree of accuracy during experimentation. The unknown coefficients are determined from the experimental data as presented in Table 3.3.

The equation is now given as

SR = 8.57074 + 2.26900Ip + 1.26900Ton + -(0.09830)V + -(0.11159)Ip2 + -(1.34509)Ton2 + -(0.45509)V2 + 1.61125IpxTon + 0.32125 TonxV + -(0.11125)IpxV.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	contribution
Ip	2	58.584	51.518	25.759	13.89	0.001	54.64
Ton	2	23.846	21.470	10.735	5.79	0.016	22.24
V	2	0.666	0.666	0.333	0.18	0.838	0.62
Error	13	24.103	24.103	1.854			22.48
Total	19	107.200					100

Table 3.4: Analysis of Variance for SR, using Adjusted SS for Test

Term	Coef	SE Coef	T	P
Constant	8.57074	0.1687	50.794	0.000
Ip	2.26900	0.1552	14.619	0.000
Ton	1.28430	0.1552	8.274	0.000
V	-0.09830	0.1552	-0.633	0.541
Ip*Ip	-0.11159	0.2960	-0.377	0.714
Ton*Ton	-1.34509	0.2960	-4.545	0.001
V*V	-0.45509	0.2960	-1.538	0.155
Ip*Ton	1.61125	0.1735	9.285	0.000
Ip*V	-0.11125	0.1735	-0.641	0.536
Ton*V	0.32125	0.1735	1.851	0.094

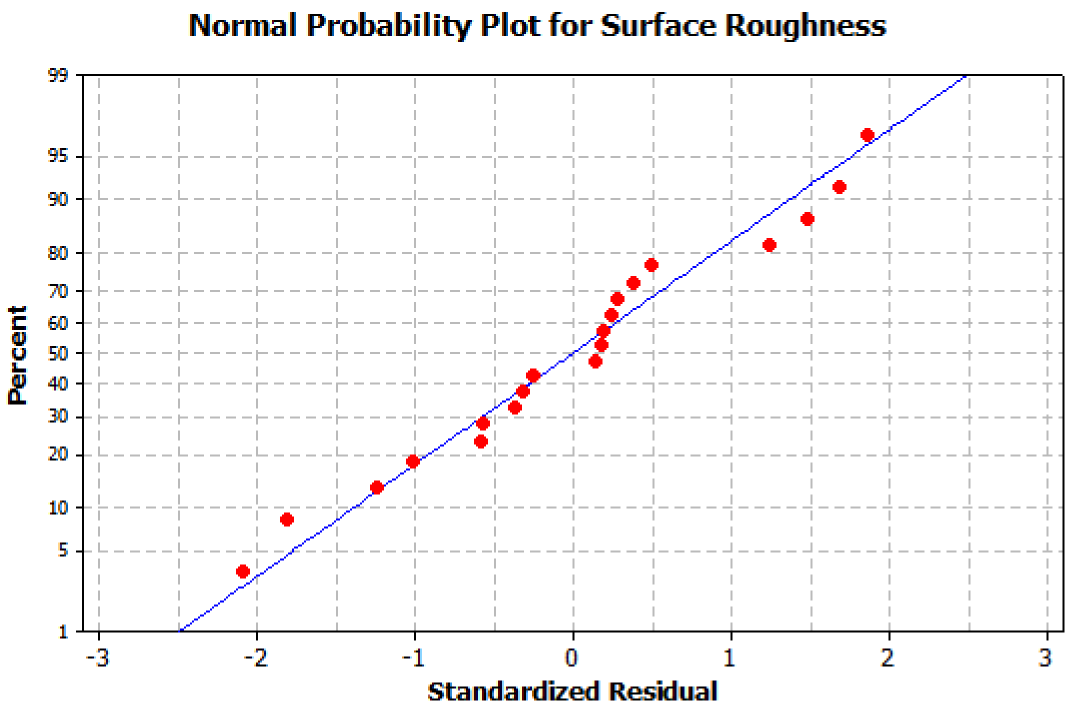
S = 0.4908 R-Sq = 97.8% R-Sq(adj) = 95.7% height

Table 3.5: For T and P

The F ratios are calculated for 95% level of confidence and the factors having p-value more then 0.05 are considered insignificant. For the appropriate fitting of SR, the non-significant terms are eliminated by some process. The regression model is re-evaluated by determining the unknown coefficients, which are tabulated in Table 3.4.

The model made to represent SR depicts that Ip and Ton are the most significant terms.

The graph given below is the normal probability plot for surface roughness. We can see that all values lie near to the line. It means that our result is very satifactory.

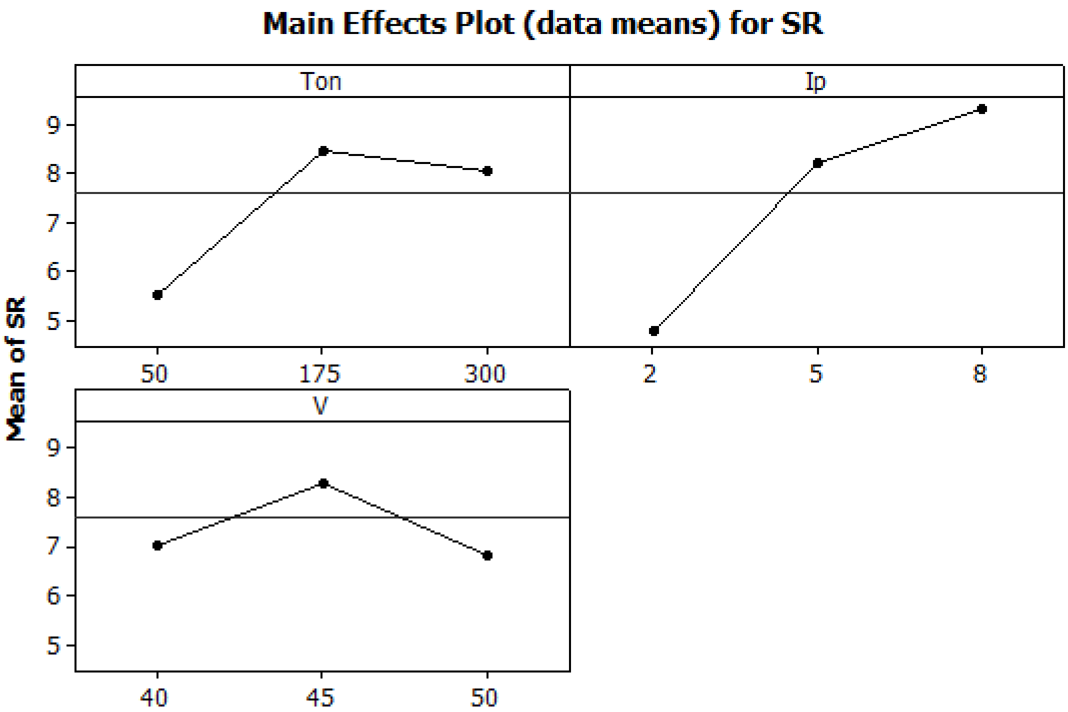


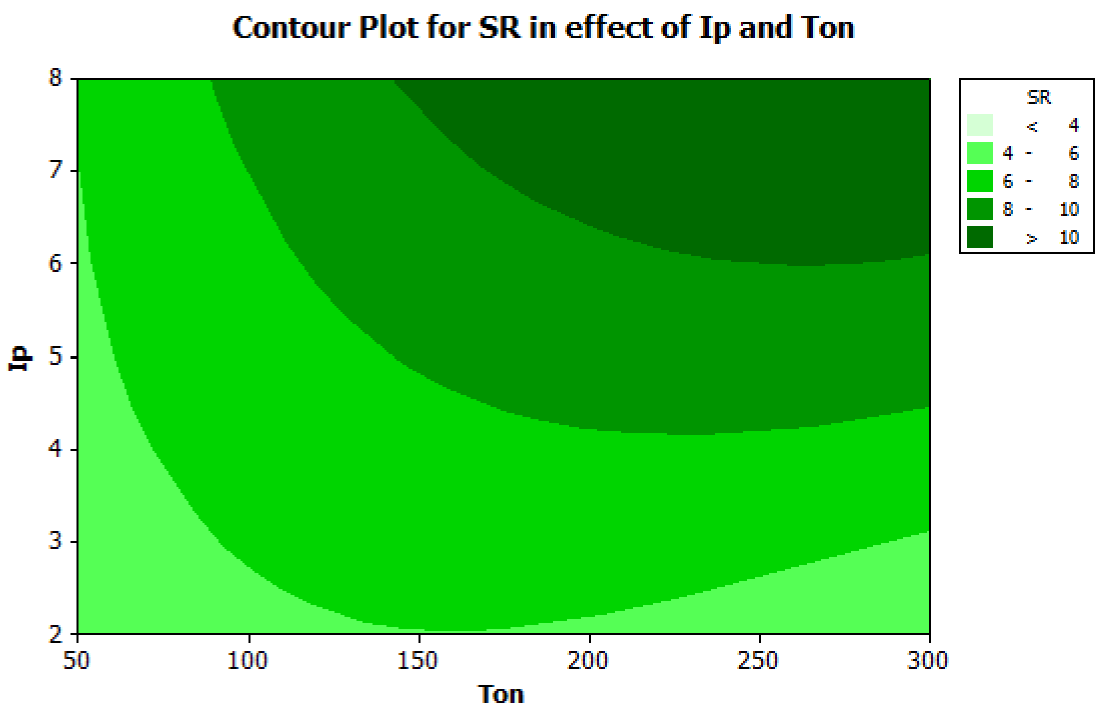
Main graphh of Surface roughness(Ra) is given below. As we can see Ip is the most significant term, Surface roughness(Ra) is directly proportional to it. Surface roughness increases with Ip.

Voltage is less significant term as shown in graph. Surface roughness is not much effected with voltage.

As regard of pulse on time(Ton) we can see that surface roughness is minimum at 50. Surface roughness(Ra) increases with Pulse on time (Ta) for some time and then it starts decreasing with it. The surface roughness is obtained best at Ton = 50micro sec.

The interaction of Ip and Ton is shown below since they are the significant terms. We can see that the best surface roughness is obtained at Ton = 50micro sec and Ip = 2 Ampere. Hence, we obtained the values of the parameters at which surface roughness is optimized.


Main Effects Plot (data means) for SR
Ton
Ip
V
Mean of SR
9
8
7
6
5
50
175
300
2
5
8
40
45
50


Contour Plot for SR in effect of Ip and Ton
SR
< 4
4 - 6
6 - 8
8 - 10
> 10
Ip
Ton
8
7
6
5
4
3
2
50
100
150
200
250
300

Chapter 4

Conclusion

In the present study, the EDM process parameters with significant influence on Surface roughness were determined by using RSM approach. A second order response model of these parameters are developed and found that discharge curren(Ip) and pulse on time(Ton) significantly affect the surface roughness. Surface roughness is directly proportional to discharge current and pulse on time. The lower value of surface roughness is achieved with Ip = 2 A, Ton = 50 s and V = 50 s within the experimental domain. The research findings of the present study based on RSM models can be used effectively in machining of Mild steel in order to obtain best possible EDM efficiency.

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