EXPERIMENTAL INVESTIGATION OF PROCESS PARAMETERS IN WEDM FOR QUALITY CUT OF COLD WORKED STEEL

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Abstract: Machine tool industry has made exponential growth in its manufacturing capabilities in last decade but still machine tools are not utilized at their full potential. This limitation is a result of the failure to run the machine tools at their optimum operating conditions. The problem of arriving at the optimum levels of the operating parameters has attracted the attention of the researchers and practicing engineers for a very long time. The objective of the present work was to investigate the effects of the various process parameters on the quality of cut in Wire Electrical Discharge Machining (WEDM) and also parametric optimization of process parameters in WEDM for Work Material. The quality of cut is observed by means of evaluating the surface roughness and dimensional deviation. The objective of optimization is achieving best cut quality with high material removal rate simultaneously. The machining parameters selected for this work are Peak Current, Pulse on Time, Pulse off Time, Spark Gap Voltage, wire tension and Water pressure. In this research, for optimizing Processes responses Taguchi Technique was selected.

1. INTRODUCTION

Electro Discharge Machining (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.EDM is mainly used to machine difficult-to-machine materials and high strength temperature resistant alloys. EDM can be used to machine difficult geometries in small batches or even on job-shop basis. Work material to be machined by EDM has to be electrically conductive.

1.1. PRINCIPAL OF WEDM:

In this process the metal is removing from the work piece due to erosion case by rapidly recurring spark discharge taking place between the tool and work piece. Show the mechanical set up and electrical set up and electrical circuit for electro discharge machining. A thin gap about 0.025mm is maintained between the tool and work piece by a servo system Both tool and work piece are submerged in a dielectric fluid .Kerosene/EDM oil/deionized water is very common type of liquid dielectric although gaseous dielectrics are also used in certain cases as shown in Figure 1.

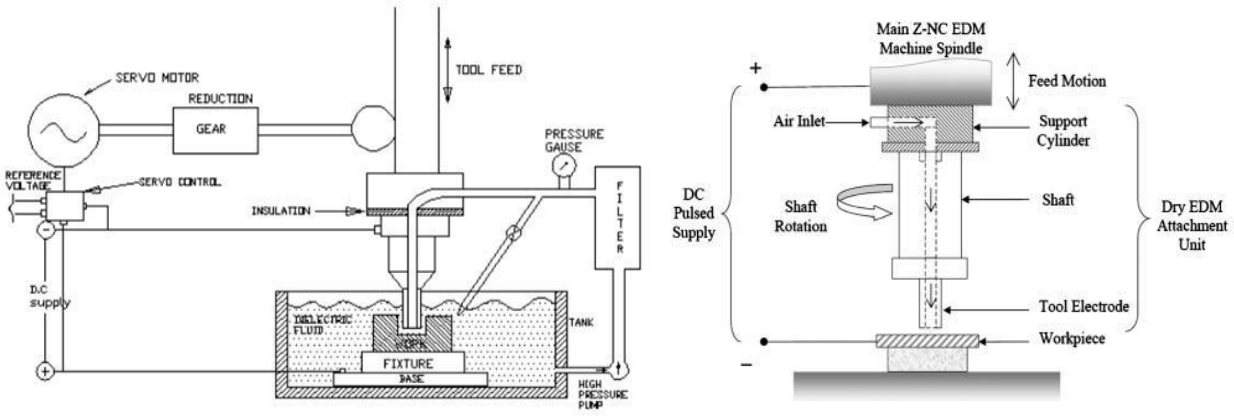

Figure 1 Setup for Wire Cut Electron Discharge Machining

1.2. APPLICATIONS OF WEDM:

1. The EDM process is most widely used by the mould-making tool and die industries, but is becoming a common method of making prototype and production parts, especially in the aerospace, automobile and electronics industries in which production quantities are relatively low.
2. It is used for forging, extrusion, wire drawing, thread cutting.
3. Higher Tolerance limits can be obtained in EDM machining. Hence areas that require higher surface accuracy use the EDM machining process.
4. It is a promising technique to meet increasing demands for smaller components usually highly complicated, multi-functional parts used in the field of micro-electronics.

2. LITERATURE REVIEW

A lot of contributions have been made on the optimization of process parameters of different materials by using WEDM been reviewed. Some of them are discussed below.

Ibrahem Maher, Liew Hui [1] has optimized the process parameters namely Ton, Toff, W.T. with consideration of multiple performance characteristics including MRR and Surface Roughness Using Taguchi technique in WEDM on AlSi 1050 carbon steel.

P.Balasubramanian [2] has optimized the process parameters namely peak current, Pulse on time, pulse off time,dielectric pressure & tool diameter over the Metak Remove Rate, Tool wear Rate & Surface Roughness using Rsponse Surface Methodology(RSM) in WEDM on EN8 & D3 steel material.

Anurag joshi [3] has optimized the process parameters namely Pulse on time, pulse off time,Discharge current & voltage over the Surface Roughness (SR) Using Taguchi technique in WEDM on EN31 material.

After a complete study of the existing literature, a number of graphs have been observed in machining of WEDM.

- Most of the researchers have investigated have investigated influence of a limited number of processes variables on the processes responses of WEDM processes.
- Literature review reveals that the researchers have carried out most of the work on WEDM developments, monitoring and control but very limited work has been reported on optimization of processes parameters.

3. EXPERIMENTAL SET UP:

3.1. MATERIAL

The Uddheleom Vancron material for good tool performance In many cold work applications tools are surface coated in order to prevent galling and adhesive wear.Furthermore it is important to have the correct hardness for the applications as well asa sufficient ductility and toughness in order to prevent premature failure due to chipping crack formation. Uddeholm Vancron 40 SuperClean is a nitrided powder metallurgical tool steel offering an excellent combination of galling resist- ance and adhesive wear resistance.

3.2. Equipment:

All experimental runs were carried out on a CNC Wire cut EDM istalled at M.B.Engineering Pvt.Ltd.,Ambathur,India.The WEDM machine has the following specifications.

Table:1- Specifications on CNC WEDM

Description	WEDM
Controlling of Machine	CNC
Types of Material cutting	MS,SS,Al,Brass,Titanium,GI
Supply voltage	3x40v-50Hz
Maximum cutting size	10^{I}x43^{I} (3000mmX13000 mm)
Hole making possibility compare with thickness	1:1
Tolerance(+/-)	Depends on thickness of material
Accuracy (+/-)	0.6-1 mm
Cutting tool	Wire electrode
Curring speed	0.4m/min
Maximum work sheet weight	Up to 12 ton
Distance between orifice and material	0.010^{11} to 0.02^{11}
Z axis travelling	200 mm

Figure 2 Set-up for Wire Cut Electron Discharge Machining

3.3 SELECTION OF ARRAY:

In Taguchi method Control factors refers to input parameters for the process,
and Response factors refers to corresponding output parameters for the process.

DOF for a Control Factor = No. of Levels – 1

DOF for A = 3-1 = 2

DOF for'AB' = (No. of Levels in 'A' - 1) × (No. of Levels in 'B' - 1) = 2 * 2 = 4

Total DOF = DOF for all Control Factors + DOF for Interactions

= 12 + 12 = 24

OA Selection Criterion:

L 27 OA was selected for carrying out experiments.

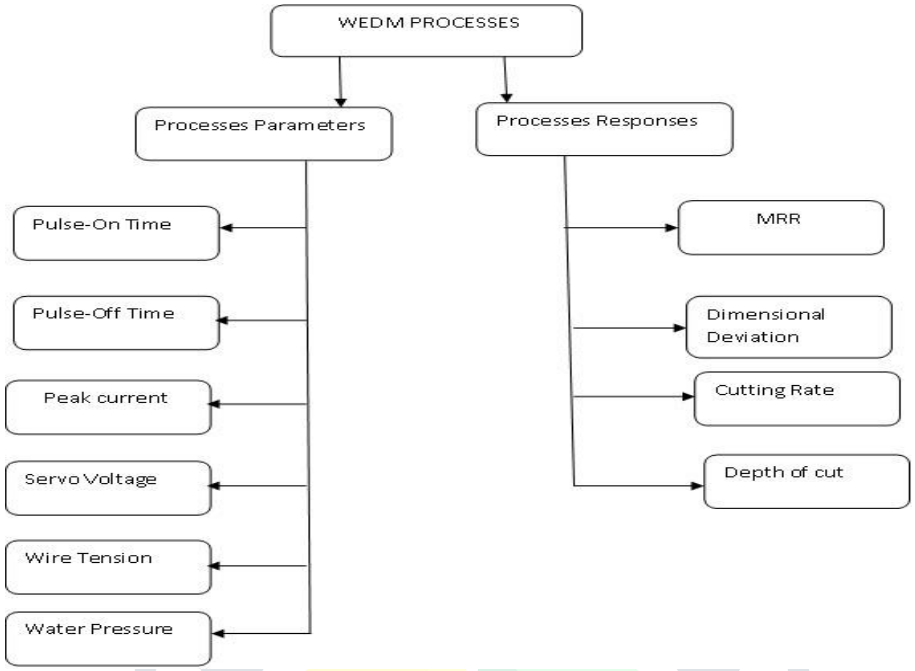

Figure 3 Schematic representation of Processes Parameters and Processes Responses for WEDM.

4. DESIGN OF EXPERIMENT (DOE):

The Design of an experiment is the synchronous calculation of two or more variables for their capacity to influence the resultant normal. Design of Experiments (DOE) was selected for carrying out experiments and the experiments were conducted as per DOE.After obtaining experimental results analysis for processes responses.ANOVA has been carried out for experimental data for obtaining percentage contribution of each processes parameter in each response and finally optimal setting for Dimensionaldeviation,MRR,Cutting rate & Depth of cut were obtained individualy.

Most researchers identified WEDM process parameters that greatly affect Response parameter. In this paper we have selected process parameter as like Pulse-On Time, Pulse-off Time, Peak current(Amp), Spark gap voltage(V), Wire Tension and Water Pressure.

4.1 CONTROL PARAMETERS:

Factor A: Pulse-on Time

Factor B: Pulse-off Time

Factor C: Peak current-Amp

Factor D: Spark gap voltage-V

Factor E: Wire Tension

Factor F: Water Pressure

4.2 ORTHOGONAL ARRAY WITH THREE FACTORS:

In Taguchi method Control factors refers to input parameters for the process, and Response factors refers to corresponding output parameters for the process. The Degree of

Table:3- L25 Orthogonal Array developed by using Taguchi method in Minitab

Parameters	Symbols	Notation	Units	Levels		
				1	2	3
Pulse on Time	ON	A	Machine units	108	118	128
Pulse off Time	OFF	B	Machine units	47	55	68
Peak Current	IP	C	Amp	11	13	15
Spark gap set Voltage	SV	D	Volts	18	47	63
Wire Tension	WT	E	--	2	5	8
Water Pressure	WP	F	Bar	8	11	14

4. RESULTS & DISCUSSIONS:

Metal Removal Rate(mm/min) ,Dimensional Deviation(mm), Cutting Rate(mm/min) & Depth of cut (mm) are most important criteria's, which help us determine how rough a workpiece material is machined. In all the investigations it was found that the machined smoother near the Pulse on time, Pulse of time, Water pressure & Peak current. This is due to the fact that as the particles moves own they loose their kinetic energy and their cutting ability deterilrates. By analyzing the experimental data of the selected material, it has been found that optimum selection of the four basic parametes,

i.e, Pulse on Time, Pulse off Time, Peak Current very important on controlling the processes outputs such as Metal Removal Rate (MRR),Dimensional Deviation, Cutting Rate and Depth of Cut. The effect of these parameters are studied while keeping the other parameters considered in this study as constant.

Table:4- Results generated by using Taguchi Analysis in Minitab

Run NO	Pulse on Time	Pulse off Time	Peak Current	Servo Voltage	Wire Tension	Water Pressure	MRR (mm/min)	Dimensional Deviation (mm)	Cutting Rate (mm/ min)	Depth of cut (mm)
1	108	47	10	18	2	8	1.60669	0.035	0.95536	0.07
2	108	47	11	43	5	11	1.10537	0.04	0.57571	0.08
3	108	47	12	68	8	14	0.83491	0.016667	1.04364	0.03333
4	108	55	10	43	8	14	0.93867	0.05333	0.36667	0.10667

5	108	55	11	68	2	8	0.34667	0.02167	0.33333	0.04333
6	108	55	12	18	5	11	0.6347	0.005	2.51444	0.01
7	108	63	10	68	5	11	0.3438	0.03	0.23875	0.06
8	108	63	11	18	8	14	0.16337	0.00667	0.51053	0.01333
9	108	63	12	43	2	8	1.05864	0.018333	1.203	0.03666
10	118	47	10	18	2	11	1.0928	0.01	2.27667	0.02
11	118	47	11	43	5	14	1.41746	0.016667	1.77182	0.03333
12	118	47	12	68	8	8	0.76946	0.008333	1.92364	0.01666
13	118	55	10	43	8	8	0.90912	0.02	0.947	0.04
14	118	55	11	68	2	11	1.20145	0.01333	1.87727	0.02667
15	118	55	12	18	5	14	0.57006	0.00667	1.78143	0.01333
16	118	63	10	68	5	14	0.48107	0.006667	1.50333	0.01333
17	118	63	11	18	8	8	0.25646	0.005	1.06857	0.01
18	118	63	12	43	2	11	0.89907	0.018333	1.02167	0.03666
19	128	47	10	18	2	14	1.34064	0.015	1.862	0.03
20	128	47	11	43	5	8	0.47267	0.00333	2.95417	0.00667
21	128	47	12	68	8	11	2.7248	0.025	2.27067	0.05
22	128	55	10	43	8	11	0.54851	0.005	2.28546	0.01
23	128	55	11	68	2	14	1.44947	0.011667	2.58833	0.02333
24	128	55	12	18	5	8	2.7642	0.028333	2.0325	0.05666
25	128	63	10	68	5	8	0.8976	0.016667	1.122	0.03333

4.1. S/N RATIO MAIN EFFECT PLOT OF MRR:

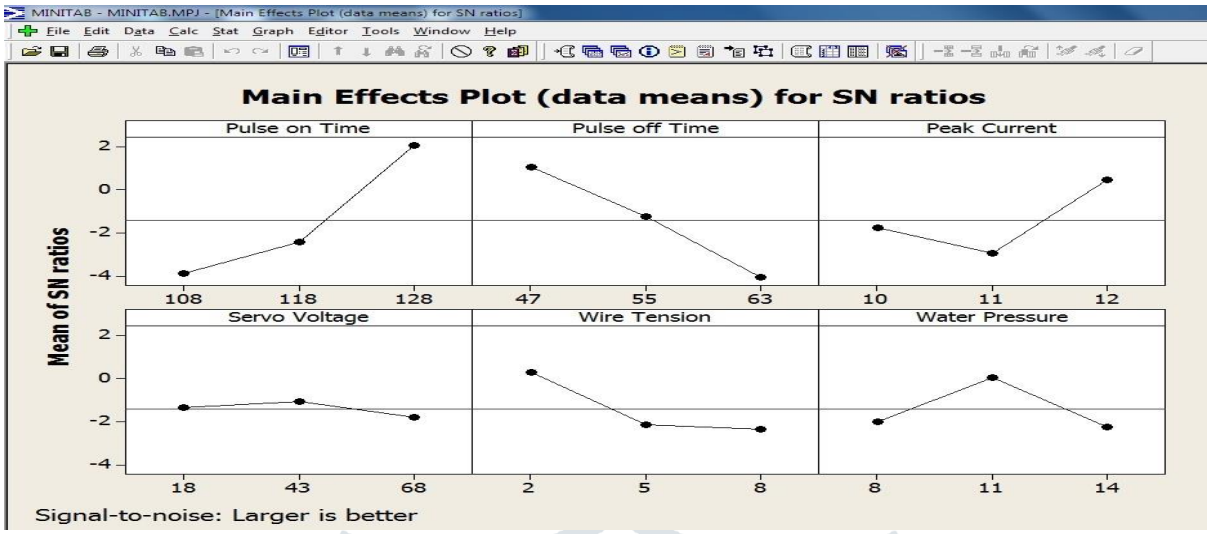

Figure 4 ***Main effect plot for SN Ratio (MRR) V/S Factors.***

Main effects of MRR of each factor for various level conditions are shown in above figure. According to above figure the MRR increases with like Pulse on Time, Pulse of Time, Peak current, Servo Voltage, Wire Tension and Water pressure. MRR is maximum in the case of Pulse on Time at level 3 (128 micro seconds), in the case of Pulse off Time at level 1 (47micro seconds), Peak Current level 3 (12 Amps), Servo Voltage at level 2 (43V), Wire Tension at level 1 (2) and in the case of Water pressure at level 2 (l1 bar) So the optimal parameter setting for the MRR found .

4.2. S/N RATIO MAIN EFFECT PLOT OF DIMENSIONAL DEVIATION:

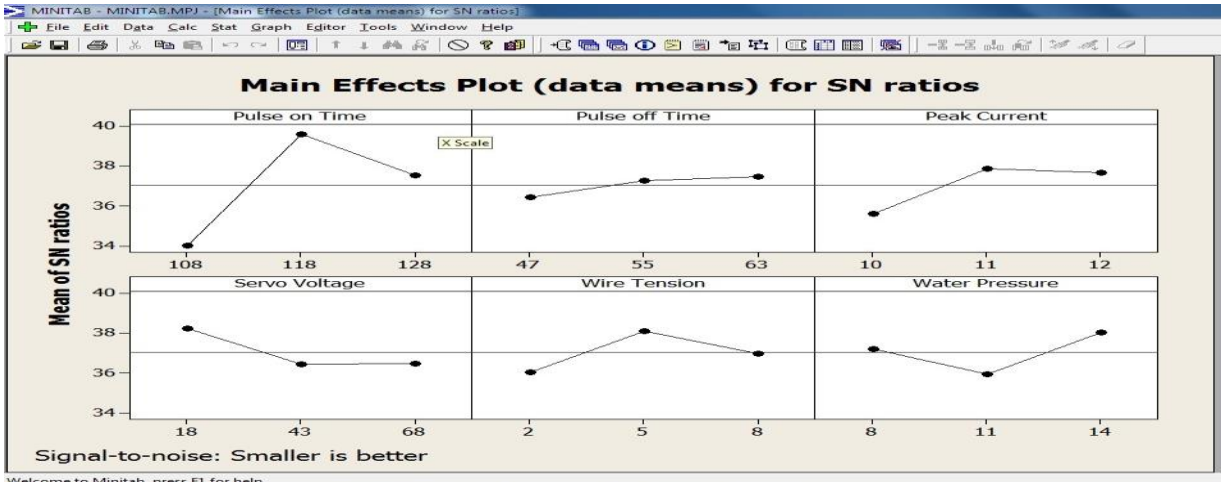

Figure 5 Main effect plot for SN Ratio Dimensional Deviation (Ra) V/S Factors.

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- Main effects of Dimensional Deviation of each factor for various level conditions are shown in above figure. According to above figure the Dimensional Deviation decreases with like Pulse on Time, Pulse of Time, Peak current, Servo Voltage, Wire Tension and Water pressure. Dimensional Deviation is minimum in the case of Pulse on Time at level 1 (108 micro seconds), in the case of Pulse off Time at level 1 (47micro seconds), Peak Current level 1 (10 Amps), Servo Voltage at level 3 (68V), Wire Tension at level 1 (2) and in the case of Water pressure at level 2 (l1 bar) So the optimal parameter setting for the MRR found .

4.3 S/N RATIO MAIN EFFECT PLOT OF DEPTH OF CUT:

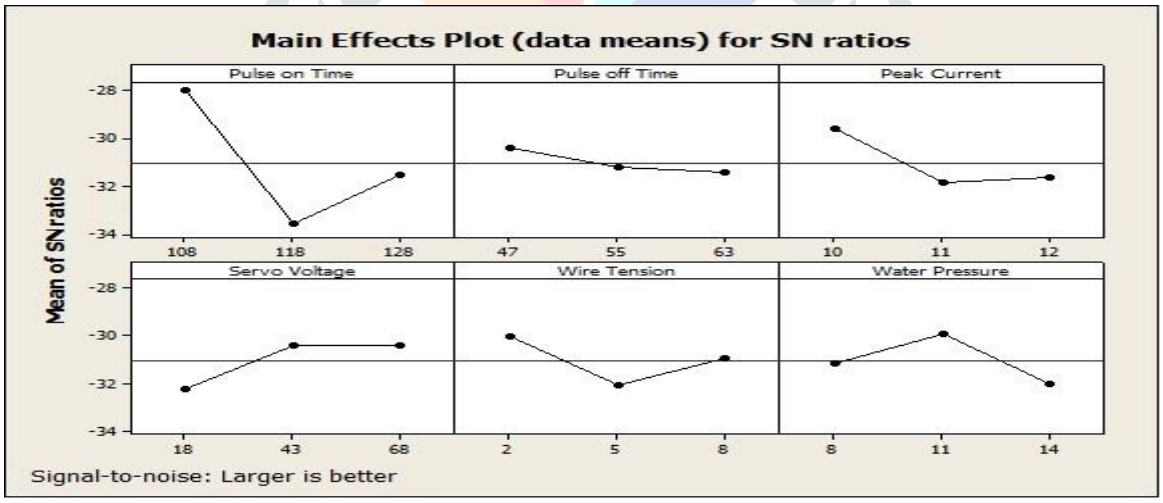

Figure 6 Main effect plot for SN Ratio Depth of Cut V/S Factors.

- Main effects of Depth of cut of each factor for various level conditions are shown in above figure. According to above figure the Depth of cut increases with like Pulse on Time, Pulse of Time, Peak current, Servo Voltage, Wire Tension and Water pressure. Depth of cut is maximum in the case of Pulse on Time at level 1 (108 micro seconds), in the case of Pulse off Time at level 1 (47micro seconds), Peak Current level 1 (10 Amps), Servo Voltage at level 3 (68 V), Wire Tension at level 1 (2) and in the case of Water pressure at level 2 (11 bar) So the optimal parameter setting for the Depth of Cut found .

4.4 S/N RATIO MAIN EFFECT PLOT OF CUTTING RATE:

Main effects of Cutting Rate of each factor for various level conditions are shown in above figure. According to above figure the Cutting Rate increases with like Pulse on Time, Pulse of Time, Peak current, Servo Voltage, Wire Tension and Water pressure. Cutting Rate is maximum in the case of Pulse on Time at level 3 (128 micro seconds), in the case of Pulse off Time at level 1 (47micro seconds), Peak Current level 3(12 Amps), Servo Voltage at level 1 (18V), Wire Tension at level 1 (2) and in the case of Water pressure at level 2 (11 bar) So the optimal parameter setting for the Cutting rate found.

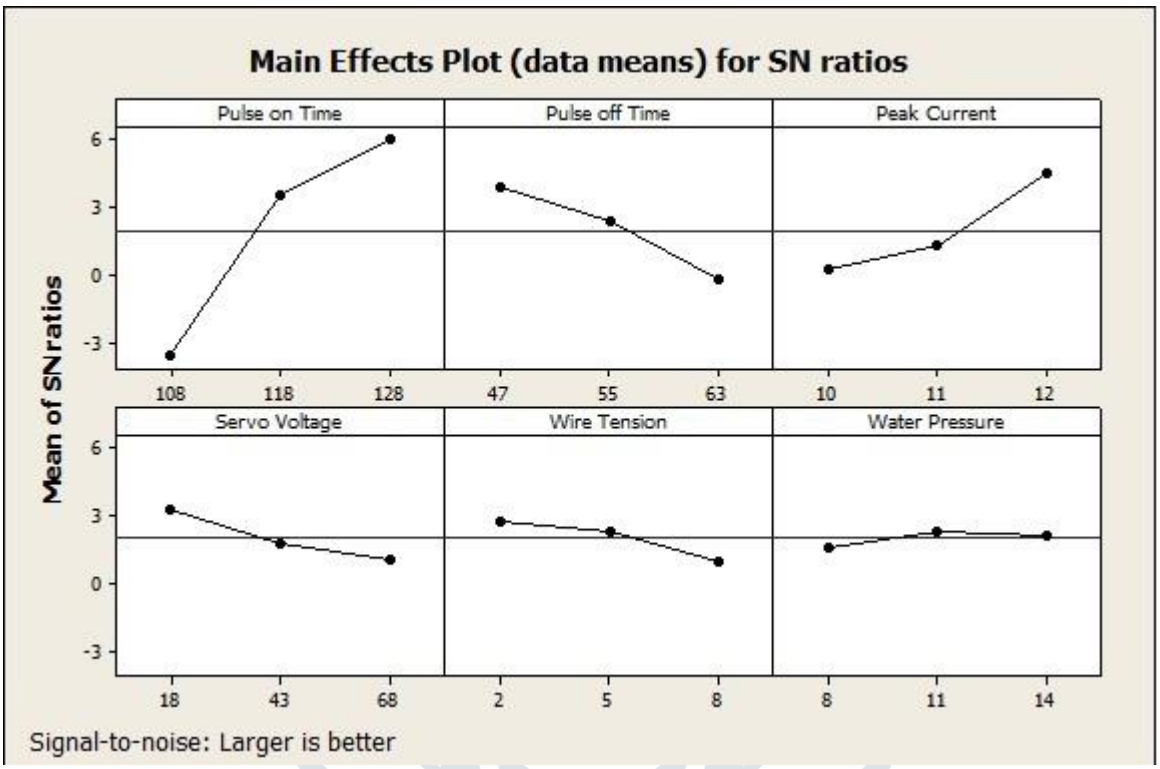

Figure 7 Main effect plot for SN Ratio Cutting Rate V/S Factors.

Table:5- Optimum Control Parameter Levels

Response	**Pulse On Time-T_{on}-Micro seconds**	**Pulse Off Time-T_{off}-Micro seconds**	**Peak Current-Amps**	**Servo Voltage-V**	**Wire Tension**	**Water Pressure-bar**
MRR	128	47	12	43	2	11
Dimensional Deviation	107	47	10	68	2	11
Depth of Cut	108	47	10	68	2	11
Cutting Rate	128	47	12	18	2	11

5. CONCLUSIONS

In this presents analysis of various parameters and on the basis of experimental results, analysis of variance (ANOVA), and SN Ratio the following conclusions can be drawn for effective machining of UddheleomVancron by WEDM process as follows:

- Pulse on Time,Pulse off Time&Peak Current is the most significant factor on MRR during WEDMServo Voltage,Wire Tension&Water pressureare sub significant in influencing. The recommended parametric combination for optimum material removal rate is of Pulse on Time at level 3 (128 micro seconds), in the case of Pulse off Time at level 1(47micro seconds), Peak Current level 3(12 Amps),Servo Voltage atlevel 2(43V),Wire Tension at level 1(2)and in the case of Water pressure at level 2 (l1 bar) So the optimal parameter setting for the MRR found .

- Pulse on Time, Pulse off Time& Peak Current is the most significant factor on Dimensional Deviation during WEDM Servo Voltage,Wire Tension & Water pressure are sub significant in influencing. The recommended parametric combination for optimum Dimensional Deviation is Pulse on Time at level 1 (108 micro seconds), in the case of Pulse off Time at level 1(47micro seconds), Peak Current level 1(10 Amps),Servo Voltage atlevel 3(68V),Wire Tension at level 1(2)and in the case of Water pressure at level 2 (l1 bar) So the optimal parameter setting for the MRR found.

- Pulse on Time, Pulse off Time& Peak Current is the most significant factor on Depth of Cut during WEDM Servo Voltage,Wire Tension & Water pressure are sub significant in influencing. The recommended parametric combination for optimum Depth of cut is of Pulse off Time at level 1(47micro seconds), Peak Current level 1(10 Amps),Servo Voltage at level 3(68 V), Wire Tension at level 1 (2) and in the case of Water pressure at level 2 (11 bar) So the optimal parameter setting for the Depth of cut found.□

- Pulse on Time, Pulse off Time& Peak Current is the most significant factor on Cutting Rate during WEDM Servo Voltage,Wire Tension & Water pressure are sub significant in influencing. The recommended parametric combination for optimum Cutting Rate is of Pulse on Time at level 3 (128 micro seconds), in the case of Pulse off Time at level 1(47micro seconds), Peak Current level 3(12 Amps),Servo Voltage at level 1(18V), Wire Tension at level 1 (2) and in the case of Water pressure at level 2 (11 bar) So the optimal parameter setting for the Cutting rate found .

- Pulse on Time, Pulse off Time& Peak Current is the most significant factor on MRR,Dimensional Deviation, Depth Of Cut and Cutting Rate during WEDM Servo Voltage,Wire Tension & Water pressure are sub significant in influencing. The recommended parametric combination for optimum Cutting Rate is of Pulse on Time at level 3 (128 micro seconds), in the case of Pulse on Time at level 3 (128 micro seconds), in the case of Pulse off Time at level 1(47micro seconds), Peak Current level 3(12 Amps),Servo Voltage at level 1(18 Amps), Wire Tension at level 1 (2) and in the case ofWater pressure at level 2 (11 bar) So the optimal

parameter setting for the Multiple processes responses such as MRR, Dimensional Deviation, Depth of Cut & Cutting Rate.

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