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Modeling and Analysis of MRR and SR in EDM of AISI 1020 through RSM

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ABSTRACT

AISI 1020 steel have many potential engineering applications for manufacturing industry. Nowadays there is a critical need for cost-effective machining processes for this material. Not much work hither to been reported for machining of AISI 1020 steel with Electrical Discharge Machining (EDM) process. In this work, an attempt has been made to model the machinability evaluation through the Response Surface Methodology (RSM) was machined manufactured through stir casting method. The experimental analysis presented in this paper aims at the selection of optimal machining conditions for EDM of AISI 1020 steel. The work piece material has been cleverly considered as control factor along with the combined effect of five controllable input variables namely Peak Current, Discharge Voltage, Pulse on Time, Pulse off Time, Oil Pressure, and its effect on the Surface Roughness and Material Removal Rate has been investigated with the minimum number of experiments. Analysis of variance is performed to get contribution of each parameter on the performance characteristics and it was observed discharge current is the significant process parameter that affects the EDM robustness .The contour plots were generated to study the effect of process parameters as well as their interactions. The experimental results for the optimal setting show that there is considerable improvement in the process. The application of this technique converts the response variable to a single response process, there by parameters are optimized using central composite design based approach RSM and therefore simplifies the optimization procedure. Result of confirmation experiments shows the established mathematical models can predict the output response that will satisfy the real requirement in practice.

KEY WORDS: Steel Material, Optimization, Response Surface Methodology, Surface Roughness, Material Removal Rate, Electrical Discharge Machining.

1. INTRODUCTION

EDM is recently a well-known electrical type unconventional machining process specifically utilized in precise machining for work pieces of intricate shape, as a choice to more traditional approaches and for details concerning the phenomena of the exterior, inherent to this process. The non-conventional techniques of machining encompass numerous explicit benefits compared to conventional machining techniques. And these promise formidable tasks to be undertaken and set a new record in the manufacturing technology whereas these involved techniques are not restricted by material’s toughness, hardness and brittleness producing any complicated shape on any work piece material by a suitable control across numerous process parameters which involve physically.

EDM is a process of thermal erosion where an electrically produced spark vaporizes the material that conducts electrically. Both electrode (tool) and work piece has to be conductive electrically occuring the spark in a gap occupied with dielectric solution among the work piece and tool. The process removes metal via electrical and thermal energy, having no mechanical contact with the work piece. Its exclusive feature of utilizing thermal energy is machining og parts that conducts electrically without even considering their hardness; its exclusive benefit is in the manufacture of above mentioned modern industry. Additionally, EDM does not create explicit contact among the work piece and electrode, getting rid off mechanical stresses, chatter and vibration problems while machining. Today, an electrode as tiny as 0.1mm could be utilized in making hole into curved surfaces at steep angles excluding drill and generates the spark because of a gap among a tool and work piece. The smaller the gap produce the better surface roughness.

Probability of estimating a global optimum solution and its preciseness rely on the kind of optimization modeling technique utilized in expressing the objective functions and constraints in terms of the decision variables. Accurate and process reliable models could compensate for inability to entirely understand and often brief the mechanism of process.

Hence, formulation of optimization model is the predominant task in optimization involving expression off optimization problem in a standard format as a mathematical model that could be explicitly resolved by RSM. For process parameters optimization of EDM, type of target function and constraints, number of objective and extend of the importance or priority to be given to objective depend on SR and input parameters namely Peak Current (Ip), Pulse On Time (Ton), Pulse Off Time (Toff), Discharge Voltage, Gap Width and Oil Pressure as input parameters. RSM have been utilized in analyzing the influence of the five input parameters and output parameter of MRR and SR of EDM process. Main objective for the EDM processes is to minimize surface roughness.

1.1. Literature survey: Different researchers did the various investigations about EDM. The results were summarizes as follows: Ho and Newman (2003) gone through the research work performed from the inception to the die-sinking EDM development and have also reported on the EDM arch associated for improvising performance measures, the process variables optimization, monitoring and the sparking processes control, the electrode design simplification and manufacturing. Fig.1 presents the classification of the various research areas and possible future research directions. Margaret (2004) exhibited the various inputs analysis into EDM and the out coming outputs into the environment. A simplified model is used in analyzing the process; the main categories of flow in the model are material and energy flow was accomplished that the materials machined by EDM do not possess any effect towards environment.

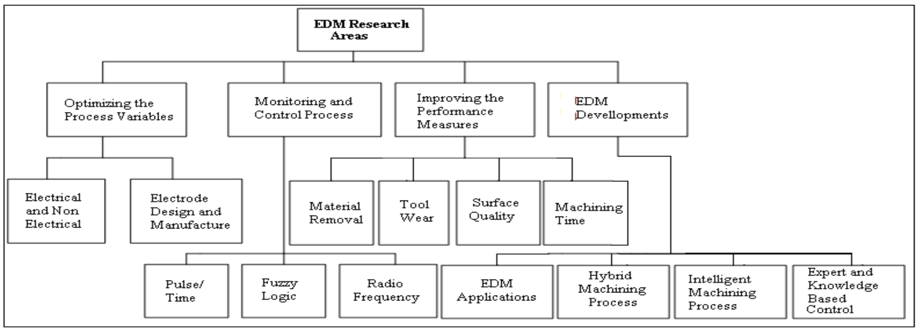

Fig.1.Classification of Major EDM Research Areas

1.2. The objectives of this work:

1.2.1. Design Variables: An optimization problem formulation commences with identifying the low lying design variables that are chiefly mottled while the process of optimization. In this paper peak current, discharge voltage, pulse on time, pulse off time and oil pressureconsidered as design variables.

1.2.2. Constraints: The constraints depict little functional association within the variables of design and other design fulfilling some physical phenomenon and certain resource are more or equal to, a value of resource. In this paper, oversize and the EDM hole are considered as constraints.

1.2.3. Objective Function: The chief function could be of two kinds. Either the objective function is to be minimized or it has to be maximized. In this paper, minimization of total SR and maximization of MRR are considered as objective function.

a) The target of this study is to examine and report the machining parameters effect viz Peak Current, Discharge Voltage, Pulse on Time, Pulse off Time, Oil Pressure and Output as Surface Roughness and Material Removal Rate while machining of AISI 1020 steel and to compare the influential performances.

b) To develop a model through RSM to predict SR and MRR machining of AISI 1020 steel.

2. EXPERIMENTAL DETAILS

Numerous experiments have been performed inorder to examine the performance and learn numerous machining parameters effects of EDM process on AISI 1020 steel in the form of rectanguar block of test pieces (120mm x 120mm x 8mm) dimensions. These studies were taken in for investigating the effects of Peak Current (I_p), Discharge Voltage (V), Pulse on Time (T_{on}), Pulse Off Time (T_{off}) and Oil Pressure (P_{oil}) on SR and MRR.

2.1. Work Material: The work materials chosen for the research of AISI1020 steel of rectangular piece (120mm x 120mm x 8mm dimensions) and are fabricated using stir die casting method. The material is chosen because of its progressing applications range in the tools manufacturing field in mould industries also used highly in aeronautical and automobile industries due to their high strength to weight ratio, mechanical and physical properties compared to monolithic material.

Table.1.Shows the physical and mechanical properties of AISI1020 Steel material

Material	Density (x1000 Kg/m^3)	Tensile Strength (Mpa)	Hardness (HB)	Modulus of Elasticity(Gpa)	% Elongation
AISI 1020 Steel	8.03	394.7	111	200	36.5

Table.2.Chemical Composition of Work Piece Material

Work Material	AISI 1020 Steel
C (%)	0.18-0.23
Mn (%)	0.30-0.60
P (%)	0.04 (Max)
S (%)	0.05 (Max)
Fe (%)	Balance

2.2. Tool Material: A cylindrical pure copper (Graphite Grade EDM) with a diameter of 10mm was used as a tool electrode (of positive polarity) and it is used to drill the work piece to 1mm depth as per ISO specification cutting tool was supplied by Sandwich and tool holder M16 type were used for the machining trials under various setting condition.

2.3. EDM Machine: Experiments are conducted on Electronica 5030 Die Sinking EDM machine as show in Fig.2. The dielectric fluid has been utilized (DEF-92) and the electrode suction flushing method has also been used. The scheme of experimental conditions for EDM machining is given in Table 3.

Table.3.EDM Machining Conditions

Conditions	Descriptions	Conditions	Descriptions
Machine	Electronica 5030 Die Sinking EDM Machine	Flushing Type	External
Test Specimen	AISI 1020 Steel Plate of Surface Dimensions 124x94mmand of Thickness 15mm	Depth of Cut (mm)	1
Tool	Copper Electrode of Diameter 10mm	Gap(mm)	0.09
Tool Polarity	Positive	Weight Measuring Instrument	Digital Balance (FX-3000)
Dielectric Fluid	EDM Oil (DEF-92)	SR Measuring Instrument	Portable Stylus Type Profilometer (Talysurf)

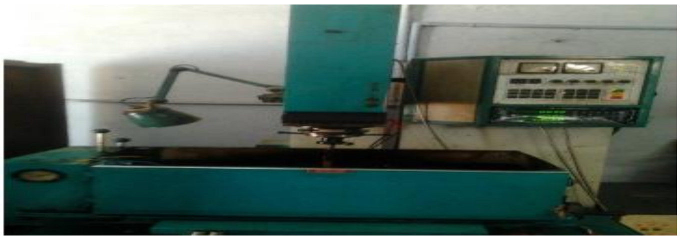

Fig.2.Electronica 5030 Die Sinking EDM Machine

2.4. Experimental Procedure: The machining process is performed in ELECTRONICA EMS5030 as show in Fig.3; the work piece is mounted on the V- block that has been spotted on the magnetic table of the machine. The tool holder holds tool and its alignment is verified with the assistance of dial gauge. Numerous runs was decided to be 32 with different parameter combinations based on Analysis of Variance. The input parameters that were varied for this study are Peak Current (I_p), Discharge Voltage (V), Pulse on Time (T_{on}), Pulse off Time (T_{off}) and Oil Pressure (P_{oil}) on SR and MRR.

Fig.3.Electronica 5030 Die Sinking EDM Machining Process Underway

2.5. Measurement Procedure: Roughness measurement has been done using a portable roughness tester SJ201 shown in Fig. 4. This portable instrument Evaluations of the parameter rely on microprocessor. The measurement outcomes are portrayed over an LCD screen and gives output to an optional printer or another computer for future investigation. Non-rechargeable alkaline battery (9V) is present in this instrument. It is equipped with a diamond stylus having a tip radius 5µm. The measuring stroke frquently gets initiated from the entirely outward position. While measuring by last pickup returns to the position alert for consecutive measurement. The selection of cut-off length determines the traverse length. Usually as a default, the traverse length is five times the cut-off length though the magnification factor can be changed. The profilometer was set to a cut-off length of 0.8mm, filter 2CR, and traverse speed 1mm/sec and 4mm traverse length. Roughness measurements, in the transverse direction, over the work pieces was recurred four times and four measurements average surface roughness parameter values has been recorded.

Fig.4.Experimental Set Up for Measuring Roughness

Material Removal rate is calculated my measuring the time of machining. It is calculated by using the formula.

MRR = W/t in mg/s

Where, W = weight of material removed, t = time taken for machining

2.6. Plan of experiment based on RSM: RSM is the wholesome of strategies of experiment, mathematical methods and statistical inferences enabling an experimenter for making well-organized system's empirical exploration of interest. RSM is explained as a statistical technique which utilizes quantitative data from suitable experiments for determining and concurrently crack multi-variable equations. The work that originally produces interest in the techniques package was a paper by Box and Wilson [3] and Iqbal and Khan [4] was put in bringing up forecasting models utilizing this renowned RSM for their superior studies over machining and is a technique recently utilized in numerous fields namely chemistry, biology and manufacturing.

RSM can be used in the following ways:

a) To determine the factor levels that will simultaneously satisfy a set of desired specifications

b) To determine the optimum combination of factors that yields a desired response and describes the response near the optimum.

c) To determine how a specific response is affected by modification in the factor level over the specified levels of interest.

d) To accomplish a quantitative considerate of the system behavior over the region tested.

e) To forecast properties of product over the entire region, even for a factor grouping not really run.

f) To locate the circumstances essential for process stability (insensitive spot).

In design optimization using RSM, the first task is determination of the optimization model, such as the identification of the interested system measures and the selection of the factors that control the system measures significantly.

To do this, a considerate of the physical meaning of the problem and some experience are both useful. After this, the important issues are the design of experiments and how to improve the fitting accuracy of the response surface models.

A prior idea of the learnt process is hence essential in achieving a original model.

It is selected only five experimental factors efficient in affecting the studied process yield. The factors are Peak Current (I_p), Discharge Voltage (V), Pulse ON Time (T_{on}), Pulse OFF Time (T_{off}) and Oil Pressure (P_{oil}).

Initial step of RSM is to explore the restrictions of the experimental domain to be explored. These restrictions are created as much as feasible in obtaining a clear response from the model.

The Discharge Current (A), Discharge Voltage (B), Pulse ON Time (C), Pulse OFF Time (D) , and Oil Pressure (E) are the machining variables, selected for our investigation.

2.7. Experimental setup: The tests were conducted under different machining conditions using on Electronica 5030 Die Sinking EDM machine, which is 3HP/2.2kW power. The input parameter was derived from the setting machining and the work piece surface shape. The tests have been performed with normal above mentioned procedure. The levels were specified for each process parameter as given in the Table 4. The parameter levels have been finalized among the intervals suggested by the machining tool manufacturer and investigation of the present study. Five process parameters at two and three levels led to a total of 32 tests for machining operation. After each test, the work piece is measured with the surface roughness tester SJ201 for determining the material removal rate and SR calculated by formula. The observations are expressed in the Table 5 for additional examination and studies. The machining operations have been performed as per the conditions given by the design matrix at random to avoid systematic errors.

Table.4.Different Variables Used in the Experiment and Their Levels

Variable	**Coding**	**Level**		
		1	**2**	**3**
Discharge Current (Ip) in A	A	10	65	70
Discharge Voltage in V	B	25	10	15
Pulse on time (Ton)in μs	C	15	30	45
Pulse off Time (Toff) in s	D	1	7	9
Oil Pressure in kg/cm^2	E	20	0.2	0.3

In the consecutive step, the aim in accomplishing the experiments using RSM involving a central composite design with five variables. Total numbers of experiments conducted with the combination of parameter corresponding to machining and the corresponding recorderd SR and MRR are established in Table 5.

Table.5.Planning Matrix of the Experiments with the Optimal Model Data

I_p(A)	V(B)	T_{on}(C)	T_{off}(D)	P_{oil}(D)	MRR	SR	I_p(A)	V(B)	T_{on}(C)	T_{off}(D)	P_{oil}(D)	MRR	SR
15	50	25	1.5	25	0.370	2.75	5	25	25	1.0	20	0.127	1.38
25	75	25	2.0	30	0.336	2.73	5	25	15	1.0	30	0.118	1.22
25	75	25	1.0	20	0.377	2.70	5	75	25	1.0	30	0.280	2.50
25	75	15	1.0	30	0.385	2.96	15	50	20	1.5	25	0.451	3.10
25	25	15	1.0	20	0.286	2.90	15	50	20	1.5	25	0.451	3.10
5	25	15	2.0	20	0.037	0.81	5	75	15	2.0	30	0.220	2.60
25	75	15	2.0	20	0.278	2.60	15	50	20	1.5	25	0.451	3.09
15	50	20	1.5	25	0.451	3.10	15	50	20	1.5	25	0.451	3.10
25	50	20	1.5	25	0.501	3.49	25	25	15	2.0	30	0.324	2.96
25	25	25	1.0	30	0.329	2.90	5	25	25	2.0	30	0.098	0.98
15	50	15	1.5	25	0.346	2.70	15	25	20	1.5	25	0.346	2.41
15	50	20	1.0	25	0.464	3.30	15	50	20	1.5	20	0.415	2.97
15	75	20	1.5	25	0.443	2.95	5	75	25	2.0	20	0.257	2.60
5	75	15	1.0	20	0.232	2.20	25	25	25	2.0	20	0.368	2.90
15	50	20	1.5	30	0.443	3.06	15	50	20	1.5	25	0.451	3.10
5	50	20	1.5	25	0.349	2.45	15	50	20	2.0	25	0.425	3.20

2.8. Mathematical Modelling:

Modeling of SR: Table 6 shows the ANOVA table for SR Estimated Regression Coefficients and Table 7 shows the ANOVA table Analysis of Variance for SR when EDM machining of MMC with copper tool. The regression model fitted for SR was obtained and is represented by Equation.

SR = [-9.19010 + 0.17994 A + 0.08520 B + 0.70224 C - 2.29177 D + 0.21528 E - 0.00114 A*A - 0.00065 B*B - 0.01438 C*C + 0.66207 D*D - 0.00278 E*E - 0.00154 A*B - 0.00102 A*C + 0.00018 A*E + 0.00460 B*D + 0.00031 B*E - 0.00425 C*E]

Table.6.ANOVA Table for SR Estimated Regression Coefficients

Term	Coef	SE Coef	T	P	Term	Coef	SE Coef	T	P
Constant	-	0.271665	-33.999	0.000	A*B	-0.00154	0.000017	-92.517	0.000
A	0.17919	0.004446	40.304	0.000	A*C	-0.00102	0.000083	-12.276	0.000
B	0.08620	0.002094	41.172	0.000	A*D	0.00050	0.000835	0.599	0.561
C	0.70324	0.017855	39.386	0.000	A*E	0.00018	0.000083	2.096	0.060
D	-	0.140269	-16.356	0.000	B*C	-0.00005	0.000033	-1.497	0.163
E	0.21678	0.021811	9.939	0.000	B*D	0.00460	0.000334	13.773	0.000
A*A	-	0.000106	-10.754	0.000	B*E	0.00031	0.000033	9.282	0.000
B*B	-	0.000017	-37.995	0.000	C*D	0.00100	0.001670	0.599	0.561
C*C	-	0.000426	-33.768	0.000	C*E	-0.00425	0.000167	-25.450	0.000
D*D	0.66207	0.042582	15.548	0.000	D*E	-0.00100	0.001670	-0.599	0.561
E*E	-	0.000426	-6.527	0.000					
S = 0.0166996 R-Sq = 99.98% R-Sq(adj) = 99.94%									

Table.7.Analysis of Variance for SR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	16	13.5567	13.5567	0.84729	3183.21	0.00
Linear	5	6.5961	2.9422	0.58844	2210.71	0.00
Square	5	4.2728	4.2728	0.85456	3210.51	0.00
Interaction	6	2.6878	2.6878	0.44797	1682.99	0.00
Residual Error	15	0.0040	0.0040	0.00027		
Lack-of-Fit	10	0.0039	0.0039	0.00039	23.46	0.01
Pure Error	5	0.0001	0.0001	0.00002		
Total	31	13.5607				

Table.8.Predicted result with experimental validation of AISI 1020 steel for SR

Optimization for surface roughness	Maching parameters				SR		
					Predicted Ra	Actual Ra	Error %
	A	B	C	D	E	F	
	5	25	15	1.65	20	0.72995	0.81	0.08005

From the Table 6 – 8 the value of "P" in Table 7 for model is less than 0.05 which indicates that the model is adequately significant at 95% confidence level, which is desirable as it indicates that the terms in the model have a significant effect on the response. The discharge current holds the most dominant effect on SR, followed by the discharge voltage and the spark gap. This is expected because, it is well known that increase in current will increase SR; the classical energy is primarily a part of the discharge current. The forecasted outcomes have been discussed through the Table viii with experimental validation. The error range obtained during that analysis was 7% and it was considered as acceptable model.

Modelling of MRR: Analysis of Variance (ANOVA) for the sufficiency of the model is then performed in the subsequent step. The F ratio is calculated for 95% level of confidence. The value which are less than 0.05 are well thought-out significant and the values greater than 0.05 are not significant and the model is sufficient in establishing the relationship among machining response and the machining parameters. Since the EDM process seems to be non-linear naturally the linear polynomial would be helpless in forecasting the answer precisely hence the Second-order model (quadratic model) is used which is noticed from the sufficiency test by ANOVA that linear terms I_p, V, T_{on}, T_{off} and P_{oil} interaction terms $I_p\times$ V, $I_p\times T_{off}$, V$\times T_{off}$, $T_{on}\times T_{off}$, $T_{on}\times P_{oil}$, and $T_{off}\times P_{oil}$ and square terms I_p^2, V^2, T_{on}^2, and P_{oil}^2 .The levels of significant are illustrated in the Table 9. The fit summary suggested that the quadratic model is statistically important to analyze MRR. To apt MRR the no of significant terms (p-value is greater than 0.05) are eradicated backwardly involving the elimination process. The ANOVA table for the curtailed quadratic model for MRR is illustrated in Table 10, the condensed model outcomes represent that the model seems to be significant (R^2 and adjusted R^2 are 99.89% and 99.78% respectively), and lack of fit is non-significant (p-value is less than 0.05). The final model tested for variance analysis (F-Test) indicates that the adequacy of the test is established. The computed values of response parameters, model graphs are generated for the further analysis.

The ultimate response equation for MRR is represented as follows:

MRR = [-2.62099 + 0.02124 A + 0.01388 B + 0.16666 C - 0.02621 D + 0.06225 E - 0.00026 A*A - 0.00009 B*B - 0.00371 C*C - 0.00087 E*E - 0.00014 A*B + 0.00093 A*D - 0.00075 B*D + 0.00270 C*D - 0.00075 C*E - 0.00130 D*E]

Table.9.ANOVA table for MRR Estimated Regression Coefficients

Term	Coef	SE Coef	T	P	Term	Coef	SE Coef	T	P
Constant	-	0.090216	-	0.000	A*B	-0.00014	0.000006	-24.343	0.000
A	0.02128	0.001476	14.410	0.000	A*C	-0.00002	0.000028	-0.811	0.434
B	0.01358	0.000695	19.538	0.000	A*D	0.00093	0.000277	3.336	0.007
C	0.16567	0.005929	27.940	0.000	A*E	0.00000	0.000028	0.090	0.930
D	0.03506	0.046582	0.753	0.467	B*C	-0.00001	0.000011	-0.992	0.343
E	0.05921	0.007243	8.174	0.000	B*D	-0.00075	0.000111	-6.762	0.000
A*A	-	0.000035	-6.960	0.000	B*E	0.00001	0.000011	1.172	0.266
B*B	-	0.000006	-	0.000	C*D	0.00270	0.000555	4.869	0.000
C*C	-	0.000141	-	0.000	C*E	-0.00075	0.000055	-13.524	0.000
D*D	-	0.014141	-1.444	0.177	D*E	-0.00130	0.000555	-2.344	0.039
E*E	-	0.000141	-5.829	0.000					
S = 0.00554571 R-Sq = 99.92% R-Sq(adj) = 99.78%									

Table.10.ANOVA Table for MRR Estimated Regression Coefficients after Backward Elimination

Optimization for MRR	Maching parameters					MRR		
						Predicted Ra	Actual Ra	Error %
	A	B	C	D	E	F		
	25	54.29	20.15	1	26.46	0.51493	0.464	0.046

Table.11.Analysis of Variance for MRR

Term	Coef	SE Coef	T	P	Term	Coef	SE Coef	T	P
Const	-	0.08747	-	0.000	C*C	-	0.000138	-	0.000
A	0.0212	0.00115	18.34	0.000	E*E	-	0.000138	-	0.000
B	0.0138	0.00058	23.70	0.000	A*B	-	0.000006	-	0.000
C	0.1666	0.00576	28.92	0.000	A*D	0.00093	0.000278	3.325	0.004
D	-	0.01930	-	0.193	B*D	-	0.000111	-	0.000
E	0.0622	0.00704	8.833	0.000	C*D	0.00270	0.000556	4.852	0.000
A*A	-	0.00003	-	0.000	C*E	-	0.000056	-	0.000
B*B	-	0.00000	-	0.000	D*E	-	0.000556	-	0.033
S = **0.00556467** R-Sq = **99.89%** R-Sq(adj) = **99.78%**									

Predicted result with experimental validation of AISI 1020 steel for MRR.

3. RESULT AND DISCUSSION

3.1. Result and Discussion for SR: The effect of the machining parameters (Ip,V, T_{on}, T_{off}andPoil) on the response variables SR have been evaluated by conducting experiments. The results are put into the Minitab software for further analysis. The Analysis Of Variance (ANOVA) was used to check the sufficiency of the second order model.

Fig.5 shows the calculated response surface for SR in association with the process parameters of I_p and T_{on} while T_{off}, V and P_{oil} remain constant at their lowest values where the figure explains that the SR rises up predominantly with the rise in I_p for any value of T_{on}. On the other hand, the SR progresses up with rise in T_{on}, particularly at higher

I_p. Therefore, least amount SR is achieved at low peak current (5A) and low pulse on time (15µs) which is because of their dominant restriction over the input energy, i.e. with the rise in I_p producing powerful spark creating greater temperature and crater, for this reason work piece rough surface and low I_p creates small crater and consequently surface is smooth.

The effect of I_p and T_{off} is on the estimated response surface of SR is depicted in Fig.6, T_{on} , V and P_{oil} remains constant in its lower levels which could be illustrious that the SR goes up on rise in I_p, the description is similar, as declared earlier. Fig.7 depicts SR as a function of T_{on} and T_{off}, while the I_p, V and P_{oil} remains constant at its lower levels and noticed that the SR values are low when T_{on} is low with higher T_{off}. Even though the effect of this two parameter is highly fewer when compared with the influence of I_p on SR. Fig.8 depicts SR as a purpose of T_{on} and V, whereas the I_p, Toff and P_{oil} remains constant at its lower levels which is noticed that the SR values are low when T_{on} and V are low.

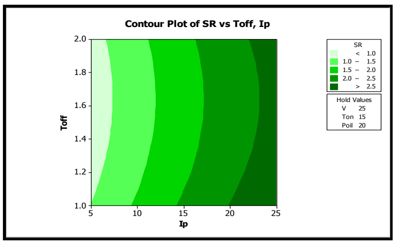

Fig.5.Contour Plot of T_{off},I_p Vs SR

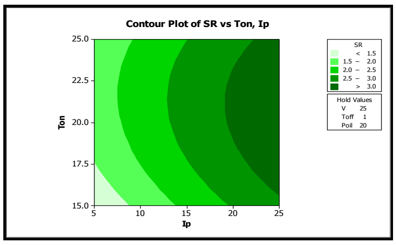

Fig.6.Contour Plot of T_{on},I_p Vs SR

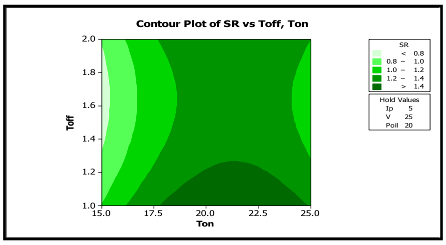

Fig.7.Contour Plot of T_{off},T_{on} Vs SR

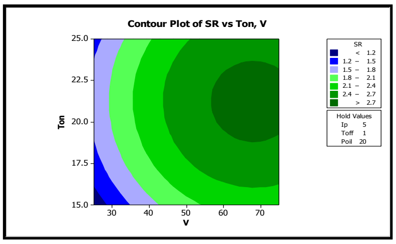

Fig.8.Contour Plot of T_{on},V Vs SR

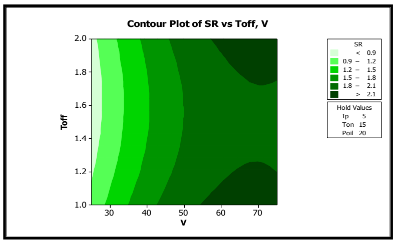

Fig.9.Contour Plot of T_{off},V Vs SR

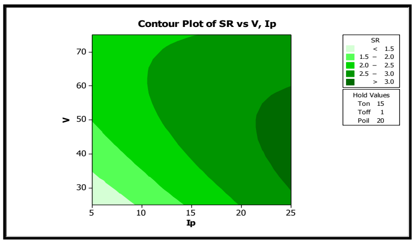

Fig.10.Contour Plot of V,I_p Vs SR

Figure 9 represents SR as a function of V and T_{off}, whereas the I_p, T_{on} and P_{oil} remains constant at its lower levels. It is observed that the SR values are low when V is low with higher T_{off}.

Figure 10 depicts SR as a function of V and I_p, whereas the T_{on},T_{off} and P_{oil} remains constant at its lower levels which is noticed that the SR values are low when V and I_p are low.

Finally, the remaining figures represents the influence of oil pressure with other four parameters (I_p, V, T_{on} and T_{off}) on SR which could be noticed that there exists no significant variation of SR with the variation of P_{oil}. On noticing it could be finalized that I_p, V and Ton are directly proportional, and T_{off} is inversely to the SR for the provided range of experiments conducted for our test.

Table.12.Comparison Table for Optimal SR Values

Parameters technique	I_p	V	T_{on}	T_{off}	P_{oil}	SR
RSM	5	25	15	1.65	20	0.72995

From this Table 12 the higher value of SR is achieved with I_p=5A, V=25v, T_{on}=15µs, T_{off}=1.6s and P_{oil}=20kg/cm^2.

3.2. Result and Discussion for MRR: The effect of the machining parameters (I_p,V, T_{on}, T_{off} and P_{oil}) on the response variables MRR have been evaluated by conducting experiments. The results are put into the Minitab software for further analysis. The second-order model was explained for finding the association among the MRR and the process variables accounted. The Analysis Of Variance (ANOVA) has been involved for checking the adequacy of the second order model.

Figure 11 depicts the predictable response surface for MRR in association to the parameters of process of pulse current and pulse on time which could be noticed from the figure, the MRR goes up, significantly with rise in peak current for any value of pulse on time. Hence, maximum MRR is achieved at high peak current (25A) and high pulse on time (25µs) which is because of their dominant control over the input energy i.e. with the rise in pulse current producing powerful spark creating greater temperature cause the more material to melt and erode from the work piece.

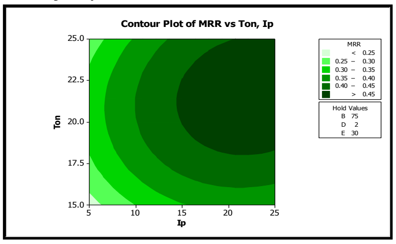

Fig.11.Contour Plot of T_{on},I_p Vs MRR

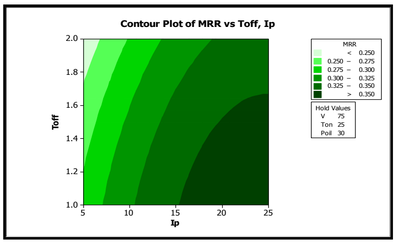

Fig.12.Contour Plot of T_{off},I_p Vs MRR

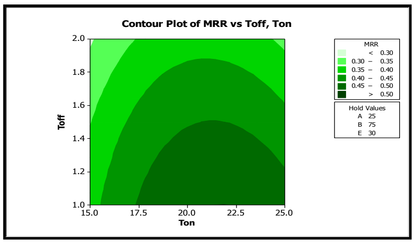

Fig.13.Contour Plot of T_{off},T_{on} Vs MRR

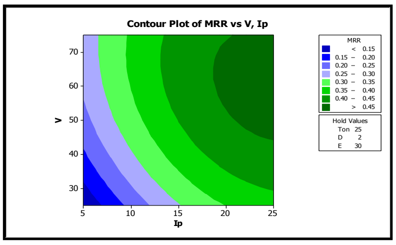

Fig.14.Contour Plot of V, I_p Vs MRR

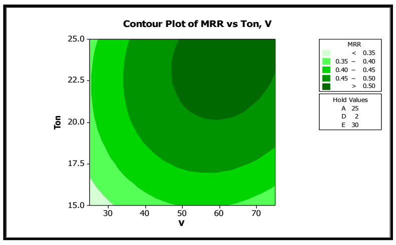

Fig.15.Contour Plot of T_{on},V Vs MRR

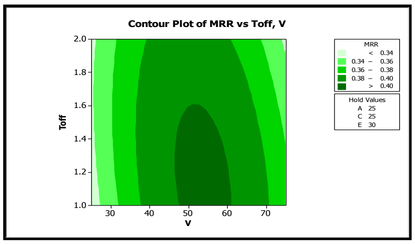

Fig.16.Contour Plot of T_{off},V Vs MRR

The effect of I_p and T_{off} is on the estimated response surface of MRR is depicted in the Figure 12, the parameters T_{on} ,V and P_{oil} remains constant in its maximum level of 25µs,75v and 30kg/cm^2 respectively noticing that the MRR goes up on rise in I_p , the description is identified to be similar, as explained previous, on the other hand with the rise in T_{off}, MRR goes down, which is because when T_{off} rises, where ending up in an unwanted heat loss that does not provide to MRR ending up in decline of the work piece temperature prior to consecutive spark begins and hence MRR drops. The maximum MRR is achieved with high I_p =25 A and lower T_{off} =1s for the given range of input parameters.

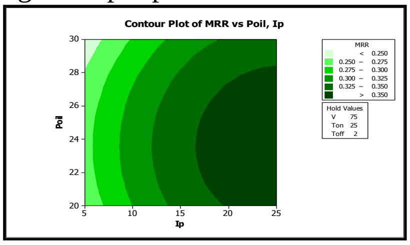

Fig.17.Contour Plot of P_{oil},I_p Vs MRR

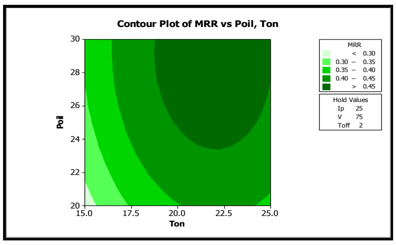

Fig.18.Contour Plot of P_{oil},T_{on} Vs MRR

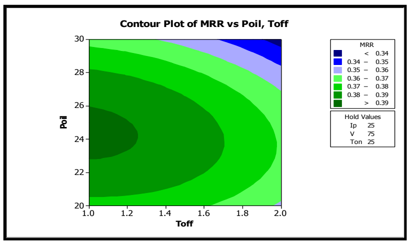

Fig.19.Contour Plot of P_{oil},T_{off} Vs MRR

Figure 13 represents MRR as a function of T_{on} and T_{off}, whereas the I_p,V and P_{oil}remains constant in its higher level. It could be viewd that greater the MRR values takes place at the greater T_{on} and at the least of T_{off}.

Figure 14 details MRR as a function of V and I_p, while the T_{on},T_{off} and P_{oil}remains constant in its superior level which could be viewed that the greatest MRR values takes place at the greater I_p and V.

Figure 15 illustrates MRR as a function of T_{on} and V, whereas the I_p,T_{off} and P_{oil}remains constant in its higher level which could be viewed as the greatest values of MRR takes place at elevvated T_{on} and V.

Figure 16 represents MRR as a function of V and T_{off}, whereas the I_p, T_{on}, and P_{oil}remains constant in its higher level which could be viewed that greatest of MRR values takes place at the elevated V and lower T_{off}.

Figure 17 represents MRR as a function of P_{oil} and I_p, whereas the T_{on},T_{off} and Vremains constant in its higher level. It can be seen that the highest MRR values occurred at the higher I_p and medium P_{oil} (25kg/cm^2).

Figure 18 suggests MRR as a function of T_{on} and P_{oil}, while the I_p , T_{off} and V remains constant in its higher level which could be viewed that the greater values of MRR takes place at elevated T_{on} and 25 kg/cm^2 of P_{oil}.

Figure 19 illustrates MRR as a function of T_{off} and P_{oil}, while the I_p, V and T_{on}remain constant in its higher level which could be viewed that the greatest values of MRR takes placce at the lower T_{off} and 25 kg/cm^2 of P_{oil}.

The contours propose that even high range of MRR might be achieved for elevated values of I_p, V, T_{on}, and medium oil pressure and lower T_{off}. On noticing those, it could be finalized that I_p, V and T_{on} are directly and T_{off} is reciprocally proportional to the MRR for the provided choice of experiments conducted for our test.

Table.13.Comparison Table for Optimal MRR Values

Parameters Techniques	I_p	V	T_{on}	T_{off}	P_{oil}	MRR
RSM	25	54.29	20.15	1.65	26.46	0.5149

From this Table 13 the higher value of MRR is achieved when I_p=25A, V=54v, T_{on}=20µs, T_{off}=1s and P_{oil}=26.5kg/cm^2.

4. CONCLUSION

Collection of parameters corresponding to machining is one of the highly significant features to take into thoughtfulness in the majority of advanced manufacturing processes. RSM model have been brought up for forecasting surface roughness The optimized machining condition that gives better surface finish when machining AISI1020 steel have been identified: I_p=5A, V=25V, T_{on}=15μs, T_{off}=1.65s and P_{oil}=20kg/cm$^{2.}$ The surface roughness improves with increase of the discharge current whilst increasing pulse off time adversely affects the surface roughness among the parameters of machining, discharge current has the most dominant effect on surface roughness through ANOVA. The higher value of MRR is achieved when I_p=25A, V=54v, T_{on}=20μs, T_{off}=1s and P_{oil}=26.5kg/cm^2. The machining parameters for EDM process are optimized using RSM techniques for minimizing the surface roughness and maximizing material removal rate. The developed model was assessed experimentally and exhibit low values of error.

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