Experimental Investigation Of AISI d3 Steel With Four Input Parameters Using Wire EDM By ANOVA Techniques.

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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. AISI D3 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. D3steel 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, material removal rate (MRR), Kerf width and wire wear ratio in wire electro discharge machining (EDM) of AISID3 Steel. The best combination of machining parameter viz. machine feed, voltage, pulse on time and pulse off time. The paper highlights the importance of process parameters and different machining conditions on MRR, surface roughness (Ra), kerf width and surface topography. In this work, machine feed, voltage, pulse on time and pulse off are input parameters and surface roughness ,MRR, kerf width and wire wear ratio as output parameters. The optimal values of these parameters have defined with the aim of achieving the better surface roughness and higher MRR and better WWR.

The experiment work had conducted with three input parameters pulse on time, pulse off time , machine feed and voltage, and also its different levels. Full factorial technique had been used for accurate results. ANOVA had been used for the analysis and defined optimum value of input parameters for getting best output on d3 steel.

Keyword : - *WEDM , MRR, SURFACE ROUGHNESS,KERF WIDTH,ANOVA….*

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1. IMTRODUCTION

Wire EDM is not the new on the block. It was introduced in the late 1960s', and has revolutionized the tool and die, mould , and metalworking industries. It is probably the most exciting and diversified machine tool developed for this industry in the last fifty years, and has numerous advantages to offer.

It 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 titanium, carbide, polycrystalline diamond compacts and conductive ceramics. The wire does not touch the work piece , so there is no physical pressure imparted on the work piece 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 work piece. The accuracy, surface finish and time required to complete a job is extremely predictable, making it much easier to quote, EDM leaves a totally random pattern on the surface as compared to tooling marks left by milling cutters and grinding wheels. The EDM process leaves no residual burrs on the work piece, which reduces or eliminates the need for subsequent finishing operations.

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. 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 work pieces come off the machine as a finished part ,without the need for secondary operations. It's a one-step process. The wire electric discharge machining shortly known as WEDM, is a variation of basically the EDM process and is commonly known as wire cutting. In this process a thin metallic wire is fed into the work piece, which is submerged in a tank of dielectric fluid such as such as de-ionized water. This process can also cut plates as thick as 300 mili meters. Therefore, this is considered to be very useful process. It is also used in making punches, tools and dies from hard metals that are difficult to machine with other metals. The wire, which is constantly fed from a spool is held between the upper and lower diamond guides.

1.2 Selection of Input and Output Parameters

There are different input parameters which affect on the output parameters such as pulse on time ,pulse off time ,wire speed ,wire tension, gap voltage ,peak current, machine feed, dielectric flow rate etc. There are different output parameters such as material removal rate , surface roughness, kerf width, wire wear ratio, duty cycle depends on input parameters. This experiment include three input parameters pulse on time ,pulse off time and machine feed from the above inputs affect on output parameters such as MRR, surface roughness of d3 steel. Details of these input and output parameters have described below.

Input parameters:

Pulse on time - Pulse duration, also called pulse on time, is expressed in micro seconds. During the pulse on time, the voltage is applied in the gap between work piece and the electrode thereby producing discharge. Higher the pulse on time, higher will be the energy applied there by generating more amount of heat energy during this period. Material removal rate depends upon the amount of energy applied during the pulse on time. Expected range of pulse on time is 100-130 µs.

Pulse off time - Pulse interval, also referred as Pulse off time, is also expressed in micro seconds. This is the time between discharges. Off Time has no effect on discharge energy. Off Time is the pause between discharges that allows the debris to solidify and be flushed away by the dielectric prior to the next discharge. Reducing Off Time can dramatically increase cutting speed, by allowing more productive discharges per unit time. However, reducing Off Time, can overload the wire, causing wire breakage and instability of the cut by not allowing enough time to evacuate the debris before the next discharge. Expected range of pulse off time is 40-60 µs

Machine Feed - It is indicate the speed of machine at which machine cut the work piece . Expected range of machine feed is 0.5-1.5 mm/min.

Voltage

Servo voltage acts as the reference voltage to control the wire advances and retracts. If the mean machining voltage is higher than the set servo voltage level, the wire advances, and if it is lower, the wire retracts. When a smaller value is set, the mean gap becomes narrower, which leads to an increase in number of electric sparks, resulting in higher machining rate. However, the state of machining at the gap may become unstable, causing wire breakage.

Output parameters:

MRR (Material removal rate): The material removal rate is expressed as the ratio to the difference of weight of the work piece before machining and after machining measured by a precision weight balance of the machining time.

MRR = (Wb- Wa)/t Whereas, Wb= weight of work piece before machining; Wa= weight of work piece after machining; t= machining time.

Surface roughness (Average): Surface finish is expressed as Ra value in micro meter and is measured with the help of contact type surface roughness tester

Kerf (Width of cut) – kerf is one of the important performance measures in WEDM. Kerf is the measure of the amount of the material that is wasted during machining. It affects the dimensional accuracy of the finished part. kerf of EDM work piece depends on gap voltage, pulse on time, pulse off time, wire feed and flushing pressure.

Wire wear ratio - As WEDM is a thermo- electrical process in which materials eroded by a series of sparks between the work piece and the wire electrode, along with the work piece material some particles from wire also will erode, this phenomenon is called wire wear and this should be kept to a minimum. Wire failure occurs in wire-EDM process as a result of severity in wire wear rate, which is a function of discharge current and discharge time.

Chemical composition:

Table : Composition of AISI Die Steel Material

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

2. DESIGN OF EXPERIMENTS

2.1 LITERATURE REVIEW:

Aniza Alias et al.(2012). In this research he worked on machine feed rate in WEDM of titaniumti-6al-4v with constant current (6a) using brass wire. Objective of the paper is to uncover the influence of three different machine rates which are 2 mm/min, 4 mm/min and 6 mm/min with constant current (6A). The effects of different process parameters on the kerf width, material removal rate, surface roughness and surface topography are also discussed. The best combination of machining parameter viz. machine feed rate (4 mm/min), wire speed (8 m/min), wire tension (1.4kg) and voltage (60V) were identified.

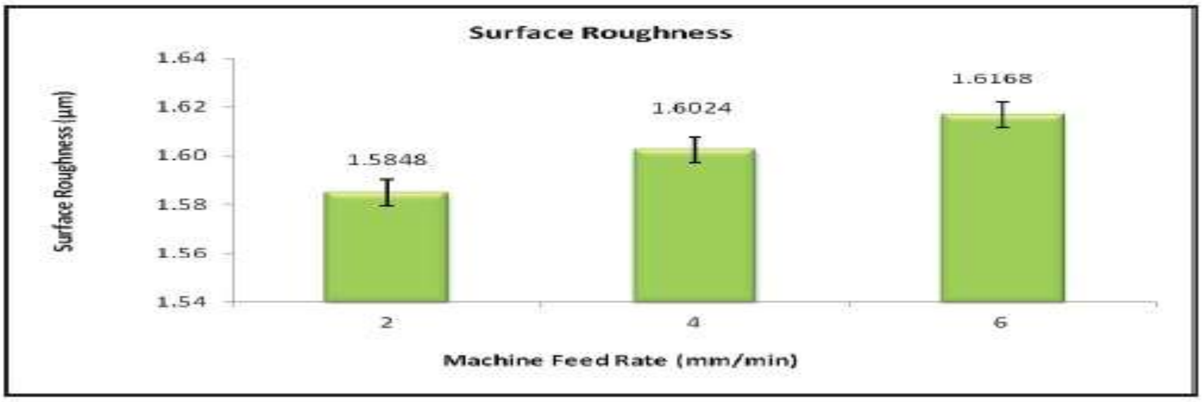


Fig. 2.1 Result on surface roughness at different machine feed rate

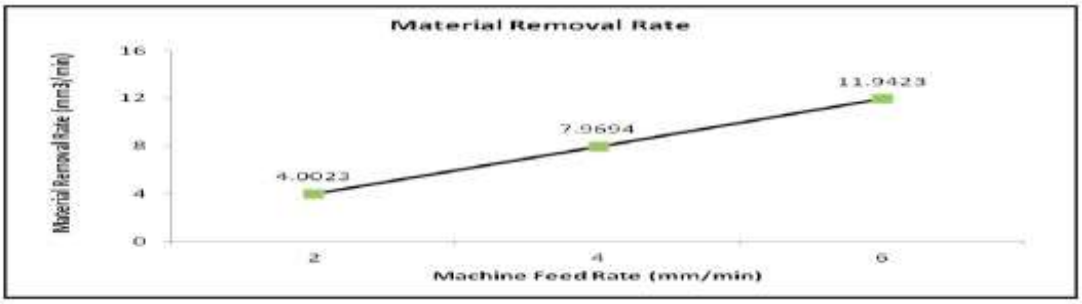


Fig.2.2 Result on material removal rate at different machine feed rate

In this paper the main goal is to find the best combination of machining parameters as known the cost and quality of WEDM which depends heavily on the process parameters. Machine feed rate have been proven to play an important role in this experimental work. Since the low kerf and the high MRR are equally important goals in WEDM, equal machine feed rate are recommended.

Hsien-Ching Chen et al.(2010). This study analyzed variation of cutting velocity and work piece surface finish depending WEDM process parameters during manufacture of pure tungsten profiles. He used integration of two method of back propagation neural network (BPNN) and simulated annealing algorithm (SAA).The specimens are prepared under different WEDM process conditions based on a Taguchi orthogonal array table. The results of 18 experimental runs were utilized to train the BPNN predicting the cutting velocity, roughness average (Ra), and roughness maximum (Rt) properties at various WEDM process conditions and then the SAA approaches was applied to search for an optimal setting. In addition, the analysis of variance (ANOVA) was implemented to identify significant factors for the WEDM process. The results of proposed algorithm and confirmation experiments are show that the BPNN/SAA method is effective tool for the optimization of WEDM process parameters. The BPNN could be utilized successfully to predict cutting velocity (CV), roughness average (Ra) and roughness maximum (Rt) properties for WEDM process during manufacture of pure tungsten profiles after being properly trained. At the same time, the BPNN prediction models yield smaller MSE after training, namely, the BPNN was gave reasonable prediction in the experimental runs based on the BPNN approach. the proposed algorithm of SAA approach is also by confirmation experiment carried out to check the validity within 3% error. Through ANOVA, the percentage of contribution to the WEDM process, the pulse on time is the most significant controlled factor for the WEDM operation.

M.durairaj and D sudharshan . In this paper analysis of process parameters in wire EDM with stainless steel using single objective Taguchi method . The machining characteristics that are being investigated are material removal rate (MRR) and surface roughness (SR) along with surface topography of the machined surface for ss304. The Investigation indicated based on Taguchi optimization of machining that input parameters combination to get the minimum surface roughness are 40Vgap voltage ,2mm/min wire feed , similarly optimized condition to get the minimum kerf width are 50 v. material removal rate and surface roughness increases with increase in pulse-on time and decreases with increase in pulse-off time.

S.R NITHIN ARVIND , S.SOWMYA IEEE(ICAESM-2012. In This Paper , Optimization of metal removal rate and surface roughness on Wire EDM using Taguchi Method. This Paper deals with finding five optimal control parameters input voltage, current , speed , pulse on-off time to maximize metal removal rate and minimize surface roughness on wire edm. Wire edm is an electro thermal production process in which a thin single stand metal wire in conjuction with de-ionised water (used to electricity) allows the wire to cut through metal by the use of heat from electrical sparks. For the purpose to get the best solution to maximize MRR and reduced SR ,here they optimize parameters using taguchi method.

T.TAMIZHARASAN , N.SENTHIL KUMAR IEEE(ICAESM-2012). In This Paper deals with the experimental investigation of effects of geometrical parameters of cuttings tool insert and analysis of output responses such as surface roughness and MRR during machining AISI 1045 steel. Th analysis is essential ,since the wear ,occurring at the cutting edge of the insert favour the surface roughness at the machine surface . taguchi's designed of experiments (DOE) is used to design the experimental array, based on which experiments were conducted .For 3 parameters and 3 level of each parameters ,L9 orthogonal array is selected. To evaluate the output quality characteristics taguchi method single to noise ratio is used, based on which the optimum condition are determined. An interaction effect of one input parameters over another parameters studies to understand their influences on output performance characteristics . analysis of variance (ANOVA) is also performed to study the contribution of individual parameters on the output quality characteristics .

Fig2.3. Shapes of cutting inserts used in turning

SAMAD DADVANDIPOUR semi 2013 IEEE , In This Paper Experimental studies of electric discharge machining (EDM) of P20 type tool steel . Evaluating customers demands to link with manufacturer may have the most important role in producing parts with utmost preciseness. Replacing traditional manufacturing process with modern and advanced process technology has already been an important alternative in competitive world market ,which may fulfill the customer satisfaction long term . EDM is the most advanced process technology

,which belongs to non traditional manufacturing process. It is quite an expensive machining process , which is most used in producing molding dies of different kinds and smart parts as well as the wire EDM processes. They can says a thermo electrical process with analyzable material removal system . the aim of this paper is to test the effect of EDM parameters on P20 type tool steel . at these research work they have used different kind of tool electrode material like graphite ,copper , and brass . keyword , advanced machining process ,EDM, effective parameters ,outputs ,tool steel.

Deepak rajendra unune and harshal singh . This study of research is on low frequency vibration assisted micro WEDM of Inconel 718, In this paper, an attempt is made to study the effect of material removal rate (MRR) and kerf width . The experiments observed in micro WEDM, it was witnessed that the low frequency work piece vibration improve the performance of micro WEDM by improving the MRR due to enhance flushing condition and reduce electrode work piece .The experimental result analysis showed that the combination of is essential to achieve maximization of material removal rate and minimization of surface roughness and kerf width.

Kamal kumar jangra and vinod kumar (2014). In this research he studied an experimental and comparative study on rough and trim cutting operation in WEDM of hard to machine material . investigation shows that in rough cutting operation ,machining speed and surface roughness increase with increasing discharge energy across the electrodes different value machining speed and surface roughness were obtained for four work material under the similar condition of discharge energy results show that using single trim cutting operation with appropriate wire offset ,surface characteristics can be improved irrespective of the rough cutting operation.

2.1FULL FACTORIAL DESIGN

A full factorial design is applied when the purpose is to determine which factors (independent variables) are important in the study and the range of values (levels) of these factors. This is the only design that can evaluate interaction among all factors.

ANOVA

Once the mathematical model has been selected, it is important to determine its significance by means of a variance analysis (ANOVA). To do that, the standard deviations of the main and the interactions effects of the selected factors should be calculated. If the standard deviations present a lower value than the mean values, it is possible to assume that the mathematical model is significant. If this does not happen, the experimental data should be evaluated in order to not presume that the effect is not significant.

In this regard, the goodness-of-fit of this model needs an assessment and the following criteria should be analysed:

- Standard deviation of the estimated parameters and model
- Statistical significance of the estimated parameters
- Regression coefficient
- Value of the objective function
- Analysis of the residuals.

It is considered a good fit to the experimental data when:

-The standard deviation of the parameter presents a lower value than the correspondent effect, indicating that the standard deviation of the proposed mathematical model is low;

-The parameters of a model need to be significant, otherwise they will not contribute to the model.

2.2INPUT PARAMETERS AND LEVELS

Symbol	Input Parameters	Level 1	Level 2	Level 3	Level4
A	Pulse on time(µs)	108	112	116	120
B	Pulse off time(µs)	45	50	55	60
C	Machine Feed(mm/min)	0.4	0.6	0.8	1.0
D	Voltage (v)	55	80	105	130

2.3EXPERIMENTAL RESULTS

Std	Run	Block	Factor1	Factor2	Factor 3	Factor4	Response1	Response2	Response3	Response4
			A: Ton	B: Toff	C:Machine feed	D:voltage	MRR	SR (micro)	Kerf width	WRR
			µs	µs	Mm/min	v	mgm/min	Avg	µm	Avg
2	1	Block 1	116	45	0.4	80	91	2.937	124	0.0680
1	2	Block 1	108	50	0.6	105	74	2.787	122	0.1093
18	3	Block 1	120	60	0.8	55	99	2.965	111	0.1043
8	4	Block 1	116	60	0.6	80	82	2.803	109	0.0790
16	5	Block 1	112	45	0.8	105	65	2.684	122	0.0833
10	6	Block 1	108	50	0.4	55	78	2.793	121	0.0757
24	7	Block 1	120	55	1.0	130	110	3.012	128	0.0649
17	8	Block 1	108	60	0.8	105	85	2.812	97	0.0813
22	9	Block 1	112	55	1.0	130	73	2.704	153	0.0743
25	10	Block 1	112	60	0.4	55	68	2.688	98	0.0884
15	11	Block 1	120	45	0.8	80	107	2.989	113	0.1160
11	12	Block 1	116	45	0.8	105	93	2.943	98	0.0955
12	13	Block 1	120	50	0.4	130	120	2.895	135	0.0507
5	14	Block 1	116	55	0.6	105	88	2.834	123	0.0933
19	15	Block 1	112	50	1.0	105	81	2.798	98	0.0803
4	16	Block 1	112	55	0.6	80	66	2.684	95	0.0700
7	17	Block 1	112	60	0.4	55	64	2.681	118	0.1027
23	18	Block	116	45	1.0	105	92	2.895	147	0.0910
14	19	Block 1	108	55	0.8	130	90	2.857	128	0.0753
26	20	Block 1	116	60	1.0	105	89	2.858	120	0.0880
20	21	Block 1	116	50	0.4	105	97	2.955	129	0.0917
3	22	Block 1	120	50	0.6	55	118	3.078	134	0.1448
13	23	Block 1	112	55	0.8	55	69	2.699	145	0.0907
6	24	Block 1	108	55	0.6	105	104	2.967	155	0.1053
21	25	Block 1	108	50	1.0	105	123	2.934	101	0.0810
27	26	Block 1	120	60	1.0	80	103	2.978	109	0.0793

9	27	Block 1	120	45	0.6	105	95	2.954	151	0.0670

3.ANALYSIS OF VARIANCE FOR DIFFERENT PARAMETERS

ANALYSIS OF VARIANCE FOR MRR

ANOVA for selected factorial model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7652	18	425.1235	402.7485	< 0.0001	Significant
A-Ton	6460	2	3230.111	3060.105	< 0.0001	
B-Toff	881.6	2	440.7778	417.5789	< 0.0001	
C-M/C FEED	162.7	2	81.33333	77.05263	< 0.0001	
D-voltage	2.286	1	2.286	23.80	<0.0001	
AB	146.9	4	36.72222	34.78947	< 0.0001	
AC	0.444	4	0.111111	0.105263	0.9774	
BC	0.444	4	0.111111	0.105263	0.9774	
Residual	8.444	8	1.055556			
Cor Total	7663	27				

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.Values greater than 0.1000 indicate the model terms are not significant.

Std. Dev.	1.03	R-Squared	0.9989
Mean89.78		Adj R-Squared	0.9964
C.V. %	1.14	Pred R-Squared	0.9874
PRESS	96.19	Adeq Precision	70.648

The "Pred R-Squared" of 0.9874 is in reasonable agreement with the "Adj R-Squared" of 0.9964."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 70.648 indicates an adequate signal.This model can be used to navigate the design .

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]D[1]+0.000 * A[1]D2]-0.11 * A[2]C[2]+0.000 * B[1]C[1]+0.11* B[2]D[1] +0.000* B[1]C[2]+0.11 * B[2]D[2]

ANALYSIS OF VARIANCE FOR SURFACE ROUGHNESS

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	0.346279	18	0.019238	15.89458	0.0002	Significant
A-Ton	0.286844	2	0.143422	118.4978	< 0.0001	
B-Toff	0.028251	2	0.014125	11.67071	0.0042	
C-M/C FEED	0.001903	2	0.000951	0.786101	0.4879	
D-voltage	0.004504	2	0.002252	120.34	0.0000	
AB	0.016876	4	0.004219	3.485725	0.0626	
AC	0.005273	4	0.001318	1.08914	0.4235	
BC	0.007134	4	0.001783	1.473469	0.2964	
Residual	0.009683	8	0.00121			
Cor Total	0.360466	28				

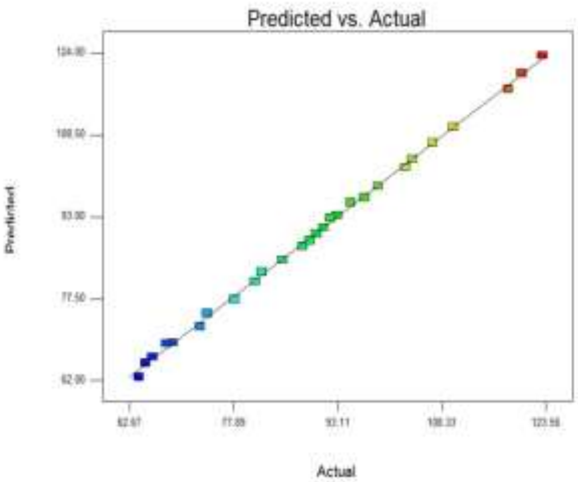
ANALYSIS OF VARIANCE FOR WRR

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
A-Ton	0.01773	2	0.01740	9.41	< 0.0001	
B-Toff	0.00249	2	0.00249	0.79	0.446	
C-M/C FEED	0.001903	2	0.000951	0.786101	0.4879	
D-voltage	0.004504	2	0.004500	120.34	0.0000	
AB	0.017540	4	0.004219	3.485725	0.0626	
AC	0.005032	4	0.001318	1.08914	0.4235	
BC	0.0071200	4	0.001783	1.473469	0.2964	
Residual	0.009600	8	0.032661			
Cor Total	0.065919	28				

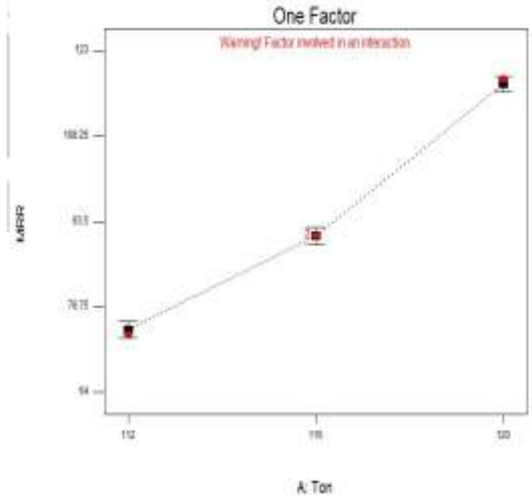
ANALYSIS OF VARIANCE FOR KERF WIDTH

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	9296.91	7	1328.13	95.69	< 0.0001	Significant
A-Ton	0.3277	3	0.1092	52.1234		
B-Toff	0.082	3	0.0275	13.1064		
C-M/C FEED	3.08	1	3.08	0.22	0.6422	
D-voltage	747.59	1	747.59	53.86	<0.0001	
AB	146.9	4	36.72222	34.78947		
AC	0.444	4	0.111111	0.105263	0.9774	
CD	0.444	4	0.111111	0.105263	0.9774	
Residual	8.444	8	1.055556			
Cor Total	907.31	28				

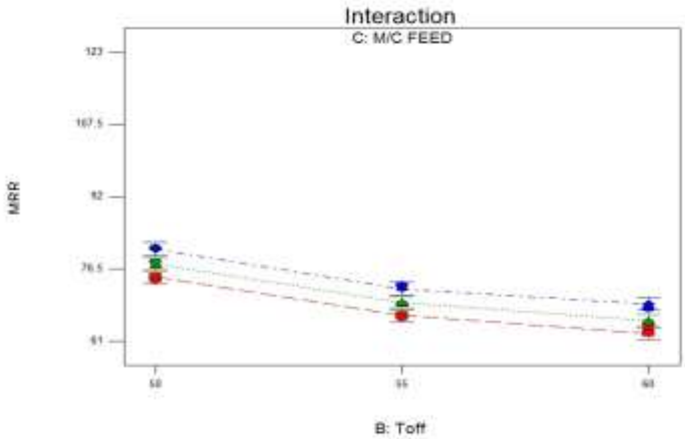
GRAPHS FOR MRR



predicted VS Actual plot



Ton VS MRR plot



T off & MC feed&V VS MRR plot

3.1RESULTS & OPTIMIZATION:

Number	Ton	Toff	M/C FEED	voltage	MRR	SR AVG	Kerf	wrr	Desirability	
1	116	55	0.6	105	87.44444	2.822556	123	0.093	0.686591	Selected
2	108	55	0.6	130	89.77778	2.865	128	0.075	0.657419	
3	116	55	0.6	105	88.55556	2.856	123	0.093	0.65506	
4	108	60	0.8	105	84.88889	2.823556	97	0.051	0.646821	
5	116	60	0.6	80	82.55556	2.793444	109	0.079	0.644689	
6	116	45	1.0	105	92.77778	2.898444	147	0.091	0.637761	
7	116	45	0.8	105	93.33333	2.923444	98	0.095	0.597383	
8	116	50	0.4	105	96.66667	2.953556	129	0.091	0.552922	
9	116	45	0.4	80	91	2.958	124	0.068	0.505013	

4. CONCLUSIONS

By performing and analyzing the experiment we can conclude that the input parameter such as Ton ,T off , machine feed,voltage are effect on material WPS D3 Steel differently with output parameters(MRR ,kerf width , SR and WRR).

- With increasing Ton time ,MRR ,SR and WRR are increase.
- With increasing T off time ,MRR and SR are decrease .
- With increasing voltage ,machine feed ,MRR and SR are increase.
- For getting maximum MRR and kerf width and better surface roughness and WRR the input values are Ton=116µs,Toff=55 µs,machine feed=0.6and voltage=105v.
- In this experiment the maximum MRR is 123 mgm/min and Average surface roughness is 2.681 micron.

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