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EXPERIMENTAL INVESTIGATION OF MACHINING PARAMETERS FOR EDM USING U-SHAPED ELECTRODE OF AISI P20 TOOL

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***Abstract*— The correct selection of manufacturing conditions is one of the most important aspects to take into consideration in the majority of manufacturing processes and, particularly, in processes related to Electrical Discharge Machining (EDM). It is a capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. being widely used in die and mold making industries, aerospace, aeronautics and nuclear industries.**

AISI P20 Plastic mould steel that is usually supplied in a hardened and tempered condition. Good machinability, better polishability, it has a grooving rang of application in Plastic moulds, frames for plastic pressure dies, hydro forming tools These steel are categorized as difficult to machine materials, posses greater strength and toughness are usually known to create major challenges during conventional and non-conventional machining. The Electric discharge machining process is finding out the effect of machining parameter such as discharge current, pulse on time and diameter of tool of AISI P20 tool steel material. Using U-shaped cu tool with internal flushing. A well-designed experimental scheme was used to reduce the total number of experiments. Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by which factor is most affected by the Responses of Material Removal Rate (MRR), Tool Wear Rate (TWR) and over cut (OC).

***Index Terms*— Electrical Discharge Machining (EDM), AISI P20 TOOL, U-shaped cu tool, Taguchi Method.**

I. INTRODUCTION OF EDM

The history of EDM Machining Techniques goes as way back it absolutely was discovered by Associate in Nursing English Scientist. However, discharge Machining was not absolutely taken advantage of till 1943 once Russian scientists learned however the erosive effects of the technique may well be controlled and used for machining functions.

When it absolutely was originally determined by Joseph Priestly in 1770, EDM Machining was terribly imprecise and riddled with failures. Commercially developed within the middle Seventies, wire EDM began to be a viable technique that helped form the metal operating trade we tend to see nowadays. Within the middle 1980s. The EDM techniques were transferred to a machine. This migration created EDM a lot of wide out there and appealing over ancient machining processes.

The new idea of producing uses non-conventional energy sources like sound, light, mechanical, chemical, electrical, electrons and ions. With the economic and technological growth, development of more durable and troublesome to machine materials, that realize wide application in region, applied science and alternative industries as a result of their high strength to weight quantitative relation, hardness and warmth resistance qualities has been witnessed. New developments within the field of fabric science have semiconductor diode to new engineering bimetal materials, composite materials and high technical school ceramics having smart mechanical properties and thermal characteristics in addition as decent electrical conduction so they'll promptly be machined by spark erosion. Non-traditional machining has full-grown out of the requirement to machine these exotic materials. The machining processes square measure non-traditional within the sense that they are doing not use ancient tools for metal removal and instead they directly use alternative varieties of energy.

A. Principle Of EDM –

In this method the metal is removing from the work piece thanks to erosion case by speedily revenant spark discharge happening between the tool and work piece. Show the mechanical originated and electrical originated and circuit for electro discharge machining. a skinny gap regarding zero.025mm is maintained between the tool and work piece by a servo system shown in fig one.1. each tool and work piece square measure submerged during a insulator fluid

.Kerosene/EDM oil/de ionized water is very common sort of liquid insulator though vaporize dielectrics are used in sure cases.

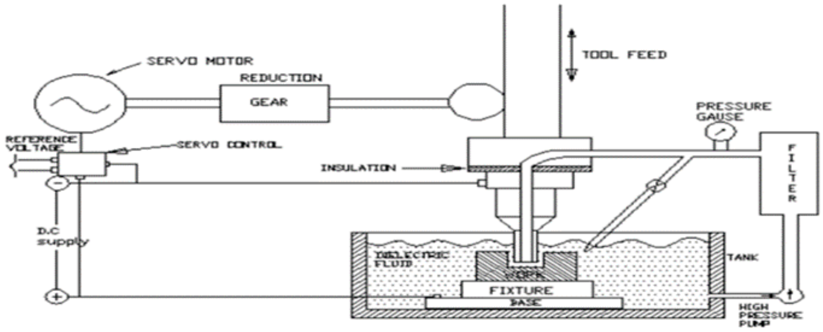

Figure1. 1 Set up of Electric discharge machining

This fig.1.1 is shown the electrical setup of the electrical discharge machining. The tool is mead cathode and work piece is anode. Once the voltage across the gap becomes sufficiently high it discharges through the gap within the style of the spark in interval of from ten of small seconds. And positive ions and electrons are accelerated, manufacturing a discharge channel that becomes semi conductive. It's simply at now once the spark jumps inflicting collisions between ions and electrons and making a channel of plasma. A unexpected drop of the electrical resistance of the previous channel permits that current density reaches terribly high values manufacturing a rise of ionization and therefore the creation of a robust force field. The instant spark happens sufficiently pressure developed between work and gear as a results of that a awfully high temperature is reached and at such air mass and temperature that some metal is dissolved and worn.

B. Workpiece Materials-

It is capable of machining geometrically advanced or laborious material parts, that area unit precise and difficult-to-machine like heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc.

There area unit differing kinds of tool material area unit exploitation the EDM technique. and also the alloy steel contains carbon and alloy steels that area unit notably well-suited to be created into tools. Their suitableness comes from their distinctive hardness, resistance to abrasion, their ability to carry a leading edge, and/or their resistance to deformation at elevated temperatures (red-hardness). alloy steel is mostly utilized in a heat-treated state. Tool steels area unit created to variety of grades for various applications. In general, the sting temperature beneath expected use is a crucial determinant of each composition and needed heat treatment. the upper carbon grades area unit generally used for such applications as stamping dies, metal cutting tools, etc.

In this experiment are using AISI P-20 plastic mould tool steel material.

II. Literature Survey

In this chapter search few selected research paper related to EDM with effect of metal MRR, TWR, OC, surface roughness (SR) workpiece material, we are broadly classified all the paper in to five different category, i.e. paper related to material related workpiece or tool, tubular electrode, tool design, some paper related to Effect of multiple discharge and rest of the paper related to CNC.

A. Workpiece and Tool Materials-

Dhar and Purohit [1] evaluates the effect of current (c), pulse-on time (p) and air gap voltage(v) on MRR, TWR, ROC of EDM with Al–4Cu–6Si alloy–10 wt. % SiC_P composites. This experiment can be using the PS LEADER ZNC EDM machine and a cylindrical brass electrode of 30 mm diameter. And three factors, three levels full factorial design was using and analyzing the results. A second order, non-linear mathematical model has been developed for establishing the relationship among machining parameters. The significant of the models were checked using technique ANOVA and finding the MRR, TWR and ROC increase significant in a non-linear fashion with increase in current.

Karthikeyan et .al [2] has presented the mathematical molding of EDM with aluminum-silicon carbide particulate composites. Mathematical equation is $Y=f(V, I, T)$. And the effect of MRR, TWR, SR with Process parameters taken in to consideration were the current (I), the pulse duration (T) and the percent volume fraction of SiC (25 µ size). A three level full factorial design was choosing. Finally the significant of the models were checked using the ANOVA. The MRR was found to decrease with an increase in the percent volume of SiC, whereas the TWR and the surface roughness increase with an increase in the volume of Sic. it shown the graph between interactive effect of the percent volume of Sic and the current on MRR Fig 2.1.

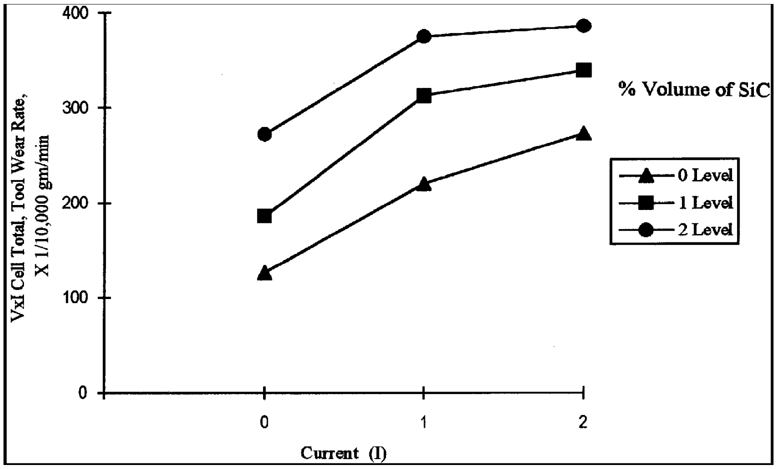

Figure 2.1 Graph between interactive effect of Sic and Current on MRR

Tool electrode material such as Al–Cu–Si–Tic composite produced using powder metallurgy (P/M) technique and using workpiece material CK45 steel was shown by Taweel [3]. The central composite second-order rotatable design had been utilized to plan the experiments, and RSM was employed for developing experimental models. Composite electrode is found to be more sensitive to peak current and Pulse on time then conventional electrode. And Fig 2.2. had shown the multi response optimization result for maximum MRR and minimum TWR.

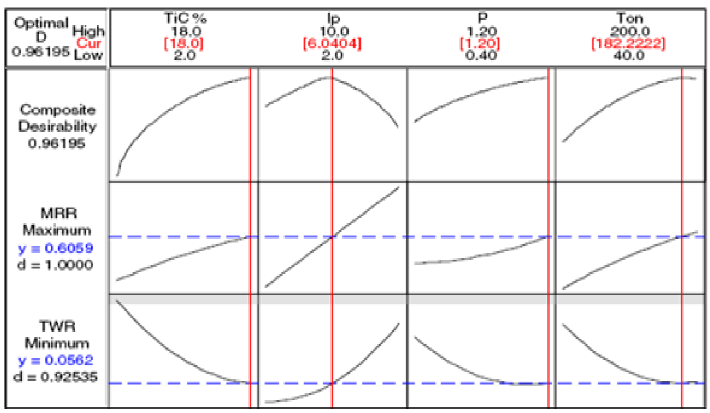

Figure 2.2 Multi Response optimization for Max. MRR and Min.TWR

B.Mohan and Satyanarayana [4] evolution the of effect of the EDM Current, electrode marital polarity, pulse duration and rotation of electrode on metal removal rate, TWR, and SR, and the EDM of Al-Sic with 20-25 vol. % SiC, Polarity of the electrode and volume present of SiC, the MRR increased with increased in discharge current and specific current it decreased with increasing in pulse duration. Increasing the speed of the rotation electrode resulted in a positive effect with MRR, TWR and better SR than stationary. The electric motor can be used to rotate the electrode(tool) AV belt was used to transmit the power from the motor to the electrode Optimization parameters for EDM drilling were also developed to summarize the effect of machining characteristic such as MRR, TWR and SR.

The effects of the machining parameters (MRR, TWR and SR) in EDM on the machining characteristics of SKH 57 high-speed steel were investigated by Yan-Cherng et.al [5]. Experimental design was used to reduce the total number of experiments. Parts of the experiment were conducted with the L18 orthogonal array based on the Taguchi method. Moreover, the signal-to-noise ratios associated with the observed values in the experiments were determined by ANOVA and F -test. The relationship of MRR and SR with pulse duration graph in different peak current is as shown in Fig. 2.3. During the experiment MRR increases with peak current MRR initially increased to a peak at around 100 µs, and then fell.

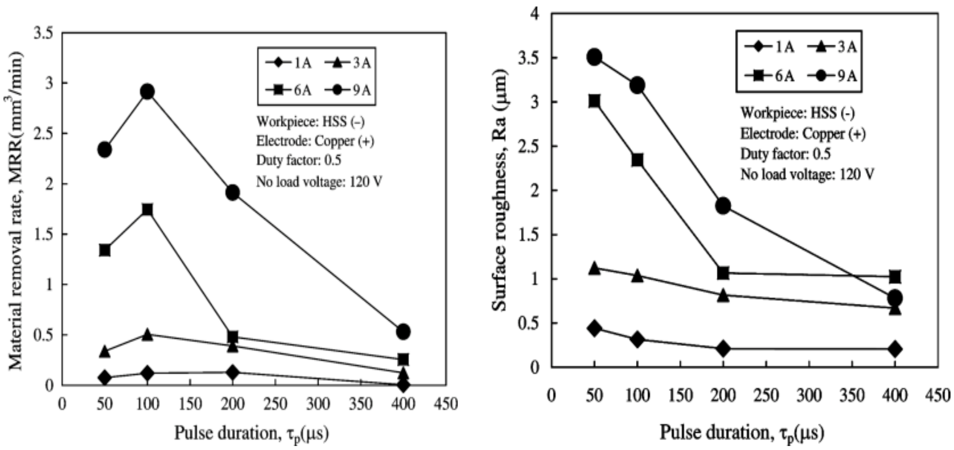

Figure 2.3 MRR and surface roughness with pulse duration graph

B. Objectives Of Present Work-

From the research papers in this classification, it is observed that few works has been reported on EDM on the material Al-Sic, EN-19, SKH 57, AISI H13, AISI D2 tool steel, and various composite materials. Study on EDM of different material and different mathematical model can be use to validated the experimental results.

The objective of the present work is an attempt to finding feasibility of machining AISI P-20 tool steel using U-shaped tubular copper electrode and internal flushing. The machining parameter selected for discharge current, pulse on time, and diameter of the tool using Taguchi design approach analyzing the responses MRR, TWR, and over cut.

III. EXPERIMENTAL WORK

In this chapter we are going to discuss about the experimental work which is consist about formation of the L-18 orthogonal array based on Taguchi design, orthogonal array is reduces the total on of experiment, in this experiment total 18 run. And Experimental set up, selection of workpiece, tool design, and taking all the value and calculation of MRR, TWR, and OC.

A. Experimental SET UP-

For this experiment the whole work can be down by Electric Discharge Machine, model ELECTRONICA-ELECTRAPULS PS 50ZNC (die-sinking type) with servo-head (constant gap) and positive polarity for electrode was used to conduct the experiments. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94˚C) was used as dielectric fluid. With internal flushing of U-shaped cu tool with a pressure of 0.2 kgf/cm^2 .Experiments were conducted with positive polarity of electrode. The pulsed discharge current was applied in various steps in positive mode.

The EDM consists of following major part as shown in the chapter Appendix (Fig 5.1)

- Dielectric reservoir, pump and circulation system.
- Power generator and control unit.
- Working tank with work holding device.
- X-y table accommodating the working table.
- The tool holder.
- The servo system to feed the tool.

1) Dielectric reservoirs pump and circulation system –

Dielectric reservoirs and pump are used to circulate the EDM oil for every run of the experiment and also used the filter the EDM oil. Dielectric reservoir is shown in Fig 3.1.

Figure 3.1 Dielectric reservoir

2) Power generator and control unit –

The power supply control the amount of energy consumed. First, it has a time control function which controls the length of time that current flows during each pulse; this is called “on time.” Then it is control the amount of current allowed to flow during each pulse. These pulses are of very short duration and are measured in microseconds. There is a handy rule of thumb to determine the amount of current a particular size of electrode should use: for an efficient removal rate, each square inch of electrode calls for 50 A. Low current level for large electrode will extend overall machine time unnecessarily. Conversely, too heavy a current load can damage the workpiece of electrode.

The control unit is control the all function of the machining for example of Ton, Ip, duty cycle, putting the values and maintain the workpiece the tool gap. The control unit is shown in this Fig 3.2.

Figure 3.2 Control unit of EDM machine

3) Working tank with work holding device–

All the EDM oil kept in the working tank working tank is used to the supply the fluid during the process of machining.

4) X-y table accommodating the working table –

They are used to the moment of the workpiece form X and Y direction.

5) The tool holder –

The tool holder hold the tool with the process of machining. The tool holder with workpiece and tool as shown in Fig 3.3.

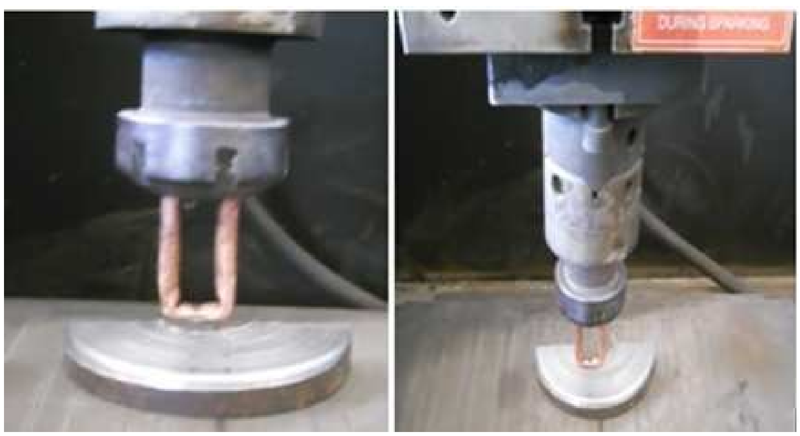

Figure 3.3 Tool holder with Workpiece and tool

6) The servo system to feed the tool –

The servo control unit is provided to maintain the pre determined gap. It senses the gap voltage and compares it with the present value and the different in voltage is then used to control the movement of servo motor to adjust the gap.

B. Selection Of Workpiece-

It is capable of machining of hard material component such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. The higher carbon grades are typically used for such applications as stamping dies, metal cutting tools, etc. AISI grades of tool steel is the most common scale used to identify various grades of tool steel. Individual alloys within a grade are given a number; for example: A2, O1, D2, P20 etc.

In this experiment using AISI P20 tool steel material this P-20 tool steel material is a pre hardened high tensile tool steel which offers ready machine ability in the hardened and tempered condition, therefore does not require further heat treatment. Subsequent component modifications can easily be carried out.

Plastic mould steel (P-20 tool steel) that is usually supplied in a hardened and tempered condition. Good machine ability, better polish ability, compared to DIN 1.2312 (AISI P20+S).

Plastic mould steel is used growing range of to Plastic moulds, frames for plastic pressure dies, hydro forming tools. And their composition of the tool is listed in this Table: 3.1, 3.2, 3.3 and 3.4.

Table 3.1 Composition of AISI P-20 tool steel material

Elements	Weight limit %	Actual weight %
C	0.28-0.40	0.40
Mn	0.60-1.00	1.00
Si	0.20-0.80	0.40
Cr	1.40-2.00	1.20
Mo	0.30-0.55	0.35
Cu	0.25	0.25
P	0.03	0.03
S	0.03	0.03

Table 3.2 AISI P20 tool steel categories

Category	Steel
Class	Tool steel
Type	General mold steel
Designations	Germany : DIN 1.2330 United States : ASTM A681 , UNS T51620

Table 3.3 Mechanical properties of P20 steel

Properties		Conditions T (°C)
Density	7.85x1000 kg/m^3	25
Poisson's Ratio	0.27-0.30	25
Elastic Modulus	190-210Gpa	25

Table 3.4 Thermal Properties of P20 tool steel material

Properties		Conditions T (°C)
Thermal Expansion (10^{-6}/°C)	12.8	20-425 more

AISI P20 tool steel material and after machining workpiece and the Cu U-shaped tool. As showing Fig 3.4 and the workpiece shows 18 total no. of experiments doing in this job.

Figure 3.4 P-20 workpiece before and after machining with tool

C. TAGUCHI DESIGN-

Dr. Genichi Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and/or sensitivity to noise. When used properly, Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. Taguchi proposed several approaches to experimental designs that are sometimes called "Taguchi Methods." These methods utilize two-, three-, four-, five-, and mixed-level fractional factorial designs. Taguchi refers to experimental design as "off-line quality control" because it is a method of ensuring good performance in the design stage of products or processes.

D. TAGUCHI DESIGN EXPERIMENTS IN MINITAB

MINITAB provides both static and dynamic response experiments in a static response experiment; the quality characteristic of interest has a fixed level. The goal of robust experimentation is to find an optimal combination of control factor settings that achieve robustness against (insensitivity to) noise factors. MINITAB calculates response tables and generates main effects and interaction plots for:-

Signal-to-noise ratios (S/N ratios) vs. the control factors.

Means (static design) vs. the control factors.

A Taguchi design or an orthogonal array the method is designing the experimental procedure using different types of design like, two, three, four, five, and mixed level. In the study, a three factor mixed level setup is chosen with a total of eighteen numbers of experiments to be conducted and hence the OA L18 was chosen. This design would enable the two factor interactions to be evaluated. As a few more factors are to be added for further study with the same type of material, it was decided to utilize the L18 setup, which in turn would reduce the number of experiments at the later stage. In addition, the comparison of the results would be simpler.

The levels of experiment parameters electrode diameter (D), spark on time (Ton), and discharge current (Ip) are shown in Table 3.5 and the design matrix is depicted in Table 3.6.

Table 3.5 Machining parameters and their level

Machining parameter	**Symbol**	**Unit**	**Level**		
			Level 1	**Level 2**	**Level 3**
Electrode diameter	**(D)**	**mm**	**4**	**6**	
Spark on time	**(Ton)**	**µs**	**50**	**500**	**1000**
Discharge current	**(Ip)**	**A**	**1**	**3**	**5**

E. CONDUCT OF EXPERIMENTS –

P20 Tool steel material particulate was using U-shaped Copper tube tool with 4mm and 6mm diameter. And the PS 50ZNC (die-sinking type) of EDM machine are used. Commercial grade EDM oil (specific gravity= 0.763, freezing point= 94˚C) was used as dielectric fluid. Internal flushing with U-shaped copper tool with internal flushing was used to flush away the eroded materials from the sparking zone. In this experiment voltage and duty cycle is kept constant is 50 v and 8. For a three factor are tackled with a total number of 18 experiments performed on die sinking EDM.

The calculation of material removal rate and tool wear rate by using electronic balance weight machine as shown in Fig 5.2. This machine capacity is 300 gram and accuracy is 0.001 gram. And the over cut measurement can be using tool maker microscope as shown in Fig 5.3 this machine accuracy is 0.0001 mm.

F. DESIGN MATRIX AND OBSERVATION TABLE

Table 3.6 Design matrix and Observation table

Run	Dia (mm)	Ip (A)	Ton (µs)	Wt of Workpiece (gm)		Wt. of Tool (gm)		Cavity dia. (mm)
				Wjb	Wja	Wtb	Wta	Djt
1	4	1	50	266.510	266.220	18.976	18.974	5.724
2	4	1	500	266.220	266.109	18.974	18.970	5.393
3	4	1	1000	266.109	266.093	18.970	18.969	4.736

4	4	3	50	266.093	264.914	18.969	18.941	5.882
5	4	3	500	264.914	264.483	18.941	18.926	5.743
6	4	3	1000	264.488	264.395	18.926	18.925	5.445
7	4	5	50	264.395	262.983	18.925	18.836	5.895
8	4	5	500	262.983	262.146	18.836	18.827	5.785
9	4	5	1000	262.146	262.061	18.827	18.801	5.964
10	6	1	50	81.783	81.491	22.214	22.196	6.143
11	6	1	500	81.922	81.783	22.224	22.214	6.089
12	6	1	1000	81.955	81.922	22.225	22.224	6.071
13	6	3	50	3841.0	3840.0	22.240	22.238	6.158
14	6	3	500	82.769	82.245	22.238	22.233	6.130
15	6	3	1000	82.245	81.955	22.233	22.225	6.144
16	6	5	50	269.264	267.862	22.196	22.187	6.180
17	6	5	500	267.862	266.807	22.187	22.161	6.136
18	6	5	1000	266.807	266.510	22.161	22.173	6.024

G. CONCLUSION-

Experiments were conducted according to Taguchi method by using the machining set up and the designed U-shaped tubular electrodes with internal flushing. The control parameters like diameter of electrode (D) , discharge current (Ip) and pulse duration (Ton) conductivity were varied to conduct 18 different experiments and the weights of the work piece and Tool and dimensional measurements of the cavity were taken for calculation of MRR , TWR and over cuts.

IV. RESULT AND DISCUSSION

In This chapter are related about influences of MRR, TWR, and OC and finding the result which factors discharge current , pulse duration, diameter of Cu tool , is most important with help of Taguchi method.

RESPONSE TABLE –

The response table for MRR, TWR and OC are shown in Table 4.1 along with the input factors.

Table 4.1 Response table

Run	Dia (mm)	Ip (A)	Ton (µs)	MRR (mm^3/min)	TWR (gm/min)	OC (mm)
1	4	1	50	1.0400	0.0170	0.8620
2	4	1	500	0.2360	0.0030	0.6965
3	4	1	1000	0.0360	0.0006	0.3680
4	4	3	50	3.9890	0.0660	0.9410
5	4	3	500	0.9040	0.0150	0.8715
6	4	3	1000	0.7970	0.0130	0.7225
7	4	5	50	2.9980	0.0400	0.9295
8	4	5	500	1.7770	0.0290	0.8790
9	4	5	1000	0.8000	0.0030	0.9820
10	6	1	50	0.6140	0.0103	0.1435

11	6	1	500	0.2950	0.0040	0.0895
12	6	1	1000	0.0700	0.0010	0.0710
13	6	3	50	3.0000	0.0500	0.5790
14	6	3	500	1.1120	0.0180	0.5650
15	6	3	1000	0.9738	0.0356	0.5720
16	6	5	50	2.9700	0.0490	0.5900
17	6	5	500	2.2390	0.0370	0.5680
18	6	5	1000	1.3000	0.0105	0.5120

A. INFLUENCES ON MRR

The S/N ratios for MRR are calculated as given in Equation 4.1. Taguchi method is used to analysis the result of response of machining parameter for larger is better criteria.

$$\text{LB}: \eta = -10 \log\left[\frac{1}{n}\sum_{i=1}^{n} yi^{-2}\right] . \quad (4.1)$$

Where η denotes the S/N ratios calculated from observed values, yi represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L-18 OA is conducted.

The analysis of variances for the factors is shown in Table 4.2 which is clearly indicates that the diameter of the tool is not important for influencing MRR and Ip and Ton are the most influencing factors for MRR and as well as the interaction Ip x Ton is significant (shown in bold). And other factors are not significant .The delta values are Dia. of tool, Ton and Ip are 1.1493, 15.0841 and 18.3901 respectively, depicted in Table 4.3. The case of MRR, it is "Larger is better", so from this table it is clearly definite that Ip is the most important factor then Ton and last is dia. of the tool.

Table 4.2 Analysis of Variance for S/N ratios for MRR

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Dia	1	5.94	5.94	5.944	3.38	0.140
Ip	2	1222.40	1222.40	611.198	347.29	0.000
Ton	2	683.05	683.05	341.524	194.06	0.000
Dia*Ip	2	2.17	2.17	1.087	0.62	0.584
Dia*Ton	2	30.98	30.98	15.491	8.80	0.034
Ip*Ton	4	163.28	163.28	40.820	23.19	0.005
Residual Error	4	7.04	7.04	1.760		
Total	17	2114.86				

Table 4.3 Response for S/N Rations Larger is better (MRR)

Level	Diameter	Ip	Ton
1	-2.1459	-13.1689	6.1093
2	-0.9966	3.2340	-1.8508
3		5.2212	-8.9721
Delta	1.1493	18.3901	15.0841
Rank	3	1	2

During the method of discharge machining, the influence of assorted machining parameter like science, Ton and Diameter of tool has vital result on MRR, as shown in main result plot for S/N magnitude relation of MRR in Fig four.1. The discharge current (Ip) is directly proportional to MRR within the vary of one to 3A. this can be expected as a result of a rise in pulse current produces sturdy spark, that produces the upper temperature, inflicting a lot of material to soften and erode from the work piece. Besides, it's clearly evident that the opposite issue doesn't influence a lot of as compared to science and similar conclusions were shown by Ghoreishi and Tabari [34]. But, with increase in discharge current from 3A to 5A MRR will increase slightly. However, MRR decreases monotonically with the rise in pulse on time.

The diameter of the tool has no vital result on MRR. The interaction plot of MRR is shown in Fig four.2, wherever

every plot exhibits the interaction between 3 completely different machining parameters like science, Ton and military intelligence. of tool. this means that the result of 1 issue relies upon another issue. it's conjointly confirmed by the multivariate analysis table (Table four.2).
It is standard indisputable fact that the spark energy will increase with Ton and therefore, MRR will increase with Ton within the vary of three hundred to four hundred µs. MRR sometimes will increase with Ton up to a most price when that that it starts to decrease. this can be thanks to the very fact that with higher Ton, the plasma shaped between the bury conductor gap (IEG) really hinders the energy transfer and therefore reduces MRR. during this experiment the worth of pulse durations ar fifty, five hundred and a thousand µs that miss the height values. So, the premeditated graph of pulse length vrs MRR, as show decreasing trend solely.

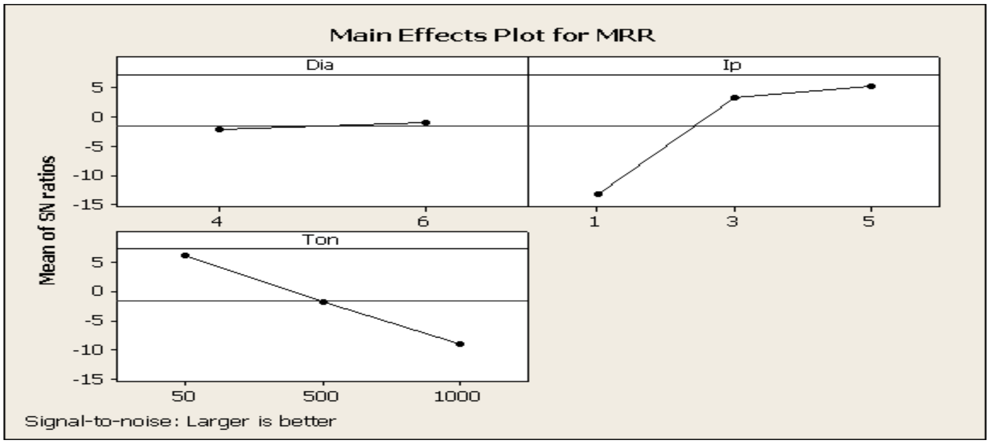

Figure 4.1 Main effect plot for S/N ratios (MRR)

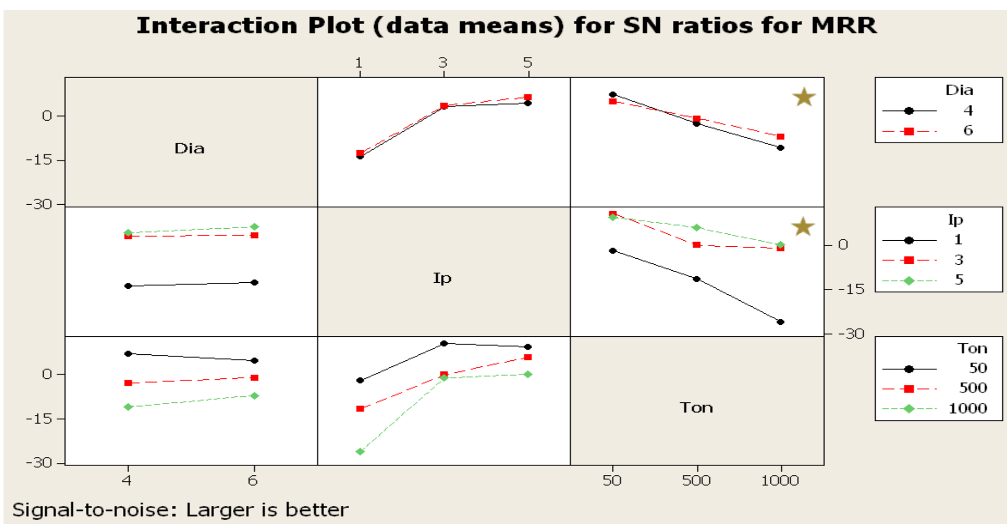

Figure 4.2 Interaction plot for MRR

V. CONCLUSION

In the gift study on the impact of machining responses are MRR, TWR and OC of the AISI P20 plastic mould steel element mistreatment the formed metal tool with internal flushing system tool are investigated for EDM method. The experiments were conducted below numerous parameters setting of Discharge Current (Ip), Pulse On-Time (Ton), and diameter of the tool. L-18 OA supported Taguchi style was performed for Minitab package was used for analysis the result and theses responses were part valid by experimentation.

Finding the results of MRR discharge current is most influencing issue then pulse length time and also the last is diameter of the tool. MRR enhanced with the discharge current (Ip).

As the pulse length extended, the MRR decreases monotonically

- In the case of Tool wear rate the foremost vital issue is discharge current then pulse on time and afterward diameter of tool.
- In the case of over cut the foremost vital issue of discharge current then diameter of the tool and no impact on pulse on time.

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