Optimization of Process Parameters on Wire Electrical Discharge Machining

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Abstract— Present study has been made to optimize of surface roughness and material removal rate in EN 24T steel. Two input parameters wire feed, wire tension were chosen as variable to study the process parameter. The analysis of variance (ANOVA) was carried out for study the effect of process parameters on process performance. In addition mathematical models have also been developed for response parameter. Properties of the machined surface have been examined by surface roughness tester. For the different values of the two input parameters developed L9 orthogonal array by taguchi method. Here the surface roughness is measured with the help of surface roughness tester SJ-210 This tester is diamond tip which measure accurate value of surface roughness. Second response parameter material removal rate is measured with the help of measurement of volume and cutting time The effect of each control factor on the performance measure is studied individually using the plots of signal to noise ratio The study demonstrates that the WEDM process parameters can be adjusted so as to achieve better metal removal rate and surface finish.

Keywords: Wire Electro Discharge Machining (WEDM), Material Removal Rate (MRR), Surface Roughness (SR), Taguchi's Orthogonal Array, Ratio Signal-To-Noise Ratio (S/N Ratio), Wire Feed (WF), Wire Tension (WT), Analysis Of Variance (ANOVA)

I. Introduction

Wire electrical discharge machining (WEDM) is among the more widely known and applied non-traditional machining processes in industry today. In this procedure, improvements to the process mechanism and control have rapidly been taking place. WEDM can machine harder, they are higher strength, corrosive and wear-resistant, and difficult-to machine materials. With WEDM, it is also possible to machine complicated shapes that cannot be achieved using traditional machining processes, such as turning, milling, and grinding [14]

II. Working principle of WEDM

Wire-cut EDM is typically used to cut plates as thick as 300mm and to make punches, tools, and dies from hard metals that are difficult to machine with other methods. Wire-cutting EDM is commonly used when low residual stresses are desired, because it does not require high cutting forces for removal of material. If the energy/power per pulse is relatively low (as in finishing operations), little change in the mechanical properties of a material is expected due to these low residual stresses, although material that hasn't been stress-relieved can distort in the machining process. Due to the inherent properties of the process, wire EDM can easily machine complex parts and precision components out of hard conductive materials. [13]

Wire EDM is an electro-thermal non-traditional machining process, where electrical energy is used to generate electrical spark and material removal mainly occurs due to thermal energy of the spark. Use electric current and fine wire to cut conductive materials. The cutting typically occurs while the work piece is submerged in deionized water. Deionized water helps to cool the process and flush away the cut material. Cutting wire does not touch the material. Cutting itself is due to the erosion that occurs when a spark forms between the cutting wire and the raw material.[13]

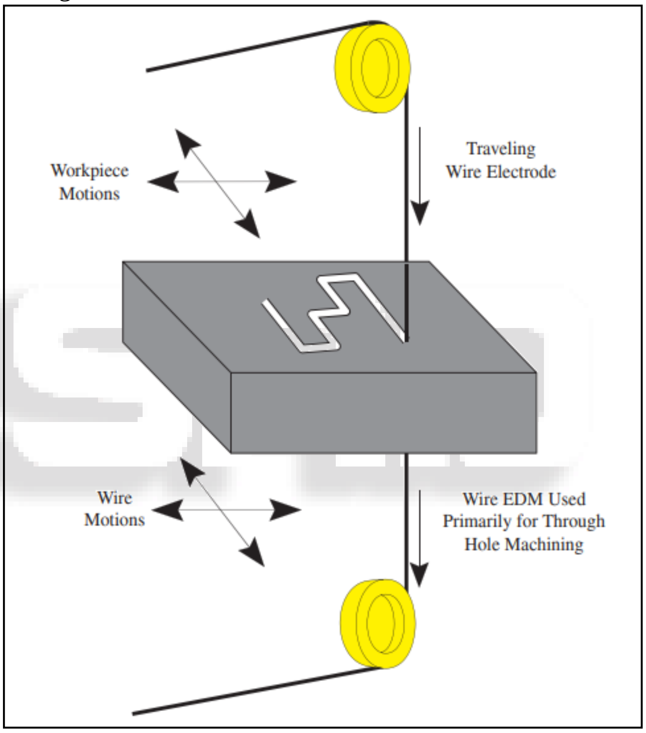

Fig. 2.1: Diagram of working of WEDM

III. Literature review

Manoj Rana (2015) investigated "Effect of Process Parameters on Material Removal Rate (MRR) of D2 tool steal on WEDM Machined Part". They chose Servo voltage T-On, and T-Off as input parameter. They measure MRR as a output parameter they conclude from their experiment that MRR increases with the increase in pulse on time, and decreases with increase in pulse off time and spark gap set voltage With increase in spark gap set voltage the average discharge gap gets widened resulting into a lower cutting rate and then sudden starts increasing [1]

H. R. Tonday (2016) investigated Analysis of "Effects of Cutting Parameters of Wire Electrical Discharge Machining on Material Removal Rate and Surface Integrity". They selected INCONEL 625 as a testing material. They chose Spark voltage, T-On, T-Off, Wire tension as input parameter. They measure SR as a output parameter they

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conclude from their experiment that Wire tension has no effect on both the output parameters. Input parameter off time has the greatest impact on MRR whereas spark voltage has the largest impact on surface roughness (Ra) among all other parameters. [2]

Pradeep Singh (2015) investigated "Experimental Investigation of Wire EDM to Optimize Dimensional Deviation of EN8 Steel through Taguchi's Technique". They selected EN 8 steel as a testing material. They chose T-off, feed, voltage as input parameter. They measure Dimensional deviation as a output parameter they conclude from their experiment that Increasing the wire feed rate decreases the dimensional deviation Increasing the pulse off time initially dimensional deviation increases and further it decreases. Increasing the pulse off time initially dimensional deviation increases and further it decreases. Among the three parameters, servo voltage has the greatest effect on dimensional deviation and is followed by pulse off time, and wire feed in that order. [3]

K. Kumara (2013) investigated "Modeling and Optimization of Wire EDM Process". They selected Al-sic (20%) as a testing material they chose Speed, Feed, T-On, T-Off as input parameter. They measure MRR and SR as a output parameter they conclude from their experiment that Factors like speed, feed, Time on and Time off have been found to play a significant role for MRR and surface roughness.. [4]

Anandkumar R. Patel (2018) investigated "Optimization of Surface Roughness (SR) in Wire Electric Discharge Machining" They selected En 24 tool steal as a testing material They chose servo voltage, T-On, T-Off, as input parameter. They measure SR as a output parameter they conclude from their experiment that value of voltage increase, value for surface roughness increase as per the range of given voltage. For pulse on time, when value increase than value of SR also increase. For pulse off time for some range SR is increase and further decrease as the pulse off time increase [5]

Vikram Singh (2014) investigated "Optimization of WEDM parameters using Taguchi technique and Response Surface Methodology in machining of AISI D2 Steel" They selected AISI D2 Steel as a testing material They chose servo voltage, Feed, T-On, T-Off as input parameter. They measure SR,MRR , CR as a output parameter they conclude from their experiment that increase in pulse on time results in increase of MRR and the increase of servo voltage and pulse off time results in decrease of MRR, Having a very ittle effect of wire feed on MRR. increase in pulse on time resulting in increase of cutting rate and by decreasing pulse off time and servo voltage cutting rate decreases depicting the same nature. With the increase in wire feed the cutting rate slightly decreased. increase in pulse on time the surface roughness decreases and with the increase in servo voltage the surface roughness decreases. With the increase of wire feed the surface roughness first increases and then decreases having a very little effect on pulse off time. [6]

Alpesh M. Patel (2013) 1investigated "Optimization Of Parameters For Wedm Machine For Productivity Improvement" They selected Aluminum alloy A1050A as a testing material They chose Feed, Wire tension, Discharge current , Discharge voltage as input parameter. They measure MRR and EWR as a output parameter they conclude from their experiment that discharge Voltage, discharge current and wire tension are most important factors influencing overall desirability. Next important process factor seems to be the wire Feed which influences lesser then other factors [7]
Rakesh Bhandari (2017) 1investigated "mathematical modelling and optimisation of wedm parameters using response surface methodology in machining of AISI D2 steel" Improvement They chose servo voltage, Feed, Time on, Time off as input parameter. They measure SR,MRR , CR as a output parameter they conclude from their experiment that increase in pulse on time results in increase of MRR and the increase of servo voltage and pulse off time results in decrease of MRR, Having a very ittle effect of wire feed on MRR. increase in pulse on time resulting in increase of cutting rate and by decreasing pulse off time and servo voltage cutting rate decreases depicting the same nature. With the increase in wire feed the cutting rate slightly decreased. increase in pulse on time the surface roughness decreases and with the increase in servo voltage the surface roughness decreases. With the increase of wire feed the surface roughness first increases and then decreases having a very little effect on pulse off time. [8]

Rajesh Khanna (2011) 1investigated "Parametric Optimization for Surface Roughness in Wire Electrical Discharge Machining" They selected D-3 TOOL STEAL as a testing material They chose pulse width , time between two pulse ,,Servo voltage , Feed Wire tension as input parameter. They measure SR as a output parameter they conclude from their experiment that pulse width, time between two pulses, servo reference mean voltage, short pulse time and maximum feed rate were significant variables to the surface roughness of wire-EDM ed D-3, high carbon high chromium alloy tool steel. The surface roughness for the test specimen became larger when the pulse width was increased. However, surface roughness first increases then decreases with increase in maximum feed rate and time between two pulses while the value of surface roughness first decreases then increases with the increase in servo reference mean voltage and short pulse time [9]

Mr. Aashish (2017) investigated "Parameter Optimization of Wire EDM for EN 24 Alloy Steel They selected EN24 as a testing material They chose Servo voltage , T-On , T-Off as input parameter. They measure MRR and SR as a output parameter they conclude from their experiment that The most predominant factors for Material removal rate is Current, rest three factors (voltage , pulse on time, pulse off time) has less impact as compare to the current. The most predominant factors for Surface roughness is also Current, rest three factors (voltage , pulse on time, pulse off time) has less impact as compare to the current [10]

Sheril Cyriac (2015) investigated "Optimization of Wire EDM Parameters of EN 24 Steel by Taguchi" They selected EN24 as a testing material They chose Current , , T-ON , T-OFF , feed, as input parameter. They measure SR as a output parameter they conclude from their experiment that current has major influence on the surface roughness and\ speed has least influence. [11]

IV. OBJECTIVES

- To Study the effect of input variable parameters on performance parameters.
- To get the optimum input & output parameter for selected wire & work piece material.
- To study about the SR and MRR in WEDM & its optimization.

V. EXPERIMENTAL SETUP

A. *Specification of Machine:*

Table size	440 x 650 ×300 mm
Max. work pieheight	200 mm Max.
Work piece weight	500 kg
Main table traverse (X,Y)	300 x 400 mm
Wire electrode diameter	0.18 mm
CNC Controller	EMT 100W-5
Input power supply	8.3 phase, AC, 415 V , 50 Hz
Average power consumption	6 to 7 kVA
Dielectric fluid	Di-ionized water
Tank capacity	250 Litters

Table 1: Machine specification

B. *Work piece material: EN–24 tool steel*

Element composition	STD. VALUE (%)	OBTAIN (%)
Carbon	0.36-0.44	0.420
Silicon	0.10-0.40	0.310
Manganese	0.45-0.70	0.570
Sulphur	0.040 MAX	0.020
Phosphorus	0.035 MAX	0.034
Chromium	1.00-1.40	1.110
Molybdenum	0.20-0.35	0.250
Nickel	1.30-1.70	1.350

Table 2: Chemical composition of work piece material of EN 24T steel

Fig. 5.1: Work piece material: EN–24 tool steel (40 mm diameter)

C. *Wire material: Hard Brass Zinc Coated Wire*

Zinc coated brass wire was one of the first attempts to present more zinc to the wire's cutting surface. This wire consists of a zinc coating over a core which is one of the standard EDM brass alloys. This wire offers significant increase in cutting speed over plain brass wires, without any sacrifice in any of the other critical properties.

Sr. No.	Machining process parameter	Level 1	Level 2	Level 3
1	Wire Feed Rate (m/min)	1	2	3
2	Wire Tension (kg-f)	6	8	10

Table 3: Factors with level values

VI. EXPERIMENTAL RESULTS

With the help of WEDM machine 9 teeth are cut on the material with proper dimension as shown below

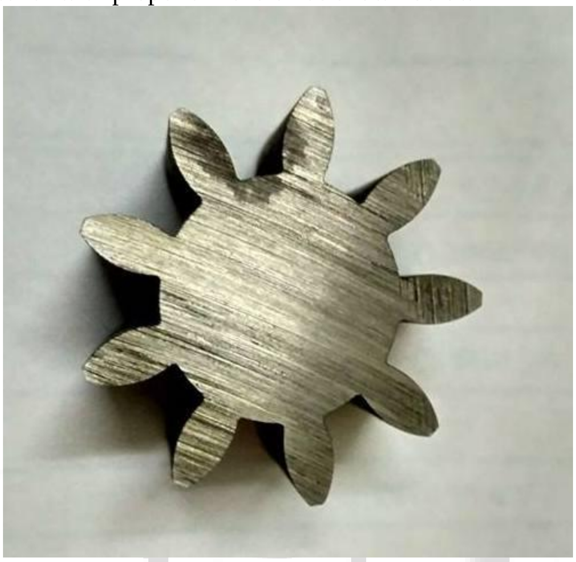

Fig. 6.1: gear cut on WEDM

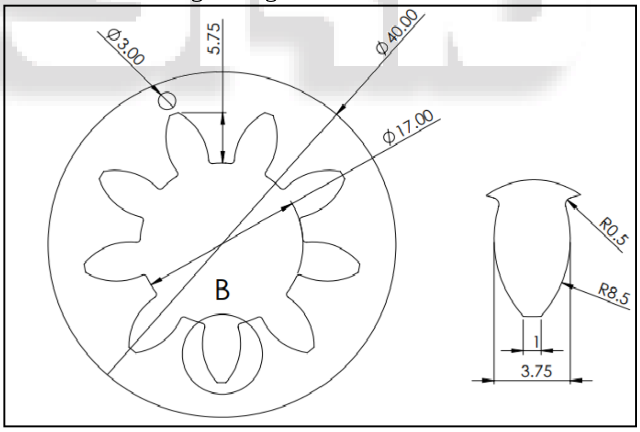

Fig. 6.2: drawing of gear with dimension

A. *Output parameter: Surface roughness*

Surface roughness is important parameter in wire EDM process. In this experiment by applying different values of wire feed and wire tension different values for SR is as table 4. Surface roughness is measure by SR tester.

Sr No	Wire Feed Rate (m/min)	Wire Tension (kg-f)	Surface roughness (μm)
1	1	6	4.024
2	2	6	4.132
3	3	6	4191
4	1	8	3.810
5	2	8	3.884
6	3	8	4.039

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7	1	10	3.680
8	2	10	3.820
9	3	10	3.880

Table 4: Experimental value table for surface roughness

B. Output parameter: Material Removal Rate

In this experiment by applying different values of wire feed and wire tension different values for MRR is as table 5 Machining time has been observed and noted after each experiment. With the help of that time and volume of the work piece MRR is calculated

Sr No	Wire Feed Rate (m/min)	Wire Tension (kg-f)	Material Removal Rate (mm^3/min)
1	1	6	11.07
2	2	6	12.80
3	3	6	14.51
4	1	8	11.22
5	2	8	13.12
6	3	8	14.80
7	1	10	11.50
8	2	10	13.65
9	3	10	15.25

Table 5: Experimental value table for Material removal rate

VII. RESULT ANALYSES

A. Anova for Surface Roughness Value

In this research work, according to design of experiment 09 experimental runs are carried out on work piece. For design of experiment, 3-levels of each factor are used

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	0.215051	88.29	0.000	
wire feed	1	0.059203	0.059203	48.61	0.000
wire tension	1	0.155848	0.155848	127.97	0.000
Error	6	0.007307	0.001218		
Total	8	0.222358			

Table 6: Analysis of Surface roughness

12	R-sq	R-sq(adj)	R-sq(pred)
0.0348979	96.71%	95.62%	94.27%

Table 7: Model Summary

B. Regression Equation

SR = 4.3860 + 0.0993 wire feed - 0.08058 wire tension

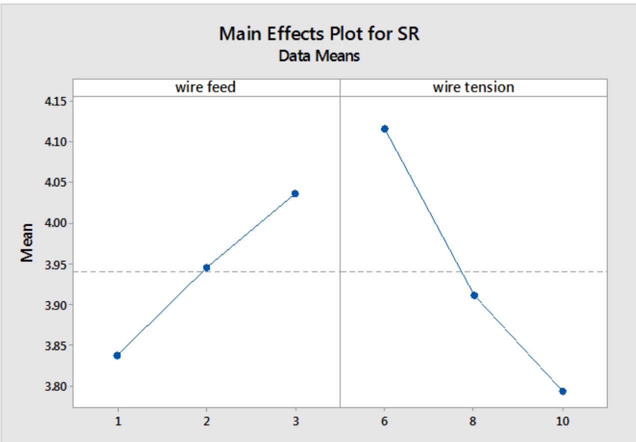

Fig. 7.1: Main Effects Plot for SR

Main effect plot for SR is as shown above fig 7.1. In which for different input parameters and there different range set of input values gives main effect plot for two input parameter. For wire feed as the value increase the value for SR has also increase. Now for wire tension for initial stage SR increase and further decrease

C. Anova for Surface Roughness Value

In this research work, according to design of experiment 09 experimental runs are carried out on work piece. For design of experiment, 3-levels of each factor are used

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	2	20.0122	10.0061	621.09	0.000
wire feed	1	19.3321	19.3321	1201.51	0.000
wire tension	1	0.6801	0.6801	45.27	0.001
Error	6	0.0965	0.0161		
Total	8	20.1088			

Table 8: Analysis of Variance for MRR

S	R-sq	R-sq(adj)	R-sq(pred)
0.126846	99.52	99.36	98.86

Table 9: Model Summary

D. Regression Equation

MRR = 8.166 + 1.7950 wire feed + 0.1683 wire tension

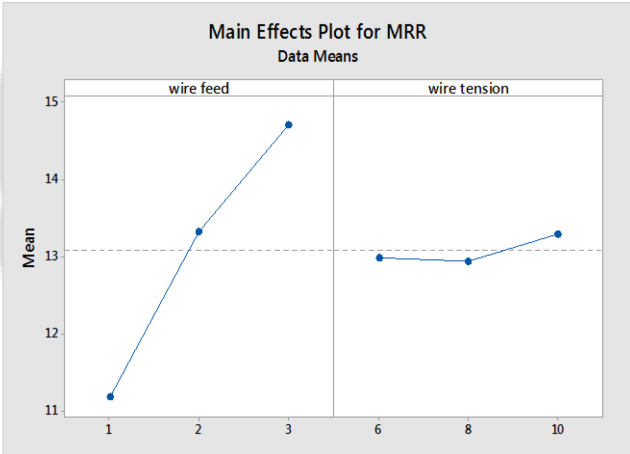

Fig. 7.2: Main Effects Plot for MRR

Main effect plot for SR is as shown above fig 7.2. In which for different input parameters and there different range set of input values gives main effect plot for two input parameter. For wire feed as the value increase the value for MRR has also increase. Now For wire tension in first input value MRR is higher but as the value increase for second stage the value of MRR is decrease. But at the last input value MRR has increase

VIII. OPTIMIZATION VALUE

From above experiment optimized value of the input parameter can be obtained as under. For the best maximize value of MRR and minimize value of SR

Sr. No.	Wire Feed Rate (m/min)	Wire Tension (Kg-f)	Material Removal Rate (mm^3/min)	Surface roughness (µm)
1	1	6	11.07	4.024

Table 10: Optimized Value

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IX. CONCLUSIONS

A. *Effect of Process Parameters on SR:*

For wire feed as the value increase the value for SR has also increase. Now for wire tension for initial stage SR increase and further decrease

B. *Effect of Process Parameters on MRR:*

For wire feed as the value increase the value for MRR has also increase. Now For wire tension in first input value MRR is higher but as the value increase for second stage the value of MRR is decrease. But at the last input value MRR has increase

REFERENCES

[1] Manoj Rana, "Effect of Process Parameters on Material Removal Rate (MRR) of WEDM Machined Part", SSRG International Journal of Mechanical Engineering (SSRG-IJME) – EFES, April 2015, pp-81-85

[2] H. R. Tonday "Analysis of Effects of Cutting Parameters of Wire Electrical Discharge Machining on Material Removal Rate and Surface Integrity", IOP Conference Series: Materials Science and Engineering, 2016, pp-112-1118

[3] Pradeep Singh, "Experimental Investigation of Wire EDM to Optimize Dimensional Deviation of EN8 Steel through Taguchi's Technique" International Research Journal of Engineering and Technology (IRJET) Volume: 02 Issue: 03 |June-2015, pp. 1753-1757

[4] K. Kumar, "Modeling and Optimization of Wire EDM Process", International Journal of Modern Engineering Research (IJMER), Vol. 3, Issue. 3, May.-June. 2013 pp-1645-1648

[5] Anandkumar R. Patel, "Optimization of Surface Roughness (SR) in Wire Electric Discharge Machining", International Journal of Advance Engineering and Research Development, Volume 5, Issue 03, March -2018, pp.-1351-1358

[6] Vikram Singh , "Optimization of WEDM parameters using Taguchi technique and Response Surface Methodology in machining of AISI D2 Steel", 12th GLOBAL CONGRESS ON MANUFACTURING AND MANAGEMENT, GCMM 2014,pp.-1597-1608

[7] Alpesh M. Patel," Optimization Of Parameters For Wedm Machine For Productivity Improvement", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) Volume 9, Issue 5 (Nov. - Dec. 2013), PP 10-14

[8] Rakesh Bhandari," Mathematical Modelling And Optimisation Of Wedm Parameters Using Response Surface Methodology In Machining Of Aisi D2 Steel", International Journal of Advanced Research in Engineering and Applied Sciences, Vol. 6 No. 7 July 2017, pp.-42-50

[9] Rajesh Khanna, "parametric Optimization for Surface Roughness in Wire Electrical Discharge Machining" International Journal of Mechanical Engineering and Materials Sciences, 4(1) January-June 2011, pp. 13-18

[10] Mr. Aashish. "Parameter Optimization of Wire EDM for EN 24 Alloy Steel", IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 14, Issue 2 Ver. III (Mar. - Apr. 2017), PP 20-26

[11] Sheril Cyriac,"Optimization of Wire EDM Parameters of EN 24 Steel by Taguchi Method", International Journal of Engineering Research & Technology (IJERT), Vol. 4 Issue 08, August-2015, pp.-633-636

[12] http://www.reliableedm.com/Complete%20EDM%20Handbook/Complete%20EDM%20Handbook_2.pdf

[13]]http://shodhganga.inflibnet.ac.in/jspui/bitstream/10603/163442/10/10_chapter%201.pdf

[14] A book of " Design and analysis of experiments" by Douglas C. Montgomery

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