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Parametric optimization on Wire EDM for the WPS Die Steel

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Abstract

An experimental study has conducted, in this work to determine statistical models for optimization of process parameters in wire EDM. Wire electrical discharge machining (WEDM) technology has extensively used in the field of medical, mould making, Die making , aerospace and automobile industries. WPS Die Steel(contains 1.5-1.8% carbon) is the hard material so that cutting by other machining is very difficult. But this cutting process make easy with wire EDM.WPS is widely used in making the press dies for cutting and forming operation therefore surface finishing of it is very important. The paper is focusing on to find out the combination of process parameters for optimum surface roughness and material removal rate (MRR) in wire electro discharge machining (EDM) of WPS Die Steel. The best combination of machining parameter viz. machine feed, pulse on time and pulse off time. The paper highlights the importance of process parameters and different machining conditions on MRR, surface roughness (Ra) and surface topography. In this work, machine feed, pulse on time and pulse off are input parameters and surface roughness and MRR as output parameters. The optimal values of these parameters have defined with the aim of achieving the better surface roughness and higher MRR.
Keywords: Wire EDM; WPS die Steel; MRR; Surface roughness

I. INTRODUCTION

Wire EDM can machine anything that is electrically conductive regardless of the hardness, from relatively common materials such as tool steel, aluminium, copper, and graphite, to exotic space-age alloys including hastaloy, waspaloy, inconel, titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the workpiece, so there is no physical pressure imparted on the workpiece compared to grinding wheels and milling cutters. The amount of clamping pressure required to hold small, thin and fragile parts is minimal, preventing damage or distortion to the workpiece.[2].

Wire EDM also gives designers more latitude in designing dies, and management more control of manufacturing, since the machining is completed automatically. Parts that have complex geometry and tolerances don't require you to rely on different skill levels or multiple equipment. Substantial increases in productivity is achieved since the machining is untended, allowing operators to do work in other areas. Most machines run overnight in a "lights-out" environment. Long jobs are cut overnight, or over the weekend, while shorter jobs are scheduled during the day. Most workpieces come off the machine as a finished part, without the need for secondary operations. It's a one-step process.

A. *Wire EDM Principle:*

The WEDM machine tool comprises of a main worktable (X-Y) on which the work piece is clamped; an auxiliary table (U-V) and wire drive mechanism. The main table moves along X and Y-axis and it is driven by the

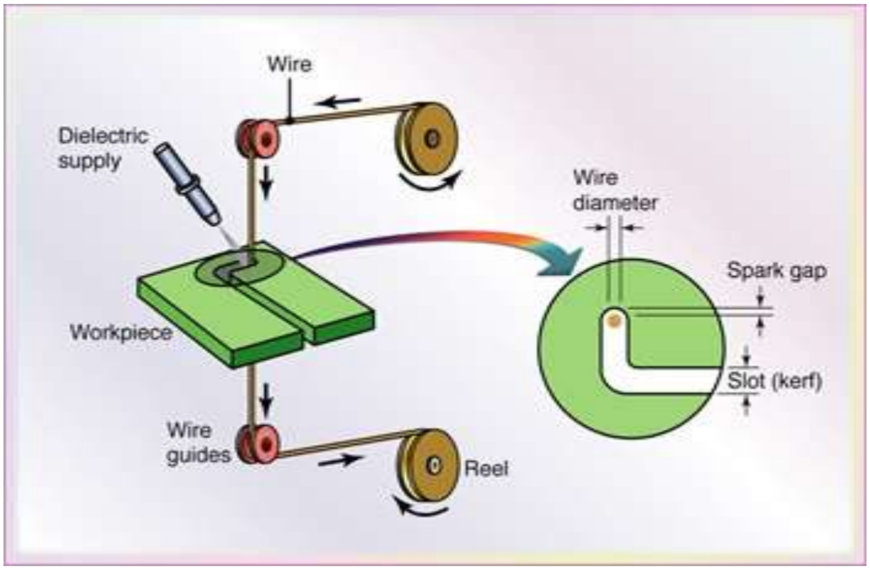


Fig. 1: Wire EDM principle

D.C servo motors. The travelling wire is continuously fed from wire feed spool and collected on take up spool which moves though the work piece and is supported under tension between a pair of wire guides located at the opposite sides of the work piece. The lower wire guide is stationary whereas the upper wire guide, supported by the U-V table, can be displaced transversely along U and V-axis with respect to lower wire guide. The upper wire guide can also be positioned vertically along Z-axis by moving the quill.Working principle is shown in Fig.1 [2].

A series of electrical pulses generated by the pulse generator unit is applied between the work piece and the travelling wire electrode, to cause the electro erosion of the work piece material. As the process proceeds, the X-Y controller displaces the worktable carrying the work piece transversely along a predetermined path programmed in the controller. While the machining operation is continuous, the machining zone is continuously flushed with water passing through the nozzle on both sides of work piece. Since water is used as a dielectric medium, it is very important that water does not ionize. Therefore, in order to prevent the ionization of water, an ion exchange resin is used in the dielectric distribution system to maintain the conductivity of water [2].

B. Material selection(WPS Die Steel)

Fig. 2:

C. Chemical Composition:

Table – 1
Composition of WPS Die Steel Material

Elements	*Weight Limits %*	*Actual Weight %*
C	*1.5-1.8*	*1.5*
Ch	*10-12*	*12*
V	*1.00-2.15*	*1.00*
Mo	*1.00-2.00*	*1.00*

D. *Wire Material:*

The copper wire had been used for the experiment and its chemical composition is CuZn37%.

1) Property of copper soft wire

- Prevent brass powder sticking
- Reduce wire breakage
- Excellence straightness
- Wire dia=0.10-0.30mm
- Tensile strength=440-540 N/mm2
- Elongation=20%

E. *Experimental setup*

This experiment had been performed at swastika wire cut-rajkot. The ECOCUT wire EDM had been used for experiment. The machine specification for the particular machine is describing in below table no 2.

Table – 2
Technical Specification of wire EDM machine

Model	Specification
Table size	440*650 mm
Max work piece height	200 mm
Max work piece weight	500 kg
Main table traverse(x,y)	300*400 mm
Aux. table traverse(u,v)	80*80 mm
Max taper angle	+_30^0/50 mm
Max JOG speed	900 mm/min
Resolution	0.0005 mm
Max wire spool capacity	6 kg
Wire electrode diameter	0.25mm
Cooling system	1700 kcal
Input power supply	3 phase, AC 415 V , 50Hz

F. *Wire EDM variables and their levels.*

Table – 3
Input parameters and levels

Symbol	*Input Parameters*	*Level 1*	*Level 2*	*Level 3*
A	*Pulse on time(µs)*	*112*	*116*	*120*
B	*Pulse off time(µs)*	*50*	*55*	*60*
C	*Machine Feed*	*0.6*	*0.9*	*1.2*

G. *Experimental readings.*

Table – 4
Experimental readings.

Std	*Run*	*Block*	*Factor 1 A: Ton µs*	*Factor 2 B: Toff µs*	*Factor 3 A: Machine feed Mm/min*	*Response 1 MRR Mgm/min*	*Response 2 Surface roughness(micron) Avg*
2	*1*	*Block 1*	*116*	*50*	*0.6*	*85*	*2.937*
1	*2*	*Block 1*	*112*	*50*	*0.6*	*68*	*2.787*
18	*3*	*Block 1*	*120*	*60*	*0.9*	*93*	*2.965*
8	*4*	*Block 1*	*116*	*60*	*0.6*	*83*	*2.803*
16	*5*	*Block 1*	*112*	*60*	*0.9*	*59*	*2.684*
10	*6*	*Block 1*	*112*	*50*	*0.9*	*72*	*2.793*
24	*7*	*Block 1*	*120*	*55*	*1.2*	*102*	*3.012*
17	*8*	*Block 1*	*116*	*60*	*0.9*	*76*	*2.812*
22	*9*	*Block 1*	*112*	*55*	*1.2*	*68*	*2.704*
25	*10*	*Block 1*	*112*	*60*	*1.2*	*62*	*2.688*
15	*11*	*Block 1*	*120*	*55*	*0.9*	*101*	*2.989*
11	*12*	*Block 1*	*116*	*50*	*0.9*	*86*	*2.943*
12	*13*	*Block 1*	*120*	*50*	*0.9*	*109*	*2.895*
5	*14*	*Block 1*	*116*	*55*	*0.6*	*82*	*2.834*
19	*15*	*Block 1*	*112*	*50*	*1.2*	*74*	*2.798*
4	*16*	*Block 1*	*112*	*55*	*0.6*	*60*	*2.684*
7	*17*	*Block 1*	*112*	*60*	*0.6*	*58*	*2.681*

23	18	Block 1	116	55	1.2	86	2.895
14	19	Block 1	116	55	0.9	84	2.857
26	20	Block 1	116	60	1.2	83	2.858
20	21	Block 1	116	50	1.2	91	2.955
3	22	Block 1	120	50	0.6	112	3.078
13	23	Block 1	112	55	0.9	63	2.699
6	24	Block 1	120	55	0.6	95	2.967
21	25	Block 1	120	50	1.2	115	2.934
27	26	Block 1	120	60	1.2	98	2.978
9	27	Block 1	120	60	0.6	89	2.954

H. ANOVA for Material Removal Rate.

Table – 5
ANOVA response for MRR

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7652.222	18	425.1235	402.7485	< 0.0001	significant
A-Ton	6460.222	2	3230.111	3060.105	< 0.0001	
B-Toff	881.5556	2	440.7778	417.5789	< 0.0001	
C-M/C FEED	162.6667	2	81.33333	77.05263	< 0.0001	
AB	146.8889	4	36.72222	34.78947	< 0.0001	
AC	0.444444	4	0.111111	0.105263	0.9774	
BC	0.444444	4	0.111111	0.105263	0.9774	
Residual	8.444444	8	1.055556			
Cor Total	7660.667	26				

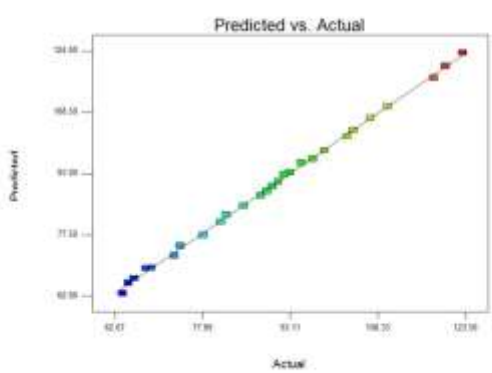
The Model F-value of 402.75 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, C, AB are significant model terms.

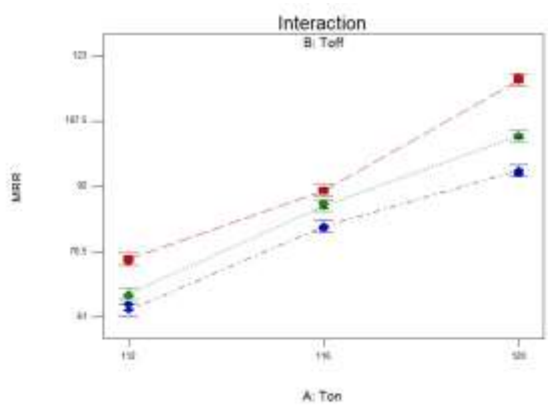
Std. Dev.	1.027402	R-Squared	0.998898
Mean	89.77778	Adj R-Squared	0.996417
C.V. %	1.144384	Pred R-Squared	0.987444
PRESS	96.1875	Adeq Precision	70.64844

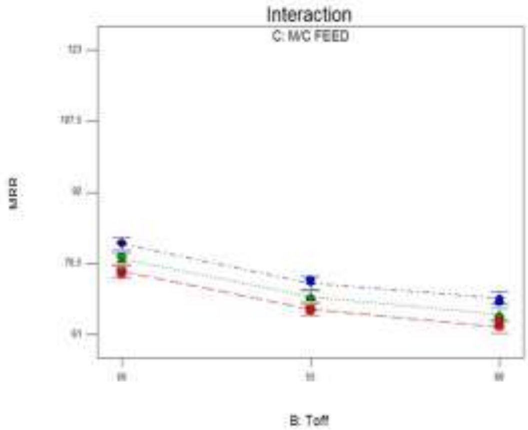
1) Final Equation in Terms of Coded Factors:

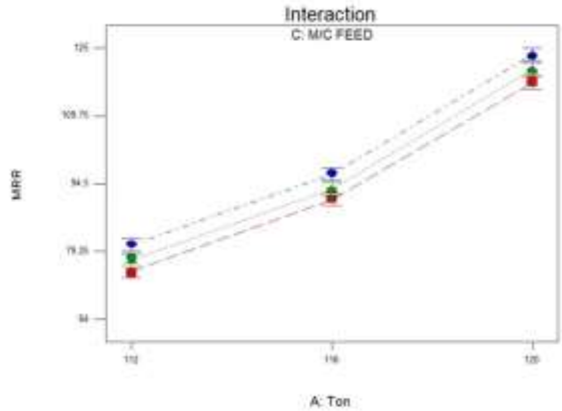
MRR =+89.78-18.89 * A[1]-0.11 * A[2]+7.44 * B[1]-1.00 * B[2]-2.89* C[1]-0.22* C[2]-0.67 * A[1]B[1]-3.44 * A[2]B[1]-0.56 * A[1]B[2]+1.33 * A[2]B[2]+0.000* A[1]C[1] +0.22 * A[2]C[1]+0.000 * A[1]C[2]-0.11 * A[2]C[2]+0.000 * B[1]C[1]+0.11* B[2]C[1] +0.000* B[1]C[2]+0.11 * B[2]C[2]

I. Graphs for MRR:









J. *ANOVA for Surface Roughness:*

Table – 6
ANOVA for Surface roughness

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.346279333	18	0.019237741	15.89458062	0.0002	significant
A-Ton	0.286843556	2	0.143421778	118.4977508	< 0.0001	
B-Toff	0.028250889	2	0.014125444	11.67070596	0.0042	
C-M/C FEED	0.001902889	2	0.000951444	0.786101166	0.4879	
AB	0.016875556	4	0.004218889	3.485724777	0.0626	
AC	0.005272889	4	0.001318222	1.089139815	0.4235	
BC	0.007133556	4	0.001783389	1.4734692	0.2964	
Residual	0.009682667	8	0.001210333			
Cor Total	0.355962	26				

The Model F-value of 15.89 implies the model is significant. There is only a 0.02% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B are significant model terms. Values greater than 0.1000 indicate the model terms are not significant.

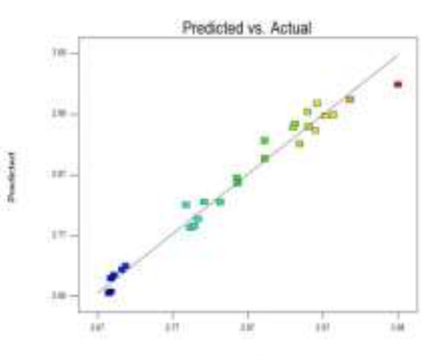
Std. Dev.	0.034789845	R-Squared	0.972798595
Mean	2.858666667	Adj R-Squared	0.911595432
C.V. %	1.21699552	Pred R-Squared	0.690158992
PRESS	0.110291625	Adeq Precision	12.35068145

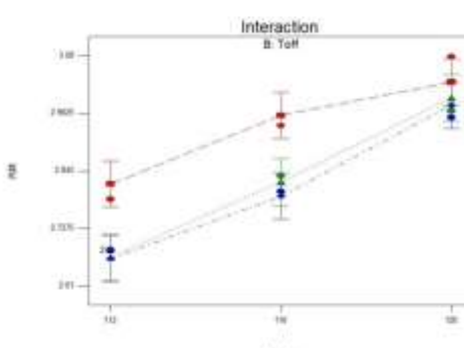
The "Pred R-Squared" of 0.6902 is not as close to the "Adj R-Squared" of 0.9116 as one might normally expect. This may indicate a large block effect or a possible problem with your model and/or data. Things to consider are model reduction, response tranformation, outliers, etc.

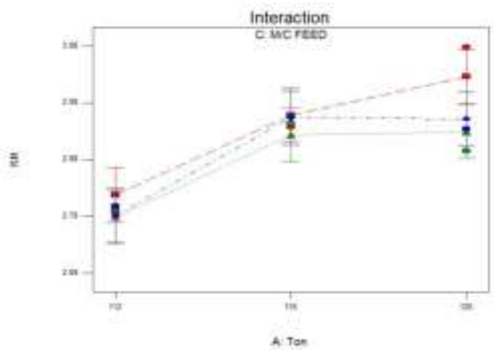
1) *Final Equation in Terms of Coded Factors:*

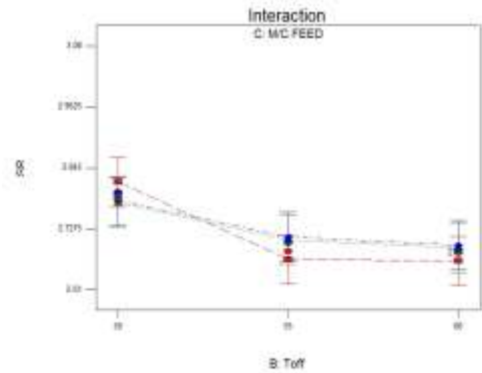
SR AVG =+2.86-0.13* A[1]+0.018 * A[2]+0.044 * B[1]-9.667E-003* B[2] -3.333E-004 * C[1] -0.010 * C[2]+0.025 * A[1]B[1] +0.024 * A[2]B[1] -0.019* A[1]B[2] -5.444E-003 * A[2]B[2]-6.556E-003 * A[1]C[1]-0.019* A[2]C[1] +0.011 * A[1]C[2] +3.667E-003* A[2]C[2] +0.032 * B[1]C[1] -0.020 * B[2]C[1]-0.015 * B[1]C[2] +9.444E-003 * B[2]C[2]

K. *Graphs for Surface Roughness:*









II. CONCLUSION

By performing and analysing the experiment we can conclude that the input parameter such as Ton ,Toff , machine feed are effect on material WPS Die Steel differently with output parameters(MRR and SR).

- With increasing Ton time, MRR and SR are increase.
- With increasing Toff time, MRR and SR are decrease.
- With increasing machine feed, MRR and SR are increase.
- By optimising ,For getting maximum MRR and better surface roughness the input values are Ton=116µs,Toff=55 µs,machine feed=0.6.
- In this experiment the maximum MRR is 123 mgm/min and Average surface roughness is 2.681 micron.

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