Experimental Investigation Of Process Parameters Of Submerged Wedm For Machining S-6 Steel Using Response Surface Methdology

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Abstract- *S6 is a shock- resisting steels. The solidify capacity of group S steels can be restrained by varying their composition instead of adjusting the liquefying procedures and grain size. These steels can grab ideal hardness at higher austenitizing temperatures. The tempering resistance of group S steels can be enhanced by addition of silicon, which also forms a microstructure to resist. S6 tool steels are gradually preheated at 750ºC. Temperature is then expanded to 917ºC trailed by holding the steel areas at that temperature for 15 to 35 minutes. Wire Electric Discharge Machine (WEDM) seems a good option for machining the complicated shapes on medium strength steel. This paper, identify the effects of various process parameters of WEDM such as pulse on (T_{on}) ,pulse off (T_{off}), peak current (IP), servo voltage (SV) for analysis the material removal rate (MRR) while machining S6 mild steel material.*

Central Composite Design is used to plan and design of experts. The output response variable being material removal rate will be measured for all the number of experiments conducted. As the lowest value of MRR indicates the poor cutting rate, the optimum parameter level combination would be analyzed which gives desired material removal rate. These optimized values of various parameters would then be used in performing machining operation in order to obtain desirable outputs.

Keywords- S6 Steel, Wire EDM, Process Parameters, RSM Technique, Material Removal Rate.

I. INTRODUCTION

The main objective of this paper is to study different parameters likes (T_{on},T_{off},IP,SV) of WEDM operations using response surface methodology, in particular central composite design (CCD), to develop empirical relationships between different process parameters and output responses namely MRR. The mathematical models so developed are analyzed and optimized to yield values of process parameters producing optimal values of output responses.

Rajyalakshmi et al.(2013) in this paper , a powerful technique ,Taguchi gray relational examination , has been connected to test results of WEDM on Inconel 825 with consideration of in excess of one response measures. The technique joins the orthogonal array design of experiment with gray relational investigation. The fundamental intention of this investigation is to get enhanced material expulsion rate, surface harshness, and spark gap. Gray relational thought is taken after to choose the outstanding procedure parameters that enhance the response measures. The test has been accomplished with the guide of the utilization of Taguchi's symmetrical exhibit L36 (21×37). Each investigation was performed under unmistakable states of info parameters. The reaction table and the gray relational review for every stage of the machining factors were mounted. From 36 tests, the best blend is found. The trial comes about confirm that the proposed procedure on this view proficiently enhances the machining general execution of WEDM framework

Rajesh Khanna et al. (2013) investigated the impact of technique factors that influence material disposal rate and surface harshness in machining of cryogenic dealt with D-3 fabric on wire-cut electric
powered discharge tool. Central composite design is utilized to program and perform the analysis. The regression is utilized to widen observational connections between specified method factors and yield reactions, and finally to analyze and yield most desirable estimations of system factors. As the impact of method factors on steel elimination and surface harshness is opposite, the problem is detailed as a multi target enhancement problem and understood utilizing weight technique. Attempt is made to find the apparatus settings to get greatest steel elimination charge and least surface harshness. On this studies paper, cryogenic remedy of work piece is executed earlier than machining for enhancing the damage resistance of the fabric that's important for die production

Chandrakanth et al. (2016) wire-EDM as a precision cutting era is feasible to fabricate made from all degrees. In wire EDM, the conductive materials are machined with a succession of electrical releases (sparkles) which may be created among an as it ought to be found moving wire and the work piece. High recurrence pulses of alternating or direct forefront is released from the twine to the work piece with an absolutely little spark rift through protected dielectric liquid (water). In this present work, Pulse on time, wire tension and Spark gap voltage are the three factors taken for improvement of MRR. The work piece is HSS M42 Grade and the work gadget is metal wire of 0.25 mm dia. The test progress toward becoming done in eight runs utilizing complete factorial outline and most colossal elements are chosen the utilization of ANOVA. Perfect estimations of parameters are gotten by means of utilizing MatLab programming (Genetic calculation). RSM is additionally taken after to confirm the exactness of procured numerical model.

Goyal et. al. (2017) on this research cores the impact of many factors on metal elimination charge and surface harshness in WEDM of Inconel 625. Machining was finished by appropriating an ordinary zinc blanketed and cryogenic treated zinc included wire.

The tests were accomplished by means of thinking about distinctive process parameters like tool electrode, pulse off time, and pulse on time, wire tension and feed. The thickness of dia. of wire and work material is kept stable. Taguchi L18 (21*35) orthogonal array of exploratory design is used for experiments. Analysis of variance (ANOVA) is thought to enhance the metal elimination rate and Surface harshness. Primarily based on evaluation it is clear that pulse on time, tool electrode and current intensity are the vital factors that have an effect on the both MRR and SR parameters..

SR. Sadeghi et al. (2011) examine the impact of release current, pulse interval, open circuit voltage and servo voltage on metal elimination charge and surface harshness. It become discovered that release current and pulse interval are the major critical factors for metal elimination charge and surface harshness.

In the present study S6 steel is chosen for parametric investigation and optimization of material removal rate by using response surface methodology and WEDM.

The rest of the paper is organized as follows. Proposed experimental methodology is explain in section II. Experimental results are presented in section III .Concluding remarks are given in section IV

II. EXPERIMENTAL METHODOLOGY

A. Machine Tool And Workpiece

In this research work, MRR is response characteristics. These response characteristics are investigated under the varying conditions of input process parameters, which are Pulse on Time (T_{on}),Pulse off Time (T_{off}), Servo gap voltage (SV), Peak current (IP). The experiments were performed on Electronica make ELEKTRA Sprintcut 734 CNC Wire cut machine. ELEKTRA Sprintcut 734 provides full freedom to the operator in choosing parameter values with in a wide range. A brass wire of 0.25 mm diameter is used as the tool material. Deionized water is used as the dielectric, which flush away the metal particle from the rectangular work piece of S6. The chemical composition of S6 is as follow.

Table -1 Composition of S6

Carbon %	Manganese %	Phosphorus %	Sulphur %	Silicon %	Copper %	Chromium %	Vanadium %	Moly %	Iron
0.45	1.3	0.02	0.02	2.1	0.2	1.3	0.35	0.45	93.8

B. Examining The Output Response

The MRR (mm³/min) is calculated from the cutting speed (directly displayed by the machine tool)*height of work piece removed *breadth of work piece removed.

I.e. MRR = cutting speed* length * height of work piece removed.

Values of the MRR are noted at a distance of 5 mm, 5 mm, and 5 mm from the initiation of cut along a particular axis. This is done to ensure that readings are to be noted only when the cutting process is properly stabilized. The offset of the wire is set at zero.

C. Response surface methodology and design of experiment

RSM is a compilation of mathematical and statistical techniques useful for the modeling and analysis of problems in which output factors are influenced by several input parameters and the main aim is to optimize this output parameters. Graphical representation of the procedure for RSM is as follows:

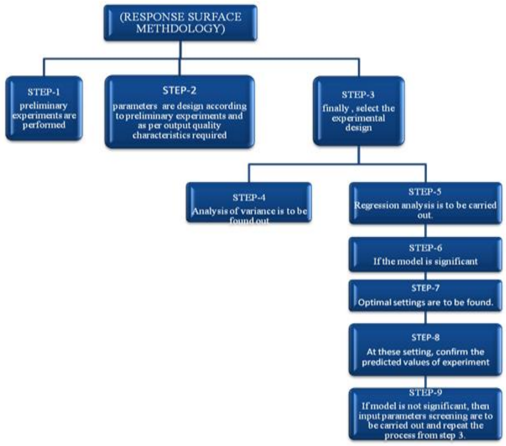


Fig.1 Graphical representation of procedure for RSM

Table 2: Different levels of Process parameters with coded form and units

Sr. no.	Parameters	Coded form	Min. value	Max. Value
1	T_{on} (µs)	A	102	120
2	T_{off} (µs)	B	20	60
3	IP (A)	C	60	180
4	SV(V)	D	20	80

Table 3: WEDM machining conditions

Work piece	S6 Mild Steel
Electrode (tool)	0.25mm Ø, Brass wire
Work piece height	10.2 mm
Dielectric Conductivity	20mho
Dielectric temperature	20-24^{0}C

Table 4: (Design of experiments and results for wire EDM output response)

Std	Run	A:T_{on} µs	B:T_{off} µs	C:IP A	D: SV V	MRR mm³/mn
1	3	120	60	180	20	161.4
2	5	120	60	60	20	131.07
3	21	120	20	180	80	154.8
4	16	102	60	60	80	67.7
5	2	120	20	60	80	135.15
6	20	102	20	180	20	139.33
7	7	102	60	180	80	98.7
8	8	102	20	60	20	116.68
9	9	95.8639	40	120	50	114.5
10	11	126.136	40	120	50	154.4
11	13	111	6.36414	120	50	152.3
12	4	111	73.6359	120	50	123.44
13	18	111	40	19.0924	50	98.02
14	1	111	40	220.908	50	137.9
15	12	111	40	120	50	133.01

III. RESULT AND DISCUSSION

There are 21 experiments in total carried out according to the design of experiments. The average values of MRR (mm³/min) are shown in Table 4. For analysis of data, checking the goodness of fit of model is required. The model adequacy checking includes test for significance of regression model, test for significance on model coefficients, and lack of fit test .For this purpose, ANOVA is performed.

A. Analysis of Material Removal Rate-

To decide about the adequacy of the model, three different tests viz. sequential model sum of squares, lack of fit tests and model summary statistics were performed for material removal rate and characteristics of WEDM process. The two tables display two different tests to select an adequate model to fit various output characteristics. The sequential model sum of squares test in each table shows how the terms of increasing complexity contribute to the model.

It can be observed that for all the responses, the quadratic model is appropriate. The "lack of fit" test compares the residual error to the pure error from the replicated design points. The results indicate that the quadratic model in all the characteristics does not show significant lack of fit, hence the adequacy of quadratic model is confirmed. Tables show the selection of adequate model for material removal rate. The p value should be less than 0.5.the value of p is less than 0.5 in case of quadratic. Which shows that quadratic model is suggested. In order to statistically analyze the results, ANOVA was performed. Process variables having p-value < 0.05 are considered significant terms for the requisite response characteristics. The insignificant parameters were pooled using backward elimination method. The pooled version of ANOVA for material removal rate indicates that (A), (C), (D), the interaction terms (AB, AC, AD, BD) and the quadratic terms (B^2, $C^{2,}$ D^2) are significant parameters affecting material removal rate.

Table 5: Sequential Model Sum of Squares [Type I]

Sequential Model Sum of Squares [Type I]						
Source	**Sum of Squares**	**Df**	**Mean Square**	**F Value**	**p-value Prob> F**	
Mean vs Total	1123.62	1	1123.62			
Linear vs Mean	137.52	4	34.38	21.02	< 0.0001	
2FI vs Linear	5.41	6	0.9018	0.4344	0.8401	
Quadratic vs 2FI	**19.40**	**4**	**4.85**	**21.37**	**0.0011**	**Suggested**
Cubic vs Quadratic	0.2095	2	0.1047	0.3637	0.7160	Aliased
Residual	1.15	4	0.2880			
Total	1287.31	21	61.30			

Lack of Fit Evaluation						
Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob> F	
Linear	25.02	12	2.08	7.24	0.0351	
2FI	19.61	6	3.27	11.35	0.0171	
Quadratic	**0.2095**	**2**	**0.1047**	**0.3637**	**0.7160**	**Suggested**
Cubic	0.0000	0				Aliased
Pure Error	1.15	4	0.2880			

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.28	0.8401	0.8002	0.7195	45.91	
2FI	1.44	0.8732	0.7464	-0.7230	282.03	
Quadratic	**0.4764**	**0.9917**	**0.9723**	**0.8876**	**18.40**	**Suggested**
Cubic	0.5367	0.9930	0.9648			Aliased

In order to statistically analyze the results, ANOVA was performed. Process variables having p-value < 0.05 are considered significant terms for the requisite response characteristics. The insignificant parameters were pooled using backward elimination method. The pooled version of ANOVA for material removal rate (Table 5.10) indicates that (A), (C), (D), the interaction terms (AB, AC, AD, BD) and the quadratic terms (B^2, C^2, D^2) are significant parameters affecting material removal rate.

Table 6: Pooled ANOVA for Material Removal Rate

Pooled ANOVA for Response Surface Reduced Quadratic Model						
Analysis of variance table [Partial sum of squares]						
	Sum of	D.F	Mean	F	p-value	
Model	**9788.21**	**14**	**699.16**	**670.68**	**< 0.0001**	**significant**
A-Ton	796.00	1	796.00	763.59	< 0.0001	
B-Toff	416.45	1	416.45	399.49	< 0.0001	
C-IP	2133.61	1	2133.61	2046.72	< 0.0001	
D-SV	423.99	1	423.99	406.72	< 0.0001	
AB	27.08	1	27.08	25.98	0.0022	
AC	1.68	1	1.68	1.62	0.2508	
AD	17.62	1	17.62	16.91	0.0063	
BC	45.27	1	45.27	43.42	0.0006	
BD	219.51	1	219.51	210.57	< 0.0001	
CD	0.6786	1	0.6786	0.6510	0.4506	
A^2	18.86	1	18.86	18.09	0.0054	
B^2	81.30	1	81.30	77.99	0.0001	
C^2	331.06	1	331.06	317.58	< 0.0001	
D^2	307.14	1	307.14	294.63	< 0.0001	
Residual	6.25	6	1.04			
Lack of Fit	4.05	2	2.03	3.67	0.1242	not significant
Pure Error	2.20	4	0.5511			
Cor Total	9794.46	20				
Fit Statistics						
Std. Dev.	1.2		R-Squared		0.9994	
Mean	127.58		Adj R-Squared		0.9979	
C.V. %	0.8003		Pred R-Squared		0.9763	
			Adeq Precision		107.53	

- The Model F-value of 670.68 stats the model is important. There is just a 0.01% shot that a "Model F-Value" this large could exist due to turbulance.
- Esteem of "Prob > F" lower than 0.0500 represents model terms are important. In present study A,B,C,D,AB,AD,BC,BD,A^2,B^2,C^2,D^2 are important model terms. Values more than 0.1000 shows the model terms aren't important.
- The "Lack of Fit F-value" of 3.67 indicates that the lack of fit is Non significant relative to pure error, there is a 12.42% shot that a "Lack of Fit F- value" this large could exist due to turbulance.
- The "Pred R-Squared" of 0.9763 is in reasonable agreement with the "Adj R-Squared" of 0.9979 i.e difference is less than 0.2. "Adeq Precision" determines the signal to noise ratio. A ratio greater than 4 is desirable. My ratio of 107.533 indicates an adequate signal.

The regression equation for the material removal rate as a function of four input process variables was developed from the software (RSM) and is given below. The coefficients (insignificant identified from ANOVA) of some terms of the quadratic equation have been omitted.

$MRR=+228.43355-2.72119*Ton-2.21808*Toff+0.545200*IP-0.170920*SV+0.015882*Ton*Toff-0.000850*Ton*IP++0.008541*Ton*SV+0.001982*Toff*IP-0.013565Toff*SV-0.000162*IP*SV+0.013869*Ton^2+0.005831*Toff^2-0.001307*IP^2-0.005037*SV^2.$

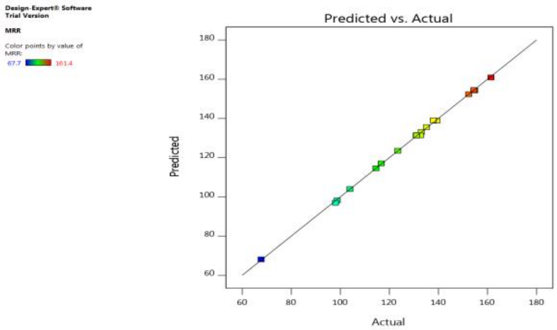
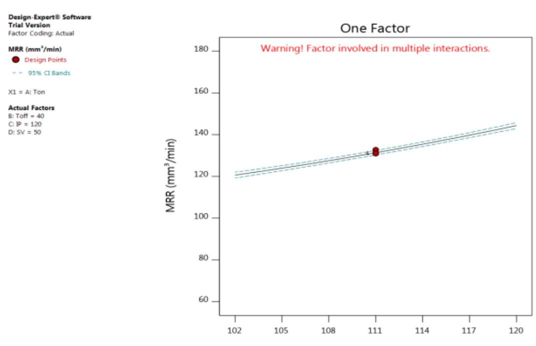
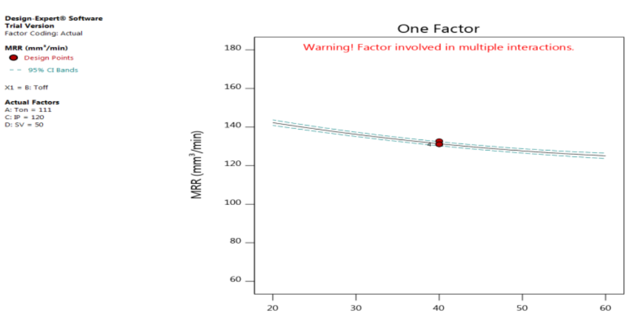


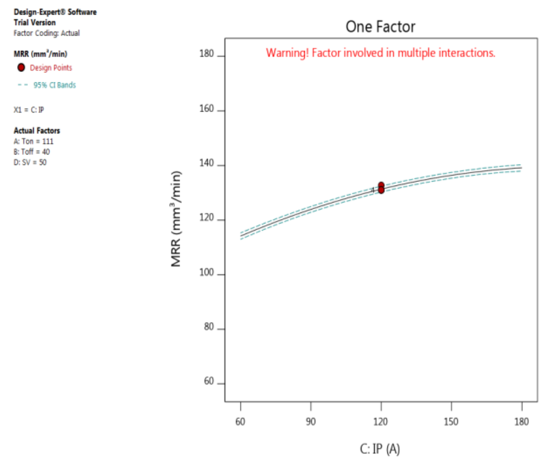
Figure 2: Predicted Vs Actual Interaction plots For MRR

B. Effect of Process Parameter (one factor) and 3-D Surfaces on MRR

The effect of single and two control factors or process parameters on the response variables is called the interaction effect. For the interaction plot, the single and two parameters vary keeping other two process parameters at the central value and observe the effect on the response characteristics. This plot is called the three-dimensional surface plot (i.e., 3D surface plot). So the significant interactions are shown in Figs. 3 (a, b, c, d)







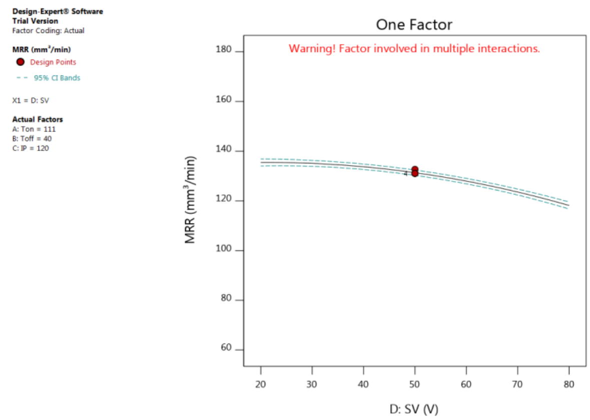


Fig 3 Significant Interaction of Factors (a, b, c, d)

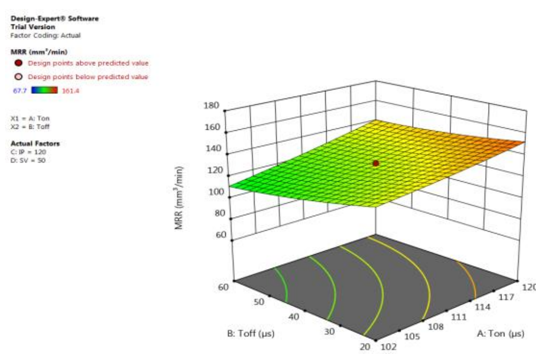


Figure 4 shows the interaction effect of T_{on} and T_{off}

After thorough study of various literatures it can be say From Figure 4 that the material removal rate is generally shows increasing effect with the increase of pulse on time and at the same time it decreases with the pulse off time on decreasing of T_{off}. At small value of T_{off} means, there will be more time duration for which current is on i.e. more number of discharges per second which implies that metal erosion will be more, hence faster MRR results. This is due to the fact that a high value of T_{ON} and lower value of T_{OFF} means that discharge will act for longer time, which results to a more discharge energy. Large discharge energy will cause violent sparks resulting in faster removal of metal. Hence metal removal rate increases.

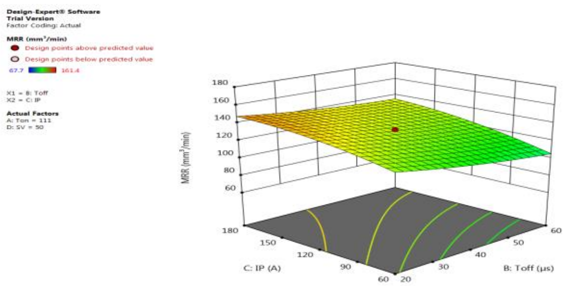


Fig 5: Interaction effect of IP and T_{off}

It is seen from Figure that material removal rate increases with increase in the peak current values and simultaneously decrease with turn off time. Various researchers state that the higher is the peak current setting, the larger is the discharge energy. This generally leads to increase in material removal rate. But, the sensitivity of the peak current setting on the cutting performance is stronger than that of the pulse on time. While the peak current setting is too high, wire breakage may occur frequently**.**Figure shows the 3D interaction plot of T_{off} and SV on MRR.

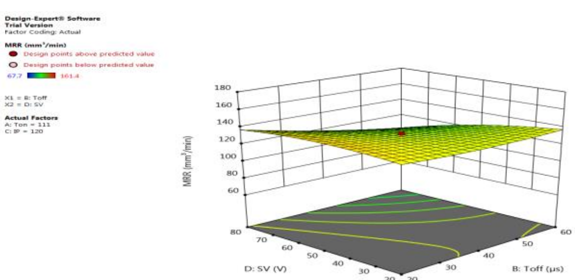


Fig 6: Interaction effect of T_{off} and SV

It is observed from Figure 6 that material removal rate decreases with increase in spark gap set voltage and turn off time. With increase in spark gap set voltage the average discharge gap gets widened resulting into a lower material removal rate.

IV. CONCLUSION

In this paper, effect of process parameters on MRR is investigated.

It is concluded that:. Response surface methodology (RSM) was applied for developing the mathematical models in the form of multiple regression equations correlating the dependent factors with the independent factors like (pulse on time, pulse off time, spark gap set voltage, peak current) in WEDM machining of S6 steel. It was found experimentally that increasing the pulse on time and peak current, the cutting rate increases, whereas increasing the pulse off time and servo voltage decreases the cutting rate. The higher discharge energy associated with the increased pulse on time, peak current and lesser pulse off time and servo voltage leads to more powerful explosions which increase the cutting rate. Using the model equations, the response surfaces have been plotted to study the effects of process parameters on the performance characteristics. From the experimental data of RSM, empirical models were developed and the confirmation experiments were performed, which were found within 95% confidence interval.

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