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Different Types of Wires Effects on Wire Cut EDM Machine by D.O.E. Approach

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***Abstract*— At present Industrial application needs the use of advanced materials like tool steels, super alloys, ceramics, and composites with high precision and high surface quality. These materials are hard and difficult to machine. To meet these challenges, non-conventional machining processes are being employed to achieve higher metal removal rate, better surface finish and greater dimensional accuracy.**

Wire cut EDM is most progressive non-conventional machining process in mechanical industries. There are so many parameter affect the performance of Wire cut EDM. Few of them are investigated in this report. In present an attempt is made to investigate the effect of varying pulse on time, pulse off time, wire feed rate and Peak current on H-11 material to analyze effect on the Kerf Width (KW) and Material Removal Rate (MRR) using ANOVA analysis and multi response Taguchi base optimization will be carried out. A Taguchi design of experiment (DOE) approach with L9 Orthogonal Array employed to conduct this experiment. The ANOVA calculation by both Mathematical steps and Minitab software.

***Keywords*— WEDM, ANOVA, MRR, KW, Mathematical Modelling**

I. INTRODUCTION

Wire electrical discharge machining (WEDM) is a unique thermal machining technique competent to machining parts with varying hardness or complex shapes with sharp edges that are very crucial to be machined by the core stream machining processes. The WEDM process is based on the conventional EDM sparking phenomenon that utilizes the conventionally accepted non-contact technique of material removal. Since the very beginning the process, WEDM has evolved as the best alternative of producing micro-scale parts with the highest degree of dimensional accuracy and surface finish quality [1].

Wire Electrical discharge machining (WEDM) is a non-conventional, thermoelectric procedure which erodes material by a series of discrete sparks between a work and tool electrode immersed in a liquid dielectric medium. These electrical discharges dissolve and vaporize tiny amounts of the work material, which are then ejected and flushed away by the dielectric. A wire EDM produces spark discharges between a small wire electrode (usually less than 0.5 mm diameter) and a work piece with demonized water and erodes the work piece to produce complex two- and three dimensional shapes as per the numerically controlled (NC) path. During the WEDM process, the material is eroded to the front of the wire and there is no straight contact between the work piece and the wire, eradicating the mechanical strains during machining. The WEDM is kind of process that enable to machine exotic and elevated might and temperature resistive (HSTR) materials and eliminate the geometrical changes occurring in the machining of heat-treated steels. The evolution of the process was the result in the hunt for a technique to substitute the machined electrode used in EDM [1].

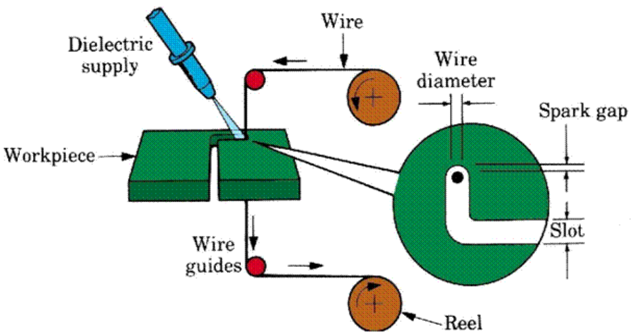


Fig. 1 Representation of Wire EDM cutting process

II. EXPERIMENTAL PLANNING

A. Material Specification

Wire-cut EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. H-11 is a Die tool steel. This can be used in the toughened condition. H-11 offers high corrosion resistance, wear strength and high hardness. The chemical composition tested at Ahmedabad Laboratories, Ahmedabad of the selected work material is shown in Table 1.

TABLE 1
MATERIAL SPECIFICATION: H11

Chemical	Obtained Value (%)	Required Value
Carbon	0.370	0.30 – 0.40
Silicon	0.865	0.80 – 1.20
Manganese	0.410	0.25 – 0.50
Chromium	4.905	4.75 – 5.25
Molybdenum	1.400	1.20 - 1.60
Vanadium	0.375	0.20 – 0.40

H-11 Material generally used in Hot-work forging, Extrusion, Manufacturing punching tools, Mandrels, Mechanical press forging die, Plastic mould, Die-casting dies, Aircraft landing gears, Helicopter rotor blades and shafts, etc.

B. Input Parameters and their levels

- For the present work a 3 level 4 factor design was developed by using Taguchi method.
- MINIAB software has been used to design the orthogonal array for the present work.
- The level for the Input parameters selected, Pulse on time (Ton), Pulse off time (Toff), Wire feed (Wf), Peak current (Ip) are shown in table.

TABLE 2
DOE TABLE

Sr. No.	Machine parameter	Unit	Level		
			1	2	3
1	Ton	Ms	110	115	120
2	Toff	Ms	30	40	50
3	Wf	Machine unit	2	5	8
4	Ip	mA	110	120	130

- In this research use taguchi design of experiment (DOE) approach with L9 Orthogonal array for experiment.

C. Experimental setup

In this Experiment carried out by varying six control factors on Ultracut f1 machine of Electronica Pvt. Limited. Zinc Coated (Hard), Plain Brass (Hard), Plain Brass (Half Hard) wires of 0.25 mm diameter was used.

D. Specimen detail

Total 27 nos. of experiments has been carried out by slit on rectangle plate 30cm x 1.5cm x 1.5 cm of H-11 material. We used three different wires; Zinc Coated (Hard), Plain Brass (Hard), Plain Brass (Half Hard).

III. ANALYSIS AND RESULTS

A. Experimental Result:-

- ZINC COATED BRASS (HARD)

TABLE 3
EXPERIMENT RESULT FOR ZINC COATED BRASS (HARD)

Sr.No.	Ton	Toff	Wf	Ip	Thickness	Time	Cutting speed	KW	MRR
1	110	30	2	110	10	5.1	2.5	0.388	9.7
2	110	40	5	120	10	4.7	2.7	0.4	10.8
3	110	50	8	130	10	5.65	2.15	0.37	7.955
4	115	30	5	130	10	4.12	3.2	0.409	13.088
5	115	40	8	110	10	4.168	2.75	0.38	10.45
6	115	50	2	120	10	4.57	2.8	0.39	10.92
7	120	30	8	120	10	4.03	3.3	0.33	10.89
8	120	40	2	130	10	3.77	3.6	0.3	10.8
9	120	50	5	110	10	4.07	3.25	0.37	12.025

- PLAIN BRASS (HARD)

TABLE 4
EXPERIMENT RESULT FOR PLAIN BRASS (HARD)

Sr.No.	Ton	Toff	Wf	Ip	Thickness	Time	Cutting speed	KW	MRR
10	110	30	2	110	10	5.44	2.25	0.307	6.9075
11	110	40	5	120	10	4.96	2.52	0.35	8.82
12	110	50	8	130	10	6.05	1.98	0.3535	6.9993
13	115	30	5	130	10	4.33	3	0.41	12.3
14	115	40	8	110	10	4.95	2.53	0.38	9.614
15	115	50	2	120	10	4.81	2.62	0.39	10.218
16	120	30	8	120	10	4.18	3.14	0.37	11.618
17	120	40	2	130	10	3.9	3.44	0.37	12.728
18	120	50	5	110	10	4.27	3.05	0.38	11.59

- PLAIN BRASS (HALF HARD)

TABLE 5
EXPERIMENT RESULT FOR PLAIN BRASS (HALF HARD)

Sr.No.	Ton	Toff	Wf	Ip	Thickness	Time	Cutting speed	KW	MRR
19	110	30	2	110	10	5.85	2.06	0.325	6.695
20	110	40	5	120	10	5.29	2.33	0.35	8.155
21	110	50	8	130	10	6.55	1.8	0.33	5.94
22	115	30	5	130	10	4.5	2.85	0.33	9.405
23	115	40	8	110	10	5.34	2.3	0.29	6.67
24	115	50	2	120	10	5.09	2.44	0.32	7.808
25	120	30	8	120	10	4.37	2.96	0.33	9.768
26	120	40	2	130	10	4.12	3.2	0.3135	10.032
27	120	50	5	110	10	4.57	2.8	0.3295	9.226

***B.** Regression Analysis:-*

- Using minitab software the regression equation was determined and the plot of actual to predictive value was made.
- The regression formula was found using the minitab software and the regression equation is given below:
- ZINC COATED BRASS (HARD)

MRR = - 632 + 10.5 Ton - 0.110 Toff + 1.94 Wf + 0.475 Ip - 0.0450 Ton * Ton + 0.000797 Toff * Toff - 0.206 Wf * Wf - 0.00200 Ip * Ip

KW = - 16.9 + 0.301 Ton - 0.0129 Toff + 0.0371 Wf + 0.00822 Ip - 0.00133 Ton * Ton + 0.000162 Toff * Toff - 0.00370 Wf *Wf - 0.000038 Ip *Ip

TABLE 6

DIFFERENCE BETWEEN PREDICTIVE AND ACTUAL RESULT (FOR ZINC COATED BRASS (HARD))

Sr. No.	MRR		KW	
	Predictive	Actual	Predictive	Actual
1	7.0233	9.7	0.3796	0.388
2	8.1252	10.8	0.3924	0.4
3	5.2785	7.955	0.3634	0.37
4	10.2923	13.088	0.40395	0.409
5	7.6362	10.45	0.37335	0.38
6	8.1235	10.92	0.38435	0.39
7	7.9533	10.89	0.326	0.33
8	7.8812	10.8	0.297	0.3
9	9.0925	12.025	0.3654	0.37

- PLAIN BRASS (HARD)

MRR = - 577 + 9.03 Ton + 0.325 Toff + 1.27 Wf + 0.535 Ip - 0.0373 Ton * Ton - 0.00449 Toff * Toff - 0.136 Wf * Wf - 0.00196 Ip * Ip

KW = - 20.9 + 0.356 Ton - 0.000792 Toff + 0.0223 Wf + 0.00891 Ip - 0.00153 Ton * Ton + 0.000017 Toff * Toff - 0.00203 Wf * Wf - 0.000032 Ip * Ip

TABLE 7

DIFFERENCE BETWEEN PREDICTIVE AND ACTUAL RESULT (FOR PLAIN BRASS (HARD))

Sr.No.	MRR		KW	
	Predictive	Actual	Predictive	Actual
10	7.809	6.9075	0.36792	0.307
11	9.712	8.82	0.41167	0.35
12	7.877	6.9993	0.41588	0.3535
13	13.2425	12.3	0.47554	0.41
14	10.5635	9.614	0.44265	0.38
15	11.1545	10.218	0.45353	0.39
16	12.621	11.618	0.43642	0.37
17	13.718	12.728	0.4375	0.37
18	12.589	11.59	0.44455	0.38

- PLAIN BRASS (HALF HARD)

MRR = 66.0 - 2.87 Ton + 0.0680 Toff + 1.11 Wf + 1.44 Ip + 0.0137 Ton * Ton - 0.00145 Toff * Toff - 0.123 Wf * Wf - 0.00582 Ip * Ip

KW = 7.17 - 0.151 Ton - 0.00776 Toff + 0.0200 Wf + 0.0333 Ip + 0.000653 Ton * Ton + 0.000096 Toff * Toff - 0.00205 Wf * Wf - 0.000137 Ip * Ip

TABLE 8

DIFFERENCE BETWEEN PREDICTIVE AND ACTUAL RESULT (FOR PLAIN BRASS (HALF HARD))

Sr. No.	MRR		KW	
	Predictive	Actual	Predictive	Actual
19	6.511	6.695	0.352	0.325
20	7.937	8.155	0.37645	0.35
21	5.695	5.94	0.3558	0.33
22	9.1845	9.405	0.356975	0.33
23	6.5185	6.67	0.318225	0.29
24	7.6275	7.808	0.347925	0.32
25	9.615	9.768	0.3588	0.33
26	9.85	10.032	0.3419	0.3135
27	9.108	9.226	0.35925	0.3295

C. Analysis of Variance (ANOVA):-

- Correction factor C.F. = T^2 / n
- Total sum of squares St = $\Sigma(Kw)^2$ - C.F.
- The total contribution of each factor level

  for eg. A1= (All kerf width reading total at 110)

  B1= (All kerf width reading total at 40)

  C1= (All kerf width reading total at 2 m/min)

  D1= (All kerf width reading total at 110 A)
- Factor sum of squares

  Sa= $((A1^2+A2^2+A3^2)/3)$ – C.F.

  Sb= $((B1^2+B2^2+B3^2)/3)$ – C.F.

  Sc= $((C1^2+C2^2+C3^2)/3)$ – C.F.

  Sd= $((D1^2+D2^2+D3^2)/3)$ – C.F.

  So=(St)-(Sa+Sb+Sc+Sd)
- Mean square (Variance)

  Va= Sa / 2 Vb= Sb / 2

  Vc= Sc / 2 Vd= Sd / 2
- Percentage contribution

  Pa= Sa / St Pb= Sb / St

  Pc= Sc / St Pd= Sd / St

  Po=So / St
- ZINC COATED BRASS (HARD)

TABLE 9
ANALYSIS OF VARIANCE (FOR ZINC COATED BRASS (HARD))

Sr.No	Para meter	Kw1	Kw2	Kw3	Total contribution	Factor sum of squares	Mean squear	Percentage contribution
1	110	0.388	0.4	0.37	A1=1.15	Sa=0.0006382889	Va=0.003191444	Pa=0.655357
2	115	0.409	0.38	0.39	A2=1.17			
3	120	0.33	0.3	0.37	A3=1			
4	30	0.388	0.409	0.33	B1=1.12	Sb=0.000524222	Vb=0.000262111	Pb=0.053824039
5	40	0.4	0.38	0.3	B2=1.08			
6	50	0.37	0.39	0.37	B3=1.13			
7	2	0.388	0.39	0.3	C1=1.07	Sc=0.00222289	Vc=0.00111144	Pc=0.22823309
8	5	0.4	0.409	0.37	C2=1.179			
9	8	0.37	0.38	0.33	C3=1.08			
10	110	0.388	0.38	0.37	D1=1.13	Sd=0.00061	Vd=0.000305	Pd=0.062586
11	120	0.4	0.39	0.33	D2=1.12			
12	130	0.37	0.409	0.3	D3=1.07			

- PLAIN BRASS (HARD)

TABLE 10
ANALYSIS OF VARIANCE (FOR PLAIN BRASS (HARD))

Sr.No	Para meter	Kw1	Kw2	Kw3	Total contribution	Factor sum of squares	Mean squear	Percentage contribution
1	110	0.307	0.35	0.3535	A1=1.01	Sa=0.0049245	Va=0.00246225	Pa=0.724297691
2	115	0.41	0.38	0.39	A2=1.18			
3	120	0.37	0.37	0.38	A3=1.12			
4	30	0.307	0.41	0.37	B1=1.08	Sb=0.000228167	Vb=0.000114083	Pb=0.033558857
5	40	0.35	0.38	0.37	B2=1.1			
6	50	0.3535	0.39	0.38	B3=1.12			
7	2	0.307	0.39	0.37	C1=1.06	Sc=0.00088817	Vc=0.00044408	Pc=0.13063196
8	5	0.35	0.41	0.38	C2=1.14			
9	8	0.3535	0.38	0.37	C3=1.10			
10	110	0.307	0.38	0.38	D1=1.06	Sd=0.000758	Vd=0.000379	Pd=0.111511
11	120	0.35	0.39	0.37	D2=1.11			
12	130	0.3535	0.41	0.37	D3=1.13			

- PLAIN BRASS (HALF HARD)

TABLE 11
ANALYSIS OF VARIANCE (FOR PLAIN BRASS (HALF HARD))

Sr.No	Para meter	Kw1	Kw2	Kw3	Total contribution	Factor sum of squares	Mean squear	Percentage contribution
1	110	0.325	0.35	0.33	A1=1.005	Sa=0.000704222	Va=0.00035211	Pa=0.335814
2	115	0.33	0.29	0.32	A2=0.94			
3	120	0.33	0.3135	0.3295	A3=0.97			
4	30	0.325	0.33	0.33	B1=0.98	Sb=0.000188722	Vb=0.0000943611	Pb=0.0899939
5	40	0.35	0.29	0.3135	B2=0.9535			
6	50	0.33	0.32	0.3295	B3=0.97			
7	2	0.325	0.32	0.3135	C1=0.95	Sc=0.00069039	Vc=0.00034519	Pc=0.32921822
8	5	0.35	0.33	0.3295	C2=1.00			
9	8	0.33	0.29	0.33	C3=0.95			
10	110	0.325	0.29	0.3295	D1=0.94	Sd=0.000514	Vd=0.000257	Pd=0.244973
11	120	0.35	0.32	0.33	D2=1			
12	130	0.33	0.33	0.3135	D3=0.97			

D. Comparison:-

- Comparison between ANOVA calculation by mathematical steps and analysis of ANOVA in MINITAB software.
- ZINC COATED BRASS (HARD)

TABLE 12
COMPARISON OF ANALYSIS OF VARIANCE (FOR ZINC COATED BRASS (HARD))

Minitab software			***Mathematical steps***		
Source	**DOF**	**SS**	**Source**	**DOF**	**SS**
Ton	2	0.0063829	**Ton**	2	0.006382889
Toff	2	0.0005242	**Toff**	2	0.000524222
Wf	2	0.0022229	**Wf**	2	0.00222289
Ip	2	0.0006096	**Ip**	2	0.00061
Error	0		**Error**	0	1.77636E-15
Total	8	0.0097396	**Total**	8	0.00974

- PLAIN BRASS (HARD)

TABLE 13
COMPARISON OF ANALYSIS OF VARIANCE (FOR PLAIN BRASS (HARD))

Minitab software			*Mathematical steps*		
Source	**DOF**	**SS**	**Source**	**DOF**	**SS**
Ton	2	0.0019984	**Ton**	2	0.0049245
Toff	2	0.0002220	**Toff**	2	0.000228167
Wf	2	0.0002220	**Wf**	2	0.00088817
Ip	2	0.0007370	**Ip**	2	0.000758
Error	0	0.0036195	**Error**	0	0
Total	8	0.0067990	**Total**	8	0.006799

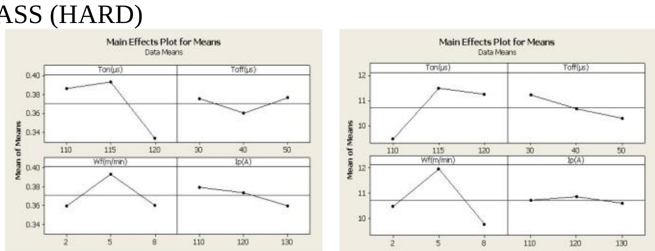
- PLAIN BRASS (HALF HARD)

TABLE 14
COMPARISON OF ANALYSIS OF VARIANCE (FOR PLAIN BRASS (HALF HARD))

Minitab software			*Mathematical steps*		
Source	**DOF**	**SS**	**Source**	**DOF**	**SS**
Ton	2	0.0001707	**Ton**	2	0.000704222
Toff	2	0.0000050	**Toff**	2	0.000188722
Wf	2	0.0000120	**Wf**	2	0.00069039
Ip	2	0.0001402	**Ip**	2	0.000514
Error	0	0.0017691	**Error**	0	3.33067E-16
Total	8	0.0020971	**Total**	8	0.002097

E. KW and MRR results in form of chart:-

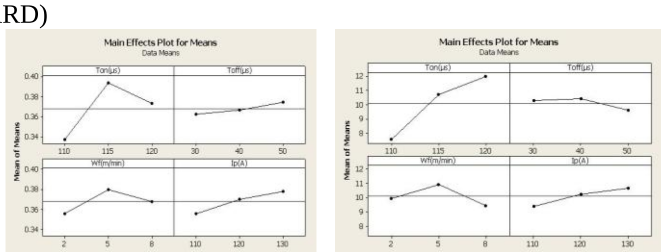
- ZINC COATED BRASS (HARD)



KW MRR

Fig. 2 Effect of Variable

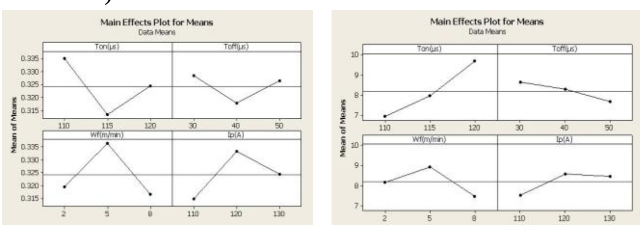
- PLAIN BRASS (HARD)



KW MRR

Fig. 3 Effect of Variable

- PLAIN BRASS (HALF HARD)



KW MRR

Fig. 4 Effect of Variable

IV. CONCLUSION

This experiment presents analysis of various process parameters and drawn following conclusions from the experimental study:

- ✓ Process parameters affect different response in different ways. Hence need to set parameter based on requirement.
- ✓ In all wires experiments WF value 5 unit that time highest KW and MRR Achieved.
- ✓ If Toff value increase then value of KW is increase and MRR is Decrease.
- ✓ If Ip value increase then value of KW is decrease and MRR is Increase.
- ✓ Ton parameter is most significant factor.

REFERENCES

[1] Amit Joshi, S.S. Samant, K.K.S. Mer, "Modelling Surface Finish In WEDM using RSM",2013

[2] Harshadkumar C. Patel, Dhaval M. Patel, Rajesh Prajapati, "Parametric Analysis And Mathematical Modelling Of MRR And Surface Roughness For H-11 Material On Wire Cut EDM By D.O.E Approach",Aug 2012

[3] S.Sivanaga MalleswaraRaouthor, Ch.V.S.ParameswaraRao "Optimization And Influence Of Process Parameters For Machining With WEDM",2014

[4] Brajesh Lodhi, Sanjay Agarwal, "Modelling of Wire Electrical Discharge Machining Of AISI D3 Steel Using Response Surface Methodology", Dec 2014

[5] *S. Rajendran and K.Marimuthu,* "Mathematical Modelling Of Material Removal Rate Of T90Mn2W50Cr45 Tool Steel In Wire Electrical Discharge Machine", Dec 2012

[6] Alpesh M. Patel ,Vishal Achwal,"Optimization Of Parameters For Wedm Machine For Productivity Improvement", Dec 2013

[7] Parveen Kr. Saini, Mukesh Verma,"Experimental Investigation Of Wire EDM Process Parameter On MRR Of Ti-6al-4v Alloy", Oct 2014