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# Analysis of Process parameters of EN8 steel processed with Wire EDM

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**ABSTRACT:** In the current exploration, utilizing the Taguchi method, EN 8 steel is proposed as a solitary reaction enhancement process for Wire cut EDM. The handling attributes being considered are the material expulsion rate and unpleasantness of surface alongside machined layer surface morphology. The exploration utilizes expected examinations led utilizing Taguchi plan procedure (L9 Orthogonal cluster). Analyses were performed under various heartbeat on-schedule, beat off-time, and pinnacle forces. A symmetrical sign to-clamour exhibit (S/N) and fluctuation examination (ANOVA) were utilized to explore the level of material evacuation and surface harshness in EN 8 steel's WEDM. The request shows that the pace of material expulsion and surface unpleasantness, alongside surface morphology. From this examination, it could be deduced that the pace of material expulsion diminishes first and afterward after heartbeat on-time diminishes, with an expansion in beat off time and unpleasantness of surface. In the investigation of microstructure, Crater increments on machined surface with heartbeat increments on schedule, while Debris increments with top current increments and heartbeat off time diminishes. Because of lopsided warming or cooling, crakes additionally create.

**Keywords**: EN-8 Steel, Morphology, Wire EDM, ANOVA, Microstructure,Roughness of Surface

## I. INTRODUCTION

Wire cutting Electrical-Discharge Machining (WEDM) is an EDM variation utilizing an extremely slight wire which goes about as a cathode. Generally, unique metal wires are utilized, the wire is taken care of step by step through the material and the electric releases are sliced through the wire. WEDM for the most part happens in a water shower. In this machinng, on the off chance that you experience a procedure under a magnifying instrument, the wire itself doesn't legitimately contact the metal that will be cut; electrical releases only evacuate little amounts of material and permit the wire to go through the workpiece. A release happens between two anode and cathode focuses, exceptional warmth is made close to the softening zone and materials vanish in the starting region[1, 2].

WEDM is an ordinarily known technique for expelling non-conventional material used to deliver unpredictable profile segments. In this machining, the work-pieces are machined with a persistent of electrical releases (sparkles) delivered between a moving wire (the cathode) accurately positioned and the workpiece. High recurrence exchanging or direct ebb and flow beats are released from the wire through protected dielectric liquid (water) into the workpiece with a little sparkle hole. WEDM strategy includes the dynamic disintegration impact of quick rehashed and particular releases of sparkles between the wire's terminal and work piece inundated in a fluid medium[3, 4].

WEDM is as of now a normally utilized industry method for the high-accuracy machining of a wide range of conductive materials of any quality, for example, metals, metal compounds, graphite or even certain earthenware materials. Most Wire-EDM machines utilized low start force and high machining capacity to stay aware of the beat creating circuit. Be that as it may, Since the vitality created by the high voltage sub circuit is too high to even think about obtaining a fine surface required, it isn't reasonable for the completing procedure, paying little heed to how short the beat on time is dispensed [5]. This technique is generally utilized for amazingly hard metals, which can't be taken care of utilizing customary machining strategies. It has been normally used to cut complex forms or fragile cavities. In any case, one major burden is that

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Wire-EDM works just with electrically conductive materials. On account of WEDM activity a wire cathode is utilized to assemble the suitable shape. Like a cheddar shaper the string is gone through the cheddar segment. The wire is quite often copper, and the wire is mounted on reels as copper wears without any problem. The wire is regularly ordinarily utilized metal or copper. This additionally takes into account the part being machined with a new terminal. The movement of the wire is coordinated in two (and now and again significantly more) headings by the gadget. This resembles each other CNC technique yet the shape is created freely in CNC EDM by managing the wire. By 1975, its noticeable quality became quickly because of a decent procedure. CNC framework was tended to into WEDM just towards the finish of the 1970s, coming about better improvement in the machining procedure [6].

Its wide range permitted it to cover the development, aviation and car enterprises and for all intents and purposes all regions of assembling of conductive materials. This is on the grounds that WEDM offers the best other option, or once in a while the main other option, to machining materials that are conductive, colorful, high quality and temperature resistive, conductive pottery designing with the assortment of mind-boggling shapes and profiles being made. WEDM has gigantic potential in the present metal slicing industry to accomplish significant dimensional accuracy, surface completion and segment or parts form age highlights. Moreover, wire costs contribute only 10 percent of the working expenses of the WEDM activity. WEDM forestalls the troubles of kick the bucket sinking EDM, since confused plan approaches are supplanted by moving conductive wire and wire direct relative development [6]. Metal expulsion system in wire electrical release machining includes basically material evacuation because of liquefying and vaporization brought about by the release of electrical sparkles made by beating A flow gracefully between the cathodes. In WEDM, negative anode is a consistently moving wire, and the positive terminal is the workpiece. Affected by dielectric fluid, the sparkles will create between two firmly dispersed anodes. Since low consistency and quick refrigeration, water is utilized as a dielectric in WEDM [7]. The applied voltage makes an ionized divert in the underlying stage between the working piece's nearest focuses and the wire cathodes. In the following stage, the genuine release happens with solid current stream and the opposition of the ionized channel steadily diminishes. The high current power further ionizes the cylinder and produces a substantial attractive field. This attractive field packs the ionized stream and aids limited warming. Indeed, even with exceptionally brief flashes, because of the change of electrons 'motor vitality into heat, terminal temperature can rise locally to a high worth, which is more than the liquefying purpose of the working material. The high vitality thickness disintegrates a bit of the material from both the wire and the workpiece by liquefying and disintegrating locally and is in this way the prevailing instrument for warm disintegration.

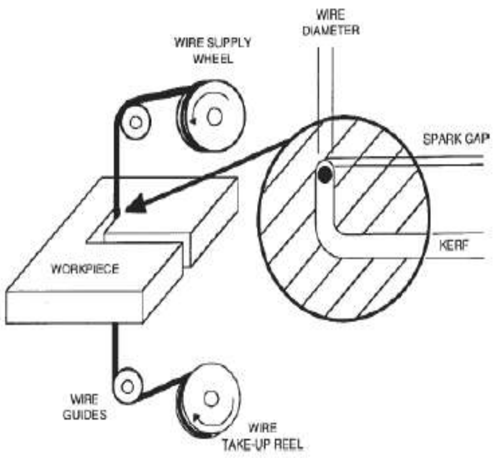


**Fig. 1** Schematic representation of WEDM cutting process [8]

## II. DESIGN OF EXPERIMENT

### Taguchi Method

Taguchi built up a technique for doing arranged examinations, including an expert's manual. This methodology took try plan from the selective space of the analyst and put it all the more altogether into the area of assembling. His discoveries have explained the professional's work by advancing the utilization of less exploratory plans and by offering a decent perspective on the idea of the varieties and the monetary ramifications of value designing in the assembling scene. Taguchi presents his technique utilizing exploratory engineering [9-11].

The motivation behind the boundary improvement is to advance the procedure boundary esteem condition so as to expand the presentation qualities and set the item boundary esteems under ideal procedure boundary esteems. Furthermore, it is accepted that the ideal boundary estimations of the procedure acquired from the boundary configuration are heartless toward changes in encompassing conditions. The production of boundaries is along these lines the key advance in Taguchi's procedure of accomplishing high caliber without cost increments. Essentially, the Fisher-manufactured old-style boundary design is intricate and not very easy to understand as the quantity of procedure boundaries increments [5, 12]. To take care of this issue, with only a set number of procedures, this strategy utilizes a course of action of symmetrical clusters to assess entire boundary space. For count of the fluctuation between the trial esteems and the ideal qualities, a misfortune work is set. Taguchi proposes that the misfortune work be utilized to quantify yield qualities that veer off from the ideal worth. Moreover, the estimation of the misfortune work is moved into a sign to clamor proportion (S/N). Ordinarily, there are three kinds of execution attributes in the S/N proportion investigation which are better the lower, the better the higher and the better the ostensible. For expanding interface boundary, the S/N proportion is a trial subordinate S/N PC [13-15]. Despite the sort of yield, the more grounded yield highlight is related with the higher S/N proportion. Henceforth ideal measure of the machining boundary is the point with the most elevated investigation of S/N and ANOVA, and the One can foresee the ideal blend of procedure boundaries. At long last, a confirmation test is performed to check the ideal gadget boundaries got from the model boundary. The Taguchi technique is embraced to accomplish most extreme machining proficiency inside the WEDM. S/N proportion was gotten utilizing Minitab 14 program [16 - 21].

• Larger is better (maximum): S / NLB=-10 log ((1/n)

• Smaller is better (minimum): S / NSB= -10 log ((1/n) = $yi^2$)

Where, n is the quantity of perceptions or rehashes of the tests and y is the watched information. We will utilize S/N to decrease vulnerability around a given objective, S/NL to advance the framework when the reaction is as extensive as could reasonably be expected and S/NS to advance the framework when the reaction is as little as could be expected under the circumstances. Level factor advancement of the related S/N proportion is ideal. The accompanying advances are remembered for the utilization of the Taguchi Process Parameter Model to upgrade a multi-yield cycle [11, 18-20].

- Define the presentation characteristics, and pick appraisal process boundaries.
- Determine the quantity of rates and possible communications between the strategy boundaries.
- Choose the right symmetrical cluster, and appoint symmetrical rundown exhibit boundaries. Perform symmetrical exhibit-based examinations;
- Use the S/N proportion and ANOVA to test the results of the analyses.
- Select the ideal measure of gadget boundaries.
- Test ideal gadget boundaries utilizing the confirmation check.

## III. EXPERIMENTAL SETUP

Experiments are conducted on an Electronica Ecocut Wire-EDM machine, ELPULS15. The machine is as shown in the figure - 4.1. The Wire electrical release machine is remembered for the 'non-customary' or 'non-ordinary' gathering of machining strategies. In a perfect world, WEDM can be as observed as a progression of breakdown and reclamation of the fluid dielectric in the middle of the cathodes.The machine is available at “Maryam Engineering Works”, Qaiserbagh Lucknow.Specifications of ELECTRONICA ECOCUT Wire-EDM machine are given in table 1.

**Table 1 Specifications of ELECTRONICA ECOCUT Wire-EDM**

| | |
|---|---|
| Design | Fixed column, moving table |
| X & Y travel | 250 x 350 mm |
| Max. work height | 200 mm |
| Max. table size | 370 x 600 mm |
| Max. cutting speed | 370 mm/min |
| Taper | $5^0$ over 100 mm |
| Best surface finish | 1.2 µm $R_a$ |
| Wire electrode diameter | 0.25 mm (standard),0.15 mm,0.20mm (optional) |
| Generator | ELPULS-40 A DLX |
| Controlled axes | X,Y,U,V simultaneous/Independent |
| Interpolation | Linear & circular |
| Input power supply | 3 phase, AC 415 V ,50 Hz |
| Connected load | 10 KVA |
| Average power consumption | 6-7 KVA |

**Figure 2** Experimental setup of WEDM

**Figure 3** Closer view of machining zone

## WORK PIECE MATERIAL

**Table 2 Chemical composition of Work-piece EN-8 steel (% by weight)**

| Material | Carbon | Silicon | Manganese | Sulphur | Phosphorus |
|---|---|---|---|---|---|
| **Percentage** | 0.36-0.44 | 0.10-0.40 | 0.60-1.00 | 0.050Max | 0.050Max |

**Table 3: Properties of EN-8 steel**

| Tensile Strength | Yield Strength | Impact Strength | Brinell Hardness | Density ($g/cm^3$) |
|---|---|---|---|---|
| 700-850 $N/mm^2$ | 465 $N/mm^2$ | 28J | 201-255 | 7.85 |

The Chemical composition and Properties of Work-piece EN-8 steel is shown in table 4.2 and 4.3 respectively.It is used in automotive parts, aerospace parts, connecting rod, axel, spindle, bolts and general engineering component. It has Reasonable elasticity, promptly machinable, moderate wear opposition if heat treated.EN8 can be heat rewarded to give a decent surface hardness and moderate wear obstruction by fire or acceptance solidifying forms.

## TOOL MATERIAL (Wire)

The experiment was accomplished on “Electronica Ecocut WEDM” machine with 0.25 mm diameter of brass wire. The work piece materials of 6 mm flat are mounted on the Electronia Ecocut WEDM machine tool and specimen of 10x10x6mm size cut out by brass wire.

## MEASUREMENTS

The objective of this thesis work is to optimize the surface roughness and material removal rate along with surface morphology which are explained below.

**Material Removal Rate**

The pace of material expulsion from the work piece is known as material evacuation rate. Some material is liquefied and afterward vanished by process boundaries of electrical release machine during machining. The material expulsion rate is determined by isolating the work piece weight reduction (in grams) to the result of thickness of the work piece (gm/cc) and the machining time. Higher the material evacuation rate higher is the profitability. Consequently, it is generally alluring to build the material removal rate. The recipe for material evacuation rate is as appeared under.

$$\text{MRR} = \frac{\text{Work piece weight loss (gm) X 1000}}{\text{Density (gm/cc) X Machining Time(min)}}$$

**Surface Roughness**

Surface roughness shows the quality of the machining of a job. It is desirable to decrease the surface roughness of the work-piece, as much as we lower the surface roughness the surface finish of the work piece will increase and the quality of the machining will improve. Surface roughness measurements are made using TR200 surface roughness tester.This is available at “Babu

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Banarasi Das University"Lucknow. Figure 4 presents the TR200 surface roughness tester and the surface roughness setup specifications are shown in Table 4.


**Figure-4** TR200 surface roughness tester

**Table 4 Specifications of surface roughness tester**

| Model No | TR200 |
|---|---|
| Roughness parameters | Ra, Rz, Ry, Rq, Rt, RpRv, R3z, RS |
| Assessed profiles | Roughness profile (R) |
| Measuring system | Metric, imperial |
| Display resolution | 0.01 µ m |
| Digital filter | RC, PC-RC, Gauss, D-P |
| Measuring Range | Ra: 0.025~12.5µ m |
| Cutoff length (L) | 0.25mm / 0.8mm / 2.5mm/Auto |
| Tracing length | (1~5)L + 2L |
| Accuracy | ≤±10% |

During the estimating method the sensor moves straightly along the deliberate length. The test moves as needs be to the profile on a superficial level. These developments are changed over into electric signs which are enhanced, separated and changed over into computerized signals by an A/D converter. These signs are then refined in the principle processor as Ra and Rz qualities (or Rq and Rt measurements) and showed on the screen.

**Surface Morphology**

Filtering Electron Microscope is a flexible logical magnifying lens with a huge example chamber and can deal with huge examples at the systematic working separation of 8.5mm inferable from a mix of the slanted identifiers and the sharp funnel shaped target focal point.Here we have used the "CARL ZEISS EVO 50" SEM instrument to observe the surface morphology.This apparatus is shown in figure 5. This is available at "IIT Kanpur" in MSE department. Technical Specification are given in table 4.5.

**Figure 5** CARL ZEISS EVO 50 SEM instrument

**Table 5 Specifications of CARL ZEISS EVO 50 SEM instrument**

| | |
|---|---|
| Resolution | 2.0nm@ 30Kv |
| Acceleration Voltage | 0.2 to 30 Kv |
| Magnification | 5x to 1,000,000x |
| Field of View | 8.5 mm at the Analytical Working Distance (AWD) |
| X-ray Analysis | 8.5 mm AWD and 35° take-off angle |
| Detectors | SE in HV - Everhart-Thornley<br>BSD in all modes - quadrant semiconductor diode |

Since SEM uses vacuum conditions and uses electron pillar to shape a picture, uncommon example arrangements are required as recorded underneath:

- The test is mounted on carbon tape that is put on the outside of the stub. Estimated size of the example 1 x 1 cm.
- All water must be expelled from the examples in light of the fact that the water would disintegrate in the vacuum.
- Electrically conductive examples don't require any arrangement before being utilized, anyway the examples must be totally dry and liberated from unpredictable substances.

- Non-conductive examples should be made conductive by covering the example (utilizing falter coater) with a slight layer of conductive material like Au/Ag/C.

**MACHINING PARAMETERS**

pulse off time (Toff), Pulse on time (Ton) and peak current (Ip), are the key variables that affect the process mechanics in WEDM.

**Pulse on time (Ton)**

It is the span of time estimated in smaller scale seconds. During this time span the current is permitted to go through the anode towards the work material inside sparkle hole. Metal evacuation rate is straightforwardly corresponding to the measure of vitality applied during the on timespan. Longer heartbeat length improves expulsion pace of flotsam and jetsam from the machined region which likewise impacts on the wear conduct of electrode. In my proposition I have differed the beat on time as 106µsec, 112µsec and 118µsec.

**Pulse off time (Toff)**

Pulse off time speaks to the length of time in microseconds, between the beginnings of two nonstop starts. The voltage is missing during this piece of the cycle. With lower estimation of heartbeat off time, there are a more prominent number of releases in a given time, bringing about the expansion in starting proficiency. Therefore, cutting rate are in like manner increases. Using low estimation of Toff period, in any case, may cause breakage, which in this manner diminishes the cutting viability. In my proposition I have fluctuated the beat off time as 30µsec, 42µsec and 54µsec.

**Peak Current**

It is the peak current which is supplied by the power source. If the current increases, the energy supplied increases. Higher energy increases the temperature of work surface and thus the material removal rate will be higher. The relations of peak current are as follows:

- Lower the peak current lower is the MRR. This is on the grounds that the low release vitality is created between working hole because of inadequate warming of work piece and low heartbeat term.
- At high heartbeat span MRR increments with increment in the pinnacle current.
- A harsh surface is created at high pinnacle current and additionally beat on schedule.
- The variation of peak current in my thesis is as 80A, 120A and 160A.

## IV. RESULTS AND DISCUSSION

**CALCULATIONS FOR MRR**

Material expulsion rate can be determined by isolating the work piece weight reduction (in grams) to the result of thickness of the work piece (gm/cc) and the machining time. Utilizing the connection, we can get the estimations of MRR which is appeared in table 6.

**Table 6 Calculation of MRR**

| Exp. No | Ton | Toff | Ip | M/c Time in minute | Work piece Wet loss(gm) | MRR(mm³/min) |
|---|---|---|---|---|---|---|
| **1** | 106 | 30 | 80 | 16.18 | 0.53 | 4.19 |
| **2** | 106 | 42 | 120 | 16.36 | 0.53 | 4.17 |
| **3** | 106 | 54 | 160 | 19.30 | 0.53 | 3.52 |
| **4** | 112 | 30 | 120 | 12.42 | 0.53 | 5.52 |
| **5** | 112 | 42 | 160 | 14.53 | 0.53 | 4.72 |
| **6** | 112 | 54 | 80 | 31.85 | 0.53 | 2.12 |
| **7** | 118 | 30 | 160 | 10.98 | 0.53 | 6.14 |
| **8** | 118 | 42 | 80 | 23.90 | 0.53 | 2.83 |
| **9** | 118 | 54 | 120 | 25.17 | 0.53 | 2.69 |

**Calculation of S/N ratio for MRR**

The S/N proportion, which gathers the numerous information focuses inside a preliminary, relies upon the kind of qualities being assessed. For computation of S/N proportion for material evacuation rate LARGERIS BETTER condition is picked. The Calculation of S/N proportion for MRR is given in table 7. The condition for the computation of S/N proportion for material evacuation rate is:

$S/N_{LB} = -10 \log ((1/n)\Sigma (1/y_i^2))$

**Table 7 Calculation of S/N ratio for MRR**

| S.No. | MRR(mm³/min) | Signal to noise ratio (db) |
|---|---|---|
| **1** | 4.19 | 12.4443 |
| **2** | 4.17 | 12.4027 |
| **3** | 3.52 | 10.9309 |
| **4** | 5.52 | 14.8388 |
| **5** | 4.72 | 13.4788 |
| **6** | 2.12 | 6.5267 |
| **7** | 6.14 | 15.7634 |
| **8** | 2.83 | 9.0357 |
| **9** | 2.69 | 8.5950 |

Mean S / N ratio is determined using formula following $nf_i= (nf_1+nf_2+nf_3)/3$

Where the mean S / N ratio for factor f is nf at the level value I of the factor chosen. $nf_1$, $nf_2$, $nf_3$ are S/N ratio for factor f at level u. The factors which affect the machining parameters show in the table 8 as their respective ranks. Rank of the parameters depends on the value of delta. If the delta value of one parameter is higher than the other that shows first rank. Higher value of S/N ratio of each factor shows the optimal level of the factor. Peak current shows the main effect in the above response table and pulse on time is less effective as compared to peak current.

**Calculation of Mean S/N ratio for MRR**

**Table 8 Calculation of mean S/N ratio for MRR**

| Level | Pulse on time | Pulse off time | Peak Current |
|---|---|---|---|
| **1** | 11.926 | 14.349 | 9.336 |
| **2** | 11.615 | 11.639 | 11.946 |
| **3** | 11.131 | 8.684 | 13.391 |
| **Delta** | 0.795 | 5.665 | 4.055 |
| **Rank** | 3 | 1 | 2 |

**Analysis of Variance for MRR**

**Table 9 ANOVA of MRR**

| Source | DOF | Seq SS | Adj MS | F Value | %contribution |
|---|---|---|---|---|---|
| **Ton** | 2 | 0.0854 | 0.0427 | 0.71 | 0.5962 |
| **Toff** | 2 | 9.4555 | 4.7277 | 79.13 | 66.02 |
| **Peak Current** | 2 | 4.6617 | 2.3308 | 39.01 | 32.54 |
| **Error** | 2 | 0.11950 | 0.0597 | | 0.83 |
| **Total** | 8 | 14.3221 | | | 100 |

% of contribution= (SS/Total) X100

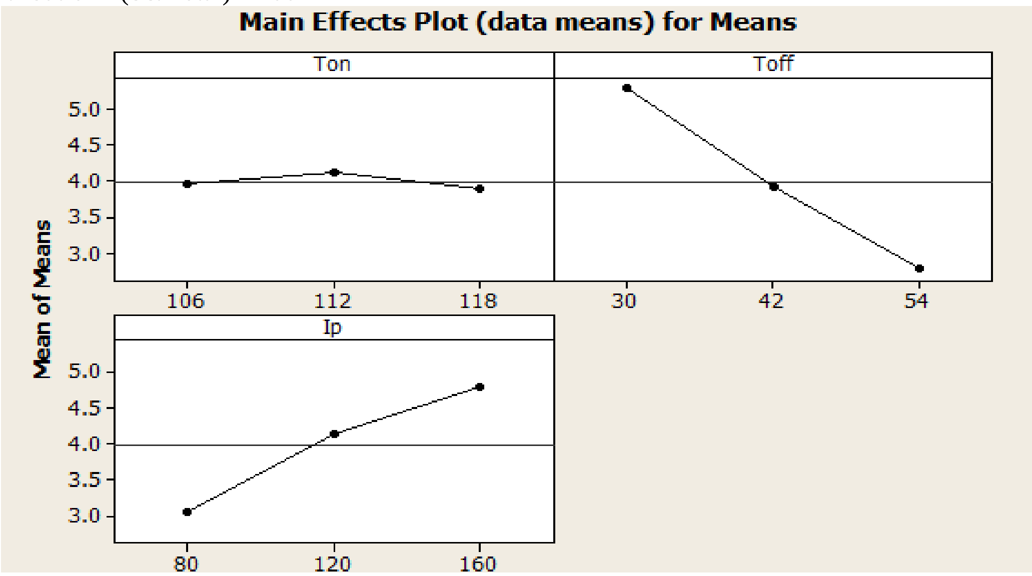


**Figure 6 Main Effect Plot for MRR**

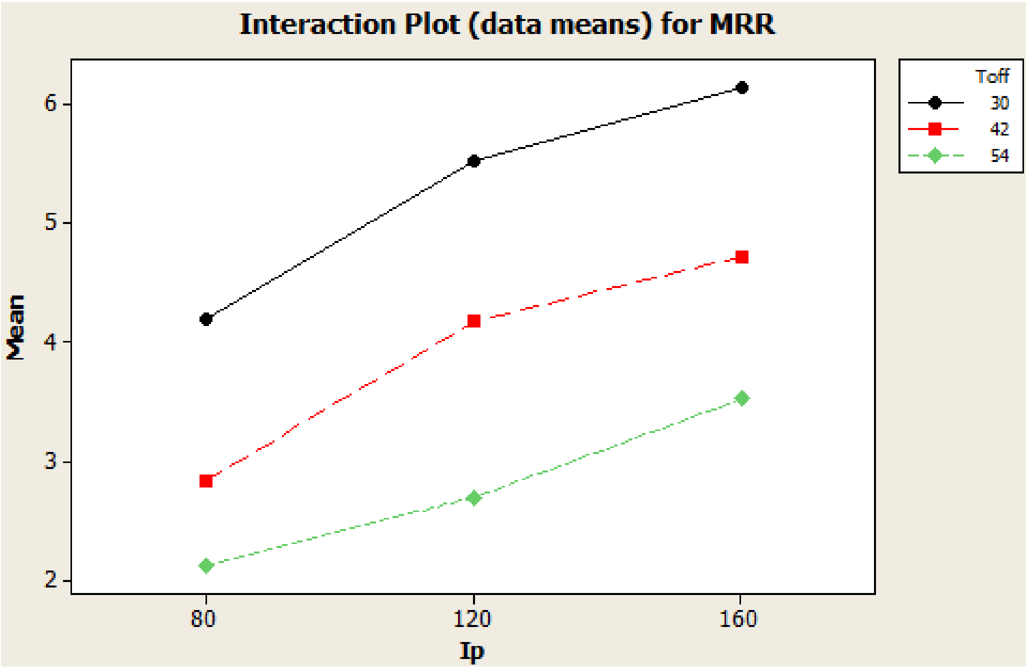

**Figure 7 Interaction Plot for MRR**

From the figure-6 and figure-7 it is clear that as we increase the peak current, the MRR tends to increase at a high rate. Consequently, the MRR increases.

**OPTIMAL LEVEL OF PARAMETER FOR MRR**

For MRR the optimal level of parameters is shown in table 10.

**Table 10 Optimal level of parameter for MRR**

| Process variables of factors | Optimum level |
|---|---|
| Ton (µsec) | 112 |
| Toff (µsec) | 30 |
| Ip (A) | 160 |

**CALCULATIONS FOR SURFACE ROUGHNESS**

Table 11 shows the calculation of surface roughness varying with pulse on time, pulse off time and Peak current.

**Table 11: Calculation for Surface Roughness**

| Exp. No | (Ton) | (Toff) | (Ip) | Ra(µm) |
|---|---|---|---|---|
| **1** | 106 | 30 | 80 | 5.161 |
| **2** | 106 | 42 | 120 | 5.446 |
| **3** | 106 | 54 | 160 | 5.792 |
| **4** | 112 | 30 | 120 | 5.971 |
| **5** | 112 | 42 | 160 | 6.319 |
| **6** | 112 | 54 | 80 | 6.711 |
| **7** | 118 | 30 | 160 | 5.651 |
| **8** | 118 | 42 | 80 | 4.253 |
| **9** | 118 | 54 | 120 | 5.387 |

**Calculation of S/N ratio for Surface Roughness**

The S/N proportion, which gathers the different information focuses inside a preliminary, relies upon the sort of attributes being assessed. For estimation of S/N proportion for surface unpleasantness SMALLER IS BETTER condition is picked. Littler the surface harshness better is the surface attributes. The Calculation of S/N proportion for Surface Roughness is given in table

12. The condition for the count of S/N proportion for surface harshness is:
S/NSB = -10 log ( (1/n) Σ yi ² )

**Table 12 Calculation of S/N ratio for Surface Roughness**

| S. No | Surface Roughness Ra (µm) | Signal to noise ratio (db) |
|---|---|---|
| 1 | 5.161 | -14.2547 |
| 2 | 5.446 | -14.7216 |
| 3 | 5.792 | -15.2566 |
| 4 | 5.971 | -15.5209 |
| 5 | 6.319 | -16.0130 |
| 6 | 6.711 | -16.5357 |
| 7 | 5.651 | -15.0425 |
| 8 | 4.253 | -12.5739 |
| 9 | 5.387 | -14.6269 |

**Calculation of Mean S/N ratio for Surface Roughness**

Mean S / N ratio is determined using formula following
$nf_i = (nf_1+nf_2+nf_3)/3$
Where the mean S / N ratio for factor f is nf at the level value I of the factor chosen.$nf_1$, $nf_2$, $nf_3$ are S/N ratio for factor f at level u.The mean S / N ratio for surface roughness calculation is given in table 13.

**Table 13 Calculation of the mean S/N ratio for Surface Roughness**

| Level | Ton | Toff | Ip |
|---|---|---|---|
| **1** | -14.74 | -14.94 | -14.45 |
| **2** | -16.02 | -14.44 | -14.96 |
| **3** | -14.08 | -15.47 | -15.44 |
| **Delta** | 1.94 | 1.04 | 0.98 |
| **Rank** | **1** | **2** | **3** |

**Analysis of Variance for Surface Roughness**

ANOVA for surface roughness is given in the table 14.

**Table 14 ANOVA of Surface Roughness**

| Source | DOF | Seq SS | Adj MS | F Value | %contribution |
|---|---|---|---|---|---|
| **Ton** | 2 | 2.4180 | 1.2090 | 4.51 | 60.52 |
| **Toff** | 2 | 0.5906 | 0.2953 | 1.10 | 14.78 |
| **Ip** | 2 | 0.4510 | 0.2255 | 0.84 | 11.28 |
| **Error** | 2 | 0.5357 | 0.2678 | | 13.40 |
| **Total** | 8 | 3.9952 | | | 100 |

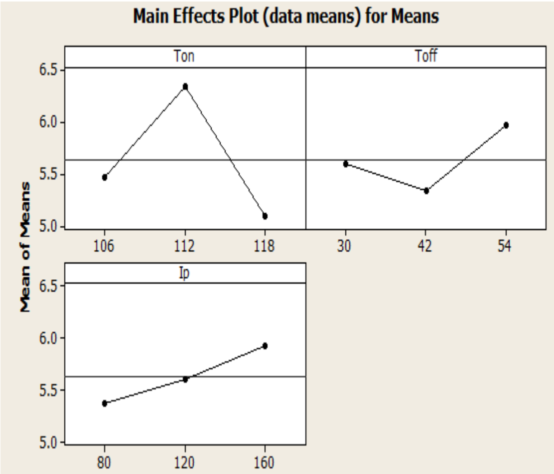


**Figure 8 Main Effect Plot for Surface oughness**

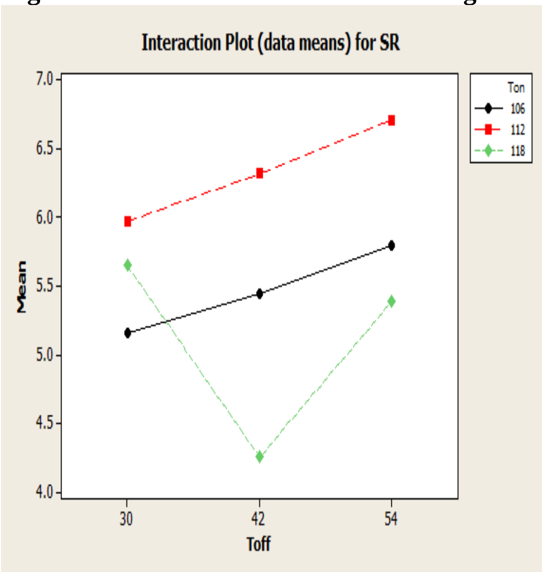


**Figure 9 Interaction Plot for Surface Roughness**

The above figure 8 shows the effect of input parameters on surface roughness. By increasing the peak current, the surface roughness increases and the surface finish starts to degrade. Very rough surface is generated as we increase peak current, we will get poor surface finish because of higher MRR.

## OPTIMAL LEVELS OF PARAMETERS FOR SURFACE ROUGHNESS

For SR the optimal level of parameters are given in table 15.

**Table 15 Optimal level of parameter for Surface Roughness**

| Process variables of factors | Optimum level |
|---|---|
| Ton (µsec) | 118 |
| Toff (µsec) | 42 |
| Ip (A) | 80 |

## CONFIRMATION TEST

Confirmation tests have been performed for MRR and Surface Roughness with their optimum levels of process variables are given in table 16 and table 17.

**Table 16: Confirmation of expected and actual values of MRR**

| Experiment No. | Optimum Machining Parameters | | | MRR ($mm^3$/min) | |
|---|---|---|---|---|---|
| | Ton (µsec) | Toff (µsec) | Ip (A) | Actual | Expected |
| 1 | 112 | 30 | 160 | 5.72 | 5.66 |
| | | | | Error (%) | 1.06% |

**Table 17: Confirmation of expected and actual values of Surface Roughness**

| Experiment No. | Optimum Machining Parameters | | | Surface Roughness | |
|---|---|---|---|---|---|
| | Ton (µsec) | Toff (µsec) | Ip (A) | Actual | Expected |
| 2 | 118 | 42 | 80 | 4.253 | 4.382 |
| | | | | Error(%) | 3.03% |

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## SURFACE MORPHOLOGY

### Microstructure of machined surface

The examination of microstructure of machined work surface was performed for evaluation of the surface quality got utilizing WEDM process. The example was seen with checking electron magnifying instrument (Carl Zeiss EVO 50) with a quickening voltage of 10.0KV. Each of the nine examples were chosen for microstructure perception. The example and work-piece after WEDM are appeared in figure 10 and figure 11.

**Figure 10**Specimen of size 10x10x6 mm after WEDM

**Figure 11**Work piece after machining

**Sample First**

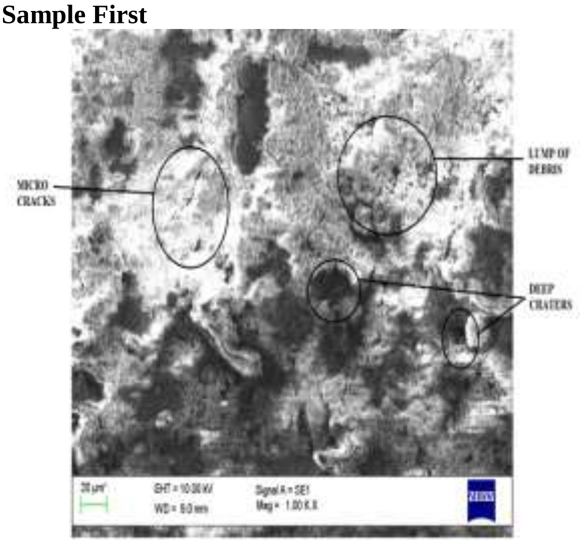


**Figure 12 Microstructure of the sample machined for Exp.no.1**

The Microstructure of first example is appeared in figure 12, has been machined at test condition relating to beat on-time at 106 µsec, beat off time at 30 µsec and pinnacle current at 80 A. Because of low warmth input i.e beat on-time at least level, beat off time at most minimal level and pinnacle current at least level.

Littler current release may just evacuate a limited quantity of metal. The break development is fundamentally credited to the quick warming and cooling of the machined surface. The lopsided warming and cooling caused the advancement of stresses, which prompts break arrangement, chunk of flotsam and jetsam show up because of deficient flush weight and because of vaporization of metal, some profound cavities are clear on the machined surface of work piece.

**Sample Second**

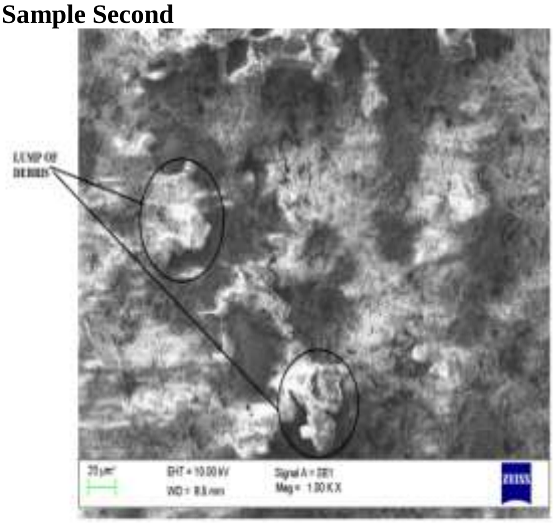


**Figure 13 Microstructure of the sample machined for Exp.no.2**

The Microstructure of second example is appeared in figure 13 has been machined at test condition relating to beat on-time at 106 µsec, beat off time at 42 µsec and pinnacle current at 120 A. In this investigation, beat on-time at most reduced level, beat off time at moderate level and pinnacle current at moderate level. Here, because of moderate degree of pinnacle current, a little rate is warmed to the dissolving stages and redeposit back on a superficial level because of inappropriate flushing. A great deal of chunk of garbage are noticeable in the microstructure of this investigation.

**Sample Third**

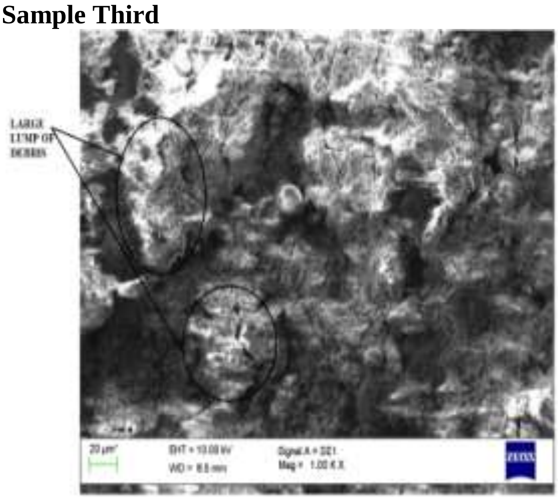


**Figure 14 Microstructure of the sample machined for Exp.no.3**

The Microstructure of third sample is shown in figure 14has been machined at exploratory condition comparing to beat on-time at 106 µsec, beat off time at 54 µsec and pinnacle current at 160 A. In this investigation, beat on-time at least level, beat off time at most significant level and pinnacle current at most significant level. Here because of most elevated level of pinnacle current, the effect of release vitality on the outside of work piece gets more noteworthy and accordingly coming about disintegration prompts increment in crumbling of surface and an enormous size of material flushed away because of increment in beat off time. There is a less chance of resolidification take place on the surface of work piece. Hence large lump of debris is visible in the microstructure of this sample.

**Sample Four**

The Microstructure of fourth sample is shown in figure 15has been machined at exploratory condition comparing to beat on-time at 112 µsec, beat off time at 30 µsec and pinnacle current at 120 A. In this examination, beat on-time at moderate level, beat off time at most reduced level and pinnacle current at moderate level. By an expansion of the beat on-schedule, release vitality produce will be higher, all the more remarkable blast and this outcome in expanded MRR a quickened consumption, on the other hand slightly increase in peak current is also erodes the surface of the work piece. Hence large crater is apparent on the machined surface of the work piece. A chance of redeposit back on the surface is occur due to low value of pulse off time, hence small debris take place.

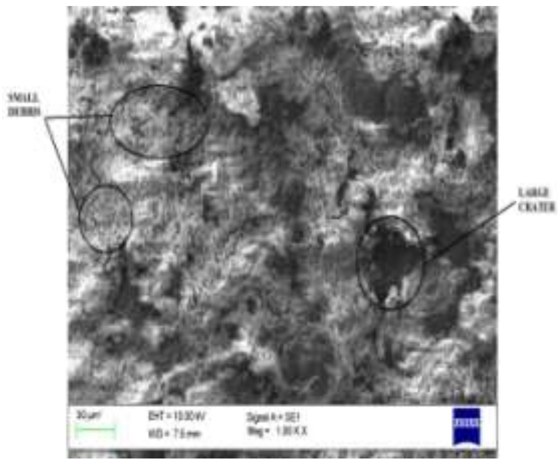


**Figure 15 Microstructure of the sample machined for Exp.no.4**

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**Sample Fifth**

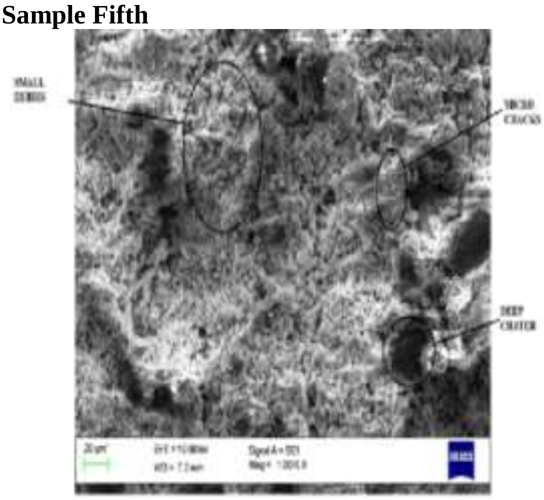

**Figure 16 Microstructure of the sample machined for Exp.no.5**

The Microstructure of fifth sample is shown in figure 16has been machined at test condition comparing to beat on-time at 112 µsec, beat off time at 42 µsec and pinnacle current at 160 A. In this trial, beat on-time at moderate level, beat off time at moderate level and pinnacle current at most significant level. Because of moderate heartbeat on-schedule and highest peak current, erosion of work piece take place, this result deep craters. Small debris and micro cracks are developed due to improper flushing of dielectric fluid and uneven heating. Hence, there is a chance of redeposit of material take place this result small debris apparent on the machined surface.

**Sample Six**

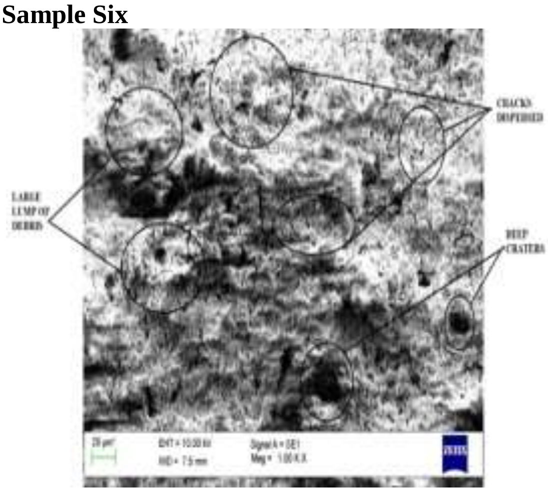

**Figure 17 Microstructure of the sample machined for Exp.no.6**

The Microstructure of sixth sample is shown in figure 17has been machined at test condition comparing to beat on-time at 112 µsec, beat off time at 54 µsec and pinnacle current at 80 A. In this investigation, beat on-time at moderate level, beat off time at most significant level and pinnacle current at least level. Due to intermediate pulse-on-time, that means with long period of spark duration, the number of discharges increases, resulting in the deep craters. Large lump of debris is developed due to improper flushing of dielectric fluid that's why material resolidification take place. The cracks are dispersed by large amount of uneven cooling.

**Sample Seven**

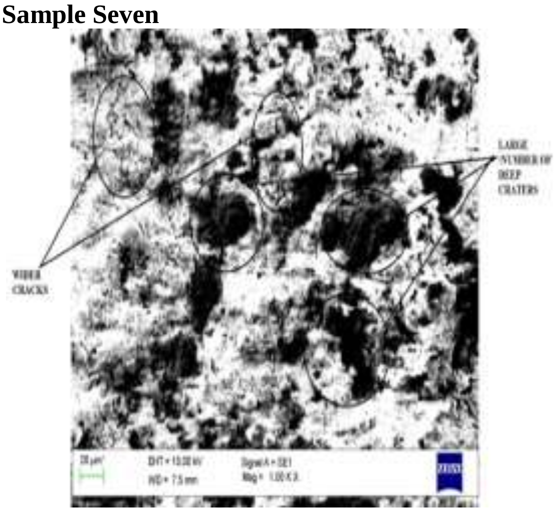

**Figure 18 Microstructure of the sample machined for Exp.no.7**

The Microstructure of seventh example is appeared in figure 18 has been machined at test condition relating to beat on-time at 118 µsec, beat off time at 30 µsec and pinnacle current at 160 A. In this analysis, beat on-time at most significant level, beat off time at least level and pinnacle current at most significant level. Heartbeat on-schedule and pinnacle current are the most critical boundaries influencing the surface properties. The expansion in beat on-schedule and pinnacle current brought about the development of cavities on a superficial level. These holes were created because of a more drawn out time of sparkle length, the quantity of releases increments, bringing about the more extensive and profound holes. More extensive profundity of breaks is straightforwardly identified with the machining conditions; the more we increment the release vitality, the more the appearance recurrence of these splits increments. These sorts of breaking are because of extremely high temperature, since splitting at high temperature is because of the wonders of isolation to cementing, which is because of the advancement

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in specific components, as hardening advances and the inside anxieties develop.

**Sample Eight**

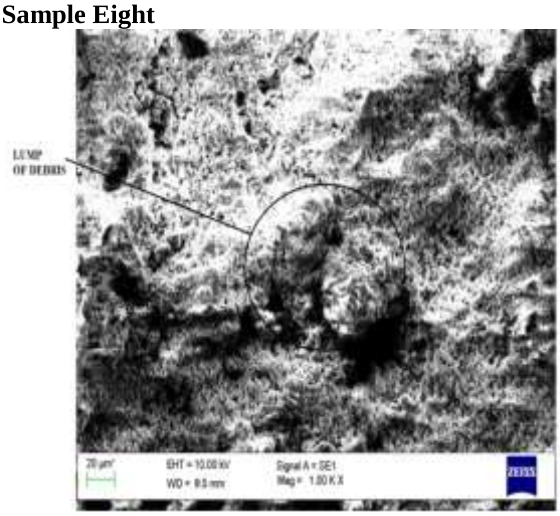


**Figure 19 Microstructure of the sample machined for Exp.no.8**

The Microstructure of eight sample is shown in figure 19has been machined at test condition comparing to beat on-time at 118 µsec, beat off time at 42 µsec and pinnacle current at 80 A. In this test, beat on-time at most significant level, beat off time at moderate level and pinnacle current at least level. Lump of debris are apparent on machined surface with longer period of spark duration and insufficient pressure of dielectric fluid in flushing process. There is a chance of a bits of material solidifies, hence lump of debris are formed on the examined surface.

**Sample Nine**

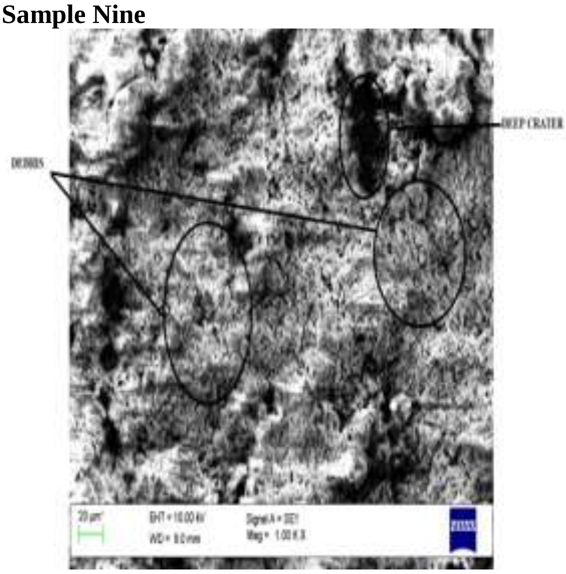


**Figure 20 Microstructure of the sample machined for Exp.no.9**

The Microstructure of nine sample is shown in figure 20 has been machined at exploratory condition relating to beat on-time at 118 µsec, beat off time at 54 µsec and pinnacle current at 120 A. In this examination, beat on-time at most significant level, beat off time at most significant level and pinnacle current at middle level. Here we watch the profound pits and flotsam and jetsam on the machined surface, because of most elevated heartbeat on-schedule and middle of the road top current. The expansion in TON and Ip brought about the arrangement of pits on a superficial level. These cavities were created because of a progression of sparkles. Little part of the liquefied material produced by the electric release was evacuated by the dielectric liquid. If flushing pressure of dielectric fluid is insufficient. Then Debris is formed on the examined surface.

## V. CONCLUSION

In this examination, the trial has been arranged and directed so as to research the impact of cutting boundaries on the material expulsion rate and surface unpleasantness in the WEDM procedure. It tends to be closed from this work EN 8 genuinely machinable utilizing WEDM process. The advanced procedure conditions have been gotten for two reactions material expulsion rate and surface unpleasantness. Following end could be drawn from this examination. material expulsion rate is diminishing with heartbeat off time and surface harshness first expands then after abatements with heartbeat on schedule. The impact of Pulse off time on MRR is most elevated and has a commitment of 66.02%. Second most dominating parameter is peak current with a contribution of 32.54%. The least affecting parameter is pulse on time with a contribution of 0.5962%.The most influencing parameter on SR is pulse on time and its contribution is 60.52%. Second most dominating parameter is pulse off time with a contribution of 14.78%. The least affecting parameter is peak current with a contribution of 11.28%. In the surface morphology study, craters increase with increase in the pulse on time due to increment in duration of discharge, debris increases due to increase in peak current and decrease in pulse off time. Because increase in peak current increase the value of current and hence increase in spark energy, more material melted and vaporized. While increase in pulse off time decreases the surface roughness because in this duration spark not generated and material removed by flush and improved surface is obtained. Some microcracks are also available due to uneven heating or cooling.

1 Researchers have been working on WEDM, but limited research on MMCs has been published.
2 The effect of different reinforcements (e.g. metal-coated ceramic strengthened MMC, composite MMC) on the machining properties of the MMCs on WEDM must be studied and optimized.
3 In most research papers, only electrical parameters were emphasized by past authors, but non-electrical parameters also influenced the machining characteristics.
4 Advances in the production of metal matrix composites include the feasibility of WED process machining in the potential machining environment. There is, however, plenty of room for machining work with the new technologies to boost efficiency.
5 The most important parameter influencing MRR is the pulse on time.
6 Decreased surface roughness as peak current and pulse on time rise, pulse off time doesn't have a significant effect.
7 The most important parameter is the pulse on time, while the pulse off time and the distance voltage are very noteworthy parameters to monitor the MRR.

## REFERENCES

[1]. A. V. S. Ram Prasad, K. Ramji, A. Verma, J. Pavan Kumar, and S. Kesava Rao, “Optimization of material removal rate, surface roughness in Wire-EDM by using desirability function analysis,” Int. J. Innov. Technol. Explor. Eng., vol. 8, no. 6, pp. 20–24, 2019.

[2]. K. H. Ho, S. T. Newman, S. Rahimifard, and R. D. Allen, “State of the art in wire electrical discharge machining (WEDM),” Int. J. Mach. Tools Manuf., vol. 44, no. 12–13, pp. 1247–1259, 2004, doi: 10.1016/j.ijmachtools.2004.04.017.

[3]. M. Manjaiah, R. F. Laubscher, S. Narendranath, S. Basavarajappa, and V. N. Gaitonde, “Evaluation of wire electro discharge machining characteristics of Ti50Ni50-xCux shape memory alloys,” J. Mater. Res., vol. 31, no. 12, pp. 1801–1808, 2016, doi: 10.1557/jmr.2016.189.

[4]. D. Sudhakara and G. Prasanthi, “Application of taguchi method for determining optimum surface roughness in wire electric discharge machining of P/M cold worked tool steel (Vanadis-4E),” Procedia Eng., vol. 97, pp. 1565–1576, 2014, doi: 10.1016/j.proeng.2014.12.440.

[5]. P. Srinivasa Rao, K. Ramji, and B. Satyanarayana, “Effect of wire EDM conditions on generation of residual stresses in machining of aluminum 2014 T6 alloy,” Alexandria Eng. J., vol. 55, no. 2, pp. 1077–1084, 2016, doi: 10.1016/j.aej.2016.03.014.

[6]. D. G. J. Kozak, Z. Gulbinowicz, “Computer simulation of rotating electrical machining (REDM),” Arch. Mech. Eng., vol. 30, no. 1, pp. 111–125, 2004.

[7]. M. M. Moheyeldein, A. M. Abd-El-Tawwab, K. A. Abd El-gwwad, and M. M. M. Salem, “An analytical study of the performance indices of air spring suspensions over the passive suspension,” Beni-Suef Univ. J. Basic Appl. Sci., vol. 7, no. 4, pp. 525–534, 2018, doi: 10.1016/j.bjbas.2018.06.004.

[8]. N. Kuruvila and H. V. Ravindra, “Parametric influence and optimization of wire EDM on oil hardened non shrinking steel,” ASME 2011 Int. Mech. Eng. Congr. Expo. IMECE 2011, vol. 3, pp. 891–899, 2011, doi: 10.1115/imece2011-63379.

[9]. A. R. Khoei, I. Masters, and D. T. Gethin, “Design optimisation of aluminium recycling processes using Taguchi technique,” J. Mater. Process. Technol., vol. 127, no. 1, pp. 96–106, 2002, doi: 10.1016/S0924-0136(02)00273-X.

[10]. Y. fong Tzeng and F. chen Chen, “Multi-objective optimisation of high-speed electrical discharge machining process using a Taguchi fuzzy-based approach,” Mater. Des., vol. 28, no. 4, pp. 1159–1168, 2007, doi: 10.1016/j.matdes.2006.01.028.

[11]. U. A. Dabade and S. S. Karidkar, “Analysis of Response Variables in WEDM of Inconel 718 Using Taguchi Technique,” Procedia CIRP, vol. 41, pp. 886–891, 2016, doi: 10.1016/j.procir.2016.01.026.

[12]. A. B. Puri and B. Bhattacharyya, “Modeling and analysis of white layer depth in a wire-cut EDM process through response surface methodology,” Int. J. Adv. Manuf. Technol., vol. 25, no. 3–4, pp. 301–307, 2005, doi: 10.1007/s00170-003-2045-8.

[13]. R. Roy, A Primer on the Taguchi Method. Van Nostrand Reinhold-USA, 1990.

[14]. G. Rajyalakshmi and P. V. Ramaiah, “Application of Taguchi, Fuzzy-Grey Relational Analysis for Process Parameters Optimization of WEDM on Inconel-825,” Indian J. Sci. Technol., vol. 8, no. 35, 2015, doi: 10.17485/ijst/2015/v8i35/50946.

[15]. S. Gunes, E. Manay, E. Senyigit, and V.

Ozceyhan, "A Taguchi approach for optimization of design parameters in a tube with coiled wire inserts," Appl. Therm. Eng., vol. 31, no. 14–15, pp. 2568–2577, 2011, doi: 10.1016/j.applthermaleng.2011.04.022.
[16]. A. Goswami and J. Kumar, "Optimization in wire-cut EDM of Nimonic-80A using Taguchi's approach and utility concept," Eng. Sci. Technol. an Int. J., vol. 17, no. 4, pp. 236–246, 2014, doi: 10.1016/j.jestch.2014.07.001.
[17]. R. K. Gadekula, M. Potta, D. Kamisetty, U. K. Yarava, P. Anand, and R. S. Dondapati, "Investigation on Parametric Process Optimization of HCHCR in CNC Turning Machine Using Taguchi Technique," Mater. Today Proc., vol. 5, no. 14, pp. 28446–28453, 2018, doi: 10.1016/j.matpr.2018.10.131.
[18]. F. Khan, J. kumar, and T. Soota, "Optimization of EDM process parameter for stainless steel D3," Mater. Today Proc., no. xxxx, pp. 7–10, 2019, doi: 10.1016/j.matpr.2019.07.529.
[19]. R. Ramakrishnan and L. Karunamoorthy, "Multi response optimization of wire EDM operations using robust design of experiments," Int. J. Adv. Manuf. Technol., vol. 29, no. 1–2, pp. 105–112, 2006, doi: 10.1007/s00170-004-2496-6.
[20]. P. Sinha, R. Kumar, G. K. Singh, and D. Thomas, "Multi-Objective Optimization of Wire EDM of AISI D3 Tool Steel Using Orthogonal Array with Principal Component Analysis," Mater. Today Proc., vol. 2, no. 4–5, pp. 3778–3787, 2015, doi: 10.1016/j.matpr.2015.07.183.