# Optimizing The Process Parameters of WEDM For MRR Using Taguchi Technique on ASTM-A681

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***Abstract***- *The main objectives of this study to investigate and evaluate the effect of different input process parameters (Gap voltage, wire feed rate, pulse on time, pulse off time) on material removal rate as response parameters have been considered for Each Experiment. Experimentation was planned as per Taguchi's L16 Orthogonal array during machining of ASTM A681 H13 steel alloy. Brass wire electrode with 0.25mm Diameter was used as tool in the Experiments. Taguchi design methodology will be used for design of experiment and L16 orthogonal array will be used for present study. Maximum MRR is obtained by setting the parameters as Gap voltage 43, Wire Feed 9.5, Pulse On Time 3, Pulse Off Time 9.*

***Keywords***- ANOVA, ASTM-A681, MRR, TAGUCHI, WEDM.

## I. INTRODUCTION

In modern mechanical industry, materials of high hardness, toughness and impact resistance are preferred for use. Like these materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including ultrasonic machining, electrochemical machining, electrical discharging machine (EDM) etc. are applied to machine for such difficult machine materials. WEDM process is a thin wire electrode transforms electrical energy to thermal energy used for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials are machined as their hardness and toughness is so high. WEDM is capable of producing a accurate, smooth, corrosion and wear resistant surface. WEDM is considered as a unique adoption of the conventional EDM process, which uses an electrode to initialize the sparking process. In WEDM electrode is of copper, brass or tungsten wire of diameter 0.05-0.30 mm. Thin wire is used for very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire, eliminating the mechanical stresses during machining. (WEDM) technology has shown tremendously since it was first applied more than 30 years ago.

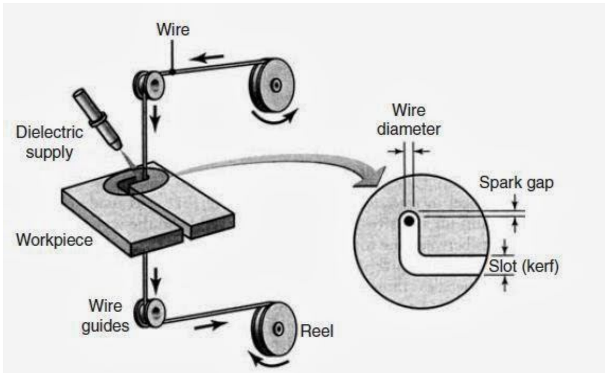



Fig.1 Shows the systematic setup of WEDM

## II. LITERATURE REVIEW

**Gajjar and Desai 2015 [1]** investigated the process parameters for surface roughness, kerf width and MRR in wire electric discharge machining of EN -31 tool steel. Taguchi design of experiments was used to conduct the experimentation by varying the process parameters servo voltage, pulse-on-time and pulse-off-time. Grey relational method was used to find the optimal values for surface roughness, kerf width and material removal rate.

**S. B. Prajapati et.al 2013 [2]** In this investigation Wire EDM most progressive non-conventional machining process in mechanical industries. Many parameters affect the performance of Wire EDM. Few of them investigated in this research paper. The effect of process parameter like Pulse ON time, Pulse OFF time, Voltage, Wire Feed and Wire Tension on MRR, SR, Kerf and Gap current were studied by conducting an experiment. Response surface methodology was used to analyze the data for optimization and performance. The AISI A2 tool steel was used as work piece material in the form of square bar.

**Jaganjeet Singh et.al 2013 [3]** To investigate the effects of the various WEDM process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized. In this work the effects of various process parameters of WEDM like pulse on time (TON), pulse off time (TOFF), Servo voltage (SV), peak current (IP), Wire feed (WF) and Wire tension (WT) have been investigated to reveal their impact on material removal rate of P20 Tool Steel by using Elektra Sprint cut 734 WEDM machine. Moreover the surface roughness was measured by MarSurf PS1 surface-roughness measuring instrument. The experiments were designed by Taguchi methodology. L18 Orthogonal Array was used and Results of the experimentation were analyzed by MINITAB software analytically as well as graphically.

**Jaganathan P. et.al 2012 [4]** In this research investigated the effect of wire electric discharge machining process parameters like applied voltage, pulse width, pulse interval and speed and response parameters like surface roughness and material removal rate. The design of experiment (DOE) in done in taguchi L27 orthogonal array. The experiments were conducted on EN 31 alloy steel material having composition of (1.0% C, 0.50% Mn, 1.40% Cr and 0.20% Si) as a work specimen. The work piece was in the form of rectangular plate having dimensions of 100mm*50mm*8mm. work piece had been machined using molybdenum wire was used as a tool having diameter of 0.20mm and deionized water as a dielectric fluid. Each sample had been machined for a length of 4 mm. Machining time were measured using a stop watch. After machining to calculate the MRR and Ra(surface roughness) values were measured using Mitutoyo SJ 201P surface tester.

**Prof. S.R.Nipanikar 2012 [5]** In this paper, the cutting of D3 Steel material using electro discharge machining (EDM) with a copper electrode by using Taguchi methodology had been reported. The Taguchi method was used to formulate the experimental layout, to analyze the effect of each parameter on the machining characteristics, and to predict the optimal choice for each EDM parameter such as peak current, gap voltage, duty cycle and pulse on time. We found that these parameters have a significant influence on machining characteristic such as material removal rate (MRR), electrode wear rate (EWR), radial overcut (ROC). The analysis used Taguchi method reveals that, in general the peak current significantly affects the MRR, EWR and ROC.

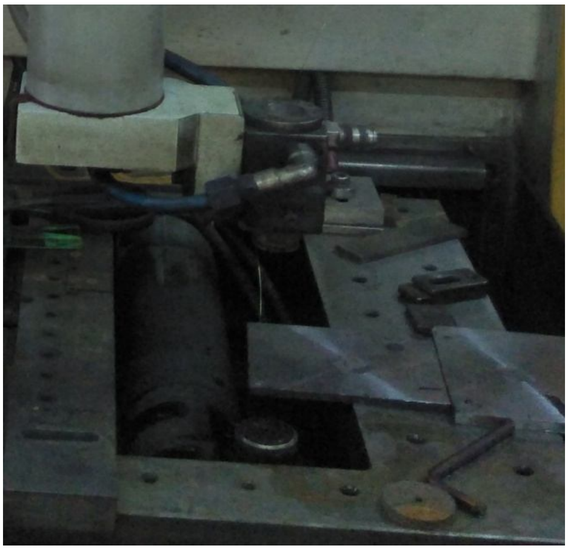
## III. EXPERIMENTAL SET-UP

The machine used for experiments is Electronica Maxicut e CNC wire cut EDM incorporated with brass wire technology. The machine consists of a coordinate worktable, wire running system, wire frame, Micro computer based control cabinet and dielectric supply system.


Electronica Maxicut e CNC wire cut EDM


Electronica Maxicut e CNC wire cut EDM Machine


Control Cabinet



Wire Electrode & Work Table

| WORK TABLE | |
|---|---|
| Design | Fixed column, moving table |
| Table size | 440 x 650 ×300 mm |
| **MAX.WORK PIECE DIMENSION** | |
| Max. work piece height | 200 mm |
| Max. work piece weight | 500 kg |
| Main table traverse (X,Y) | 300 x 400 mm |
| Aux. table traverse (U,V) | 80 x 80 mm |
| Wire electrode diameter | 0.25 mm (std.) 0.15, 0.20 mm (opt.) |
| **PULSE GENERATOR** | |
| Pulse Generator | Pulse Generator |
| Pulse peak voltage | 1 Step |
| CNC Controller | EMT 100W-5 |
| Input power supply | 8.3 phase, AC, 415 V , 50 Hz |
| Connected load | 10 kVA |
| Average power consumption | 6 to 7 kVA |
| **DIELECTRIC SYSTEM** | |
| Dielectric Unit | DL 25 P |
| Dielectric fluid | Deionised water |
| Tank capacity | 250 Litters |
| Cooling system | 1700 k Cal |

## IV. WORKPIECE MATERIAL SELECTION\

The material selected for this dissertation work is ASTM A681 H13 Alloy Steel. Chemical composition of this material is shown in table given below. ASTM A681 H13 has the wide applications in stamping dies, metal cutting tools or any other industries because of its high strength and heavy weight. In general the edge temperature under expected use is an important determine of both composition and required heat treatment.

Density (kg/m$^3$) – 7750, Melting Point (Deg F) – 2600
Specific Gravity - 7.8, Modulus of Elasticity Tension – 29

| CHEMICAL | REQUIRED VALUE | OBTAINED VALUE |
|---|---|---|
| Carbon | 0.35 - 0.45 | 0.40 |
| Manganese | 0.20 – 0.60 | 0.40 |
| Phosphorus | 0.03 | 0.03 |
| Sulphur | 0.03 | 0.03 |
| Silicon | 0.80-1.25 | 1.10 |
| Chromium | 4.75 – 5.50 | 5.10 |
| Vanadium | 0.30 – 0.60 | 0.50 |
| molybdenum | 1.10 – 1.60 | 1.30 |

## V. METHODOLOGY

Taguchi's approach is a method for improving the quality of a product through minimizing the effect of variation without eliminating the causes. Reducing in variation may be the same as increasing in S/N ratio. The S/N ratio can be defined as nominal-the-best, smaller-the-better or larger-the better according to the characteristics of the problem. Since the response is Material removal rate, S/N ratio is defined to be Larger the better. Taguchi's robust design is a simple, systematic and more efficient method to determine optimum or near optimum settings of design parameters. Many researchers have attempted to analyze and optimize a single performance characteristic of a manufacturing process using Taguchi methodology. In this present work, optimization of WEDM operations using Taguchi's robust design methodology with single performance characteristics is proposed. The system involves deciding the best values/levels for the control factors. The signal to noise (S/N) ratio is an ideal metric for the purpose. An important class of design optimization problem requires minimization of the variance while keeping the mean on target. Between the standard deviation and mean, it is typically easy to adjust the mean on target, but reducing the variance is difficult. Therefore, the designer should minimize the variance first and then adjust the mean on target. Among the available control factors most of them should be used to reduce variance. Only one or two control factors are adequate for adjusting the mean on target. The design optimization problem can be solved in two steps:
Step.1 Maximize the S/N ratio. Maximizing this S/N is to maximize the mean and to minimize standard deviation. This is the step of variance reduction.

Step.2 Adjust the mean on target using a control factor that has no effect on S/N ratio. This is the step of adjusting the mean on target.

## VI. SELECTION OF CUTTING PARAMETERS

Throughout this dissertation work input parameters considered for Wire cut EDM are machining parameters like as wire feed, gap voltage, pulse on time and pulse off time and output parameters is material removal rate.

| Process parameters | Symbols | Units | Levels Selected | | | |
|---|---|---|---|---|---|---|
| | | | Level 1 | Level 2 | Level 3 | Level 4 |
| Wire feed | WF | m/min | 2.5 | 5.5 | 7.5 | 9.5 |
| Gap Voltage | GV | volt | 38 | 43 | 48 | 53 |
| Pulse on-time | $T_{on}$ | µs | 3 | 5 | 7 | 9 |
| Pulse off-time | $T_{off}$ | µs | 3 | 5 | 7 | 9 |

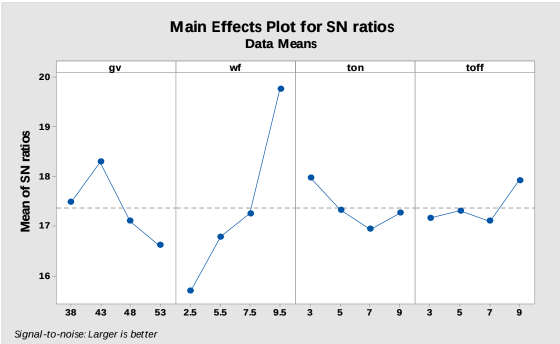
| Sr. No. | Fixed Parameters | Set Value |
|---|---|---|
| 1 | Wire material | Brass (0.25mm) |
| 2 | Peak current (IP) | 230 |
| 3 | Flushing pressure (kgf/cm2) | 5.5 |
| 4 | Wire Tension (gms) | 550 |

As per table, L16 orthogonal array of "Taguchi method" has been selected for the experiments design in MINITAB 18.

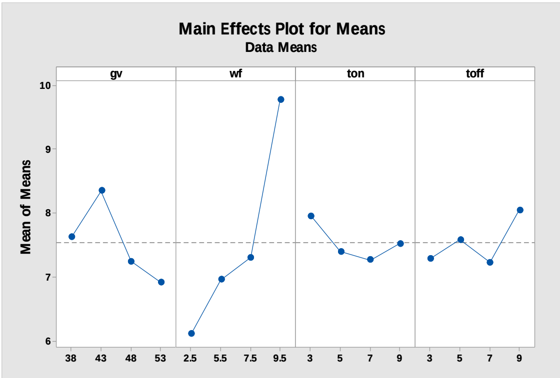
## VII. EXPERIMENTAL RESULTS

Sixteen experiments were performed to find how the output parameter varies with the variation in the input parameters according to the experimental design given by theMINITAB 18.

| GV | WF | $T_{ON}$ | $T_{OFF}$ | MRR | SNRA1 | MEAN1 |
|---|---|---|---|---|---|---|
| 38 | 2.5 | 3 | 3 | 6.7675 | 16.60857 | 6.7675 |
| 38 | 5.5 | 5 | 5 | 6.7449 | 16.57951 | 6.7449 |
| 38 | 7.5 | 7 | 7 | 6.5632 | 16.34231 | 6.5632 |
| 38 | 9.5 | 9 | 9 | 10.4566 | 20.38781 | 10.4566 |
| 43 | 2.5 | 5 | 7 | 6.578 | 16.36188 | 6.578 |
| 43 | 5.5 | 3 | 9 | 8.4334 | 18.52005 | 8.4334 |
| 43 | 7.5 | 9 | 3 | 7.6334 | 17.65436 | 7.6334 |
| 43 | 9.5 | 7 | 5 | 10.7442 | 20.62348 | 10.7442 |
| 48 | 2.5 | 7 | 9 | 5.8484 | 15.34074 | 5.8484 |
| 48 | 5.5 | 9 | 7 | 6.7286 | 16.55849 | 6.7286 |
| 48 | 7.5 | 3 | 5 | 7.5762 | 17.58903 | 7.5762 |
| 48 | 9.5 | 5 | 3 | 8.8247 | 18.914 | 8.8247 |
| 53 | 2.5 | 9 | 5 | 5.2679 | 14.43275 | 5.2679 |
| 53 | 5.5 | 7 | 3 | 5.9273 | 15.45714 | 5.9273 |
| 53 | 7.5 | 5 | 9 | 7.4412 | 17.43286 | 7.4412 |
| 53 | 9.5 | 3 | 7 | 9.0515 | 19.13441 | 9.0515 |




Effect of various factors on SN ratios




Effect of various factors on Means

In the above graphs effects of various factors i.e. gap voltage, wire feed, pulse on time, pulse off time is shown on material removal rate, the results of which are discussed below:

1. It is clear from the graph that the MRR is very small at low values of gap voltage and as the gap voltage is increased MRR is increased corresponding to gap voltage. When the voltage between the two electrodes is increased, the intensity of the electric field in the volume between the electrodes becomes greater than the strength of the dielectric, which breaks down, allowing current to flow between the two electrodes. As a result, material is removed from the electrodes.
2. This is the speed at which the wire is fed to cut the work piece. The increase in wire feed rate leads to increase in MRR. The variation of curve in graph shows that as the wire feed increases results in increase in MRR. So we can say that as the cutting speed is increased along with the wire feed rate then the MRR is increased correspondingly.
3. During pulse on time controlled sparks are produced between work piece and electrode which helps in erosion and hence precisely melts and vaporize the material. The variation of curve in graph shows that as the pulse on time decreases results in decrease in MRR. So we can say lesser the pulse on time higher the MRR.
4. During pulse off time pressurized dielectric fluid cools the material and flushes away the eroded particles. The variation of curve in graph shows that as the pulse off time increases results in increase in MRR. So we can say higher the pulse off time higher the MRR.

**Regression Analysis of Variance for MRR**

$$MRR=7.36 - 0.0647\ GV + 0.4758\ WF - 0.072\ T_{ON} + 0.096\ T_{OFF}$$

| SOURCE | DF | Adj SS | Adj MS | F-Value | P-Value | %C |
|---|---|---|---|---|---|---|
| GAP VOLTAGE | 3 | 4.518 | 1.5061 | 4.12 | 0.137 | 11.91 |
| WIRE FEED | 3 | 29.571 | 9.8572 | 27.00 | 0.011 | 77.99 |
| PULSE ON TIME | 3 | 1.069 | 0.3562 | 0.98 | 0.508 | 2.82 |
| PULSE OFF TIME | 3 | 1.664 | 0.5547 | 1.52 | 0.370 | 4.39 |
| ERROR | 3 | 1.095 | 0.3651 | | | 2.89 |
| TOTAL | 15 | 37.918 | | | | |

From the results of the ANOVA table, it is clear that wire feed is found to be the most significant factor P-value 0.011 which is less than 0.05 & its contribution to MRR is 77.99%.

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