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Optimization of Machining Parameters on Wire Electric Discharge Machining of Maraging Steels C300

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Abstract: *Electric discharge machining (EDM) is categorized under thermoelectric process in which heat energy of spark is used to remove the material from work piece. This process involves controlled deterioration of electrically conducting material by the initiation of rapid and repetitive electrical spark discharges among tool and work piece, which are divided by dielectric. The present thesis aimed that is to characterizing the wire electric discharge machining parameters of maraging steels 300 on WEDM by using Molybdenum as a wire. The total of 18 experiments are conducted (9holes and 9 slots.).The Machining is executed by varying WEDM cutting parameters such as pulse off time, current and pulse on time. The outputs are measured like material removal rate and surface finish are assessed. It is found that metal removal rate is increasing with increasing with current and pulse on time. Surface finish is also increases with increasing in current. As the pulse on time goes on increasing the material removal rate increases but surfaces finish increases slightly. As the current value increases from 2 to 4amps the MRR is increasing by gradually, but SF is increased significantly.*

Keywords: EDM, Spark, maraging steels, WEDM, Material Removal Rate, Surface Finish

I. INTRODUCTION

The aim of any machining process is to machine the extra material to obtain the recommended size and shape. These operations use different forms of energies like chemical, electrical, mechanical, etc. The non-traditional machining processes are having several advantages over conventional machining processes. These methods are applicable to all materials which may be hard, brittle and high toughness. However unconventional machining process is not a substitute for conventional machining methods, but is only complementing them. All the methods are not applicable for every the materials.

A. Electrical Discharge Machining Process

Electro Discharge Machining delivers high frequency sparks for machining hard materials & contours. The average gap maintained among the tool and work piece is 20 to 200 μ m in dielectric medium through which the spark discharge occurs. There are two forms of EDM techniques are there .In one, the tool is kept rigid and preformed to shape of the desired contour of the machined surface. This process is known as sinking type EDM. The other process employs a flexible wire of less than 0.25 mm diameter as the electrode, continuously passing through the machining zone of work piece. In SEDM machine kerosene used as dielectric fluid and In WEDM machine demineralise water is used as medium.

B. Principle and Description of EDM Process

The material deterioration mechanism primarily makes use of electrical energy and which is converted into thermal energy through a sequence of different electrical discharges developing among work piece and electrode are dipped in a dielectric. The thermal energy generates a channel of plasma between the cathode and anode at temperature range of 8,000 to 12,000⁰C or as high as 20,000⁰C initializing a substantial amount of heating and melting of material at the surface of each pole. When highly pulsating current supply developing nearly at a rate of 20-30K Hz is turned off, the plasma channel breaks down. Which results a sudden depletion in the temperature and allows the flow of dielectric fluid to push the plasma channel.

C. Wire-Cut EDM (WEDM) Process

The WEDM is one of the discharge machines that uses CNC movement to produce the desirable shape or contour. It doesn't require special type of electrodes. Instead that it uses a vertical wire travelling continuously under tension. The electrode used in WEDM is about a small diameter needle in size and its path is controlled by a controller which is attached to computer to obtain the required shape.

II. LITERATURE SURVEY

A serious amount of work has been focused on the WEDM to find optimal EDM performance measures of high metal removal rate (MRR) and satisfactory surface roughness (SR). Guo studied the mechanism of wire EDM combined with ultrasonic vibrations of the wire. He established that the combination of WEDM and ultrasonic vibrations form the multiple channel discharge and raises the utilization ratio of the energy that results that the improvement in cutting rate and surface finish. Highly frequenced vibrations of wire reduces the possibility of rupture wire and improves the removal concentration. Guo established that with the help of ultrasonic, the cutting speed of wire EDM can be increases by 30% and surface of the machined reduces from 1.96Ra to 1.6Ra [1]. Kunieda and Furudate are conducted research on dry WEDM. In this process the reaction force is very small and negligisble. As compared with the conventional wire EDM, the vibrations of the wire electrode is very less and the gap among work and electrode in dry WEDM is very small. Than the conventional WEDM, which results the dry WEDM to realize the high precision in finish cutting. There is no oxidation of the work piece, which gives an advantage to dry WEDM in manufacturing of high precision molds and dies. These are agreed that WEDM is suitable for finishing cut, specifically for correcting the flatness of the machined surface. Machined surface of dry EDM is better than that of the machined surface is removed by using water and also have better straightness. These are found some imperfections in dry WEDM [2]. Joerres and Koenig established that, Water with some of additives, gives the advantage over the hydrocarbon mediums when working with long pulse durations and high discharge currents. Pashby and Leao found that some of investigators have studied the optimality of adding organic compounds such as polyethylene glycol 200, ethylene glycol, sucrose and dextrose to enhance the performance of ionized water. The machined surface of titanium work piece has been changed after urea solution mixed with water. The nitrogen element dissolved in the dielectric medium that contains urea that means it is migrated in to the work piece, so that it forms a hard layer called titanium nitride. This layer has exceptional wear resistance [3]. The EDM of advanced materials has been widely accepted by the metal cutting industry, because it has their own special properties and features. Dauw and Koangare classified different types of grades of engineering ceramics such as conductors, natural conductors and nonconductors. Sanchez et. provided a literature survey on the EDM of advanced materials which has been frequently machined by laser beam machining (or) ultrasonic machining and proved that machining of advanced materials such as Boron Carbide (B₄C) and Silicon Carbide (SiC) are also machined by using EDM and wire EDM [4]. A combination of EDM and USM was also examined to enhance the circulation of dielectric medium in the spark gap, while machining of advanced materials they are found that significant change in the performance measures and reduction in the thickness of the white layer. A lot of research work is done in case of tool steels, die steels, hybrid composites and ceramics. But available literature on advanced materials such as Ti-6Al-4V and maraging steels (M250) is scanty. The present thesis is concentrated on Maraging steels C300 which are extensively used in pump shafts, shipbuilding, aerospace, valves, automobiles and heat exchangers etc [5].

III. PROBLEM DEFINITION

The objective of this project is to analyse the effect of current, pulse on time and pulse off time on the machining characteristics (MRR, SF) and optimization of the machining parameters of CNC WEDM process to achieve better metal removal rate (MRR) and surface Finish (SF) using Taguchi design method and ANOVA.

Description of work piece material and tool material:

Work piece material: Maraging Steel C300

Dimensions of Work Piece material: 60x55x6mm (2 pieces)

Electrode material: molybdenum wire

Dimensions of electrode material: 0.18mm diameter

IV. EXPERIMENTAL SETUP

The experiments are conducted to find the effects on the various machining input parameters on WEDM process. These effects have been taken into account to find the effects of current, pulse on time & pulse off time on the MRR and Surface Finish. The Maraging Steels C300 is machined with molybdenum wire. The demineralised water is used as dielectric medium. In this project the outcome of current, pulse on time and Pulse off time on the performance indices of WEDM i.e., MRR and surface finish. The machining is done for two specimens of 9 experiments each (9 holes and 9 slots) by changing current, pulse on time and off time. The important parameter for machining efficiency is the polarity; here the straight polarity is taken as we are working on the material removal rate

Table I CNC wire electric discharge machine specifications

Item	Units	Level – 1
Maximum output Current	Amps	5
Input Voltage	Volts	220/360
Maxi consumption rate	Kw	1
Non-load output voltage	Volt	100
ON TIME setting range	seconds	1-99
OFF TIME setting range	seconds	1-15
Eroding frequency	Hertz	90-500K
Main power cable	Millimeter	8
Ground cable	Mm	8
Weight	Tonn	1.2



Fig. 1 Example of an unacceptable low-resolution image



Fig. 2 After machining of holes on WEDM



Fig.3 Molybdenum wire

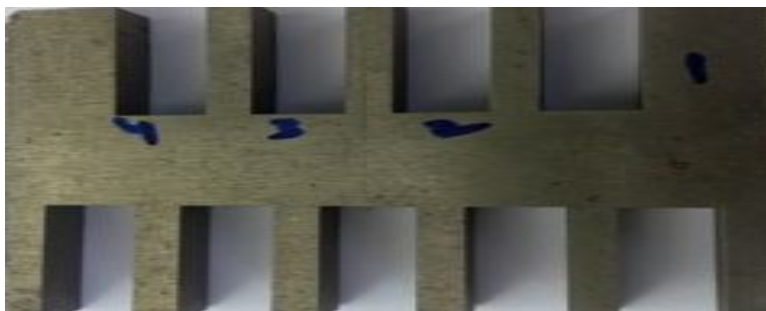


Fig.4 After machining of slots on WEDM

V. TAGUCHI TECHNIQUE

Competitive changes in manufacturing in the year 1980 that gave rise to the modern quality development, leading to the introduction of Taguchi methods. Taguchi's method is a system of design engineering to increase quality. Taguchi's method refers to a assembling of fundamentals which formulate the framework of a continually evolving approach to quality. Taguchi's approach was created on popular concepts of 'design of experiments' (DOE) that is fractional and factorial designs. He created some unique DOE techniques like robust designs, signal-to-noise ratios and parameter & tolerance designs. The main objective of this robust design is to identify the controllable parameters settings for which noise has minimum effect on the product's functional characteristic i.e. not to determine uncontrollable noise parameter settings, but it for the controllable design process parameters.

A. Signal to Noise Ratio

By using the S/N ratio the performance characteristics due to the effect of the noise variables can be found. Where S represents the standard deviation of the performance parameters for each factor and N represents the total number of experiments. The functional variation due to the effect of the noise is denoted by the ratio. Robust design of product and the concept of S/N ratio is closely related. A Robust Design or product delivers a strong 'signal'. It execute its expected function and can cope with variations ("noise"), both internal as well as external. In signal-to-noise Ratio, the signal represents desirable value and the noise represents undesirable value.

B. Orthogonal Array

To reduce the total number of runs "Ronald Fisher" find the solution called orthogonal arrays. The orthogonal array allows the designer to alter multiple variables at any time. Orthogonal array is a matrix of numbers arranged in columns & rows. Each of the columns entitled with a specific factor or condition that can be alter from every experiment. Each of the row represents the state of factors in a given experiment. The array is called orthogonal because the levels of various factors are balanced and can be separated from the effects of the other factors within the experiment.

VI. RESULTS AND DISCUSSIONS

In this present thesis there are two design factors and three input variables are selected and as well as the design methodology also employed for this thesis as shown in table 2. There are many factors which are affecting the WEDM process but in this thesis current, pulse on time and Pulse off time on have been taken into as design factors. The main reason behind selecting the design factors is that they are the most widespread and used amongst WEDM researchers. The variables selected for this study is to refer the responses of the WEDM process, i.e., material removal rate & surface finish. According to the L9 Array, 9 experiments are conducted on two work pieces by using WEDM machine. Table 3 shows the response of process variables on surface finish & material removal rate on Maraging steels C300 work piece.

Table II Input parameters and levels

Number of Levels	Pulse on time (Sec)	Pulse off Time (Sec)	Current (Amps)
1	20	8	2
2	25	10	3
3	30	12	4

Table III Effect of WEDM process parameters on MRR and SR of Maraging steels C300 for Hole

S.No	Pulse on time	Pulse off time	Current	MRR	Surface roughness	S/N _{MRR}	S/N _{SR}
1	20	8	2	3.0840	2.645	9.7823	-8.4485
2	20	10	3	3.2960	3.313	10.3597	-10.4044
3	20	12	4	3.3340	3.442	10.4593	-10.7362
4	25	8	3	3.5270	3.401	10.9481	-10.6321
5	25	10	4	3.7236	3.390	11.4193	-10.6040
6	25	12	2	3.4196	2.620	10.6795	- 8.3660
7	30	8	4	4.1891	4.052	12.4424	-12.1534
8	30	10	2	3.8080	3.363	11.6139	-10.5268
9	30	12	3	3.9500	3.431	11.9319	-10.7084

At 4amp current the pulse on time is 30 and pulse off time is 8 at that Surface roughness was high, that is 4.052 μm . Because, when the current is increased from 2A to 4A the material removal rate is increased with current. This means, when current is high, melting of material starts as early as possible i.e. low machining initiation time. It shows that the material removal rate is proportional to the product of pulse frequency and energy. Increasing the peak current at constant rate frequency increases the energy of the pulse and then ultimately higher metal removal rates are produced. The surface finish increases with increasing in current. When the discharge current is high, the discharge power and intensity of sparks produced more which results large crater depth on the surface of the work piece and also increasing in surface roughness value. From the above table it is observed that when current is kept at 2A the material removal rate is gradually increased but it is very low rate. Surface finished produced is very effective as compared with the current 3 and 4amp.

A. Data Analysis

In this thesis the total analysis is based on Taguchi method by using MINI TAB2017 software (in that DOE is used) the main effects are found by using input process parameter values and percentage contribution of individual effects are also found. By using ANOVA and Taguchi optimum conditions are found. From above table IV we observed that pulse off time is not showing any effect on the material removal rate. But pulse on time and current are effecting the MRR much.

Table IV Analysis of variance test for MRR of holes

Factor	DF	Adj SS	Adj MS	F-value	P-value	Percentage contribution
Pulse on time	2	0.804009	0.418418	88.56	0.011	80.8
Pulse Off time	2	0.032827	0.026414	0.30	0.770	3.20
current	2	0.145744	0.072872	15.42	0.061	14.6
Error	2	0.009449	0.004725			1.40
Total	8	0.994857				100

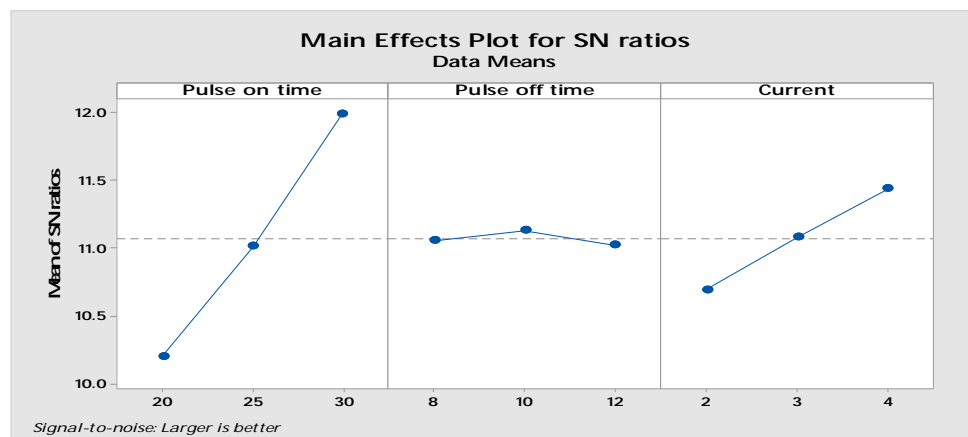


Fig. 5 Main effect plots for MRR

From fig.5 we can write results as the pulse on time increases the material removal rate also increase, at 30sec of pulse on time the material removal rate is maximum. As the pulse off time increases the material removal rate increases first and then decrease. The optimum MRR value is obtained at 10sec of pulse of time. As the current increases the material removal rate also increases, the optimum MRR is found at 4amps.

Table V Analysis of variance test for Surface roughness for holes

Factor	DF	Adj SS	Adj MS	F-value	P-value	Percentage contribution
Pulse on time	2	0.45922	0.22961	4.8156	0.172	34.2
Pulse Off time	2	0.09556	0.04778	0.80	0.554	6.28
current	2	0.88440	0.44220	9.25	0.098	58.18
Error	2	0.07556	0.03845			1.34
Total	8	1.51609				100

From table V the observed values of P-value we can say that pulse off time is not effecting much on surface roughness. The current plays major role than the pulse on time.

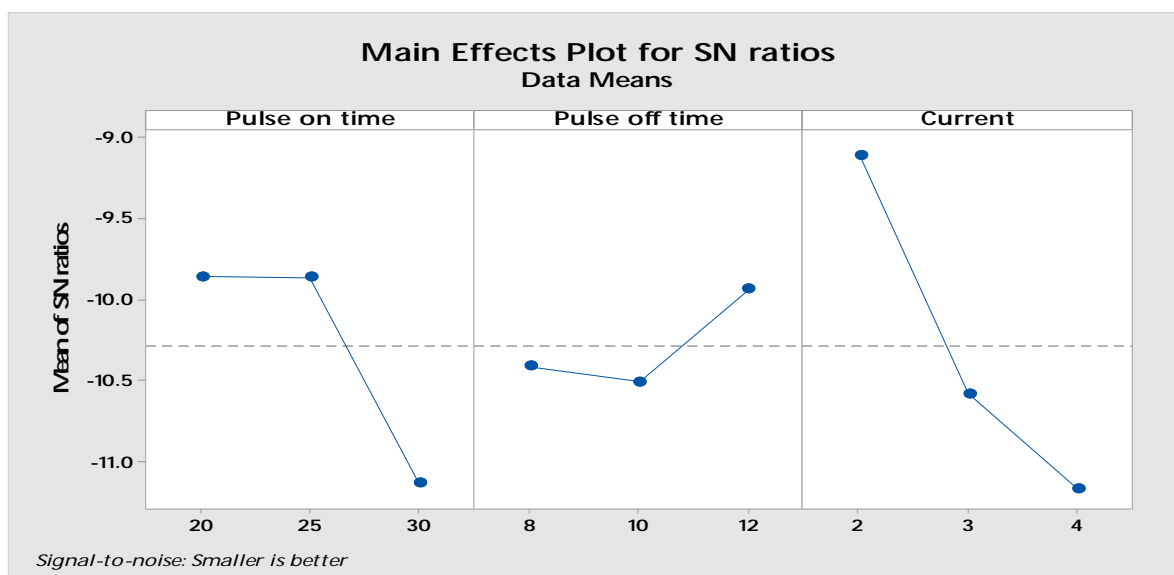


Fig. 6 Main effect plots for surface roughness

From fig.6 we can write results as from fig 5 we can say that as the pulse on time increases surface finish value increasing. The optimum surface finish value is found at 25sec of pulse on time. As the pulse of time increases there is a significant change in surface finish value. At 10sec of pulse off time the optimum surface finish value found. As the current increase surface finish value is increasing gradually, the optimum value of surface finish is produced at 4amps.

Table VI Effect of current, Pulse on time and Pulse off time on MRR and SR of Maraging steels C300 for slots and observed values

S.No	Pulse on time	Pulse off time	Current	MRR	Surface roughness	S/N_{mrr}	S/N_{SR}
1	20	8	2	3.0265	2.626	9.6188	-8.3859
2	20	10	3	3.8453	3.053	11.6986	-9.69450
3	20	12	4	4.6220	3.348	13.2966	-10.4957
4	25	8	3	4.5897	3.018	13.2357	-9.59440
5	25	10	4	4.9001	4.403	13.8041	-12.8750
6	25	12	2	3.2157	2.784	10.1455	-8.89340
7	30	8	4	5.0607	4.439	14.0842	-12.9457
8	30	10	2	3.4308	2.788	10.7061	-8.90590
9	30	12	3	4.7640	3.314	13.5594	-10.4071

From table VI we observed that when current is 4amp, pulse on time at 30 and pulse off time is 8 at that material removal rate is very high, that is 5.0607 mm³/min. Because, when the current is increased from 2A to 4A the metal removal rate is increased with current. This means, when current is high, melting of material starts as early as possible i.e. low machining initiation time. It shows that the material removal rate is proportional to the product of pulse frequency and energy. Increasing the peak current at constant rate frequency increases the energy of the pulse and ultimately higher metal removal rate. When current at 2amps, pulse on time 20sec and pulse off time 8sec the surface roughness produced is very low that is 2.626μm. When current increased from 2to 4amps also the surface finish produced is slightly increased but it is significant.

Table VII Analysis of variance test for MRR

Factor	DF	Adj SS	Adj MS	F-value	P-value	Percentage contribution
Pulse on time	2	0.54122	0.27061	8.170	0.109	10.97
Pulse Off time	2	0.24875	0.22437	0.740	0.576	5.04
current	2	4.07398	2.13699	64.48	0.0015	82.6
Error	2	0.06628	0.03314			1.33
Total	8	4.93023				100

From table VII The material removal rate is mostly effected by the pulse on time and current. As pulse off time increases there is scanty effect on the material removal rate. From table it shows the percentage contribution of individual process input parameters of WEDM on maraging steels of holes. The percentage contribution of current is 82.6% pulse on time is 10.97%, pulse off time 5.04% and error is 1.33%. This is due to machine vibration.

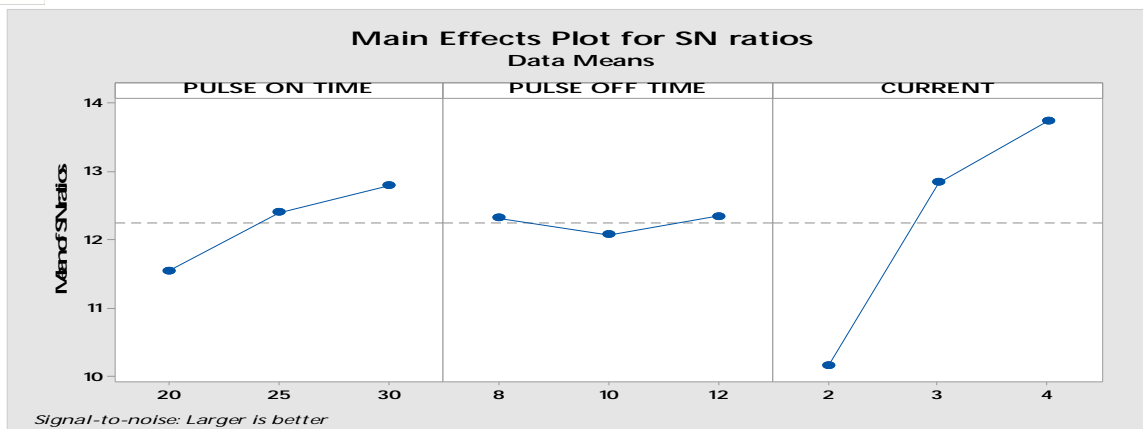


Fig. 7 Main effect plots for MRR

From fig.7 we can write results as the pulse on time increases the material removal rate also increase, at 30sec of pulse on time the material removal rate is maximum. As the pulse off time increases the martial removal rate increases first and then decrease. The optimum MRR value is obtained at 8sec and 10sec of pulse of time. As the current increases the material removal rate also increases, the optimum MRR is found at 4amps.

Table VIII Analysis of variance test for surface roughness

Factor	DF	Adj SS	Adj MS	F-value	P-value	Percentage contribution
Pulse on time	2	0.4214	0.21071	1.42	0.4149	11.58
Pulse Off time	2	0.2975	0.14873	0.40	0.7156	8.09
current	2	2.8015	1.40073	9.42	0.096	77.13
Error	2	0.1187	0.05936			3.26
Total	8	3.6390				

From table VIII the surface roughness produced in the slots is not affected by any parameter but it is slightly affected by current. There is no effect in increasing pulse time. From table it shows the percentage contribution of individual process input parameters of WEDM on maraging steels of holes. The percentage contribution of current is 77.13%, pulse on time 11.58%, pulse off time 8.09% and error is 3.26%. This is due to machine vibrations.

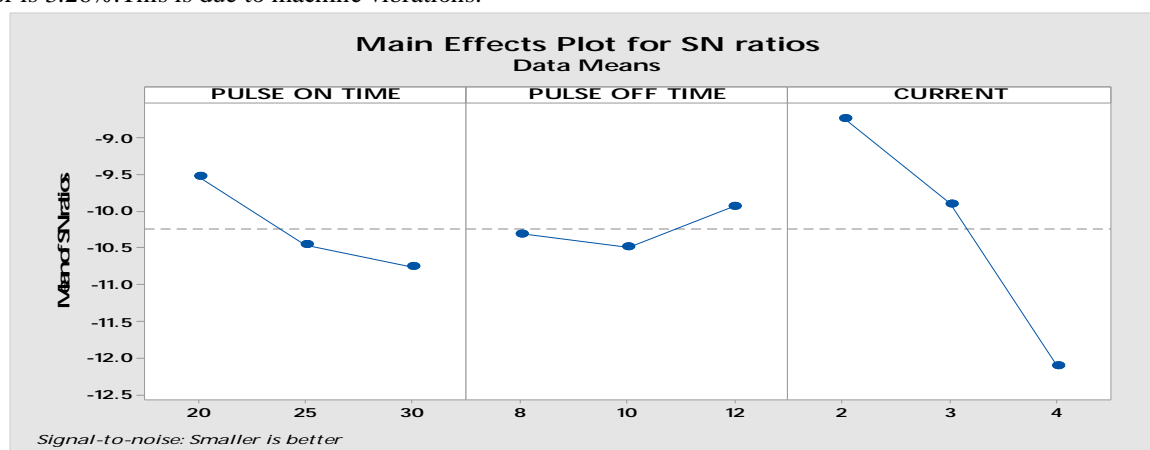


Fig. 8 Main effect plots for surface roughness

As the pulse on time increases surface finish value increasing. The optimum surface finish value is found at 30sec of pulse on time. As the pulse of time increases there is a significant change in surface finish value. at 10sec of pulse off time the optimum surface finish value found. As the current increase surface finish value is increasing gradually, the optimum value of surface finish is produced at 4amps.

VII. CONCLUSIONS

- A. Taguchi orthogonal array method is done to find the optimum parameters levels for holes and slots. It is found that pulse on time at level3 (30sec), pulse off time at level2 (10sec), current at level3 (4A) are the best process parameters for the material removal rate of holes.
- B. In addition it is also used to found that pulse on time at level2 (25Sec), pulse off time at level3 (12sec), current at level1 (2A) are the best parameters for the surface roughness for holes. Process parameters do not have some little effect for every response. Significant parameters and its percentage contribution changes as per the behaviors of the parameters with objective response.
- C. From experimental results and Taguchi design it is found that when the current is 4A, at pulse on time 30sec and pulse off time 8sec are the best process parameters for material removal rate of rectangular slottings.
- D. It is also found that pulse on time at level1 (20Sec), pulse off time at level3 (12sec), current at level1 (2A) are the best parameters for the surface roughness for slots.
- E. It is evident from the results obtained that, the current have a significant effect on the Material Removal Rate and whereas and pulse on time have a significant effect on the Surface Roughness. It is clear that surface roughness increases with increasing the pulse on time and current.
- F. In this work an attempt was made to consider the effects of different settings of pulse on time, pulse off time and current on material removal rate in maraging steels c300. From table it shows the percentage contribution of individual process input parameters of WEDM on maraging steels of holes. The percentage contribution of pulse on time is 80.8%, current 14.6%, pulse off time 3.20% and error is 1.4%. This is due to machine vibration.

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