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Optimization of MRR in EDM Process with Different Job Material i.e Stainless Steel and Cast Iron by Taguchi Method.

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ABSTRACT

Electro discharge machining (EDM) has been recognized as an efficient method of producing dies and machining of hard material such as ceramics and high strength metal matrix composites for the modern metal industry (1). In this process the metal are remove through melting or vaporization of job metal by high frequency spark discharge. Although in this process the metal removal rate is lower than the other non-conventional machining process. But the dimensional accuracy is higher than the other process and more complex shape can be produce generally composite material are fascinated as thy exhibit exceptional mechanical and physical properties such as high strength, high hardness, and high density at elevated temperature. For this extra ordinary behavior it has wide range of application on the metal industries like aerospace, dies or mould making industries, automobiles industries etc. The metal removal rate (M.R.R.) and surface smoothness not only depend on the selection of tool material also depend on the number of input parameter (such-input current, voltage, spindle speed, duty factor, dielectric medium), job metal property (conductivity ,hardness, strength, density etc.),machine condition and machining condition(machine performances, temperature, depth of cut or area of cut etc.). It is most difficult to select machining condition for optimal performances due to large number of parameters and inherent complexity of material removal mechanism taking place in EDM process. In the present work, the experiments were conducted using Taguchi L9 orthogonal approach, to ascertain the effect of EDM process parameters on material removal rate (MRR) of stain less steel and cast iron by using tool material such copper and graphite.

Keywords: MMR, Taguchi orthogonal approach.

I. INTRODUCTION

The electro discharge machining was first traced far back in 1770's by English scientist Joseph Priesty who discovered the erosive effect of electrical discharges or sparks (2). In the year 1943 it was develop by Lazarenko. Now a days it is an acceptable technology all over the world. Traditional machining process that make chips formation have a number of inherent limitation which limit their application in industry. Large amount are expanded to produce unwanted chip which must be removed and discarded. Much of the machining energy ends up with an undesirable heat that often produces problem of distortion and surface making. Cutting force required that the work pieces be held which can also lead to distortion. Unwanted distortion, residual stress and burrs caused by machining process often require further processing. Finally some geometries which are difficult to machining by conventional methods. In this sense that the metal like tungsten, hardened stainless steel, titanium, some high strength steel alloy etc. are such that they can't be machined by conventional method but required some special technique. EDM is that most important machining technique.

The Main advantage of this process is that the machining process is not depend on the hardness, toughness, and brittleness of the work material and can produce any intricate shape on any work piece material by a suitable control over various physical parameters of the process.

In this machining process there is no direct contact between tool and work piece. The metal is removed from the work piece through localized melting and vaporization of material. Electric sparks are generated between two electrodes when electrodes are held at a small distance from each other in a dielectric medium and high potential difference is applied across them. Localized regions of high temperatures are formed due to the sparks occurring between the two electrode surfaces. Work piece material in this localized zone melts and vaporizes. Most of the molten and vaporized material is carried away from the inter electrode gap by the dielectric flow in the form of debris particles.

II. EXPERIMENTAL PROCEDURE

2.1 EXPERIMENTAL MATERIAL :

The material that are normally used as electrodes in EDM are copper, graphite, tungsten and brass. In this present work copper and graphite are taken as the tool material. Both electrode are prepared with dia. Φ-6m.m. and length of 45 mm. and stainless steel(SUS410) and cast iron (HT200)are taken as work material both have wide range of application in industrial filed like manufacturing ,cryogenic, space application etc. the spectra analysis results for the composition of the work piece are listed as under

Table 1. Chemical composition of stainless steel

Element	C	Si	Mn	P	S	Cr	Pb
Comp(%wt)	0.12	0.95	0.97	0.039	0.029	12.58	0.047

Table 2. Chemical composition of cast iron

Element	C	Si	Mn	P	S	Cr
Comp(%wt)	3.27	1.96	0.67	0.17	0.14	4.20

Table 3. Major properties of the tool and work piece are listed as flows:

Material Property	Tool Material		Work Piece	
	Copper	Graphite	Stainless steel	Cast iron
Density	8940 kg/m^3	2157 kg/m^3	7850 kg/m^3	7570 kg/m^3
Thermal conductivity	401 Wm^{-1}k^{-1}	130 Wm^{-1}k^{-1}	18 Wm^{-1}k^{-1}	55 Wm^{-1}k^{-1}
Electrical resistivity	16.78 nΩm(at 20^{0}C)	10 nΩm(at 20^0 C)	69 nΩm(at 20^0 C	10 nΩm(at 20^0 C
Specific heat capacity	0.385J/g ^{0}C	0.72 J/g ^{0}C	0.49 J/g ^{0}C	0.46 J/g ^{0}C
Melting point	1085 ^{0}C	4300^0 C	1535 ^{0}C	1200 ^{0}C

2.2DESIGN OF EXPERIMENT

In this present work we have experimental research work at MSME tool room, Kolkata with different work pieces, stainless steel (112*47*11) and cast iron (d=50mm, h=12 mm) and different tool materialscopperand graphite(dia. φ=6mm, h=70 mm). The whole experiments have been done by electro discharge machine, modelAGITRON COMPACT -1 (die sinking type) and the positive polarity for electrode is used to conduct the experiments. RUSTLICK E.D.M. 20 oil is used as dielectric fluid which specific gravity 0.763 and freezing point 93^0 C

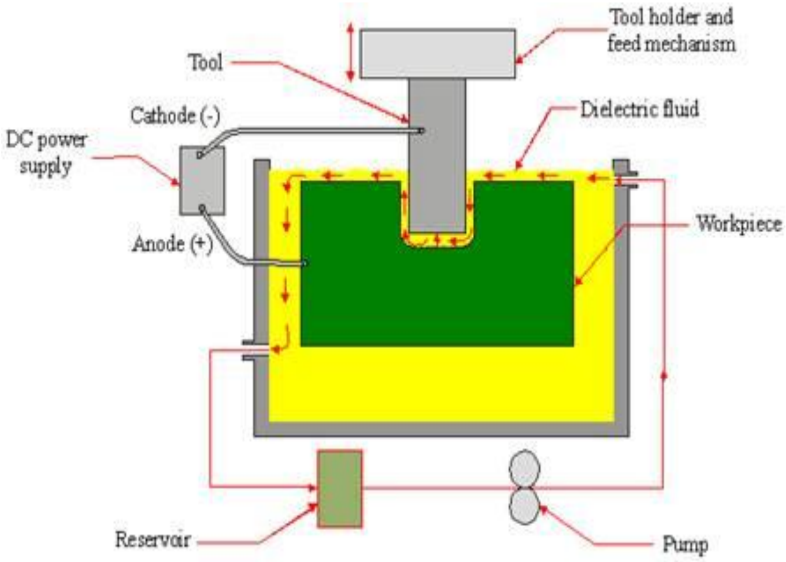

Fig.-1 Working principle of EDM machine

2.3 PARAMETERS AND RANGE SELECTION

In this present work I have selected the parameter as below.

Table-4 Parameter selection

Parameters	Symbol	Level		
		Low	Medium	High
Electrode speed (mm/min)	S	500	600	700
Current(amp)	I	3	4	5
Depth of cut(mm)	h	2	3	4

III. TAGUCHI L_9 ORTHOGONAL ARRAY

Table-5 orthogonal array

Exp. No	Control factor		
	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	2
8	3	2	3
9	3	3	1

IV. OBSERVATION TABLE

EXPERIMENT NO. 1

Table -6. Work piece-CAST IRON Electrode-COPPER Dia. φ=6mm

Exp. no	Spark gap(mm)	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Machining time(sec)	MRR (mm^3/min)
1	0.14	500	3	2	432	8.6075
2	0.20	500	4	3	611	9.4810
3	0.23	500	5	4	685	11.488
4	0.14	600	3	3	688	8.107
5	0.20	600	4	4	832	9.283
6	0.23	600	5	2	260	15.133
7	0.14	700	3	4	1042	7.137
8	0.20	700	4	2	310	12.45
9	0.23	700	5	3	461	12.80

EXPERIMENT NO. 2

Table -7 Work piece-CAST IRON Electrode-GRAPHITE Dia. φ=6mm

Exp. no	Spark gap(mm)	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Machining time(sec)	MRR (mm^3/min)
1	0.14	500	3	2	468	7.945
2	0.20	500	4	3	681	8.506
3	0.23	500	5	4	823	9.553
4	0.14	600	3	3	744	7.490
5	0.20	600	4	4	895	8.622
6	0.23	600	5	2	316	12.440
7	0.14	700	3	4	1026	7.248
8	0.20	700	4	2	448	8.620
9	0.23	700	5	3	504	11.710

EXPERIMENT NO. 3

Table -8 Work piece-STAINLESS STEEL Electrode-COPPER Dia. φ=6mm

Exp. no	Spark gap(mm)	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Machining time(sec)	MRR (mm^3/min)
1	0.14	500	3	2	694	5.35
2	0.20	500	4	3	1129	5.13
3	0.23	500	5	4	1320	5.96
4	0.14	600	3	3	695	8.03
5	0.20	600	4	4	956	8.07
6	0.23	600	5	2	330	11.92
7	0.14	700	3	4	643	11.56
8	0.20	700	4	2	218	17.715
9	0.23	700	5	3	297	19.87

EXPERIMENT NO. 4

Table-9 Work piece-CAST IRON Electrode-GRAPHITE Dia. φ=6mm

Exp. no	Spark gap(mm)	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Machining time(sec)	MRR (mm^3/min)
1	0.14	500	3	2	1735	2.143
2	0.20	500	4	3	4409	1.308
3	0.23	500	5	4	8525	1.919
4	0.14	600	3	3	2742	4.293
5	0.20	600	4	4	5254	3.092
6	0.23	600	5	2	964	0.86
7	0.14	700	3	4	3538	4.459
8	0.20	700	4	2	643	1.428
9	0.23	700	5	3	1651	7.6086

V. CALCULATION OF MATERIAL REMOVAL RATE (MRR)

Material removal rate refers to the amount of metal removed from work piece per unit time.

$$MRR = \frac{VOLUME}{TIME} = \frac{\frac{\pi}{4}h}{time} d^2 mm^3/min$$

[Where d = diameter of electrode, h = depth of cut]

VI. REGRESSION ANALYSIS

In statistics, regression analysis is a statistical process for estimating therelationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between dependent and one or more independentvariables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed (wiki).

In this problem there is more than one predictor variable is involve so simple regression can't be used (4). So need to help multiple regression analysis.

Multiple regression analysis have two type i) simple multiple regression analysis (first order regression analysis) ii) polynomial multiple regression analysis (second order regression analysis)

Simple multiple regression analysis is represented by the equation of first order regression

$Y = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\ldots\ldots+\varepsilon$ Where β is constant terms & X is the variables & ε is the experimental error. Polynomial multiple regression analysis equation is

$$Y = \beta_0 + \beta_1X_1+\beta_2X_2 +\beta_3X_3 + \beta_4 X_1^2+ \beta_5 X_2^2+ \beta_6X_3^2+ \beta_7 X_1X_2 + \beta_8 X_2 X_3 + \beta_9 X_1 X_3$$

The above equation is second order polynomial equation for 3 variables. Where β are constant, X_1, X_2, X_3 are the linear terms. Here, MRR is Response variable, Electrode Speed (S), Current (I), Depth of Cut (h) are the predictor variables. Polynomial regression equation becomes after replacing real problem variables

$$MRR = \beta_0 + \beta_1(S) + \beta_2(I) + \beta_3(h) + \beta_4 (S)*(S) + \beta_5 (I)*(I) + \beta_6 (h)*(h) + \beta_7 (S)*(I) + \beta_8 (I)*(h) + \beta_9 (S)*(h) \quad \ldots\ldots (1)$$

To solve this equation following matrix method is used

$$MRR= [\beta] [X] \quad \ldots\ldots (2)$$

$[\beta]= [MRR] [X^{-1}]$

where [β] is the coefficient matrix, MRR is the response variable matrix; $[X^{-1}]$ is the inverse of predictor variable matrix ……………….(3)

In this problem there are 3 independent variables and each variable has 3 levels and hence from the Taguchi Orthogonal Array (OA) table L_9 OA is best selected

VII. RESULTS AND DICUSSIONS

Value of coefficients for the predicted equation

β0 = 6.8541, β1 =0.0585, β2 =-3.1504, β3 =-16.4153, β4 =0.0001, β5 =1.3254, β6 =-0.8858, β7 =-0.0278, β8 =4.3390, β9 =0.0047

So, the Predicted equation is

$$MRR=6.8541+0.0585(S)-3.1504(I) - 16.4153(h) +0.0001(S^2) +1.3254(I^2)- 0.8858(h^2) - 0.0278(S*I) + 4.3390(I*h) + 0.0047 (h*S)$$

VIII. Percentage Difference between Experimental & Predicted MRR

Table-10 Work piece-CAST IRON Electrode-COPPER Dia. φ=6mm

SL. no	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Experimental MRR (mm^3/min)	Predicted MRR (mm^3/min)
1	500	3	2	8.6075	7.041867
2	500	4	3	9.481	7.872567
3	500	5	4	11.488	9.836667
4	600	3	3	8.107	8.035867
5	600	4	4	9.283	9.160567
6	600	5	2	15.133	15.04627
7	700	3	4	7.137	8.831067
8	700	4	2	12.45	14.18577
9	700	5	3	12.8	14.47587

Table-11 Work piece-CAST IRON Electrode-GRAPHITE Dia. φ=6mm

SL. no	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Experimental MRR (mm^3/min)	Predicted MRR (mm^3/min)
1	500	3	2	7.945	4.556689
2	500	4	3	8.506	4.991289
3	500	5	4	9.553	12.54589
4	600	3	3	7.49	6.178089
5	600	4	4	8.622	5.896689
6	600	5	2	12.44	11.78029
7	700	3	4	7.248	9.092689
8	700	4	2	8.62	12.54229
9	700	5	3	11.71	14.55009

Table-12 Work piece-STAINLESS STEEL Electrode-COPPER Dia. φ=6mm

SL. no	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Experimental MRR (mm^3/min)	Predicted MRR (mm^3/min)
1	500	3	2	5.35	2.5335
2	500	4	3	5.13	2.3006
3	500	5	4	5.96	11.6249
4	600	3	3	8.03	6.9762
5	600	4	4	8.07	7.0007
6	600	5	2	11.923	10.8851
7	700	3	4	11.56	12.5873
8	700	4	2	17.71	18.7789
9	700	5	3	19.87	20.9158

Table-13 Work piece-CAST IRON Electrode-GRAPHITE Dia. φ=6mm

SL. no	Electrode speed(mm/min)	Current (amp)	Depth of cut(mm)	Experimental MRR (mm^3/min)	Predicted MRR (mm^3/min)
1	500	3	2	2.14	2.277922
2	500	4	3	1.3	3.177222
3	500	5	4	1.91	13.68348
4	600	3	3	4.29	2.383278
5	600	4	4	3.09	1.113978
6	600	5	2	0.86	1.148922
7	700	3	4	4.459	5.524478
8	700	4	2	1.428	2.441578
9	700	5	3	7.608	8.542278

IX. Graphical Representation

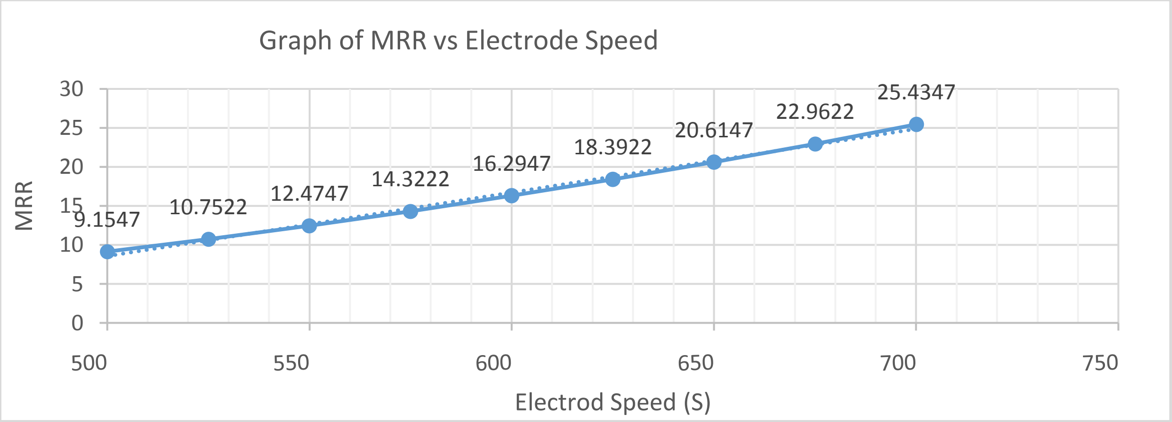

Fig. 2. MRR vs Electrode Speed

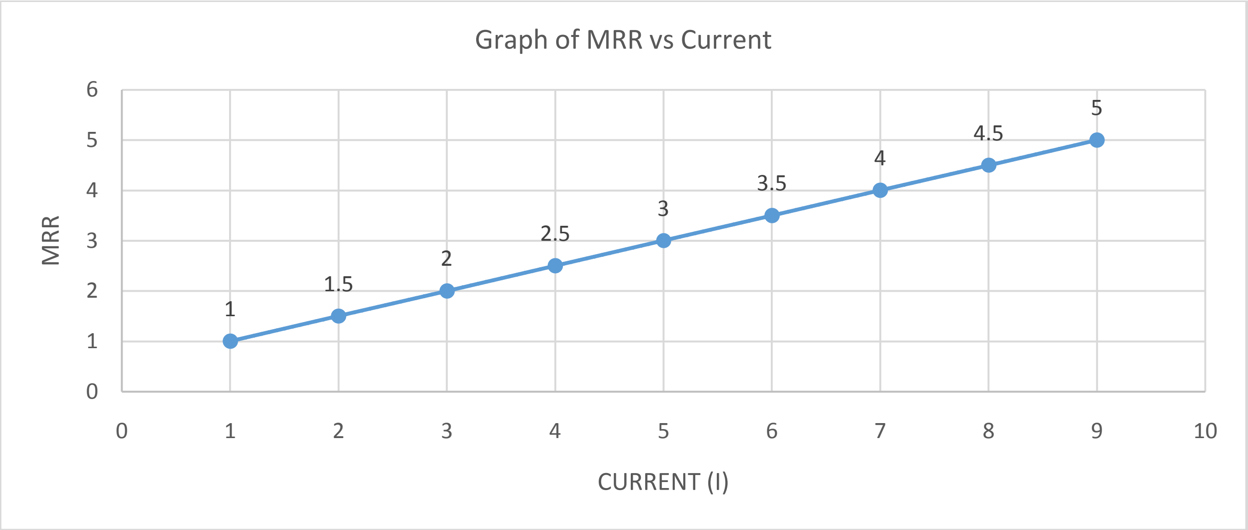

Fig. 3.MRR vs Current

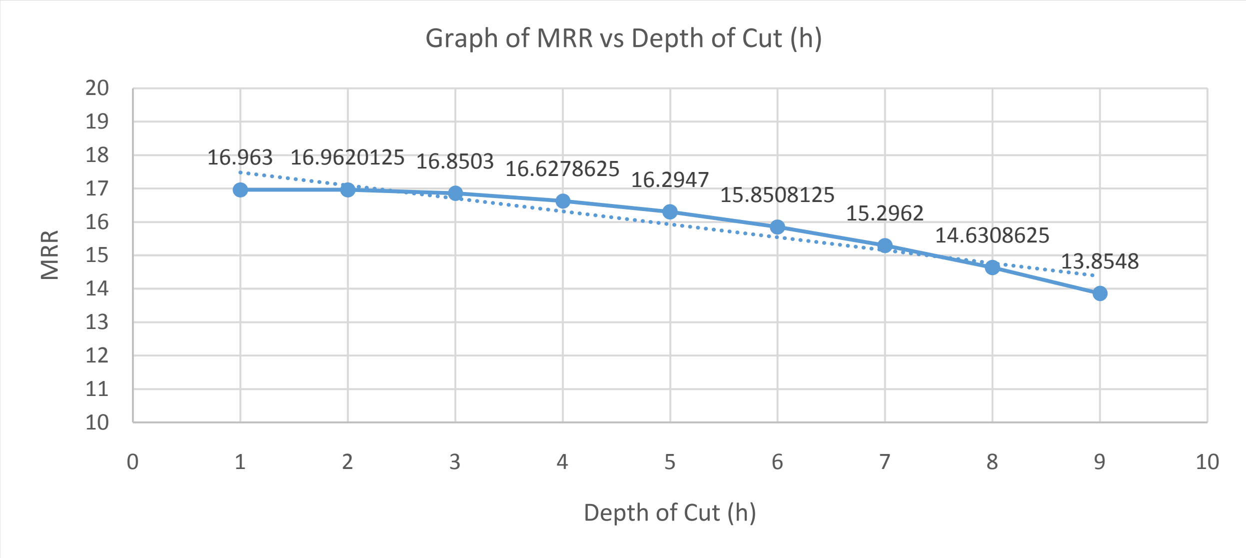

Fig. 4.MRR vs Depth of Cut (h)

X. CONCLUSION

In this work we have shown, how the MRR is differed with the Electrode speed,Current and Depth of cut in different job material cast iron, stainless steel with the different tool material copper and graphite and we show in fig. (2) MRR depend on the electrode speed in hyperbolic relationship if the electrode speed increases MRR also increases as like hyperbolic carveand in fig (3) show that MRR linearly depends on applied current ,MRR increases proportionally with increase the applied current .Also show in fig(4) parabolic decrease with increase the depth of cut. and shown that, maximum MRR obtain for the combination of-Work piece-STAINLESS STEEL ,Electrode-COPPER ,spindle speed 700 rpm ,current 5amp, and depth of cut 4 mm.

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