IJSRD - International Journal for Scientific Research & Development| Vol. 8, Issue 1, 2020 | ISSN (online): 2321-0613

Analysis and Optimization of Input Parameters of WEDM for MRR and SR by Using Taguchi Method on Hot Work Tool Steel A2

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Abstract— WEDM has changed the scenario of machining in the field of tool industry, aerospace, dies, moulds and counter cutting. WEDM is based on the principle of removal of material through electro erosion. This is a hybrid methodology which has overcome all the complex issues faced by the conventional machining processes. WEDM provides high material removal rate and good surface finishing with low tool wear rate so, this machining method is adapted by the manufacturing industries for machining of challenging jobs. The performance of the WEDM is estimated by the parameters such MRR, WWR, SR and kerf width but in this research work we studied the effect of input parameters on SR &MRR only. The objective of this study is to analyze the influence of input parameters such as TON, TOFF, IP, & WT on performance parameters. We have reviewed different types of optimization and analysis techniques but Taguchi design approach with L9 orthogonal array and ANOVA was applied to our study because these techniques are most frequent used optimization techniques. MRR is mostly influenced by the parameters TON, TOFF, WT, & IP as compared to other input parameters of WEDM.

Keywords: WEDM, MRR, Taguchi Method

I. INTRODUCTION

Whenever any material comes in to existence for any particular use it requires machining. It is a manufacturing process. In this process unwanted material is removed from the work piece and it is transformed in to a shape according to the customer requirement. All these materials have complicated geometries. Therefore, it is quite impossible to carry out the process of machining with the help of usual methods. Machining cleans away certain parts of the work piece to change them into final parts. At present in most of the industries two types of machining process have been utilized conventional and non- conventional machining process.

A. *Electro-Chemical Energy Process*

In this process, work piece submerged in the chemical solution and material removal from the work piece by using electrolytic dissolution process. This process includes

a) Electro-Chemical Machining (ECM)
b) Electro-Chemical Grinding (ECG)
c) Electro-Chemical Honing (ECH)
d) Electro-Chemical Deburring (ECD)

B. *Chemical Energy Process*

This process includes, machining of the work piece by the chemical reaction. Work piece is contact with the chemical solution (strong acidic or alkaline chemical reagent) with controlled etching during machining. Chemical Machining (CHM) is a type of this machining process.

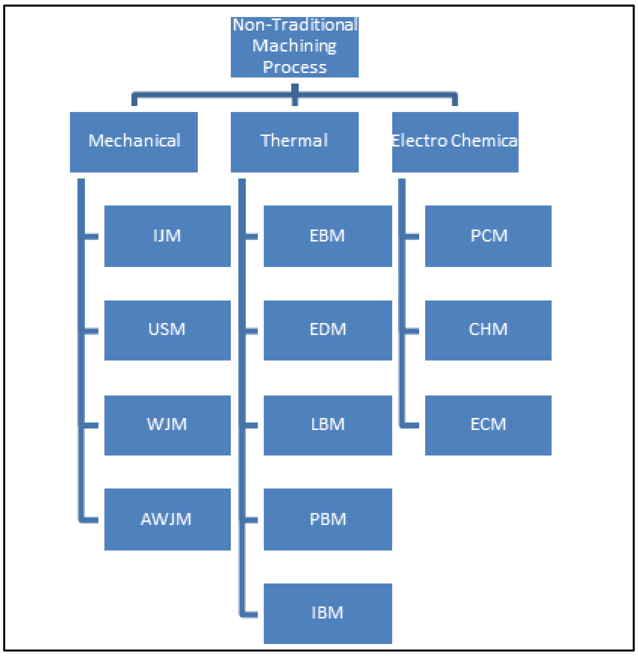

Fig. 1: Block diagram of Non-Conventional machining process

C. *Thermal Energy Process*

In thermal energy process, thermal energy is used to melt and vaporize small particles of work piece by applying the heat energy on the small area of work piece, the final product is obtained by repeating the process, this process comprises

a) Electric Discharge Machining (EDM)
b) Laser Beam Machining (LBM)
c) Plasma Arc Machining (PAM)
d) Electron Beam Machining (EBM)
e) Ion Beam Machining (IBM)

In the modern industries, utilization of advanced manufacturing technologies in metal cutting faces new challenges with development of new material such as ceramics, alloy steel, titanium alloy, nickel based alloy, and super alloys are widely used in various modern fields of industries and machining of these materials are difficult by conventional method because of material properties like hardness, toughness and impact resistance, therefore machining of these material by non-conventional process can be done easily. Among these procedures, EDM is broadly used in modern manufacturing industries because of its widely industrial application [1].

D. *Working Principle of EDM process*

It is a metal removal process. It is based on the principle of material removal in which a material is removed by giving an interrupted electric spark discharge between the electrode tool and the work piece. A potential difference between the tool and work piece is applied in this process. For this process it is essential that both apparatus and work material are to be conductors. Initially apparatus and material are submerged in to a dielectric medium. Commonly kerosene or de ionized water is utilized as the dielectric medium. It is necessary that a gap is maintained between the apparatus and material. Depending upon the applied potential difference (50 to 450 V) and the gap between the apparatus and material, an electric field would be established. Normally material is connected to anode and equipment is connected to the cathode of the generator. Cathode is a negative terminal whereas anode is a positive battery.

As soon as the electric field is established between the apparatus and material electrostatic forces are applied to the free electrons on the tool. In the situation where the bonding energy of the electrons is less, electrons would be transmitted from the tool. This type of emission of electrons is known as ‘cold emission’. After that cold emitted electrons are then accelerated in the direction of the job by means of dielectric medium. A collision among electrons and dielectric molecules takes place when these cold emitted electrons gain velocity and energy, and start moving towards the job. As a result of these collisions ionization of the dielectric molecule takes place. Ionization depends on the ionization energy of the dielectric molecule and the energy of the electron. With the increment in electrons speed, more positive ions and electrons are produced due to collisions.

As a result of this repeated process the concentration of electrons and ions in the dielectric medium between the tool and the job at the spark gap is increased. The concentration would be so high that the matter presented in that channel could be mark as “plasma”. It is necessary that the electrical resistance of such plasma channel would be exceptionally few. Thus surprisingly, a large number of electrons will flow from tool to job and ions from job to tool. This is called avalanche motion of electrons. This progress of electrons and ions can be considered as a spark.

In this way the electrical energy is exhausted as the thermal energy of the spark. The high-speed electrons then impose on the job and ions on the tool. The kinetic energy of the electrons and ions would be transformed into thermal energy or heat flux depending upon their collision with the surface of the job and tool respectively. As a result of this intense localized heat flux a large immediate and restricted increase in temperature takes place. It would be in excess of $10,000^{o}$C.

Due to this tremendous increase in temperature the process of material removal starts. The process of material removal takes place as a result of immediate vaporization of the material as well as due to melting. The molten metal is not absolutely detached but only partially. At the time of withdrawal of potential difference, plasma channel collapses. Due to this compression shock waves are produced on both the electrodes particularly at high spots on work piece surface, which are closest to the tool. As a result, molten material is removed and a hole is created around the site of the spark. The entire cycle of procedure take place within a few microseconds.

Therefore, it is said that, generally the removal of material in EDM happens due to development of shock waves as the plasma channel collapse owing to discontinuation of applied potential difference. Usually the material is made positive and the equipment is made negative. Consequently, the electrons hit the job. As a result, a hole is formed due to high temperature and melting and material removal. In the similar way, the positive ions are impose on the tool. Due to this tool wear take place. In EDM, voltage pulses are applied between the equipment and material with the help of generator. The applied voltage is irregular. Only sparking is preferred to a certain extent in place of arcing. Due to arcing localized material removal at a particular point take place whereas sparks get distributed all over the tool surface leading to uniform material removal.

II. LITERATURE SURVEY

Sharma P. et Al. (2017) used Taguchi design approach with Grey relational analysis (GRA) for robust design while machining Inconel 706 .The design was used for optimization of input parameters (pulse on time (T_{ON}), pulse off time (T_{OFF}), servo voltage (V) and wire feed (WF) on output parameters (material removal rate (MRR) and surface roughness (SR)). For experimentation, they used a 0.25 mm diametric zinc coated brass wire as tool electrode. For investigation they used Electronic Ekocut CNC wire cut electronic discharge machine (WEDM). Analysis of variance (ANOVA) and Principal Component Analysis (PCA) were used for the analysis of experiment results. After analysis of experimental results, they found that Ton and Toff are significant process parameters on MRR and SR. Theycalculated the optimized values (Ton-105µs, V- 32v, WF- 4m/min and T_{off} - 27µs) of process parameters on WEDM for better and efficient machining [9].

Mouralova KA. et Al. (2016) experimented on MAKINO EU 61 WEDM CNC Machine to study the comparison between four types of workpiece as titanium alloy (Ti-6Al-4V) with two types of heat treated processes and a thermally untreated workpiece of titanium alloy and iron-rhodium alloy on output parameter of surface roughness whereas input parameters were Ton, Toff, WF, I_P (Peak current) and V (Spark gap set voltage) .They used penta cut E brass wire with diameter 0.25mm as tool electrode. Analysis on surface roughness of the work pieces was done by FIB (focused ion beam fabrication) and surface morphology approach. After analysing the results, they found that only untreated Titanium alloy among the four workpiece materials had no sign of Globules [10].

Sharma H. et Al. (2016) provided an examination on outcome and optimization of input parameters for output parameters Cutting speed, Kerf width and SR in WEDM using H21 die tool steel as work piece material. Tungsten wire was used as tool electrode for this work. Discharge current, T_{ON}, T_{OFF}, WF and WT (Wire tension) was used as input process parameters. After analysis and optimization of experiments results, it was found that the average cutting speed was mostly affected by T_{ON}, T_{OFF} and WF during the rough cut and SR was not affected by any selected factor. Kerf width was mostly affected by discharge current, T_{ON}, T_{OFF} and WF during ruff cut [11].

Choudhuri B. et Al. (2016) described the influence of input parameters (T_{ON}, T_{OFF}, I_P, V and WT)on performance parameters (cutting speed and kerf width) for optimization. H21 tool steel was used as workpiece and Soft brass wire (0.25 mm diameter) as tool electrode on Elektra Sprintcut CNC WEDM. For this investigation, Experiments were designed by central composite design technique (CCD) and total number of experiments that were performed is 47. For optimization and analysis of experimental results two methodologies viz. RSM and ANN (artificial neural network modelling), particle swarm optimization (PSO) was used throughout. After optimization and analysis of experimental results, they concluded that ANN- particle swarm optimization (PSO) hybrid methodology is ideal technique than RSM and better alternative of RSM because of its optimal level of optimization of WEDM process parameters [12].

Goswami A. et Al. (2016) had performed experiment on Electronica Sprintcut CNC to examine the influence of input parameters like T_{ON}, T_{OFF}, I_P and wire off-set (W_O) on performance parameters i.e. MRR, SR and WWR. For the experiment they used Nimonic 80A alloy as Cutting material and Brass wire as tool. L27 orthogonal array of Taguchi methodology was applied for design of experiments. For analysis and optimization ANOVA and GRA techniques were used. After optimization and analysis of experimental results, they found that T_{ON} is the most significant parameter for MRR and SR. During trim cut machining it is also revealed that trim cut machining is compatible with high value of surface finish [13].

Rajmohan K. et Al. (2016) used Taguchi technique of L27 orthogonal array to examine the major influencing factors that affect the performance parameters MRR, SR and kerf width whereas the process parameters was T_{ON}, bed travel speed .For experimentation they used molybdenum wire with diameter of 0.18 mm and 2205 DSS alloy as workpiece material on EDM DK 7744 WEDM machine. ANOVA was used for analysis of experimental result. After analysis of experimental results, they found that T_{ON} is influential process parameter on SR and Kerf. They also concluded that value of SR and kerf width decreased with the increases in the level of T_{ON} [14].

Mandal A. et Al. (2015) researched on WEDM for process parameters like as T_{ON}, T_{OFF}, WF, WT, V and water pressure (WP) on performance parameters like as MRR, SR and Wire wear ratio (WWR). For experimentation, they used zn coated brass wire of 0.25 mm diameter and Nimonic C-263 alloy as workpiece material on Electra Maxicut 7348 CNC machine. RSM was used for D.O.E and optimization. ANOVA was used for analysis of experimental results. After optimization and analysis of experimental results, they found that Ton, Toff, V and WF are influenced process parameters on MRR. Ton, Toff and V are significant parameters on WWR and Toff is influenced process parameter on SR [15].

III. WORKPIECE MATERIAL

Due to presence of alloying elements tool steels are different from carbon steels. These all are iron based alloys and belong to various types of steel, exhibiting different properties like high hardness, high wear resistant and high strength after heat treatment process. In this research work, Cold work tool steel A2 material with dimensions are 150 mm x 100 mm x 10 mm is used as workpiece material for machining on WEDM. It is group A tool steel, type A2 tool steel are using most of manufacturing work due to its high hardness and non-deformation properties. Ingredients of A2 tool steel are molybdenum, magnesium, chromium, which provides hardness to it. It is cheaper than chromium type of tool steel because of less percentage of chromium content. The range of carbon is 0.5% to 2% which is used for minimum cracking and non-deformation.

Characteristics of Cold work tool steel A2:

1) Good wear resistance
2) Good machinability and hardenability
3) High stability
4) High compressive strength
5) Good toughness

Elements	Content in %
Carbon (C)	1 %
Chromium (Cr)	4.98%
Manganese (Mn)	0.88%
Silicon (Si)	0.24%
Vanadium (V)	0.24%
Molybdenum	0.98%
Nickel	0.02%
Sulphur (S)	0.017%
Phosphorus (P)	0.018%
Iron (Fe)	Balance

Table 1: Chemical Composition of workpiece

Physical Properties	Metric
Density	7.861 g/cm^3
Melting Point	1424°C

Table 2: Physical Properties of workpiece

Mechanical Properties	Metric
Hardness	60-64 HRC
Bulk Modulus	140 GPa
Shear Modulus	78 GPa
Machinability	70 % of 1 % of carbon tool steel
Elastic Modulus	191-210 GPa

Table 3: Mechanical Properties of workpiece

A. Applications of Workpiece

Tool steel A2 relatively easy to machine, so it has many areas of application for industrial purpose:

1) Thread rolling dies
2) Blanking tools
3) Punch dies
4) Trimming dies
5) Stamping dies
6) Forging dies
7) Shear blades
8) Gausses

B. Parameters of WEDM

In present research work, two types of parameters as process parameters and performance parameters are selected. Process parameters are independent while performance parameters are dependent on process parameters. Process parameters are required to run the WEDM.

C. Process parameters

There are following process parameters measured during experimentation:

1) Pulse on time:

The time interval in which voltage is applied across the tool electrode is known as pulse on time. The discharge of current in each cycle is represented by T_{ON}. It is an electrical parameter and spark is produced during this interval of time. 100 to 131 µs range is available on machine tool during step 1. Increase in T_{ON} results to single pule discharge energy due to which speed of cutting tool and surface roughness increases. Higher the value of Ton the surface roughness will also tends to higher value. Wire breakage may cause due to the higher value of discharge energy. T_{ON} measures in micro second (µs).

2) Pulse off time:

The time between two alternating spark measures in micro second and represented by T_{OFF}. It is an electrical parameter. No spark is generated in this interval of time because of the absence of voltage. 00 to 63 µs range is available on machine tool during step 1. Lower the value of T_{OFF} will give more number of discharges in given interval. Lower value of Toff increases the sparking efficiency and cutting rate. Wire breakage may cause due to lower value of T_{OFF}. Average gap current will reduce due to lower pulse duty factor.

3) Peak current:

The maximum value of current passing in given pulse through electrode is the peak value of current and it is represented by I_P. It is an electrical parameter and measure in ampere (A), the range of I_P can be set 1 to 12 A during machining operation. Cutting speed can be improved by increasing I_P value as a result pulse discharge energy increase.

4) Wire tension:

The wire tool electrode is being tensed between the wire guides (upper and lower), this position of wire is known as wire tension.it is represented by W_T and measured in newton; Thickness is directly proportional to W_T. The wire tool electrode can break due to Inappropriate setting of wire tension it may also produce inaccuracies in the machined workpiece. Following table 3.7 givesthe nominal values of wire tension for different setting during experimental work on WEDM. Minimum tension (for 0 setting of WT) is approx. 200~300 gms. It can be adjusted by clutch adjustment provided on feed spool mounting rod. This should be adjusted for different weight of spools.

Signal to Noise Ratio Single to noise ratio is also known as SN ratio, it is defined as the logarithmic function which helps to predict the variation between the experimental and targeted value. With the help of SN Ratio prediction and optimization of the experiment becomes quite easy.

There are total four conditions in SN ratio which are written below

a) Larger is better
b) Nominal is best
c) Nominal is best (default)
d) Smaller is better

Noise in the system produced due to the transformation of the energy in the system, there are some factors such as noise factor, control factor and non-control factors which have combined effect on the system. SN ratio evaluates all the factors in log equation so that a mathematical model can be designed to optimize the value.S/N ratio is used as a catalogue of strength because it defines energy transformation value. S/N ratio is calculated with the summation of the impacts of noise factors, input signal & control factors in a system on the output responses. The energy transformation quality is conveyed as the ratio of the transformed energy to perform the planned function to the energy transformed to other than the planned function. The S/N ratio is directly proportional to the quality function. Single to Noise ratio equations are shown in table 3.8 and the formula for S/N ratio is stated below:

$$\mathbf{S/N} = \frac{Energy\ transformed\ to\ perform\ the\ intended\ function\ (work\ done\ by\ signal)}{Energy\ transformed\ to\ other\ than\ the\ intended\ function\ (work\ done\ by\ noises)}$$

Signal to noise ratio	Goal of the experiment	Data characteristics	Signal-to-noise ratio formulas
Larger is better	Maximize the response	Positive	S/N =10*log(Σ(1/Y2)/n)
Nominal is best	Target the responses that you want to base the S/N ratio on standard deviat.	Positive, zero, or negative	S/N = -10 *log(σ2)
Smaller is better	Minimize the response	Non-negative with a target value of zero.	S/N = -10*log(Σ(Y2)/n)

Table 4: Single to Noise ratio equations

D. Degree of Freedom in DOE

Though, there is no noticeable analysis of DOF is useful to experimental data. DOF indicates all information about data set. In DOE processes, DOF is applied to portray as given in following four steps:

- DOF of a variable = number of levels of the variable
- DOF of a column = number of levels of the column
- DOF of an array = total of all column DOFs for the array
- DOF of an experiment = total number of results of all trial

IV. ANALYSIS & DISCUSSION OF RESULTS

In this chapter, we describe the effects of input parameters on output parameters (MRR and SR) of Wire EDM. The work material (Tool steel A2) is mounted on Electronica Sprintcurt 734 for the experiments and zinc coated brass wire was selected as tool electrode. All the experimental data is obtained through Taguchi Design method and experimental data is analyzed in Minitab-18 (statically analytical software) by using Taguchi methodology and ANOVA.

A. Experimental Results

After the machining process on Wire EDM, we calculated material removal rate by the formula (referring equation 3.1) and we used surface roughness tester for the purpose of calculating the surface roughness. Experimental results of MRR and SR with input parameters and their levels are shown in table 4.

Exp. No.	TON	TOFF	WT	IP	MRR	SR
1	115	50	8	220	11.177	2.152
2	115	55	9	225	11.579	2.415
3	115	60	10	230	12.230	2.348
4	120	50	9	230	12.155	2.379
5	120	55	10	220	11.630	2.470
6	120	60	8	225	10.455	2.050
7	125	50	10	225	11.929	2.269
8	125	55	8	230	12.556	2.325
9	125	60	9	220	11.824	2.302

Table 5: Experimental Data of MRR and SR

B. *Description of analytical result for MRR*

Taguchi design methodology is used for design of experiments and analysis of experimental results for MRR. By using this method, we get influence input parameter on MRR in the form of delta and rank. Delta and rank values of each input parameter shows the high and less influence on MRR. Delta and rank are represented by numerical values in tabular form (shown in table 4.3). SN ratio and mean data was obtained through analysis in Minitab software by Taguchi method, analytical results of MRR are shown in table 4.2. in table 4.2, SNRA is SN ratio data and MEAN data are equivalent to MRR and by taking “larger is better” approach in account for SN ratio. SN ratio values and Means values of different input parameters and numeric value of delta and rank are shown in response table 4.3 and 4.4 respectively. The input parameter which has rank 1 is most affective and which have rank 4 is less affective parameter on MRR. As shown in response table 4.3 and 4.4, by referring rank value IP, TON are most affective and WT, TOFF are less affective input parameters on MRR. The effect and graphical representation of each input parameter and their level is shown in figure 4.1 (SN ratios) and 4.2 (Means). As shown in figure 4.1, with increases in the level (1st to 2nd level) of TON, IP then the value of MRR decrease but when we increases the level (2nd to 3rd level) then we observes instant increment in the value of MRR, when we increase the levels (1st to 3rd) of WT then the value MRR continuously increase and the value of MRR firstly increase and then instant decrease with increases in the levels of Toff (1st to 3rd level), so we can say that the IP and TON have the most affective and WT , TOFF have less effective input parameters on MRR. Figure 4.3 shows the plots for residual, which are used to calculating the data for the problems such as non-constant variance, non-random variation, non-normality and higher order relationship with observation order.

C. *SN Ratio for MRR*

As we discussed in chapter-3(article 3.5.3) and here we use “Larger is better” quality characteristic of SN Ratio is perfect in case of MRR for analysis purpose. We need maximum material removal rate in less span of time so we choose larger is better characteristic of SN ratio. It is for MRR is calculated by the following equation 4.1

$$\text{S/N ratio} = -10 \log10 \left(\text{sum}\,(1/y^2)/N\right)$$

Where y= mean value and N= total no. of experiments

Exp. No.	TON	TOFF	WT	IP	MRR	SNRA1	MEAN1
1	115	50	8	220	11.177	20.9665	11.177
2	115	55	9	225	11.579	21.2734	11.579
3	115	60	10	230	12.230	21.7485	12.230
4	120	50	9	230	12.155	21.6951	12.155
5	120	55	10	220	11.630	21.3116	11.630
6	120	60	8	225	10.455	20.3865	10.455
7	125	50	10	225	11.929	21.5321	11.929
8	125	55	8	230	12.556	21.9770	12.556
9	125	60	9	220	11.824	21.4553	11.824

Table 6: Analytical Results of MRR

Level	TON	TOFF	WT	IP
1	21.33	21.40	21.11	21.24
2	21.13	21.52	21.47	21.06
3	21.65	21.20	21.53	21.81
Delta	0.52	0.32	0.42	0.74
Rank	2	4	3	1

Table 7: Response Table for Signal to Noise Ratios (Larger is better)

Level	TON	TOFF	WT	IP
1	11.66	11.75	11.40	11.54
2	11.41	11.92	11.85	11.32
3	12.10	11.50	11.93	12.31
Delta	0.69	0.42	0.53	0.99
Rank	2	4	3	1

Table 8: Response Table for Means

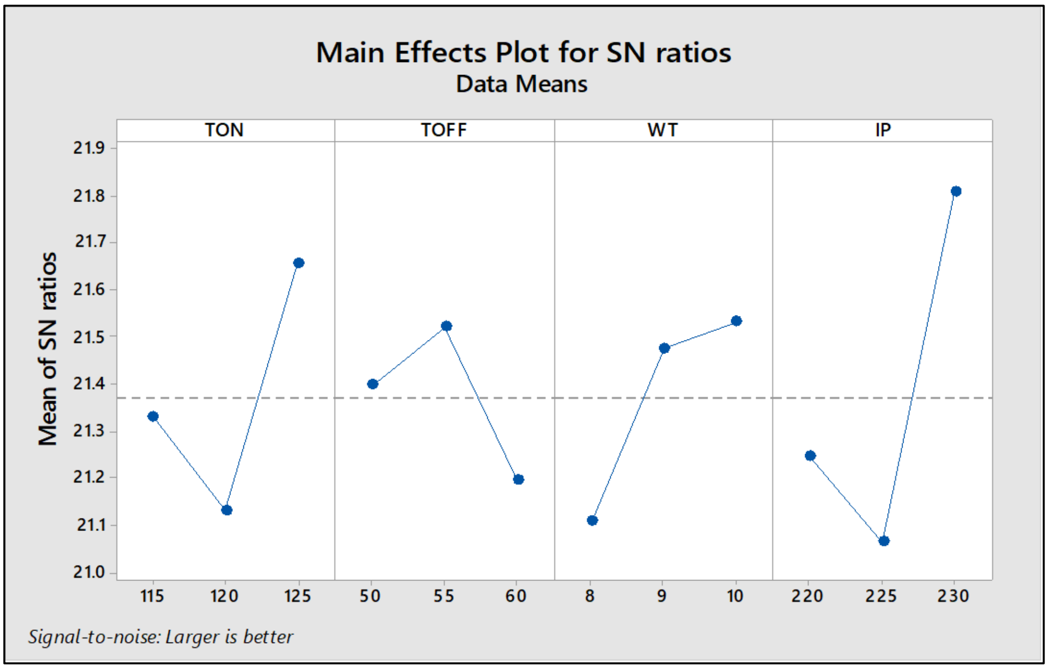

Fig. 2: Effect of input parameter on MRR (SN ratios)

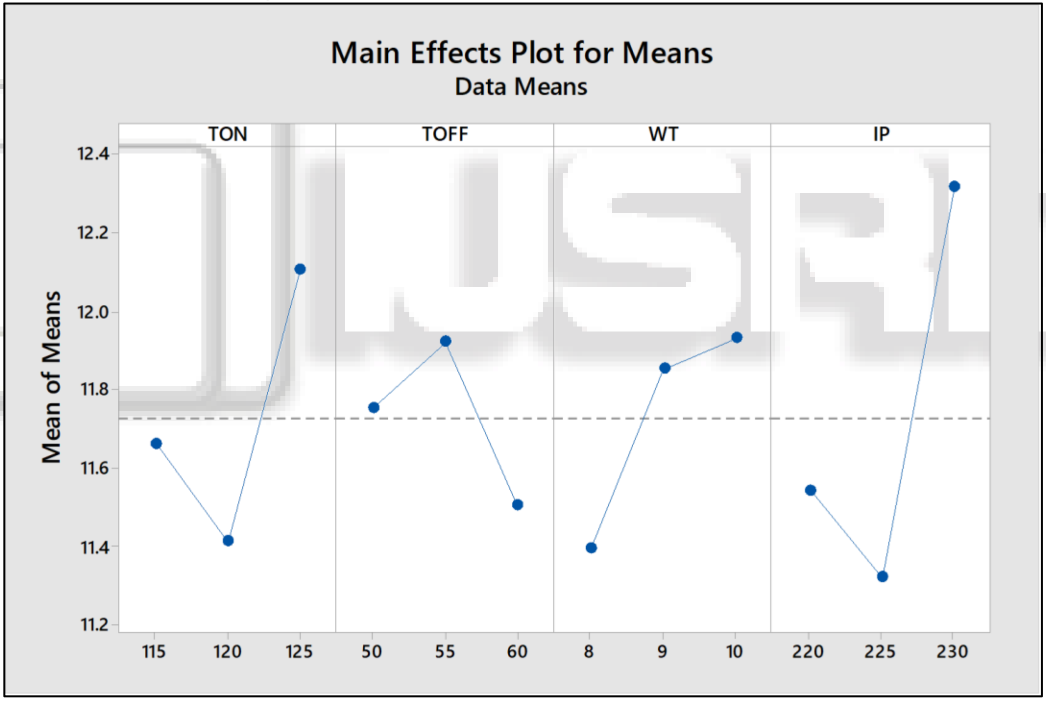

Fig. 3: Effect of input parameter on MRR (Means)

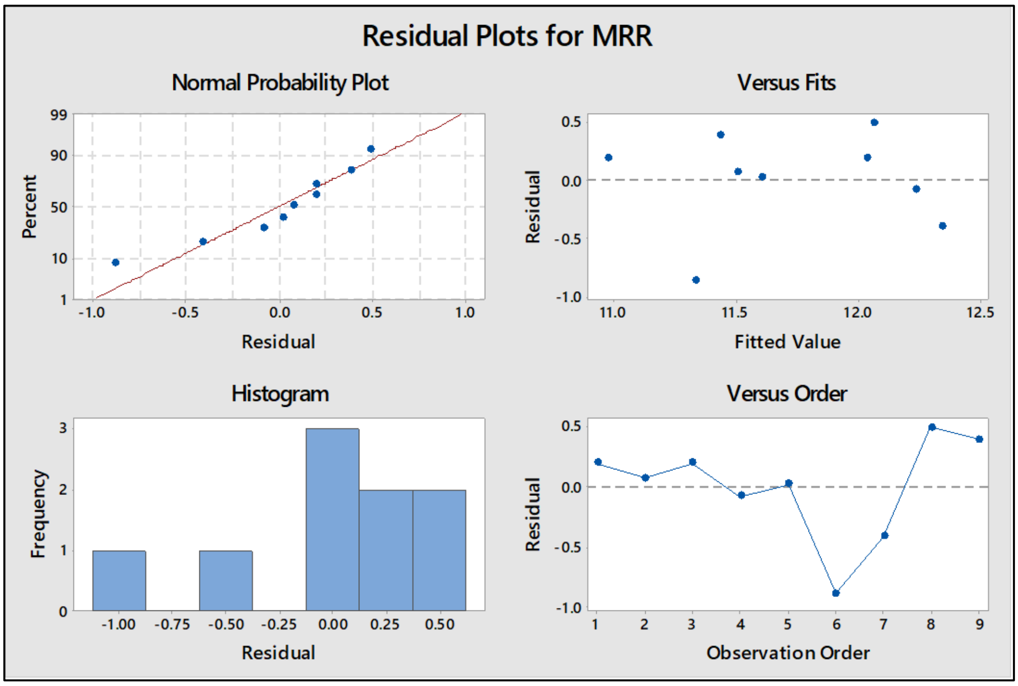

Fig. 4: Residual Plot for MRR

V. CONCLUSION

The effect on MRR and SR are experimentally tested by using four input parameters like T_{ON}, T_{OFF}, WT and IP in WEDM using Tool Steel A2. Taguchi and ANOVA are respectively used to analyse and evaluate the experimental results.

A. *Conclusion for MRR*

I_P and T_{ON} are the most significant input parameters while T_{OFF} and WT are less effective for MRR. The third level of IP has highest value (larger is better) for MRR i.e. 12.31 mm^3/min. It is found that IP has maximum contribution (50.21%) followed by T_{ON} (23.39%), WT (17.45%) and T_{OFF} (8.94%) in WEDM operation (From ANOVA Table 4.I). Optimum setting of input parameters comprises of $T_{ON}3=125$ µs, $T_{OFF}2= 55$µs, $I_P3= 230$ A, and WT3= 10 N, during machining on WEDM for tool steel A2 at which the maximum value of MRR can be obtained.Predicted optimum value for MRR with $T_{ON}3$, $T_{OFF}2$, I_P3, and WT3 is found to be 13.082 mm^3/min. The 95 % confidence interval (CI_{CE}) for MRR is $11.017 \leq 13.082 \leq 15.147$ mm^3/min. From regression analysis it is found that the experimental values of MRR are much better than the predicted values.

B. *Conclusion for SR*

WTand T_{OFF} are the most significant input parameters whileI_P and T_{ON} are less effective for SR. The first level of WT has lowestvalue (smaller is better) of SR i.e. 2.176 micron. It is found that WT has maximum contribution (52.16%) followed by T_{OFF} (34.58%), IP (13.13%) and T_{ON} (0.105%) in WEDM operation (From ANOVA Table 4.R). Optimum setting of input parameters comprises of $T_{ON}3=125$ µs, $T_{OFF}3= 60$µs, $I_P2= 220$ A, and WT1= 8 N, during machining on WEDM for tool steel A2 at which the minimum value of SR can be obtained.Predicted optimum value for SR with $T_{ON}3$, $T_{OFF}3$, I_P2, and WT1 is found to be 2.050 micron. The 95 % confidence interval (CI_{CE}) for SR is $1.560 \leq 2.050 \leq 2.540$ micron. From regression analysis it is found that the experimental values of SR are not much differing than the predicted values.

C. *Scope for future work*

In this experimental study, effects of input parameters on output parameters of WEDM is evaluated while machining cold work tool steel A2. Zinc coated brass wire was used as tool electrode in Electronica Sprintcut 734 WEDM machine to perform experiments. T_{ON}, T_{OFF}, I_P, and WT are used as input parameters with three levels, while MRR and SR as output parameters. Taguchi's L_9 orthogonal array was selected for DOE on WEDM. ANOVA is used in research work for optimization and analysis of experiments results.

Future scope forWEDMis designed as follows: -

1) Results of this experimental study can be compared by using same parameters and levels on different WEDM machines like Electronica Ecocut, Electronica Esuntek etc.
2) Experiments can be done by taking different wire electrodes other than zinc like molybdenum, tungsten, copper etc. and the results can be compared with the present results.
3) Different orthogonal array like L_{16}, L_{18}, L_{25}, L_{32} and L_{50}might be used for the experiments and analysis. Some new techniques other than Taguchi and ANOVA can be used for better results.
4) The experiments of this work can be done with combination of four or five levels with moreinput parameters.
5) For better optimization of cold work tool steel A2 it can be machined with other unconventional machining methods such as ECM, LBM, EBM, AJM and WJM etc.

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