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Efect of Silicon Carbide (Sic) Abrasive Particles Mixed In Die Electric Fluid on the Performance of Edm by Regression Analysis

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Abstract:- In this paper the Silicon carbide(SiC) abrasive particles are mixed in dielectric fluid to find out its effect on the performance of EDM. The Electric discharge machining is used particularly when complex shapes are to be produced on the hard materials. The surface roughness is one of the most considerable characteristics in EDM. An good surface finish significantly improves the corrosion resistance, creep life etc. The silicon carbide abrasive mixed dielectric fluid facilitates the bridging effect and it will minimize the insulating strength of the dielectric fluid. The abrasive particle mixed into the dielectric fluid significantly affects the performance of EDM. As a result, it improves the surface finish and the machining efficiency. The regression technique is used to optimize the process parameter combination that yields desirable machining characteristics. The result indicates that the significant parameters found are discharge current and abrasive particle concentration.

Keywords:- Surface roughness, Silicon carbide abrasive, Regression analysis, Dielectric fluid, Abrasive particle size.

I. INTRODUCTION

EDM has been recognized as an excellent machining to obtain more accurate and complex shapes on hard and brittle materials. However the machining process has limited application when there is high metal removal and high surface quality is required. Advanced materials like super alloys, Die steel are having wide spread industrial applications. Silicon carbide abrasive particles are mixed with the dielectric fluid to conduct the experiments on D3 die steel. The discharge break down at the beginning will occur when the electrical field density surpasses the breakdown resistance capacity then the discharge break down causes a short circuit between the two abrasive particle takes place. The electric charges then leads to the discharge between the phenomenon increases the sparking intensity leading to faster erosion from the work surface other abrasive particles resulting in series discharge and discharge between the electrode and work piece take place. Thus it has found that the addition of Silicon carbide abrasive particles increases the MRR and improves the surface finish

The purpose of the study is to find out the effect of Silicon carbide abrasive particles on the performance of EDM for D3 Die steel and optimize the process parameters to develop mathematical model to predict surface roughness, by investigating the most dominant variables among the nozzle flushing, discharge current, duty cycle, pulse on time, abrasive particle concentration, abrasive particle size, and gain. The linier regression technique is used to optimize the process parameters with the use of Minitab software. The experiments are designed as per the Taguchi's orthogonal array and in this study the L18, mixed orthogonal array is used for experimentation.

II. LITERATURE REVIEW

The summary of the review of Literature is given as follows.
Pecas and Henrique's(2003), carried out the work on Silicon powder mixed dielectric on EDM. They observed that by addition of 2g/lit of silicon powder to the dielectric fluid the operating time and surface roughness decreases. The average surface roughness depends on machining area. In this paper the machining time has a greater effect on decreasing the surface roughness and it almost eliminates the undesirable discharge conditions
Y.F.Tzeng and C.Y.Lee(2001), investigated the effects of powder characteristics on electro discharge machining efficiency. This paper presents the effects of various powder characteristics on the efficiency of EDM on SKD-11. The spark gap was increased for appropriate amount of powder addition. With the addition of copper and chromium powder to the dielectric fluid the MRR increases and the TWR decreases as well as surface roughness improves.

Kun Ling Wu,Biing Hwa Yan(2005), carried out the work on improvement of surface finish on SKD Steel using EDM with aluminum and surfactant added dielectric. It can lower the insulation and increases the gap distance between electrodes. It is observed that when the Aluminum powder and surfactant is added to the dielectric fluid the surface roughness is improved.

G.S.Prihandana, M.Hamdi, Y.S.Wong(2011), investigated the effect of Nano graphite powder in dielectricfluid and found that improvement in MRR and reduction in machining time as well as improvement in surface quality by eliminating the micro-cracks in the surface

Muhammad Pervej Jahan,Mustafiur Rahman,Yoke San Wong(2011), carried out the study on the Nano-powder-mixed sinking and milling micro-EDM of WC-CO. The addition of semi conductive graphite Nano powder in the dielectric oil provides smooth & defect free machined surface. The spark gap and MRR increases with increased amount of powders added in dielectric. Paulo Pecas.E.Henriques(2003), investigated the effect of the powder concentration and dielectric flow in the surface morphology in EDM with powder-mixed dielectric. This paper presents the improvement in the polishing performance of EDM. The evaluation was done by surface morphologic analysis

H. Narumiya, investigated the effects of powder in dielectric fluid on material removal rate and surface roughness. It was reported that aluminum and graphite powders in the dielectric, yield better surface than the silicon powder. The improved results are found for aluminum and graphite powder particles
M.L.Jeswani, carried out the work by mixing the graphite powder into kerosene oil dielectric on EDM. He observed that addition of graphite powder increases the inter space for electric discharge initiation and improvement in machining process stability.

P.Pecas, E.Henriques(2008), carried out the work on EDM using simple & powder-mixed dielectric, the effect of the electrode area in the surface roughness and topography. The use of powder mixed dielectric promotes the reduction of surface roughness, it is confirmed that the electrode area influence the surface quality.

III. EXPERIMENTAL SET UP

The abrasive mixed EDM system is developed to conduct the experiments on D3 die steel. The dielectric circulation system is designed for 5 liters of dielectric fluid with micro pump for better circulation of the abrasive particles in the dielectric fluid. The experiments were conducted on PNC-480 EDM. Magnets are used to separate the abrasive particles from the debris of the machining. Stirrer is introduced to mix the abrasive particles thoroughly with the dielectric fluid and to avoid the settling of the abrasive particles at the bottom of the tank.

As per the orthogonal array L18, the experiments were carried out. The parameters selected are nozzle flushing, pulse on time, discharge current, abrasive particle size, abrasive particle concentration, duty cycle, and gain was taken as per the level design. In this type of process, Silicon carbide(SiC) abrasive particles are mixed into the dielectric fluid. the electrode material selected is brass and work material is D3-Diesteel. When a voltage is applied between the electrode and work piece, an electric field is created. The gap is maintained between tool and work piece and is filled up with abrasive particles. The abrasive particles get energized and move in a zigzag manner. The grains come close to each other and the inter locking between the other abrasive particle takes place. The abrasive particles form a chain under the sparking zone. due to bridging effect the gap voltage and insulating strength of the dielectric fluid decreases. Therefore very fast short circuit takes place and early explosion in the gap. The series discharge takes place between the electrode and work piece, very fast sparking takes place due to increase in frequency of discharge, which helps for faster erosion of metal from the work piece.

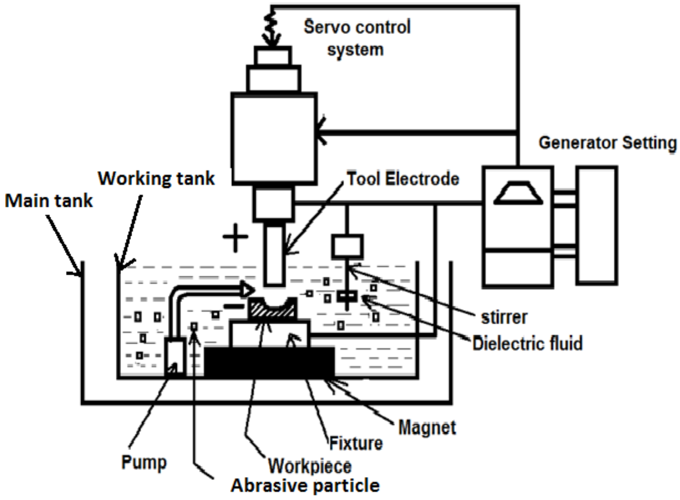

Fig 1. Schematic diagram of abrasive mixed EDM- setup

3.2 Work piece and Abrasive material

AISI D3 Die steel was selected as work material. D3 die steel is an air hardening high carbon high chromium tool steel. It displays excellent wear resistance, good dimensional stability and high compressive strength. It is heat treatable and will offer a hardness in the rage 58-64 HRC. It is used in manufacturing of blanking tools, thread rolling dies, drawing dies and pressing tools for the ceramics and cold rolls for multiple roller strands. A typical chemical composition of AISI D3 die steel is C(2.10%), Si(0.30%), Cr(11.50%), Mn(0.40%), Ni(0.311%).

Silicon carbide is one of the hardest abrasive material and it is a compound of silicon and carbide with a chemical formula of SiC. The density of Silicon carbide is 3.21g/cm3 and melting point is 27000c and it is not attacked by any acids or alkalis at 8000c and is able to be used up to 16000c. The high thermal conductivity coupled with low thermal expansion and high strength give this material exceptional thermal shock. The Silicon carbide is an attractive semiconductor material for high temperature electronic and electro-optic applications. It is also used for stone polishing, rock polishing, engraving and grinding for non ferrous materials.

3.3 Experimental Design

Minimum No. of experiments considered are = 18

The orthogonal array selected is L18 (2^1 x3^6)

Table 2- Process parameters and Levels

Code	**Parameters**	**Levels**		
		1	**2**	**3**
A	Nozzle flushing	Yes	No	**-**
B	Discharge current(Amp)	6	9	**12**
C	Duty Cycle (%)	0.6	0.7	**0.8**
D	Pulse on time (sec)	50	100	**150**
E	Abrasive Particle concentration (g/lit)	2	4	**6**
F	Abrasive Particle size (Grit size of abrasive)	180	300	**400**
G	**Gain (mm/sec)**	**0.8**	**0.9**	**1.00**

(a) **(b)**

Fig 2: (a)&(b) Photographs of Sic abrasive mixed EDM and Surface roughness tester

Table 3- Experimental layout of L18 ($2^1 \times 3^6$) orthogonal array

Expt. No.	**Parameters**							**Response**
	A	B	C	D	E	F	G	X1
1	1	1	1	1	1	1	1	
2	1	1	2	2	2	2	2	
3	1	1	3	3	3	3	3	
4	1	2	1	1	2	2	3	
5	1	2	2	2	3	3	1	
6	1	2	3	3	1	1	2	
7	1	3	1	2	1	3	2	
8	1	3	2	3	2	1	3	
9	1	3	3	1	3	2	1	
10	2	1	1	3	3	2	2	
11	2	1	2	1	1	3	3	
12	2	1	3	2	2	1	1	
13	2	2	1	2	3	1	3	
14	2	2	2	3	1	2	1	
15	2	2	3	1	2	3	2	
16	2	3	1	3	2	3	1	
17	2	3	2	1	3	1	2	
18	2	3	3	2	1	2	3	

Table 4 - Factors and Experimental observations L18 ($2^1 \times 3^6$) orthogonal array

Expt. No.	Parameters							Ra (µm)	S/N Ratio	Predicted Ra (µm)
	A	B	C	D	E	F	G			
1	Y	6	0.7	50	2	180	0.8	1.90	-5.5751	1.9077
2	Y	6	0.8	100	4	300	0.9	1.60	-4.0824	1.5531
3	Y	6	0.9	150	6	400	1.0	1.08	-0.6685	1.1331
4	Y	9	0.7	50	4	300	1.0	2.03	-6.1499	2.5289
5	Y	9	0.8	100	6	400	0.8	1.76	-4.9103	1.8515
6	Y	9	0.9	150	2	180	0.9	2.66	-8.4976	2.5985
7	Y	12	0.7	100	2	400	0.9	3.52	-10.9309	3.3898
8	Y	12	0.8	150	4	180	1.0	3.01	-9.5713	3.2968
9	Y	12	0.9	50	6	300	0.8	2.75	-8.7867	2.6773
10	N	6	0.7	150	6	300	0.9	1.26	-2.0074	1.3731
11	N	6	0.8	50	2	400	1.0	2.02	-6.1070	1.7856
12	N	6	0.9	100	4	180	0.8	1.65	-4.3497	1.4352
13	N	9	0.7	100	6	180	1.0	2.77	-8.8496	2.3168
14	N	9	0.8	150	2	300	0.8	2.16	-6.6891	2.5448
15	N	9	0.9	50	4	400	0.9	1.83	-5.2490	2.1173
16	N	12	0.7	150	4	400	0.8	3.27	-10.2910	3.0265
17	N	12	0.8	50	6	180	0.9	2.88	-9.1878	2.9260
18	N	12	0.9	100	2	300	1.0	3.61	-11.1501	3.4114

IV. RESULTS AND DISCUSSION

Table 5- Response table for Signal to Noise ratios for Ra(Smaller is better)

	Flushing	Discharge Current (Amp)	Duty Cycle (%)	Pulse on time (Sec)	Abrasive Particle con.(g/l)	Abrasive Particle Size	Gain mm/sec
Level	A	B	C	D	E	F	G
1	-6.575	-3.798	-7.301	-6.843	-8.158	-7.672	-6.767
2	-7.098	-6.724	-6.758	-7.379	-6.616	-6.478	-6.659
3		-9.986	-6.450	-6.287	-5.735	-6.359	-7.083
Delta	0.523	6.188	0.850	1.091	2.423	1.312	0.424
Rank	6	1	5	4	2	3	7

Each level of parameters of response table for the average value of S/N ratios are displayed in table 5. The response table gives the relative importance of parameters and the rank gives the sequence for optimum conditions. As per the rank the discharge current is the most important parameter, which is going to influence the surface roughness, next parameter is followed by abrasive particle concentration, abrasive particle size, pulse on time, duty cycle, flushing and gain is having least effect on surface roughness.

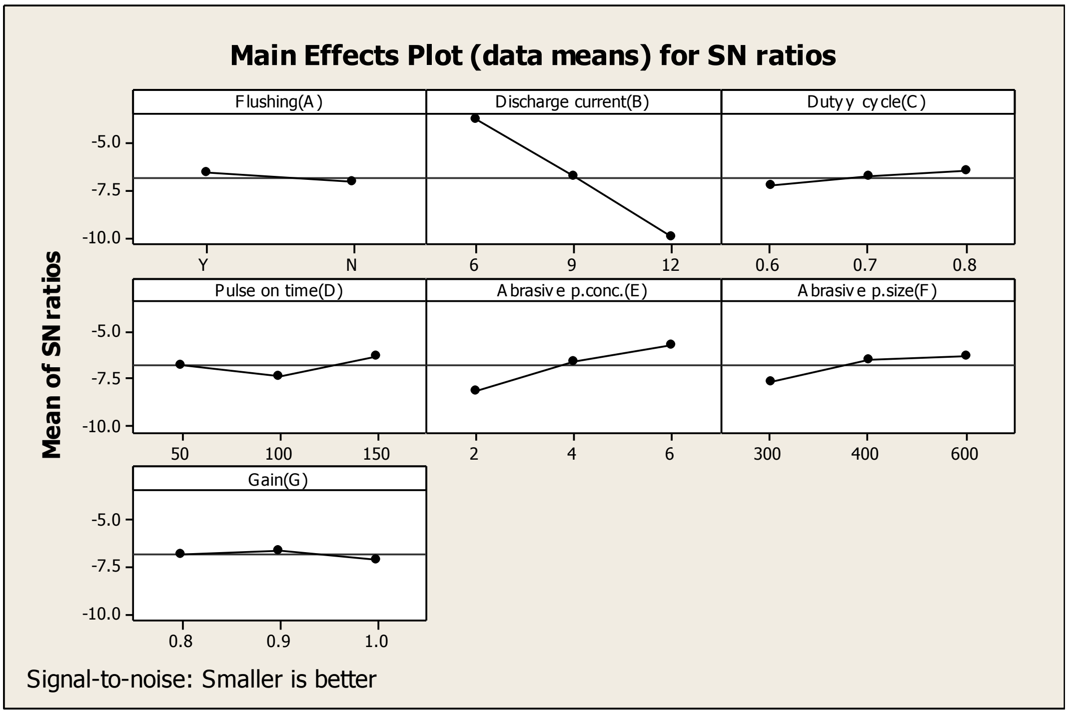

Fig- 3 Main Effects Plot (data means) for SN ratios

Table 6. Analysis of Variance for S/N Ratio of Ra

Source	DF	Seq.SS	Adj.MS	F	p	Contribution (%)
Flushing (A)	1	1.231	1.231	0.62	0.475	1.65
Discharge current (B)	2	114.985	57.493	28.99	0.004	77.69
Duty cycle% (C)	2	2.225	1.112	0.56	0.610	1.50
Pulse on time (D)	2	3.573	1.787	0.90	0.475	2.40
Abrasive.p.c (E)	2	18.055	9.028	4.55	0.093	12.178
Abrasive.p.s (F)	2	6.325	3.163	1.59	0.310	4.25
Gain(mm/sec)(G)	2	0.581	0.291	0.15	0.868	0.401
Error	4	7.932	1.983			
Total	17	154.909				

S=0.618074 R-Sq=98.77%

To investigate the statistical significance of process parameters, Analysis of variance(ANOVA) is performed. As per the probability values(p-value)the significance of each parameter is tested. The value of S/N ratio as per the ANOVA table is less than 0.05, it is considered as significant parameter and the percentage of contribution expresses the importance of the parameters. From the table 6 it is found that the discharge current is the most significant parameter and is followed by the abrasive particle concentration. The other parameters are not having significant effect on the response

The regression equation is

Ra = 0.69 + 0.265 Discharge current (B) - 0.975 Duty cycle(C)
+ 0.00005 pulse on time (D) - 0.140 Abrasive particle concentration.(E)
- 0.000654, Abrasive particle size) + 0.858 Gain (G)

Table 7 - Response table of Regression analysis

Predictor	Coef	SS Coef	T	P
Constant	0.687	1.097	0.63	0.544
Discharge current (B)	0.26472	0.02931	9.03	0.000
Duty cycle% (C)	-0.9750	0.8793	-1.11	0.291
Pulse on time (D)	0.000050	0.001759	0.03	0.978
Abrasive.p.c (E)	-0.14042	0.04397	-3.19	0.009
Abrasive.p.s (F)	-0.0006536	0.0005756	-1.14	0.280
Gain(mm/sec)(G)	0.8583	0.8793	0.98	0.350

Table 8 - Analysis of variance

Source	DF	SS	MS	F	P
Regression	6	8.8370	1.478	15.87	00.00
Residual Error	11	1.0206	0.0928		
Total	17	9.8576			

S=0.3046 R-Sq=90.40%

The regression equation establish the mathematical relationship between process parameters and surface roughness. The regression model is analyzed by ANOVA and the values are shown in table7. As per the probability values the coefficients for discharge current and abrasive particle concentration are statistically significant. Regression model shows that for Ra value is statistically significant at 95% confidence level. The confirmation values of the responses were compared with the predicted values.

V. EXPERIMENTAL VALIDATION

With the optimal process parameter settings A1B3C3D3E3F2G2, the confirmation experiment was conducted and the results are shown in the table 9.

Table 9 - Confirmation of optimum test result

	Optimum conditions		
	Predicted	**Experimental**	
Levels	A1B3C3D3E3F2G2	Trial No.	A1B3C3D3E3F2G2
Ra(µm)	1.0473	1) 2) 3)	1.0356 1.0347 1.0407
		Mean value is 1.0370 (µm)	

The mean Ra value obtained is 1.0370µm.The predicted value from the regression model is1.0470µm.The optimum Ra value obtained from confirmation test is 1.0370µm which is lower than all the measured Ra values shown in table 4, hence the regression model is validated

VI. CONCLUSIONS

The investigation has been carried out to find out the effect of Silicon carbide abrasive particles on the performance of EDM for D3 Die steel. The regression technique is used to optimize the process parameters with the use of Minitab software. The ANOVA was used to evaluate the statistical significance of each factor on the performance characteristics. Based on the results the fallowing conclusions are made.

1) The machining efficiency is improved by the addition of abrasive particles into the dielectric fluid.
2) The Abrasive particles enlarges the discharge gap and discharge break down is easier in EDM
3) As per the main effects plot the optimal sequence obtained is A1B3C3D3E3F2G2
4) It is observed that the most influencing parameter is discharge current and its contribution is 77.69% and it is fallowed by abrasive particle concentration and its contribution is 12.18% and other parameters are not having significant effect on the response
5) Regression model is developed with the help of Minitab software to predict the surface roughness
6) Based on the confirmation test the surface roughness value of 1.0370µm is in accordance with the predicted value and it is in the acceptable range of error, hence it validates the regression model

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