EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF VARIOUS PROCESS PARAMETERS OF EDM BY TAGUCHI METHOD

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***ABSTRACT*:-Electrical discharge machining (EDM) is one of the important non-traditional machining process.Here material Removal Rate (MRR),surface roughness (Ra) are some of the important performance attributes of EDM process. The objective of this study is to get high MRR along with achieving reasonably good surface quality of machined element. Machining of Inconel 625 is carried out by copper electrode by varying various process parameter like pulse current, pulse on time and duty cycle are considered for investigation. The different response table and graph is obtained by ANOVA (minitab17) and analysis is carried out by taguchi method.**

***KEYWORDS*: EDM, Inconel Alloy 625, MRR, surface roughness, Minitab,Taguchi.**

I.INTRODUCTION:-Electrical Discharge Machining (EDM) is now most widely used in manufacturing industries to get high Accuracy, productivity & quality of the product by thermo-electrical process. In EDM process, the removal of the material is obtained by continuous sparks between work piece and wire electrode (tool).

In this process, the material is eroded by a series of discrete electrical discharges between the work piece and tool. These discharges cause sparks and result in high temperatures instantaneously, up to about 10000º C. These temperatures are huge enough to melt and vaporize the work piece metal and the eroded chips cools down swiftly in working liquid and flushed away.The effectiveness of the whole process depends on number and value of input process parameters such as pulse on time, pulse off time, servo voltage, peak current, dielectric flow rate, wire feed, and wire tension. The important machining responses include material removal rate (MRR), surface roughness (Ra). In this paper description of various process parameters and their influence respective responses have been presented. At nearby, EDM is a used in industry for high meticulousness machining of all types of conductive materials such as metallic alloys, metals, graphite, composite supplies or a variety of ceramic materials. The selection of optimized Manufacturing conditions is one of the most important aspects to consider in the die dipping electrical discharge machining (EDM) of Inconel Alloy 625 , as these conditions arethe ones that are to determine such important characteristics: surface bumpiness, material removal rate (MRR). A properly premeditated and accomplish experiment is of the overriding importance for originating clear and truthful conclusions from the investigational observations. Design of experiment is painstaking to be a very useful stratagem for accomplishing these responsibilities. The science of statistical experimental design originated with the occupation of Sir Ronald Fisher in England in 1920s. Fisher founded the fundamental principleof uncertain design and the connected data-analysis technique called Analysis of Variance (ANOVA) during his hard work to improve the defer of agricultural crops. The theory and applications of experimental design and the related technique of reaction surface methodology have been advanced by many sums researchers as Box and huntsman, Box and Draper, Hicks. Various types of matrix are used for preparation experimentsto learning several pronouncement variables. Among them, Taguchi's idea makes heavy use of orthogonal-arrays. Dr. Taguchi of Nippon Telephones and Telegraph band, Japan computerized ameans based on "orthogonal-array" experimentations which gives much determined "variance" for the experiment with "optimum settings" of be in command of parameters. Thus the supervise of DOE with optimization of be in charge of parametersto attain BEST results was achieved in the Taguchi technique. "Orthogonal Arrays" (OA) make available a set of fighting fit objective (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are supervise functions of adored output, serve as purpose functions for optimization, assist in data analysis and anticipation of most select outcome. Now a day's Taguchi's methodology is distant and spacious used in all over the world for compose exploration resolutions, distinctively to optimize the machining uniqueness. In this paper an analysis is done on various process parameters to get the optimum condition in EDM machining.

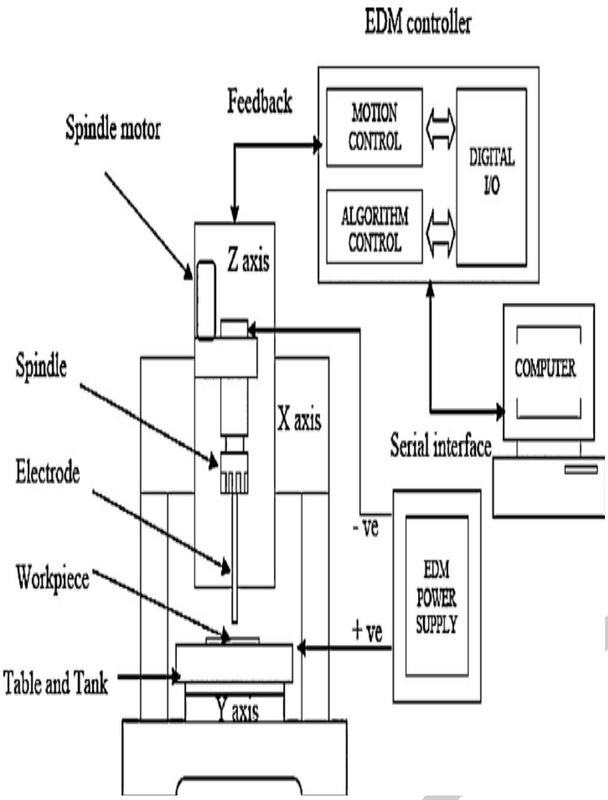

Figure1.Schematicdrawing of EDM, Servo-control, electrode, work piece, dielectric fluid, pulse generator, oscilloscope, DC motor

II.EXPERIMENTAL ANALYSIS:-For this experimentation the total work is done by using Electric Discharge Machine, model ELECTRONICA- EMS 5535 (die-sinking type), having condition of programming in the Z-vertical axis and by hand operated X and Y axes. The tool is connected to cathode and the work piece to anode. Viablegrade EDM oil (specific gravity= 0.763 kg/m3), freezing point= 94°C) was used as dielectric fluid with lateral flushing (pressure of 0.3kgf/cm2) system for effective flushing of machining debris from working gap region. Nickel alloy is one of the majority expansively used. It is a resourceful heat treatable extruded alloy with standard to high strength capabilities. Typical properties of Inconel Alloy 625include:

- Outstanding resistance to chloride pitting and crevice corrosion cracking
- Immune to chloride ion stress corrosion cracking
- Resistant to caustics
- Resistant to seawater, in both flowing and stagnant conditions, and under fouling.

Applications of Nickel Alloy 625

Typical Applications for the Nickel Alloy 625 include:

- Chemical process equipment handling mixed acids both oxidizing and reducing
- Flue gas desulfurization scrubbers
- Evaporators for wet-process phosphoric acid containing H_2SO_4, HF and ferric salts
- Weld Overlay

Table 1 Typical composition of Inconel Alloy 625

	Cr	Mo	Co	Nb+Ta	Al	Ti	C	Fe	Mn	S	P	Ni
Min	20	8	__	3.15	__	__	__	__	__	__	__	Balance
Max	23	10	1	4.15	.4	.4	.1	5	.5	.5	.015	Balance

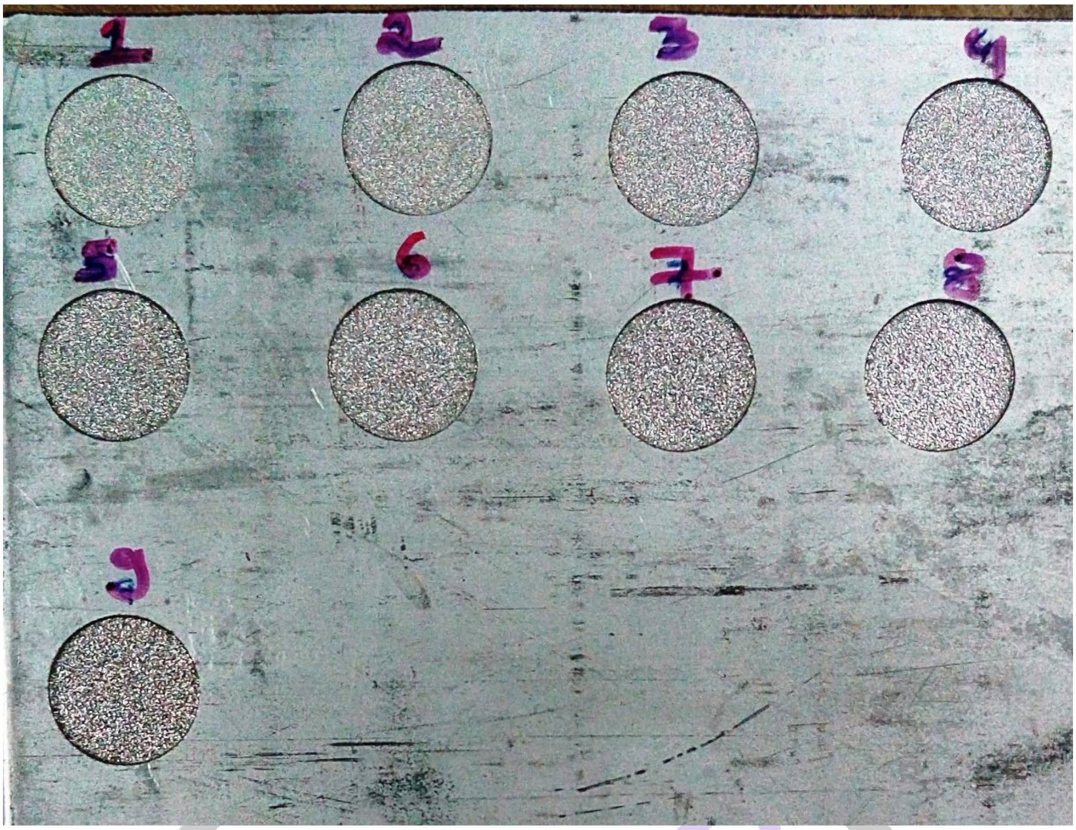

Figure 2. Machined Workpiece

The experiments were conducted on EMS-5535 exactness die sink electric liberation machine as shown in Fig.1 which consist a work table, a servo control system and adielectric supply system. The machine has 3 current settings from 15A to 45A, 3settings of pulse on time 50µs to 150µs, 3 settings of duty cycle 6 to 10 and spark cleft of 50-75 microns. The experiments are conducing on aluminum 6061 alloy and the work piece dimensions are 100 mm x 100 mm x 5 mm. EDM oil Grade 30 is used as the dielectric fluid and the experiments wereperformed for a particular set of input parameters. The number of experiments and input levels are strong-willed based on the purpose of experiments and the enter parameters and their levels are presented in Table 1.
The MRR is preferred as output factor which is determine by using formula

MRR=(Initial weight of workpiece – final weight of work piece)/time taken in machining .

Table 2 parameter and levels

Parameter	Level 1	Level 2	Level 3
Pulse on time(µs)	100	300	500
Duty cycle	7	8	9
Current(A)	5	6	15

III.TAGUCHI ORTHOGONAL ARRAY:-Orthogonal Arrays (often referred to Taguchi Methods) are frequently employed in industrial experiments to study the outcome of several direct factors. Popularized by G.Taguchi. Other Taguchi assistance contain: Model of the Engineering Design Process, Robust Design Principle, hard work to push quality upstream into the engineering design process An orthogonal array is a type of experiment where the columns for the free variables are "orthogonal" to one another. Benefits: 1. Conclusions valid over the complete region spanned by the be in charge of factors and their setting, large economy in the experimental endeavor , psychotherapy is easy to define an orthogonal array, one must classify.

Table 3 Taguchi L9 Orthogonal Array

Experiment run	pluse on time(µs)	Duty cycle	Cureent (A)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

IV.RESULT ANALYSIS:-Taguchi's Design of Experiment is a commanding technique for humanizing process designs and solving productions harms and it is well established tactic for experimental design. This technique gives the affiliation between the machining parameter and performance parameter successfully. The machining parameters preferred for this experiment are: Pulse on time, Duty cycle & Current. The machining situation and number of level of the parameters elected is shown in Table 2. As shown in Table 4, the investigational pragmatic valuesfor Depth of cut and MRR are changed in to the signal to noise ratio, it is the quality indicator by which we be capable of appraise the effect of machining parameter on the performance parameter.
Taguchi method involves dipping the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. Taguchi urbanized a method for manipulative experimentation spect how different parameters affect the stand for and dissent of a process routine characteristic that defines how well the process is functioning. The experimental design projected by Taguchi involves using orthogonal arrays to organize the parameters disturbing the practice and the levels at which they should be varied; it allows for the anthology of the necessary data to conclude which factors most involve product eminence with a least amount amount of conducting tests, thus saving time and property. Taguchi design technique is to make out the parameter settings which render the quality of the product or development robust to obvious variations in external noise. The relative "quality" of a meticulous parameter design is evaluated using a common signal-to-noise (S/N) ratio. Depending on the particular design problem, different S/N ratios are applicable, including "lower is better" (LB), "nominal is best" (NB), or "higher is better" (HB).As the purpose is to obtain the high material removal rate. It is apprehensive with obtaining larger value for MRR, smaller value of tool wear rate and smaller value of surface roughness. Hence, the required excellence characteristic for high MRR is larger the better, which states that the amount produced must be as large as possible.

Table 4 Experimental Table

Sl no	PULSE ON TIME	DUTY CYCLE%	PULSE CURRENT	MRR	Ra
1	100	7	5	0.0134	11.8790
2	100	8	6	0.0137	10.8000
3	100	9	15	0.0170	10.5450
4	300	7	6	0.0225	11.0110
5	300	8	5	0.0268	11.2550
6	300	9	15	0.0225	11.0133
7	500	7	5	0.0211	11.4430
8	500	8	15	0.0265	12.7240
9	500	9	6	0.0187	10.9910

V.ANALYSIS OF VARIANCE (ANOVA):-The knowledge of the donation of individual factors is significantly imperative for the direct the concluding comeback. The analysis of variance (ANOVA) is a common statistical method to find out the percent involvement of each feature for results of the experiment. It calculates parameters known as sum of square SS, degree of freedom (DOF), variance and percentage of each factor. Since the process of ANOVA is a very complex and employs a significant of statistical formula. The Sum of Squares SS (tr) is a calculate of the divergence of the Experimental data from the mean value of the data. The Fisher's ratio is also called F value. The principle of the test is that the larger value for a particular parameter, the greater the effect on the performance characteristics due to the change in that limitation. F value is defined as the ratio of Mean square for the term to Mean square for the inaccuracy term. All the calculation is done in MINI TAB 16 software. From Table 5, we conclude that the current has the maximum contribution with 61.89% on MRR.Figure 3 shows that, when Pulse on time increases MRR increases for some values then it is nearly constant , when Duty cycle increases then MRR increases but when current increases then MRR increases significantly then decreases.

For MRR

Table 5Analysis of Variance for SN ratios S = 1.241 R-Sq = 92.3% R-Sq(ad) = 69.1%

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Pulse on time	2	30.927	30.927	15.463	10.04	0.091	77.7
Duty cycle	2	2.422	2.422	1.211	0.79	0.560	6.085
Current	2	3.373	3.373	1.687	1.10	0.477	8.474
Residual error	2	3.080	3.080	1.540			7.738
Total	8	39.802					

Table 6 Response Table for Signal to Noise Ratios Larger is better

Level	PULSE ON TIME	DUTY CYCLE	PULSE CURRENT
1	-36.70	-34.64	-33.98
2	-32.45	-33.41	-34.93
3	-33.20	-34.30	-33.45
Delta	4.25	1.23	1.48
Rank	1	3	2

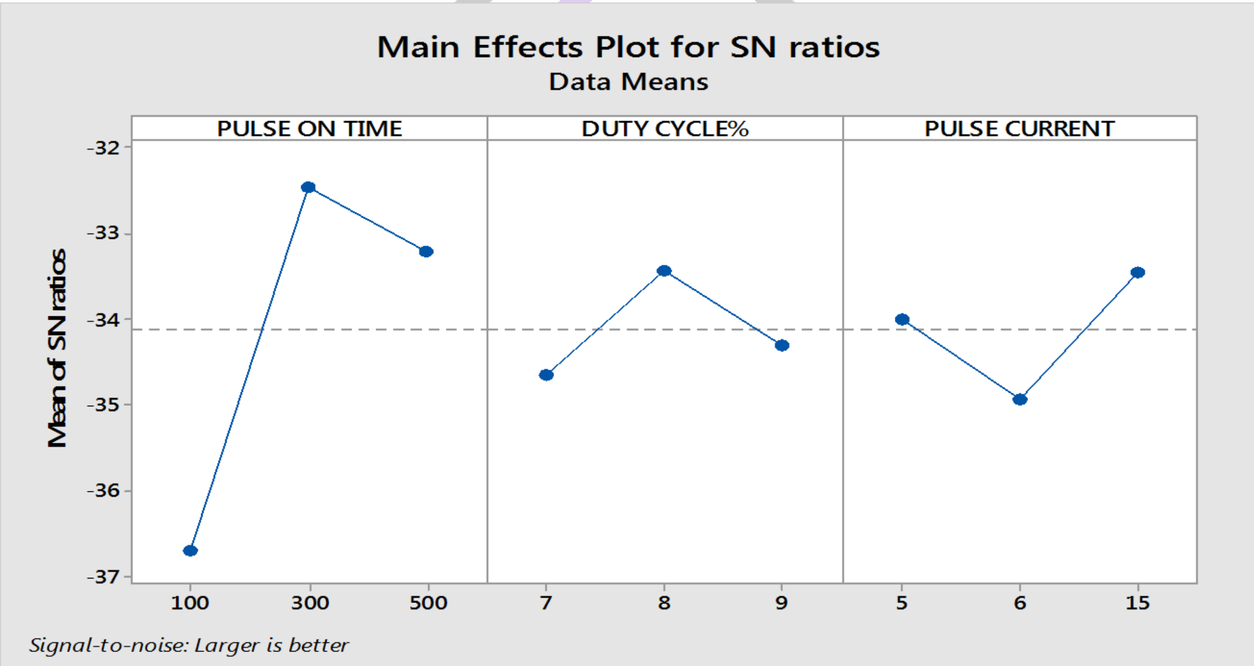

Figure 3. SN Ratio (Mean SN ratio Vs Data means)

Table 7 Response Table for Means

Level	PULSE ON TIME	DUTY CYCLE	PULSE CURRENT
1	0.01470	0.01900	0.02080
2	0.02393	0.02233	0.01830
3	0.02210	0.01940	0.02163
Delta	0.00923	0.00333	0.00333
Rank	1	3	2

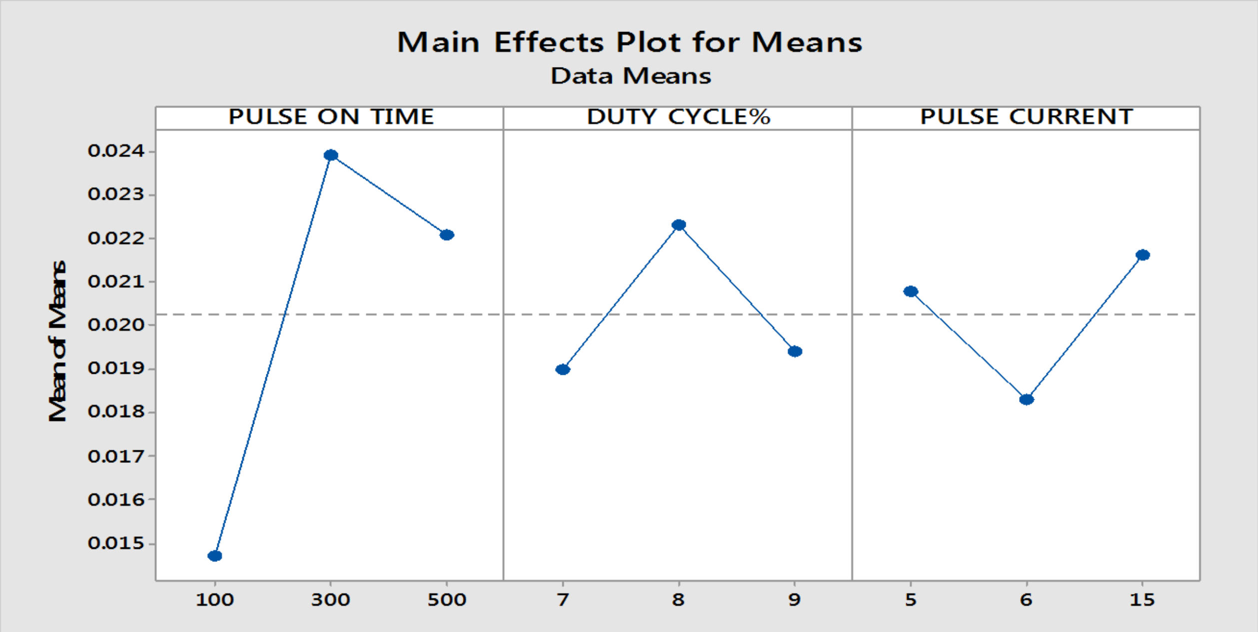

Figure 4. Means of means vs data means

The table above gives the effect of various factors on the response MRR. The factor whose p values are less than 0.500 are significant and greater than 0.1000 are not significant. P values of pulse on time, duty cycle,pulsecurrent are 0.091,0.560,1.10 respectively.The optimum set is obtained by the combination of A2B2C3as in MRR we have larger the better condition to be followed here the contribution of pulse on time is 77.77% which is the major parameter to determine the MRR.

Table 8 ForSurfaceRoughness (Ra):-
Analysis of Variance for SN ratios
S = 0.2301 **R-Sq = 94.5%** R-Sq(adj) = 78.1%

Source	**DF**	**Seq SS**	**Adj SS**	**Adj MS**	**F**	**P**	**% Contribution**
PULSE ON TIME	**2**	**0.4495**	**0.4495**	**0.22473**	**4.25**	**0.191**	**23.221**
DUTY CYCLE	**2**	**0.5306**	**0.5306**	**0.26529**	**5.01**	**0.166**	**27.411**
PULSE CURRENT	**2**	**0.8499**	**0.8499**	**0.42493**	**8.03**	**0.166**	**43.906**
RESIDUAL ERROR	**2**	**0.1058**	**0.1058**	**0.05292**			**5.465**
TOTAL	**8**	**1.9357**					

Table 9 Response Table for Signal to Noise RatiosSmaller is better

Level	**PULSE ON TIME**	**DUTY CYCLE**	**PULSE CURRENT**
1	**-20.88**	**-21.17**	**-21.48**
2	**-20.90**	**-21.26**	**-20.78**
3	**-21.36**	**-20.71**	**-20.89**
Delta	**0.49**	**0.56**	**0.70**
Rank	**3**	**2**	**1**

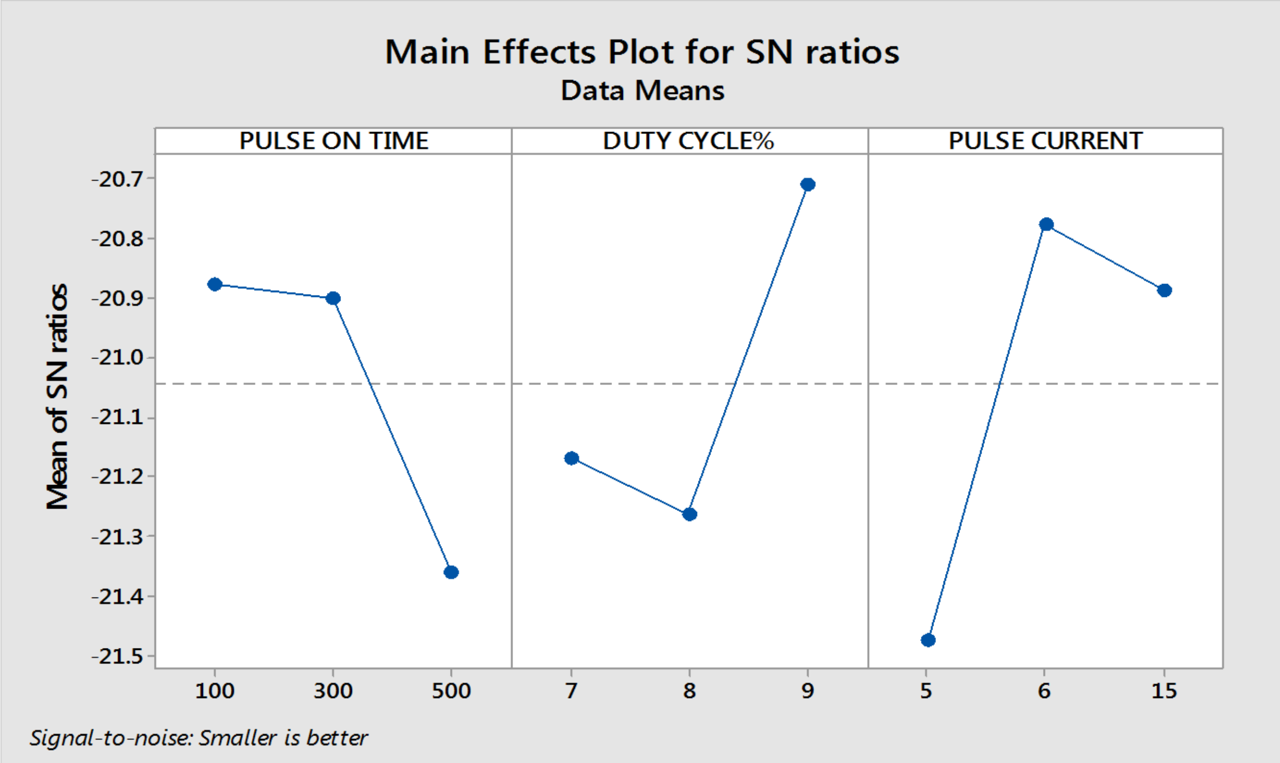

Figure 5. Mean of SN ratio vs Data means

TABLE 10 Response Table for Means

Level	PULSE ON TIME	DUTY CYCLE	PULSE CURRENT
1	11.07	11.44	11.87
2	11.09	11.59	10.93
3	11.72	10.85	11.08
DELTA	0.64	0.74	0.94
RANK	3	2	1

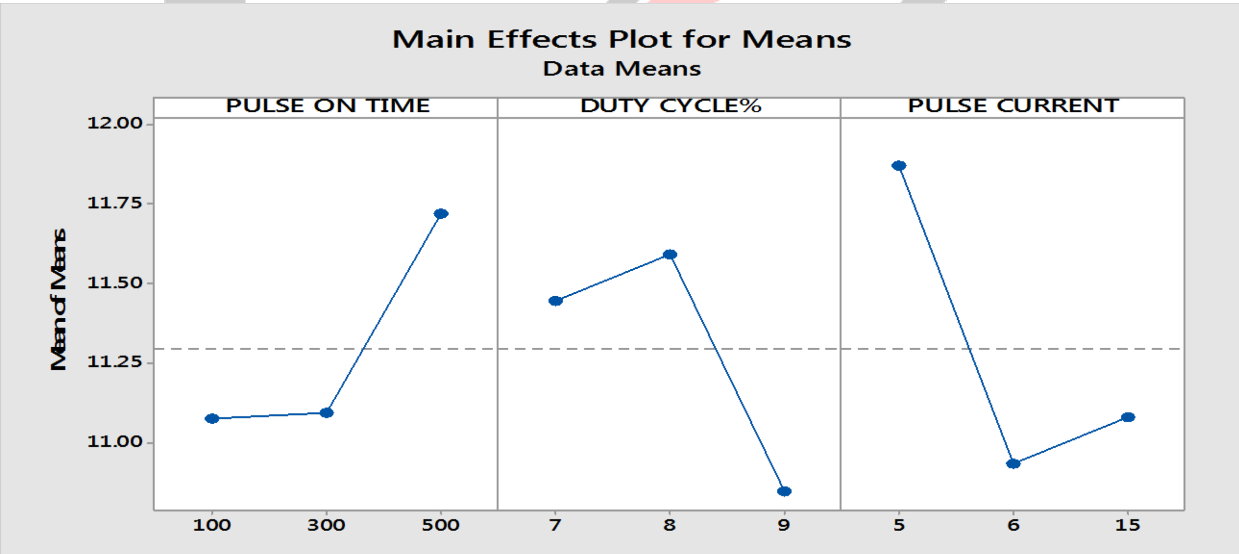

Figure 6. MAIN RFFECT OF SURFACE ROUGHNESS

As smaller is better in case of surface finish so for optimum condition to be achieved by the combination of A1B3C2 and the contribution of pulse current is 43.906% which is play major role in determining the surface roughness .

CONCLUSION

The present paper investigated and optimized the machining parameters i.e. Pulse on time, Duty cycle & current for MRR of EDM of Inconel 625 by using cupper electrode. The significant parameter for MRR is determined by using S/N ratio and ANOVA. The important conclusion summarized below: From the main effect plot, the optimum parameter setting obtained as

Pulse on time 0.02393s, Duty cycle 0.02233, Current 0.02163 A.From Analysis of Variance, we conclude that among all the parameters PULSE ON TIME has a significant effect on the response.

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