Experimental investigation and Optimization of process parameters for surface roughness & Material removal rate of Inconel 625 in Wire EDM by using Taguchi method

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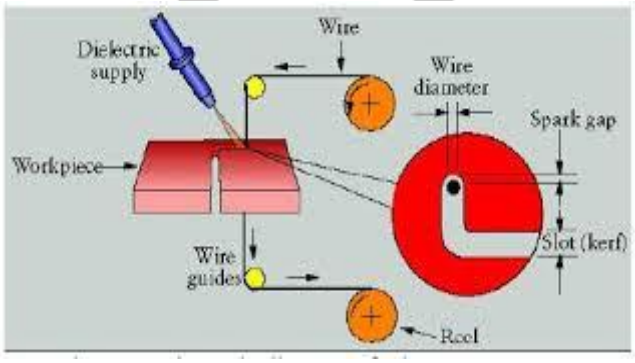
***Abstract:*-The parameter settings & material to be machined are two factors which influenced the quality of wire EDM surface.Generally, mostof the work is done on heavy metals & partly on light metals like titanium & magnesium alloy. Here, an attempt has been made to study the effect of wire EDM parameters on INCONEL 625 alloy because of its growing applications in various industries. In the present research, TAGUCHI METHOD was performedforparametric analysis of wire EDM parameters on surface roughness (SR) and material removal rate (MRR). The obtained results show a good agreement with experimental values. In four different levels the suggested parameters were taken and experiment was conducted.Experiment is done on INCONEL 625 alloy for checking the material removal rate and surface roughness. In this paper, different process parameters like pulse on time, pulse off time and wire feed are the three parameters usedto optimize the surface roughness and material removal rate by MINITAB 17. Taguchi L16 orthogonal array along with ANOVA is used for optimize the different parameters so that minimum surface roughness &maximum material removal rate is obtained. At the end, confirmation test have conducted to verify the results.**

***Keyword*: -WEDM, Inconel 625, MRR, Ra, Taguchi method, ANOVA, Optimization**

I. INTRODUCTION: Inconel 625 is super alloy of nickel and chromium which is mainly used in gas turbine blades, high temperature fasteners, heat exchanger tubing, seals, combustors, steam generators as well as turbocharger rotors and seals due to its superiority mechanical and thermal properties. These super alloys are facing very difficulties for machining with convectional machining due to limitation of temperature developed in machining. To machining these super alloys non convectional machining such as electro chemical machining, electric discharge machining, ultrasonic machining etc. are used because these are capable to machining with high accuracy and excellent finishing. Wire EDM is the advancement of EDM in which wire is used as electrode. WEDM is an electro– thermal machining in which a series of spark is produced between the electrode (wire) and work piece which is submerged in the dielectric fluid. During the pulse-on time or discharge period, work material is rapidly melted and vaporized to form a cut on the work piece which is flashed by the dielectric fluid. Dielectric is used to cooling the cutting zone and to remove the debris from the cutting zone to ready for the next pulse discharge. Electrode wire is made of brass, copper or zinc coated which have good electrical conductivity with diameter of 0.25mm. In wire EDM there is no direct contact between the work piece and electrode so that there is no mechanical stress development. The schematic diagram of WEDM is shown in fig -1.



[Fig.1 WEDM PROCESS]

II. LITERATURE REVIEW: -Ibrahem Maher.[1] The experiment was done using L18 orthogonal array by wire-edm process. The research was focused to optimize the wire rupture. Statistical methods of signal to noise ratio(S/N ratio) is applied to study the effects of peak current, pulse width, charging time, wire speed, and wire tension on wire rupture. Peak current, pulse width and wire tension have most significant effect on wire rupture. **Jaskarnsingh. [2]** They reviewed the effects of various wire-edm process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire tension on Material removal rate(MRR), Surface roughness(Ra) and Wire wear ratio(WWR). They also worked on development in wire electrode's material.**Kishore et. al. [3]** Work piece material Al7075+10%Al203 Metal Matrix Composite(MMC) and Molybdenum wire

were taken through wire-edm process to check the effects of the process parameters like pulse on time, pulse off time, voltage, bed speed and current on MRR and Surface roughness. Taguchi method had been used and it was found that bad speed was the most significant factor for MRR and Surface roughness is effected by peak current.

Ravindranadhbobbili. [4] Hot pressed Boron Carbide was used as a work piece material on wire-edm process. They investigated the effects of pulse on time, peak current, flushing pressure and Spark voltage on MRR and surface roughness. It was found that wear rate of Brass wire used increases with rise in input energy in machining of hot pressed boron carbide and they also found that higher pulse on time and peak current leads to better surface finish and higher MRR.

Bobbili R. [5] in this, they used a multi response optimization technique based on Taguchi method coupled with Grey relational analysis for wire-edm operation on Ballistic Grade Aluminum alloy for armor application. The process parameters had been taken are pulse on time, pulse off time, peak current and spark voltage to optimize MRR, surface roughness and Gap current(GC).It was found that pulse on time, peak current and spark voltage were significant factors to grey relational grade.**Madhu V. [6]** They did a comparative study of wire electrical discharge machining (WEDM) of armor materials such as aluminum alloy 7017 and rolled homogeneous armor (RHA) steel using Buckingham pi theorem to model the input variables and thermo-physical characteristics of WEDM on material removal rate (MRR) and surface roughness (Ra) of Al 7017 and RHA steel. Out of parameters like pulse on time, flushing pressure, input power, thermal diffusivity and latent heat of vaporization taken, pulse on time and current plays as important factor for MRR and surface roughness.**B. Naga Raju. [7]**They produced the work piece composite material which containing aluminum alloy as matrix and silicon carbide as reinforcement which was produced by stir casting techniques. They applied wire edm machining process along with process parameters like pulse on time, pulse off time and input voltage. They used Response Surface Methodology to optimize the MRR and surface roughness. . **Rao M and Venkaiah N [8]** They just checked the effect on material removal rate, Kerf, Surface roughness, wire wear ratio by applying the process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire feed, wire tension using wire-edm process. They just found the future trends applying methods of various researchers.

III. EXPERIMENTAL DETAIL

3.1 Theme of experiment

In this paper an attempt have made to optimize the cutting conditions to minimize the surface roughness based on the Taguchi method. WEDM involves many process parameters like pulse on time, pulse off time, peak current, servo voltage, wire feed rate,wire tension, dielectric pressure etc. In this paper only consider first three parameters as mentioned above.

- Pulse on time - The time for which current is applied is called pulse on time, denoted as Ton in second (sec).
- Pulse off time - The duration time between the two simultaneous sparks is known as the pulse off time denoted as T_{off} (sec). No voltage is applied during this time.
- Peak Current - It is the maximum value of the current passing through the electrodes for the given pulse and represented by IP.

3.2 Experimental Setup

Experiment were performed on a wire-cut EDM machine with specification like design fixed column, moving table type with size of the work piece 250*350mm, type of interpolation linear & circular, power supply 3 phase, AC 415 V, 50 Hz. Inconel 625 is taken as work material of size 30*15*2 mm plate. Wire diameter 0.25mm made of Brass is used for experiment. Wire is tensioned between upper and lower guide to obtained higher accuracy. Deionized water is taken as the dielectric fluid with 12 to 16 TDS (total dissolved solid). Surface roughness tester is used to measure surface roughness as shown in figure 2

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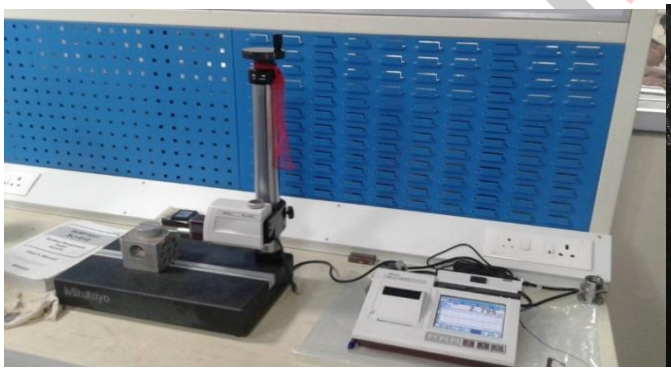


[Fig.2 SURFACE ROUGHNESS TESTER]

[Fig.3 WEDM MACHINING]

[Fig.4 cut out pieces by wire EDM]

3.3 Experimental design

Taguchi method with L9 orthogonal array and ANOVA is used for this study. Taguchi method is applied were reduce the number of trial so that cost and time minimized. In Taguchi method only perform few experiments instead of all possible setting of experiments which required in full factorial design. Each parameters at three levels are selected. The levels are taken from the previous study of literature review. The levels of selected parameters are shown in table 1.

Table 1 PARAMETERS IN DIFFERENT LEVELS

Factors	**Parameters**	**Levels**			
		L1	L2	L3	L4
A	Pulse on Time (µs)	1	2	3	4
B	Pulse off Time (µs)	8	9	10	11
C	Wire Feed(mm/sec)	1	2	3	4

IV. Result and Discussion: -The WEDM experiments were conducted to study the effect of process parameters over surface roughness. The values surface roughness obtained from the roughness tester is shown in Table 2.

Table 2 EXPERIMENTAL RESULTS

Sl no	PULSE ON TIME	PULSE OFF TIME	SPARK VOLTAGE	WIRE FEED	MRR(gm/min)	Ra
1	1	8	40	1	0.01810	2.057
2	1	9	50	2	0.01986	2.640
3	1	10	60	3	0.02710	2.432
4	1	11	70	4	0.02120	2.610
5	2	8	50	3	0.02890	2.349
6	2	9	40	4	0.02312	2.429
7	2	10	70	1	0.01890	2.322
8	2	11	60	2	0.02150	2.795
9	3	8	60	4	0.02110	2.077
10	3	9	70	3	0.02160	2.304
11	3	10	40	2	0.02180	2.944
12	3	11	50	1	0.01440	2.566
13	4	8	70	2	0.02440	2.704
14	4	9	60	1	0.02210	2.521
15	4	10	50	4	0.02140	2.730
16	4	11	40	3	0.02996	2.853

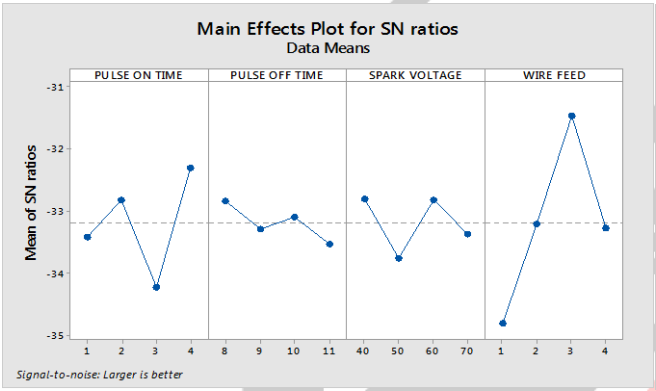
FOR MRR

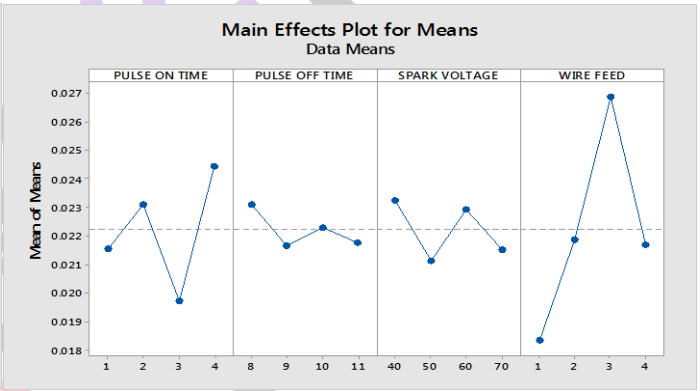
Analysis of Variance for SN ratios

Table 3 ANOVA FOR MRR

Source	DF	Seq SS	Adj SS	AdjMS	F	P	% Contribution
PULSE ON TIME	3	8.122	8.122	2.7072	3.43	0.169	22.33
PULSE OFF TIME	3	1.003	1.003	0.3345	0.42	0.750	2.75
SPARK VOLTAGE	3	2.524	2.524	0.8412	1.07	0.480	6.9394
WIRE FEED	3	22.356	22.356	7.4521	9.44	0.049	61.4648
Residual Error	3	2.368	2.368	0.7892			6.5105
Total	15	36.372					

From the above table wire feed has maximum contribution of 61.4648%





[Fig.2 SN RATION OF MRR][Fig.3 MEANS OF MRR]

FOR Ra

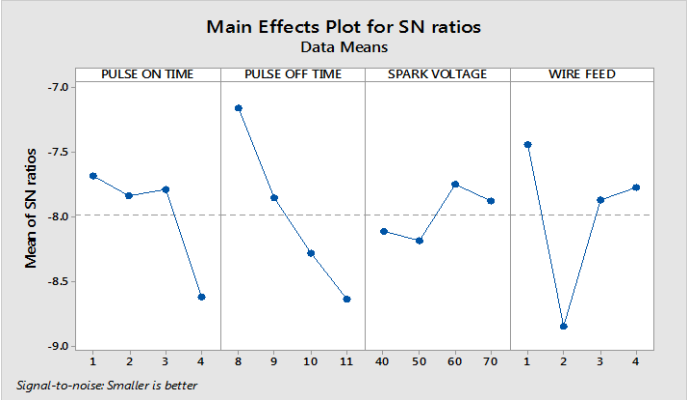
Analysis of Variance for SN ratios

Table 4 ANOVA FOR Ra

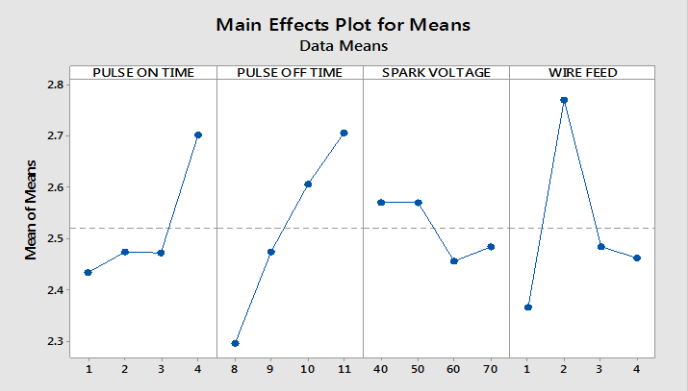
Source	DF	Seq SS	Adj SS	Adj MS	F	P	%contribution
PULSE ON TIME	3	2.2263	2.2263	0.7421	3.26	0.179	17.78
PULSE OFF TIME	3	4.8026	4.8026	1.6009	7.04	0.072	38.36
SPARK VOLTAGE	3	0.4828	0.4828	0.1609	0.71	0.609	3.85
WIRE FEED	3	4.3233	4.3233	1.4411	6.34	0.082	34.53

Residual Error	3	0.6825	0.6825	0.2275			5.45
Total	15	12.5175					

From the above table pulse off time has highest contribution of 38.36%.



[Fig.4 SN RATIO OF Ra]



[Fig.5 MEAN OF Ra]

V. CONCLUSION:-In this experiment optimization of process parameters for material removal rate and surface roughness in Inconel 625 was carried out. The machining parameters are pulse on time, pulse off time and peak current. After successful application of Taguchi method and ANOVA it is conclude the following:

1. FOR MRR:-

- For MRR, pulse on time, spark voltage and wire feed are significant factor.
- Wire feed has highest contribution of 61.4648%

2. FOR ROUGHNESS:-

- For surface roughness, pulse on time, pulse off time and wire feed are the significant factor.
- Pulse off time has the highest contribution of 38.36%.

3. Optimum setting for MRR is at $A_4B_1C_1D_3$ i.e. MRR will be maximum at 4 (Pulse on time), 8(Pulse off time), 40(Spark voltage), 3(Wire feed).

4. Optimum setting for surface roughness is at $A_1B_1C_3D_1$ i.e. Ra will be Maximum at 1(Pulse on time), 8 (pulse off time), 60 (spark voltage), 1 (wire feed).

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