INVESTIGATION OF MATERIAL REMOVAL RATE, SURFACE ROUGHNESS AND SURFACE MORPHOLOGY IN WIRE-ELECTRO DISCHARGE MACHINING OF DIE STEEL D3

A Thesis

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Submitted by

Ajay Kumar Singh

Under the Supervision of

Dr. Shahnwaz Alam

Department of Mechanical Engineering
Faculty of Engineering
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This is to certify that **Mr. Ajay Kumar Singh** (Enroll. No.-**1900101356**) has carried out the research work presented in the thesis titled **"INVESTIGATION OF MATERIAL REMOVAL RATE, SURFACE ROUGHNESS AND SURFACE MORPHOLOGY IN WIRE-ELECTRO DISCHARGE MACHINING OF DIE STEEL D3"** submitted for partial fulfillment for the award of the **Master of Technology** from **Integral University, Lucknow** under my supervision.

Signature of Supervisor

Full Name: **Dr. Shahnwaz Alam**

Designation: Associate Professor,

Department of Mechanical Engineering

Integral University, Lucknow.

Date:

Place:

DECLARATION

I hereby declare that the thesis titled **INVESTIGATION OF MATERIAL REMOVAL RATE, SURFACE ROUGHNESS AND SURFACE MORPHOLOGY IN WIRE-ELECTRO DISCHARGE MACHINING OF DIE STEEL D3”** is an authentic record of the research work carried out by me under the supervision of **Dr. Shahnwaz Alam,** Associate Professor**, Department of Mechanical Engineering, Integral University, Lucknow**. No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

I declare that I have faithfully acknowledged and referred to the works of other researchers wherever their published works have been cited in the thesis. I further certify that I have not willfully taken other’s work, text, data, results, tables, figures etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available at web-sites without their permission, and have not included those in this Master of Technology thesis citing as my own work.

Date:

Signature:

Name: **Mr. Ajay Kumar Singh**

Enroll.No: **1900101356**

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Enroll. No. **1900101356**

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ABSTRACT

Wire-EDM is a non-ordinary cutting procedure used machine materials with high hardness, affect obstruction and durability. It defeats the challenges looks by ordinary EDM as it machines with the assistance of a moving wire terminal. This examination is led on Wire-EDM of machining of Die Steel D3 with bass wire cathode in order to set up the connection between WEDM process parameters with material expulsion rate and surface unpleasantness. It was found from the vertex of current that the Material Removal Rate and Surface Roughness of material were significantly affected during the test. Pulse on time was observed to be the second most overwhelming parameters for both execution measures while wire strain was the slightest commanding parameters for both execution measures. The present work has been divided in six chapters.

Chapter one focuses on the introduction part of Wire-EDM continue with its importance, mechanism of metal cutting, application, advantages and limitations of using Wire-EDM process in modern manufacturing era.

Chapter two elaborates the literature review to formulate the problem and research gap for processing of existing work.

In Chapter three the methodology and materials has been discussed. Taguchi approach and ANOVA method has been found the best suitable method for result and analysis.

Chapter four discusses the experimental approach and machine setup to find the various results to fulfill the objective of work. Sample preparation and various data collection for Material Removal Rate and Surface Roughness has been examined and data storage has been done for further calculations and analysis.

Chapter five reveals the result and discussion part of this report on the basis of data collected in chapter four and methodology proposed in chapter three. S/N ratio of Taguchi all the experiments have been calculated. ANOVA proposes 95% of confidence ratio for both Material Removal Rate and Surface Roughness. During the confirmation test the error of 6.39% and 3.33% were reported for Material Removal Rate and Surface Roughness respectively. The chapter continues with reporting

Surface Morphology using SEM for all the specimen at 72X. It was found that roughness of the surface increases with the increment in hole voltage.

Chapter six explains the conclusions and scope of future work of above said studies. It was found that all experimental approach were aligned with the result computed and follows L9 symmetrical cluster of Taguchi technique. It was concluded that high current is the critical factor for Surface roughness expansion.

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

Wire cut Electrical-Discharge Machining (Wire-EDM) is a variation of EDM which utilizes a thin wire (around 0.18mm) which fills in as the terminal. For the most part metal wires are normally utilized, which is nourished gradually through a wire reel into the material and the power releases through the wire cuts the work piece in type of sparkles. In Electrical-Discharge Machining (EDM) Wire Cut is typically performed in a shower of dielectric (ordinarily utilized is water). On the off chance that we watch the procedure under a magnifying instrument, the wire itself does not really interacts with the metal to be machined; the electrical releases in type of sparkles expel little measure of material and afterward enables the wire to movement through the work piece. A release happen between the two nearest purposes of the anode and cathode, the extraordinary warmth is produced close to the zone liquefies and dissipates the materials in the starting zone.

Wire-EDM is a broadly acknowledged as a non-contact and non-traditional machining process utilized for creation of segments having unpredictable profiles. In wire EDM, the conductive materials are machined with a progression of electrical releases (known as sparkles) that are delivered between a precisely situated moving wire (the anode) and the work piece. High recurrence beat of AC or DC supply is released from the wire onto the work piece with a little start hole through the protected dielectric medium. WEDM process by and large includes the disintegration impact of discrete start releases between the device cathode in type of wire and work piece submerged in a liquid dielectric medium. WEDM is utilized for generation in aviation ventures while machining small scale gas turbine sharp edges and other electronic segments.

Wire electrical release machining (WEDM) is a warm material evacuation process that is prepared to do exactly machining parts with much hardness and complex structures, having sharp edges which are extremely hard to cut by the regular machining forms. WEDM is likewise a generally spread strategy utilized in enterprises for exactness machining for a wide range of conductive materials of any hardness. Wire-EDM machines have likewise embraced the beat creating circuit that utilizations bring down capacity to touch off and higher power for cutting. Since fine surface isn't accomplished as the vitality produced by the high-voltage sub-circuit is too high subsequently it isn't used for some activities.

As more current and more extraordinary materials are created, and more intricate shapes are introduced, customary machining tasks will keep on reaching their confinements and the expanded utilization of wire EDM in assembling will keep on growing at a quick enedrate.

WEDM machining technique is usually used to cut hard metals that are unthinkable by other customary machining forms. It has been broadly utilized, particularly to cut confused shapes or fragile depressions that are hard to deliver with regular machining techniques. In any case, one basic confinement is that Wire-EDM just works with electrically conductive materials.

The movement way of the wire is controlled by a numeric control of PC, that enables complex shapes to be created. Movement of wire through the work piece creates the coveted shape. The wire is gone through the part much like a cheddar shaper through cheddar. The wire utilized is generally metal or copper and since they wear quickly along these lines the wire is encouraged on reels. Different materials for wire are tungsten, zinc or metal covered. Movement of wire gives the part being machined a new device without fail.

PC controls are utilized to screen the development of the wire along two hub (and some of the time more). This is like other CNC controlled machines yet for CNC WEDM, the cavity is created freely by movement of the wire. For the instance of complex shapes, it requires cuts or calculated, helical, tapered, or other unordinary surfaces, while the upper and lower wire direct framework well to do diverse developments in like manner.

1.2 IMPORTANCE OF WEDM PROCESS

WEDM innovation has extended step by step since it was designed around thirty years back. The optical-line supporter framework for self controlling the states of the parts to be cut was created for WEDM process by D.H. Dulebohn. In 1975, its request quickly expanded, as the technique and its capacities were better disclosed to the business. Before the finish of 1970s, noteworthy advancement of the machining procedure was brought when PC numerical control (CNC) framework was fused into WEDM.

It incorporated the creation in aviation and car businesses because of its expansive changeability and for all regions of conductive material cutting. The purpose for this is the WEDM gives the best option or in few cases the main option for cutting conductive, fascinating, high hardness and high quality and pottery, conductive building earthenware production with the point of making many-sided shapes and profiles.

WEDM has colossal potential in the present day machining industry to accomplish an extensive dimensional exactness, surface quality and creating form highlights of part or items. Facilitate the cost of terminal wire just contributes 10% of the aggregate working expense of the procedure. WEDM experiences the challenges looked in the pass on sinking EDM, as intricate structure apparatuses are supplanted by moving conductive wire and guided by relative development.

1.3 THE MECHANISM OF MATERIAL CUTTING IN WEDM PROCESS

The system of material expulsion in wire EDM by and large includes the evacuation of material by dissolving and vaporization caused because of age of electric start release made in the start hole by a throbbing DC control supply between the two anodes. In WEDM, negative cathode is set to be a constantly voyaging wire while the positive anode is set as the work piece. The sparkles are created between two most close spaces of terminals in a dielectric medium. Water is for the most part utilized as dielectric medium in WEDM as it is low gooey and have fast cooling rate.

The connected potential contrast at first creates an ionized channel between the nearest purposes of the work piece and the cathodes. Encourage the genuine release occurs with substantial stream of throbbing current and the opposition offered by the ionized channel bit by bit diminishes. This high force of current is constantly produced with additionally ionizes the channel subsequently making a great attractive field. The weight of this attractive field packs the made ionized channel and subsequently confined warming happens. Notwithstanding when the flashes are of brief length, the temperature of cathodes can locally ascend to such a high esteem, to the point that it is more than the liquefying purpose of the work material as a result of the change of the dynamic vitality of moving electrons from the anode and the vitality is changed over into warm. This high vitality thickness disintegrates a segment of material and makes a pit on both the wire and work piece by locally liquefying and vaporizing and hence it is an over whelming warm disintegration process.

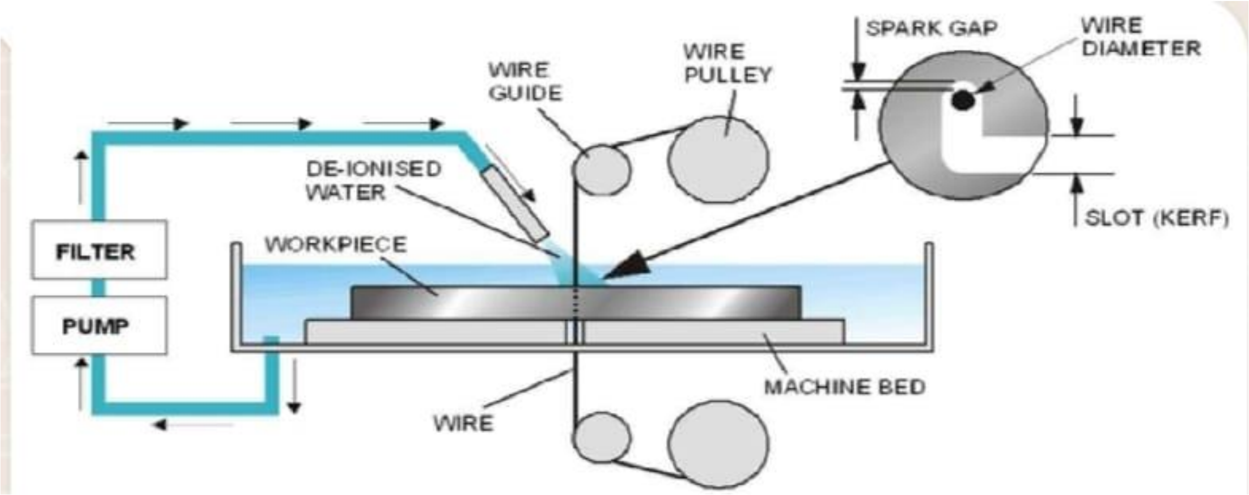


Figure 1.1 Basic mechanism of Wire-EDM

1.4 ADVANTAGES OF WEDM PROCESS

- No creation of cathode is required as in the anode for this situation is a wire that is consistently bolstered into the machining zone for material evacuation.
- No mechanical worries amid machining since there is no immediate contact between the work piece and the wire.
- This process can be connected to all leading metals and compounds with no reliance on their dissolving focuses, hardness, and sturdiness or weakness.

1.5 DISADVANTAGES OF WEDM PROCESS

- It requires high starting capital cost for WEDM process.
- Formation of recast layer or white layer thickness is an imperfection that makes the surface somewhat hard.

- Slower cutting rate.
- Small work pieces must be machined.

1.6 APPLICATIONS OF WEDM PROCESS

The present utilization of WEDM process incorporates car, aviation, form, instrument and pass on making enterprises. WEDM application is likewise found in the restorative instruments, optical instruments, dental instruments, goldsmith enterprises, and in the car and aviation R&D regions. The machine's capacity to work consequently without human intercession for a considerable length of time or even couple of days have expanded the engaging quality of the procedure. Machining thicker material areas, around 200 mm thick, also of consolidating PC for exactness in the span of the part, makes this procedure profitable for the generation of bites the dust of different shapes. Without WEDM, the manufacture procedure requires numerous long stretches of terminals creation for the regular EDM strategy, and additionally numerous long stretches of manual crushing and cleaning. According to ponders it diminishes the general manufacture time by around 37%, while the preparing time can be lessened by around 66%. Another real use of WEDM process is in the machining of expulsion passes on and for the bites the dust of powder metal.

CHAPTER-2

LITERATURE REVIEW

2.1 LITERATURE REVIEW

Real examinations have been led to enhance the profitability and nature of generation by Wire-Electrical release machining (WEDM) process. It has been ceaselessly developing from an insignificant creating geometrically perplexing or hard material parts and making kicks the bucket to a contrasting option to smaller scale application machining that draws in a lot of research interests. Wire-EDM inquires about investigated a numerous courses for enhancing the starting effectiveness that incorporates one of a kind trial methodology that leave from the customary Wire-EDM starting wonder.

S. B. Prajapati et al[1] through their examination found that for cutting rate and surface harshness, the beat ON and beat OFF time are generally critical. The start hole and voltage are noteworthy for the kerf. In another examination conveyed by Goswami Amitesh et al [2], the examination demonstrated that cutting rate and material evacuation rate (MRR), the two increments with increment the level of heartbeat on-time and pinnacle current, while it diminishes with increment in the levels beat off-time and start hole voltage.\

Kuldeep Ojha et al [3] illustrated that in spite of a scope of various methodologies, all the examination work here offers similar destinations of accomplishing more proficient material expulsion what's more with decreasing the apparatus wear and enhancing the surface quality. The paper reports explore on EDM identifying with change in MRR alongside some knowledge into instrument of material expulsion. J.- P. Kruth and Ph. Bleys [4] conveyed the examination and the outcomes demonstrate that the most extreme pliable pressure and the entrance profundity of tractable pressure diminish with expanding number of completing advances. For few cases leftover burdens are seen in unpleasant wire EDM process. The negative impact of remaining burdens is expelled after unpleasant Wire-EDM machining of thin bars. The unpleasant machining causes real disfigurement of the part that makes higher completing unthinkable.

M. Durairaja et al [5] conveyed inquire about for enhancement of surface unpleasantness of Stainless Steel (SS304) utilizing metal wire of 0.25mm. Ghodsiyeh et al [6] conveyed a survey of the examination patterns for WEDM to discover the connection between various process parameters, that incorporates beat on time, beat off time, voltage, current, dielectric stream rate, wire speed, wire strain on various process estimates like material expulsion rate (MRR), surface unpleasantness (Ra), Kerf width, wire slack and wire wear proportion and surface honesty factors. In addition, it concentrated on various sorts of WEDM techniques presented and those which were prior talked about.

What's more the paper likewise featured diverse displaying and streamlining procedures and furthermore examined their favorable position and impediment. The last piece of the paper incorporates a few suggestions about the patterns for future WEDM examines.

Khanna [7] from their examination presumed that the machining rate diminishes with increment in the beat width, that is the time between two heartbeats, and with servo reference mean voltage. Cutting rate first reductions and afterward increments with increment in wire mechanical strain. H. Singh, R. Garg [8] assessed the work on WEDM and found that the scientific models have been created to foresee material expulsion rate and surface complete while machining AISID2 apparatus steel at various machining conditions. Neural system displaying and Simulated Annealing calculation have been viewed as in order to anticipate and upgrade the surface quality and cutting velocity of the WEDM procedure amid machining of SUS 304 treated steel materials. The cutting rate and surface harshness of EDM process have been demonstrated through the reaction surface procedure and counterfeit neural systems (ANNs). L. Li et al [9] from their exploration demonstrated that the ED Med surface geography indicates overwhelming coral reef microstructures at high release vitality, while arbitrary small scale voids are predominant at low release vitality. Surface unpleasantness is observed to be same for parallel and opposite wire bearings, and the normal harshness was fundamentally diminished at low release vitality. It was discovered that at higher release vitality, the thick white layers are intermittent transcendently and non-uniform. Miniaturized scale openings were additionally bound to the thick white layers and no smaller scale breaks were unmistakable in the subsurface. Trim cut at low release vitality prompts thin white layers and it turns out to be more ceaseless, uniform, and free from small scale voids. Contrasted with the mass material, white layers have intense decrease for miniaturized scale hardness due to huge warm debasement. Besides, it is likewise inferred that the surface alloying from wire anode and water dielectric are impacting at high release vitality, however this can be brought down by trim cuts at low release vitality.

N. Tosun et al [10] through their examination found that the expanding beat term, voltage and wire speed, builds the

surface unpleasantness while the expanding the weight of dielectric liquid abatements the surface harshness. They additionally displayed the variety of workpiece surface harshness with machining parameters by utilizing a power work. Ravindranadh Bobbili et al [11] found that heartbeat on time, beat off time, and start voltage are critical factors to MRR and surface unpleasantness(SR).

Malik et al [12] did probes Tungsten Carbide Ceramic with graphite terminal and found that pinnacle current was the most overwhelming component that impacts MRR and TWR while beat obligation factor is the minimum critical factor. It was likewise reasoned that the beat on time has significant impact on surface unpleasantness of the material while obligation factor influence is slightest affecting. K. Kumar et al [13] from their exploratory examination decide the ideal machining parameters for MRR and surface harshness amid the procedure of WEDM. The parameters chosen by them were speed, feed, Time on and Time off and every one of them were found to assume a fundamental part to influence the MRR and surface unpleasantness. H. Singh et al [14] by their examination demonstrated that wire feed and wire strain have irrelevant impact on the MRR, though beat on time straightforwardly impacts the material evacuation rate. It is reasoned that when we increment the beat on time the material expulsion rate likewise increments. For the instance of the beat off time, its expansion would diminishes the material evacuation rate while when the pinnacle current is expanded, it was watched that the material expulsion rate likewise increments lastly it was additionally presumed that the material expulsion rate diminishes when there is increment in servo voltage.

Liao et al [15] conveyed a test examination utilizing SKD11 compound steel to built up scientific models relating the machine execution with different machining parameters and after that have decided the ideal parametric settings for WEDM process for utilization of practical bearing technique for non-straight programming. Spedding and Wang [16] attempted to advance the procedure parametric blends by demonstrating the procedure utilizing fake neural systems and furthermore describing the WEDM machined surface by time arrangement strategies. A feed-forward and back- proliferation NN in view of a RSM focal composite rotatable exploratory outline was created to show the machining procedure.

They chose ideal parametric mixes for the procedure. They additionally recognized intermittent part of the surface and an auto-backward model was utilized to depict its stochastic segment.

Klocke et al [17] conveyed trial of various electrical parameters with a progression of analyses. Slicing speed was seen to be least for material having more number of electrically non-conductive particles. Scott et al [18] in their examination created scientific models for anticipating material evacuation rate and surface unpleasantness amid machining D-2 instrument steel for various machining conditions. They reasoned that there is none of single mix of levels of the considerable number of variables that can be ideal under all conditions.

Lin and Lin [19] gave another approach of streamlining for electrical release machining process having numerous execution attributes relying upon the symmetrical cluster with the dark social investigation. Mill operator et al [20] conveyed an examination for concentrate the impact of start on-time span and start on-time proportion over the material expulsion rate and surface honesty of permeable metal froths, jewel pounding wheels, sintered Nd-Fe-B magnets and C-C bipolar plates. They additionally connected relapse investigation for demonstrating the wire EDM MRR. They likewise performed examining electron microscopy examination for examination of impact of critical EDM process parameters on surface wrapup.

Ramakrishnan and Karunamoorthy [21] have depicted the multi target advancement in their examination for WEDM process utilizing parametric plan of Taguchi approach. They examined the impact of different machining parameters like heartbeat on time, wire strain, postpone time, wire feed speed, and start current force amid machining of warmth treated device steel. They found that the beat on time and start current force impact more than alternate parameters. Anoop Mathew Kurian et al [22] through their investigation for surface unpleasantness of SS 15-5 PH. The parameter beat term was seen to be the most proficient for surface harshness which is trailed by the release current. The minimum impacting parameter was found as wire speed. They found that the commitment of heartbeat term, release current and wire speed were roughly 64.92 %, 18.83 % and 0.36 % individually. Most minimal surface harshness was found at 40 µsec beat span, 1 A present and 150 mm/min wire speed.

Baljit Singh et al [23] conveyed an examination on Titanium compound with molybdenum composite. It was discovered that heartbeat on time was the most impacting machining parameter which has coordinate impact on metal evacuation rate in the machining of Ti compound and the greatest MRR was accomplished at Ton 120 µsec.

CHAPTER-3

TAGUCHI APPROACH AND ANOVA

3.1 TAGUCHI METHOD

Taguchi has generated a methodology for the application of designing of experiments, which includes a practitioner’s handbook. This methodology has taken the experiment design from the world of statistician and is applied fully into the world of manufacturing. This contribution have made the work much simpler by making the use of only fewer experimental designs, and providing a better understanding of the variations and the economic consequences of better quality engineering in the world of production. He introduced his approach using the experimental design for:

- Designing the products and processes which are robust to environmental conditions;
- Designing and developing products and processes which are robust to component variation;
- To minimizing variation about a target value, this philosophy of Taguchi is applicable. He proposed that optimizing engineering process or product should be carried out in three step procedure, they are the design of system, parameter design and tolerance design. In system design the engineer applies scientific engineering knowledge to produce a basic functional prototype design. During the stage of product design stage, the selection of the work materials, components, parameter values etc. are involved. Since system design is an initial step, functional design may be far from optimum in terms of quality and cost.

The objective of parameter design is to optimize the setting of process parameter value for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. Also it is expected that the optimum level of process parameters obtained by the parameter design are insensitive to the varying environmental conditions and other noise factors. Hence the parameter design plays a key role in Taguchi approach for achieving high quality without increasing cost. To solve the problem, Taguchi approach utilizes a special design of orthogonal arrays for studying the entire parameter space using small number of experiments. Loss function is afterwards defined so as to find the deviation between the desired values and experimental values. The value of this loss function is then transformed into a signal-to-noise ratio. Basically there are three category of performance characteristic during the analysis of the signal to noise ratio, they are the lower-the-better, the nominal-the-better, and the higher-the– better. The S/N ratio for each level of process parameter is computer based on the S/N analysis. Larger S/N ratio basically are corresponding to the better performance characteristic and hence the optimal level of the process parameter is the level having the highest S/N and ANOVA analysis, the optimum process parameters can be predicted. Finally, a confirmation test experiment is conducted to verify the experimental optimal set of process parameters obtained from the parameter design. The Taguchi method is adopted to obtain optimal machining performance in the die sinking.

Larger is better (maximum) : $S/N_{LB} = -10 \log \left((1/n) \Sigma (1/y_i^2) \right)$

Smaller is better (minimum) : $S/N_{SB} = -10 \log \left((1/n) \Sigma y_i^2 \right)$

Where, n is the number of observations or repetitions of a trial and y is the observed data.

The S/N ratios are basically expressed on a decibel scale. We would use S/NT for reducing the objective around a specific target, S/NL when the response is as large as possible, and S/NS when the response is as small as possible. Factor level that optimizes the appropriate S/N ratio is optimal.

The following steps are undertaken while using parameter design of the Taguchi method for optimizing a process with multiple performance characteristics:

- Identifying the performance characteristics and then selecting the process parameters to be evaluated.
- Determine the number of levels for the process parameters and possible interactions between the process parameters.
- Selecting appropriate taguchi orthogonal array and assigning the process parameters to the orthogonal array.
- Conducting the experiments on the basis of the orthogonal larray.
- Analyzing the experimental results by using signal to noise ratio and ANOVA.
- Selecting the optimal level of process parameters by the S/N ratio and ANOVA.
- Verifying the optimum level process parameters by conducting confirmation experiment.

3.2 APPLICATION OF S/N RATIO

The change in the product's quality characteristics which is under investigation, in response to a factor introduced in design of experiment is basically the signal of desired effect. Although, when experiments are conducted, there may be numerous external parameters which are not designed into the experiment and may influence the outcome of the experiments. Usually the noise factors are these external factors and their effect on the results of the quality characteristic under experiment is known as noise. The signal to noise ratio is the source of measuring the sensitivity of the quality characteristic which is investigated in a controlled environment, to those external dominating factors (known as noise factors) which are not under control. The concept of S/N ratio was originated in the electrical engineering field. Taguchi effectively applied this theory to achieve the optimum level of parameters from the experiments.

The aim of carrying experiments is always to find the highest possible S/N ratio for the result. A higher value of S/N ratio shows that the signal is much high than the random influence of the noise factors. Product design or process operation consistent with highest S/N ratio, always yields the optimum quality with minimum variance.

The S/N ratio is designed to measure the quality characteristics.

The Signal to Noise ratio basically expresses the scatter around a specific target value. Scatter is smaller for larger ratios. Having knowing the S/N ratio value of the samples before and after the experiment, Taguchi's loss function is used for estimating the potential cost saving from the improved product.

3.3 ADAVANTAGE OF S/N RATIO OVER AVERAGE

For analyzing the influence of experiments involving multiple runs, the use of signal to noise ratio over standard analysis is preferred. Analysis using the signal to noise ratio will offer the following advantages:

- It will provide guidance for selecting optimum level parameter based on least scatter around the target and also on the average value close to the target.
- It will offer objective comparison between two sets of experimental data having variation around target and the deviation of the average data from the target value.

3.4 ROLE OF ANOVA

Taguchi replaces full factorial experiment method with a lean, low cost, quicker, partial factorial experiment. Taguchi's design for the partial factorial is based on specially developed OA's. Since the partial experiment is just a sample of the full set of experiment, the analysis of the partial experiment must be included by an analysis of the confidence that must be placed in the results. Analysis of Variance is routinely used that provides a measure of confidence. This technique does not directly analyze the data, but instead determine the variance of the data. The confidence is generally measured from the variance.

This analysis provides the variance for controllable and the noise factors. By understanding the source and magnitude of variance, robust operating conditions can be predicted. This is second benefit of this methodology.

3.5 ANALYSIS OF VARIANCE(ANOVA)

Sir Ronald Fisher in the 1930’s developed this methodology to interpret the results from agricultural experiments. It is not a complicated method but has a lot of mathematics associated with it. ANOVA is a statistically based methodology and an objective decision-making tool for determining and differentiating the average performance of groups of items tested.

3.6 TABLES FOR TAGUCHI DESIGN OF EXPERIMENT

Tables for Taguchi design of experiment are shown below:

Table 3.1: Process Parameters and their levels

S.No.	**Parameters**	**Units**	**Level 1**	**Level 2**	**Level 3**
1	Current (Ip)	A	4	6	8
2	Pulse-on-time (Ton)	µsec	5	7	9
3	Wire Tension	N	300	600	900

Table 3.2: L9 Orthogonal Array

Exp. No	**Ip**	**Ton**	**WT**
1	4	5	300
2	4	7	600
3	4	9	900
4	6	5	600
5	6	7	900
6	6	9	300
7	8	5	900
8	8	7	300
9	8	9	600

CHAPTER-4

EXPERIMENTATION

4.1 EXPERIMENTAL SETUP

Table 4.1 Specifications of ELECTRONICA Wire-EDM

Table Travel X,Y Axis (mm)	250 x 320
Work Table Size L x W (mm)	380 x 525
Maximum Work Piece Thickness (mm)	300
Maximum Work Piece Weight (kgs)	300
Machine Weight (kgs)	1600
Display	LCD Display
Control System	CNC
Axis Control	4 - axes (X,Y,U,V)
X, Y Axis Guide Ways	Linear motion guide ways for X, Y axis
Resolution	0.001 mm
Wire Dia	0.18mm (Std.), 0.15mm, 0.12mm (Optional)
Interpolation	Linear and Circular
Programming	Incremental
Input Power Supply	3 Phase, 415 Volts, 50 Hz with Neutral and Earth
Total Machine Load	1.5 KVA
Processing and Data Entry	Dual Screen, New programs can be entered while cutting previous programme
Dielectric Fluid	Soft water (D.M Water) + Gel
Dielectric Tank Capacity	55 Litres

Investigations were directed on an Electronica Wire-EDM machine. The machine is appeared in the figure 4.1 on next page. The Wire EDM is incorporated into the 'non-regular' gathering of machining procedures and machines the work without having any contact between the anodes. In a perfect world, WEDM process is viewed as a progression of breakdown and rebuilding of the dielectric liquid in the middle of the electrodes. The machine for tests was accessible at Dilawar Engineering Works, Lalbagh, Lucknow.

Figure 4.1 Electronica Wire-EDM Computer panel

Figure 4.2 Machining on Electronica Wire-EDM

Figure 4.3 Parts of Electronica Wire-EDM

4.2 DIELECTRICFLUID

Dielectric liquids assume an essential part amid the EDM procedure. As it has a high dielectric quality, the dielectric medium essentially keeps the untimely release between the terminals until the point that the most reduced hole for release is set up between the anodes. Persistent dielectric fluid stream in the start hole serves to diverting shaped garbage in the zone while the release and guarantees an appropriate flushing. The dielectric medium additionally cools the machining zone via diverting overabundance warm slopes from the instrument terminal and the work piece.

4.3 WORK PIECE MATERIAL

The material used for this work is **Die Steel D-3**.

Table 4.2 Properties of Die Steel D-3

Density (g/cm³)	Melting Point (ºC)	Yield Strength (MPa)	Elastic modulus (GPa)	Possion's Ratio	Brinell Hardness
7.87	1421	470	190	0.28	215

Table 4.3 Chemical composition of the workpiece material (DIE STEEL D-3) by weight

Material	Fe	Ni	Mn	Cr	C	Si	Cu	V	Mo
% Composition	86.58	0.0689	0.269	11.05	2.07	0.191	0.00367	0.0218	<0.002

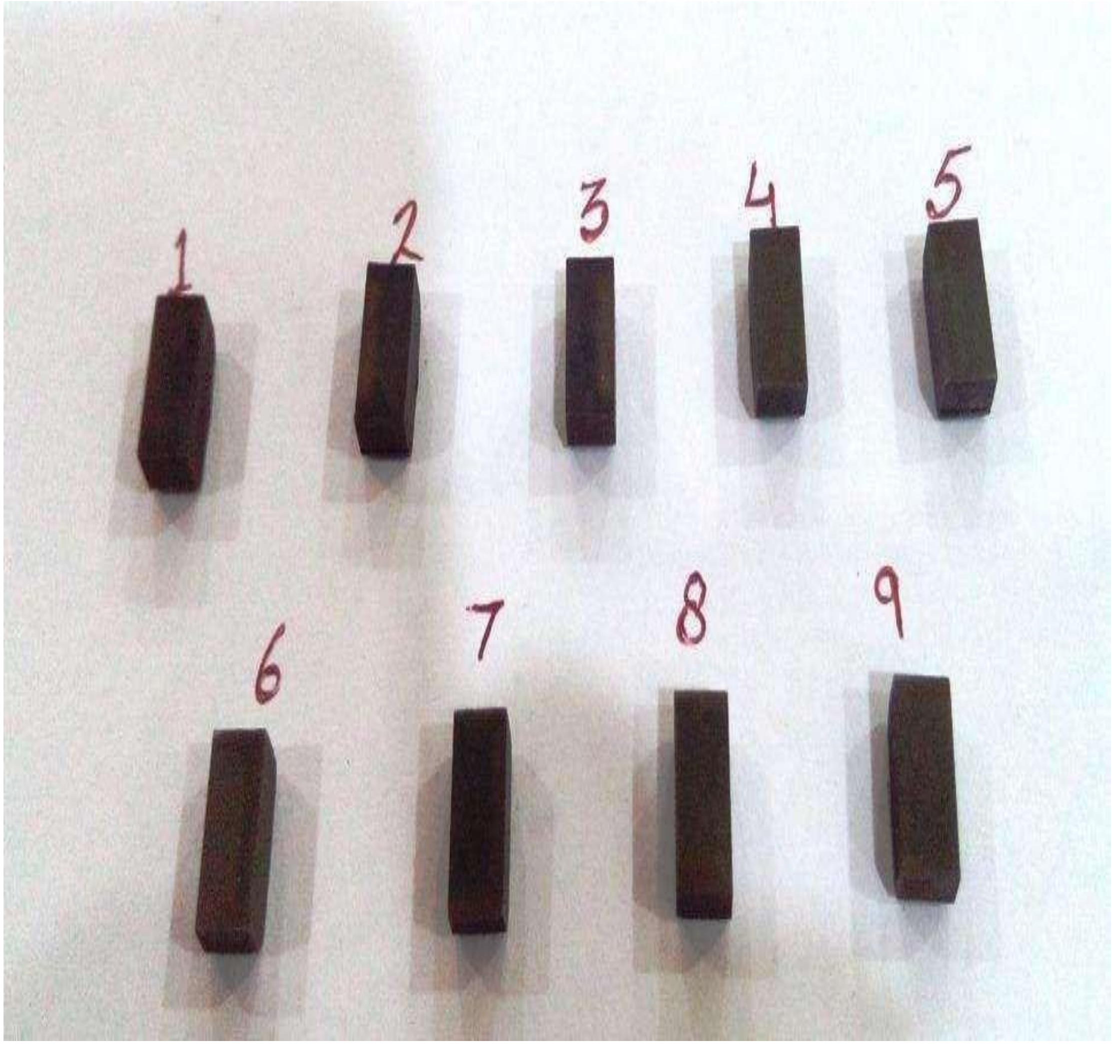


Figure 4.4 Die-Steel D3 pieces cut by Wire-EDM

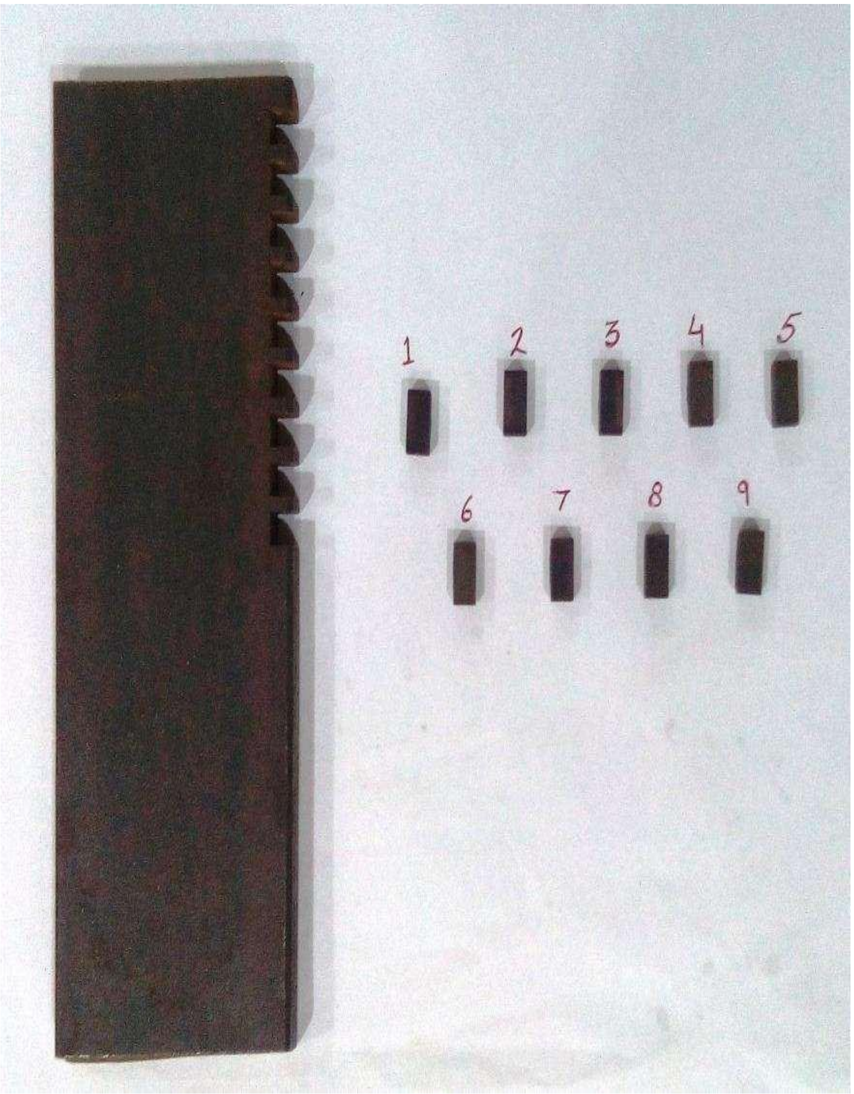


Figure 4.5 Die-Steel D3 bar and the cut pieces by WEDM

4.4 TOOL MATERIAL(Wire)

The wire utilized for this work is Brass wire of width 0.18mm.

4.5 MEASUREMENTS

The target of this postulation work is to ascertain the material evacuation rate and surface unpleasantness which are clarified underneath.

4.5.1 Material Removal Rate

The rate at which the material expulsion happens from the work piece is known as material evacuation rate. Some metal is dissolved and after that dissipated by process parameters of electrical release machine amid machining. The material evacuation rate is ascertained by partitioning the loss of weight work piece amid machining (in grams) to the result of thickness of the work piece in gm/cc and the machining time in minutes. Higher is the material expulsion rate, more is the profitability. Along these lines it is most alluring to have bigger material evacuation rate. The recipe used to compute material expulsion rate is as appeared under.

$$\textbf{Material Removal Rate} = \frac{\textbf{Work piece weight reduction (gm) X 1000}}{\textbf{Density (gm/cc) X Machining Time}}$$

4.5.2 Surface Roughness

Surface harshness portrays the quality surface of the machined work or a vocation. It is attractive to lessen the surface harshness of the work surface. The more we bring down the surface harshness the surface complete of the work piece will get upgraded and accordingly the nature of the machining will get made strides. Surface harshness estimation for display think about was estimated utilizing Mitutoyo 178-602 surface unpleasantness analyzer.

Figure4.6 Mitutoyo 178-602 Surface Roughness Tester Measruring. The Roughness Of Surface Machined By Wire-Edm

4.6 MACHININGPARAMETERS

The pinnacle current (Ip), beat on time (Ton) and wire strain (WT) are the key factors that influence the procedure mechanics in EDM.

4.6.1 Peak Current (Ip)

The pinnacle current is given by the power source. At the point when the present expands, the provided vitality increments. Higher vitality will expand the temperature of work surface and hence higher material evacuation rate will be accomplished.

The relations of pinnacle current are as per the following:

a) Lower the pinnacle current lower is the MRR. This is on the grounds that the low release vitality is delivered between working hole because of lacking warming of work piece and low heartbeat term.

b) At high heartbeat span MRR increments with increment in the pinnacle current.

c) A harsh surface is created at high pinnacle current or potentially beat on time.

d) The variety of pinnacle current in my proposition is as 4A, 6A and 8A.

4.6.2 Pulse on time (Ton)

It is the length of time estimated in small scale seconds. Amid this era the current is permitted to go through the cathode towards the work material inside start hole. Metal expulsion rate is specifically corresponding to the measure of vitality connected amid the on day and age. Longer heartbeat term enhances expulsion rate of garbage from the machined region which likewise consequences for the wear conduct of terminal.

In my proposal I have shifted the beat on time as 5μsec, 7μsec and 9 μsec.

4.6.3 Gap Voltage(Vg)

It is a voltage created between the little hole of work piece and apparatus cathode. On the off chance that the voltage expands, MRR will increment however with a high voltage we will get poor surface complete on account of higher MRR. In my proposal work, I have changed the voltage in levels – 100V, 125V and 150V.

CHAPTER-5

RESULT AND DISCUSSION

5.1 CALCULATIONS FOR MATERIAL REMOVAL RATE

Table 5.1 Calculation of Material Removal Rate

Exp. No	**Current**	**Pulse on Time**	**Wire Tension**	**Material Removal Rate (mm^3/min)**
1	4	5	300	3.079
2	4	7	600	4.775
3	4	9	900	5.940
4	6	5	600	9.830
5	6	7	900	10.748
6	6	9	300	10.928
7	8	5	900	6.715
8	8	7	300	8.050
9	8	9	600	9.390

5.1.1 Calculation of S/N ratio for Material Removal Rate

The S/N ratio, which condenses the multiple data points within a trial, depends on the type of characteristics being evaluated. For calculation of S/N ratio for material removal rate LARGER IS BETTER condition is opted. The equation for the calculation of S/N ratio for material removal rate is:

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

Table 5.2 Calculation of S/N ratio for MRR

S.No	Material Removal Rate	Signal to noise ratio (db)
1	3.079	9.7682
2	4.775	13.5795
3	5.940	15.4757
4	9.830	19.8511
5	10.748	20.6266
6	10.928	20.7708
7	6.715	16.5409
8	8.050	18.1159
9	9.390	19.4533

5.1.2 Calculation of Mean S/N ratio for MRR

Mean S/N proportion is figured by utilizing following equation

nfi= (nf1+nf2+nf3)/3

Where nf is mean S/N proportion for factor f at the level esteem I of the chose factor.

nf1, nf2, nf3 are S/N proportion for factor f at level u

The elements which influence the machining parameters appear in the table as their individual positions. Rank of the parameters relies upon the estimation of delta. On the off chance that the delta estimation of one parameter is higher than the other that shows first rank. Higher estimation of S/N proportion of each factor demonstrates the ideal level of the factor. Pinnacle current demonstrates the primary impact in the above reaction table and heartbeat on time is less viable when contrasted with top current.

Table 5.3 Calculation of mean S/N ratio for Material Removal Rate

Level	Current	Pulse on Time	Wire Tension
1	12.94	15.39	16.22
2	20.42	17.44	17.63
3	18.04	18.57	17.55
Delta	7.48	3.18	1.41
Rank	**1**	**2**	**3**

5.1.3 Analysis of Variance for Material Removal Rate

Table 5.4 ANOVA of Material Removal Rate

Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	52.789	26.395	160.10	86.25
Pulse on Time	2	7.424	3.712	22.51	12.13
Wire Tension	2	0.658	0.329	1.99	1.07
Error	2	0.330	0.165		0.53
Total	8	61.200			100%

At least 95% confidence

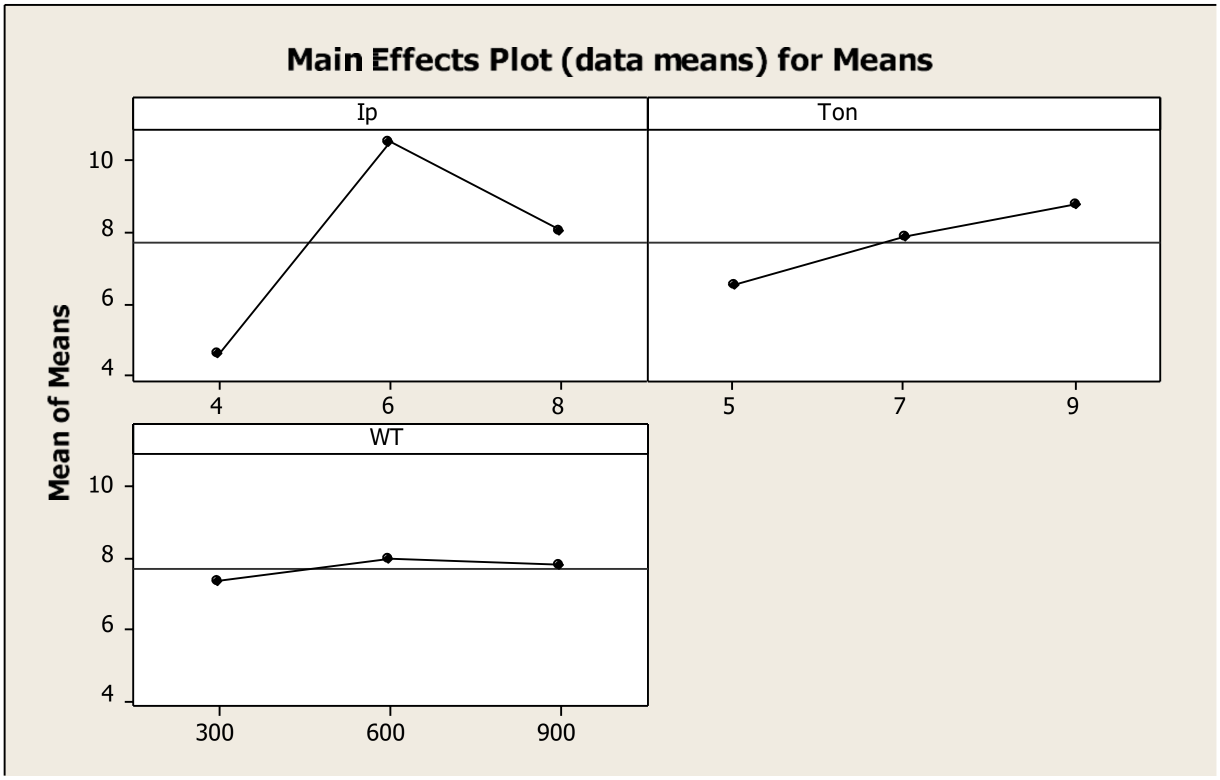


Figure 5.1 Mean Effect Plot for Material Removal Rate

From the above chart plainly as we increment the current, the MRR tends to increment at a high rate than beat on time and voltage. It demonstrates that pinnacle current is the most critical factor for MRR. MRR at first increments with top current however with additionally increment in its esteem MRR has a tendency to decrease. The purpose behind such conduct is that the flotsam and jetsam display between the cathode wire and the workpiece does not permit adequate spaks to strike the surface of work. MRR increments with increment in heartbeat on time however at a slower pace when contrasted with that of current. The release vitality is higher at larger amounts of heartbeat on time accordingly we get higher material evacuation rate. For bring down heartbeat on time, the release vitality is lacking along these lines the material expulsion rate is low. On account of wire pressure, at first the MRR tends to increment, however additionally increment in its esteem has a tendency to debase the MRR. Wire strain has relatively irrelevant impact on MRR and the chart got between them is level. Wire strain is the minimum affecting parameters for material expulsion rate. The commitment of wire pressure towards the material expulsion rate is just 1.07%.

Optimal Levels of Parameters for Material Removal Rate

For MRR the optimal level of parameters are as follows

Table 5.5 Optimal level of parameter for Material Removal Rate

Process variables of factors		**Optimum level**
Peak Current	**Ip (A)**	6
Pulse on Time	**Ton**	9
Wire Tension	**WT**	600

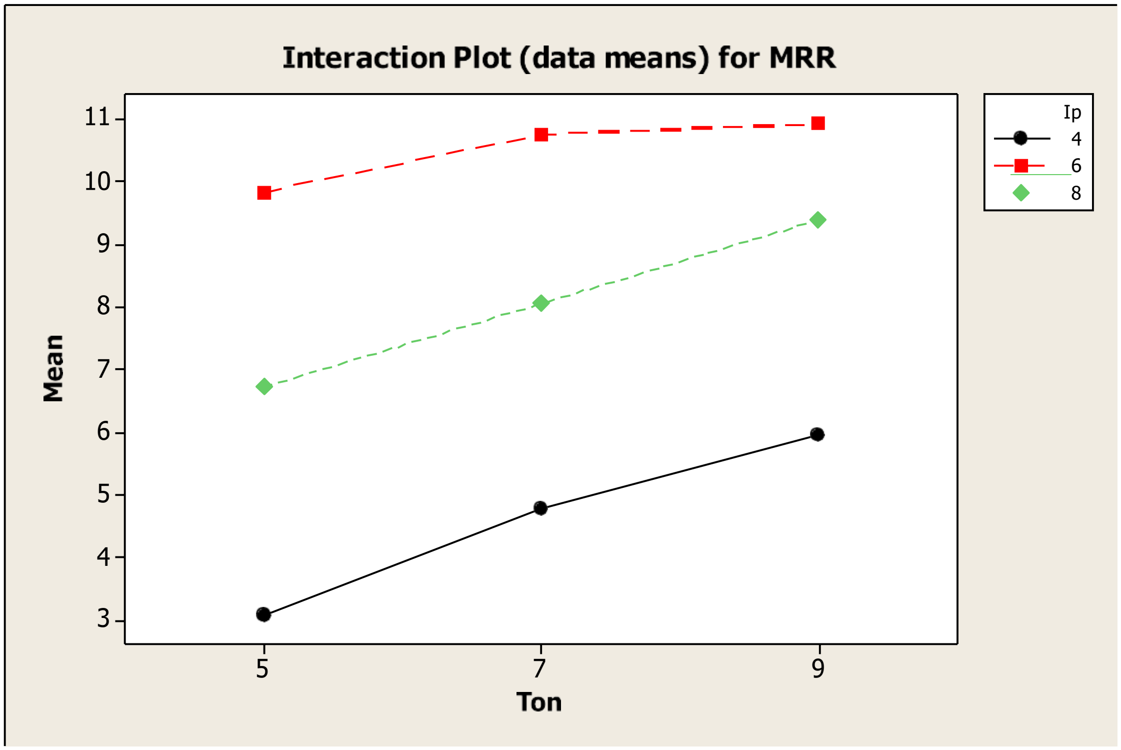


Figure 5.2 Interaction plot between WEDM parameters and MRR

The above plot in Figure 5.2 shows the interaction plot between MRR and pulse on time at various levels of peak current. The graph elucidates that at each level of peak current, the material removal rate of the work piece follows an increasing trend with pulse on time. Moreover, it is also observed that with increase in the value of peak current, there is a gradual increase in the MRR.

5.2 CALCULATIONS FOR SURFACE ROUGHNESS

Table 5.6 shows the calculation of surface roughness varying with peak current, pulse on time and wire tension.

Table 5.6: Calculation for Surface Roughness

Exp. No	Current	Pulse on Time	Wire Tension	Surface Roughness Ra(μm)
1	4	5	300	6.59
2	4	7	600	6.80
3	4	9	900	7.10
4	6	5	600	7.38
5	6	7	900	7.69
6	6	9	300	7.35
7	8	5	900	7.76
8	8	7	300	7.70
9	8	9	600	8.10

5.2.1 Calculation of S/N ratio for Surface Roughness

The S/N ratio, which condenses the multiple data points within a trial, depends on the type of characteristics being evaluated. For calculation of S/N ratio for surface roughness SMALLER IS BETTER condition is opted. Smaller is the surface roughness, better the surface characteristics.

The equation for the calculation of S/N ratio for surface roughness is:

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

Table 5.7 Calculation of S/N ratio for Surface Roughness

S.No	Surface Roughness Ra(µm)	Signal to noise ratio (db)
1	6.59	-16.3777
2	6.80	-16.6502
3	7.10	-17.0252
4	7.38	-17.3611
5	7.69	-17.7185
6	7.35	-17.3257
7	7.76	-17.7972
8	7.70	-17.7298
9	8.10	-18.1697

5.2.2 Calculation of Mean S/N ratio for Surface Roughness

Mean S/N ratio is calculated by using following formula

$nf_i = (nf_1+nf_2+nf_3)/3$

Where nf is mean S/N ratio for factor f at the level value i of the selected factor. nf_1, nf_2, nf_3 are S/N ratio for factor f at level u

Table 5.8 Calculation of mean S/N ratio for Surface Roughness

Level	Current	Pulse on time	Wire Tension
1	-16.68	-17.18	-17.14
2	-17.47	-17.37	-17.39
3	-17.90	-17.51	-17.51
Delta	1.21	0.33	0.37
Rank	**1**	**3**	**2**

5.2.3 Analysis of Variance for Surface Roughness

ANOVA for surface roughness is given in the following table-

Table 5.9 ANOVA of Surface Roughness

Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	1.60549	0.80272	43.29	84.46
Pulse on Time	2	0.11262	0.05631	3.04	5.92
Wire Tension	2	0.14562	0.07281	3.93	7.66
Error	2	0.03709	0.01854		1.95
Total	8	1.90082			100%

At least 95% confidence

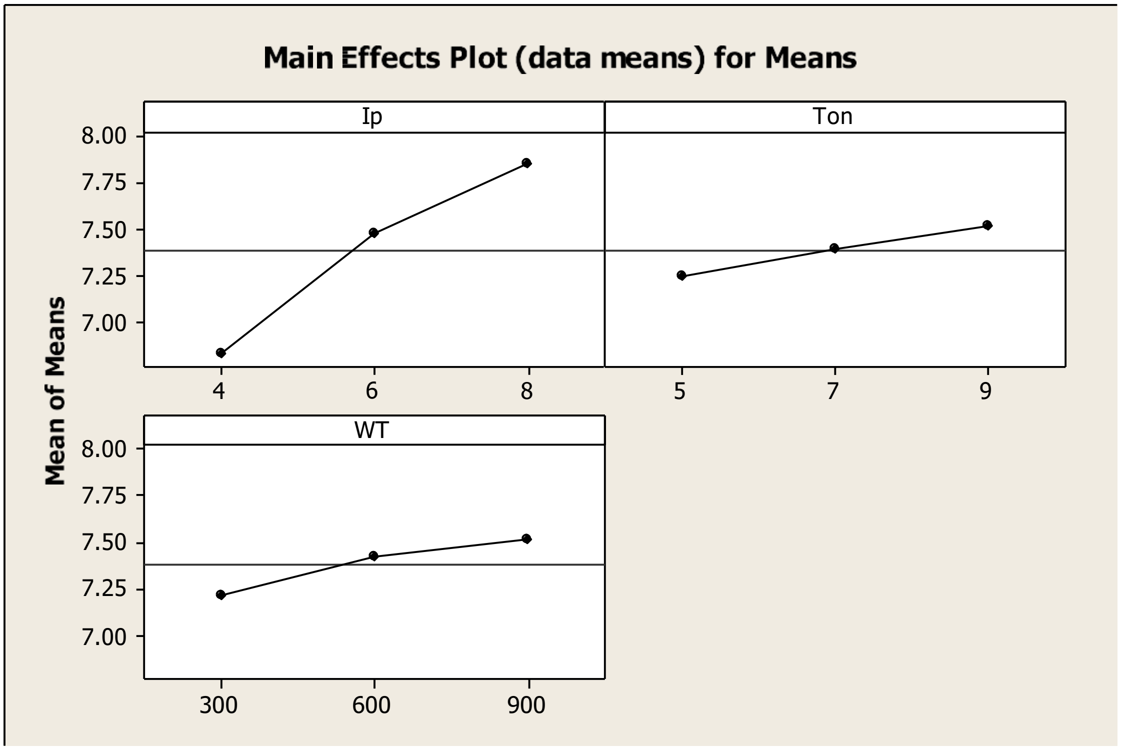


Figure 5.3 Main Effect Plot for Surface Roughness

The above chart demonstrates the impact of information parameters on surface unpleasantness. All the three parameters demonstrate an expanding pattern with surface harshness i.e. with increment in the levels of WEDM parameter, the surface unpleasantness of the machined surface increments. By expanding the current the surface harshness increments and the surface complete debases. Rough surface is produced as we increment the current. Pinnacle current is the most huge factor having a commitment of 84.46%. As present builds, the start force increments and consequently the surface debases more. The base surface harshness is seen at 4A. With increment in heartbeat on time and wire strain the surface harshness increments however at an ease back pace when contrasted with current. The base surface harshness was seen at 5µsec beat on time and 300 wire pressure. The commitments of heartbeat on time and wire pressure are 5.92% and 7.66%individually.

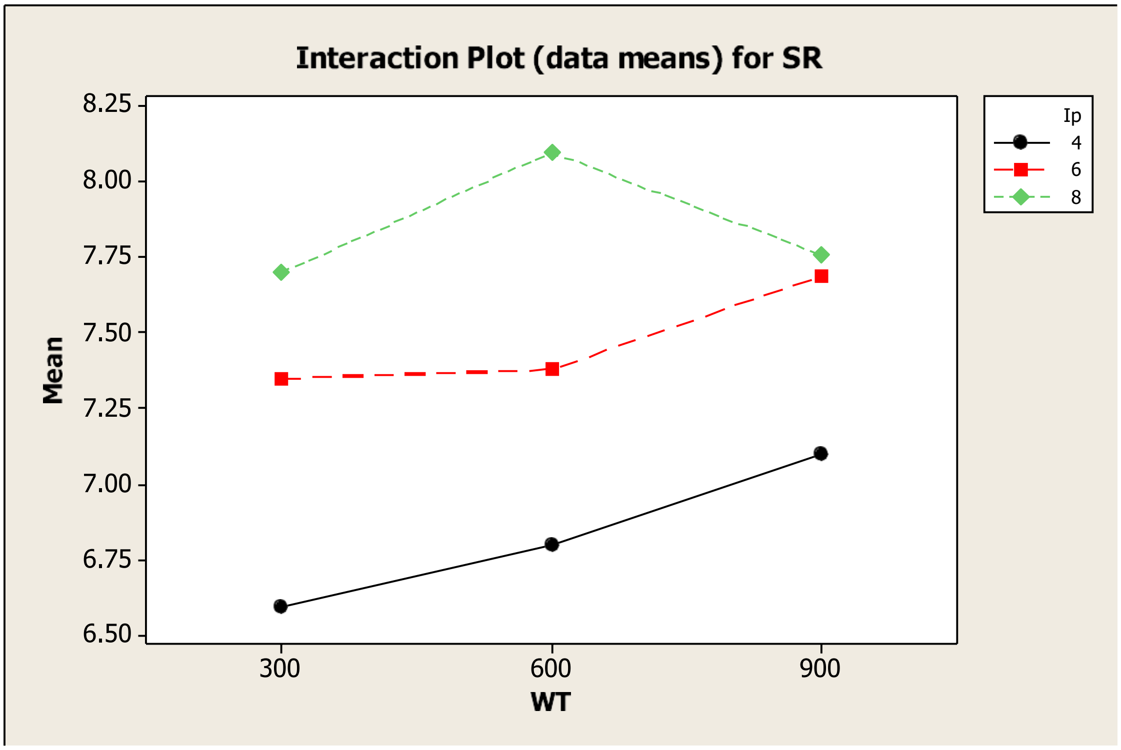


Figure 5.4 Interaction plot between Surface Roughness and WEDM parameters

The above plot in Figure 5.4 shows the interaction plot between surface roughness and wire tension at various levels of peak current. The graph elucidates that at lowest level of peak current, the material removal rate of the workpiece follows an increasing trend with wire tension.

Moreover, when the value of peak current in increased i.e. at 4A, SR first decreases and then tends to increase with wire tension. At 6A peak current, the SR first increases and then decreases with wire tension.

Optimal Levels of Parameters for Surface Roughness

For MRR the optimal level of parameters are as follows

Table 5.10 Optimal level of parameter for Surface Roughness

Process variables of factors		**Optimum level**
Peak Current	**Ip (A)**	4
Peak Current	**Ton (µsec)**	5
Wire Tension	**WT**	300

5.3 CONFIRMATION TEST

Confirmation tests have been performed for MRR, Surface Roughness and Surface Integrity with their optimum levels of process variables.

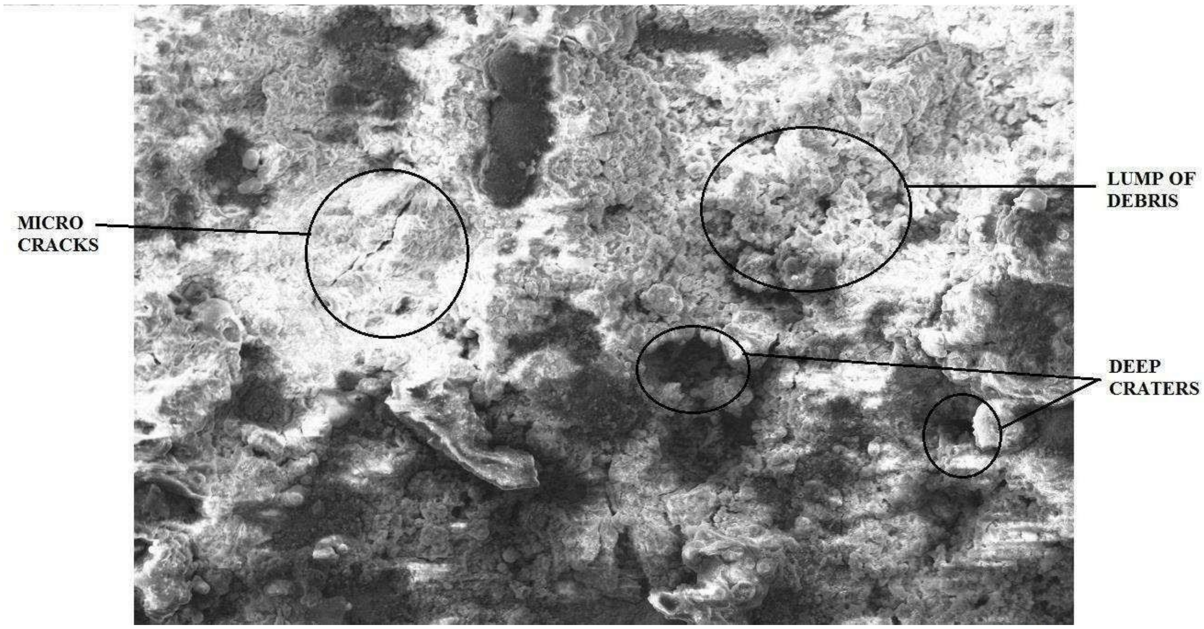
Table 5.11: Confirmation of expected and actual values of MRR

Experiment No.	**Optimum Machining Parameters**			**MRR (gm/min)**	
	Current (A)	**Pulse on Time (µsec)**	**Wire Tension**	**Actual**	**Expected**
1	**6**	**9**	**600**	**10.835**	**10.142**
				Error (%)	**6.39%**

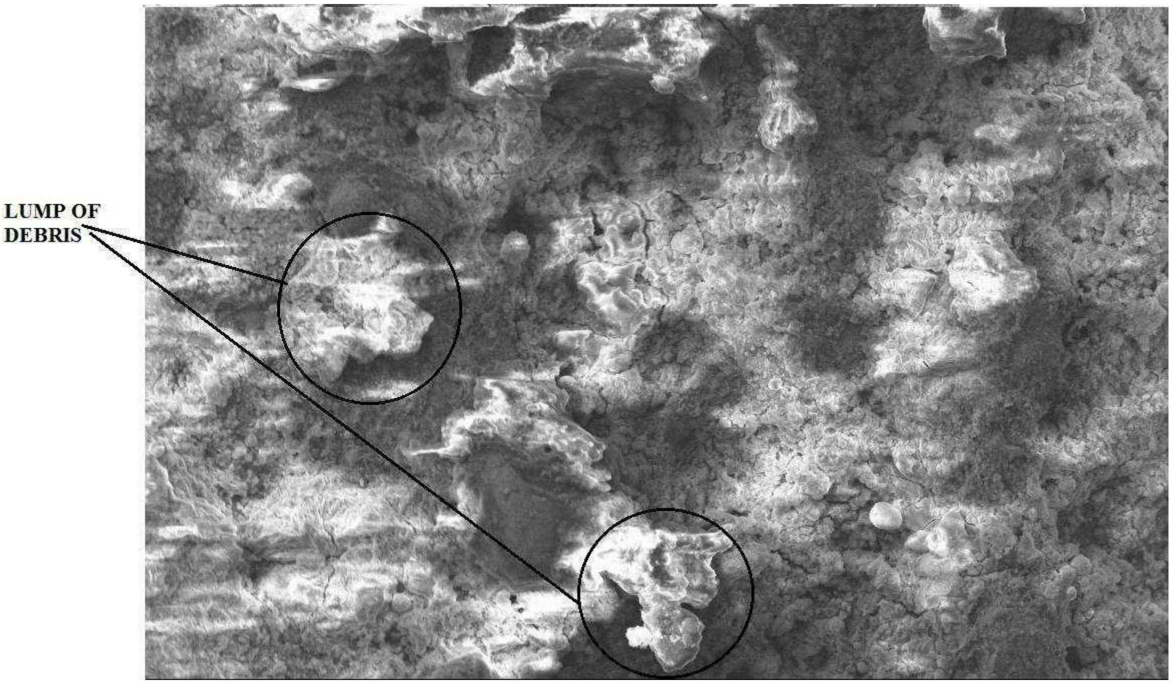
Table 5.12: Confirmation of expected and actual values of Surface Roughness

Experiment No.	**Optimum Machining Parameters**			**Surface Roughness**	
	Current (A)	**Pulse on Time (µsec)**	**Wire Tension**	**Actual**	**Expected**
1	**4**	**5**	**300**	**6.59**	**6.81**
				Error (%)	**3.33%**

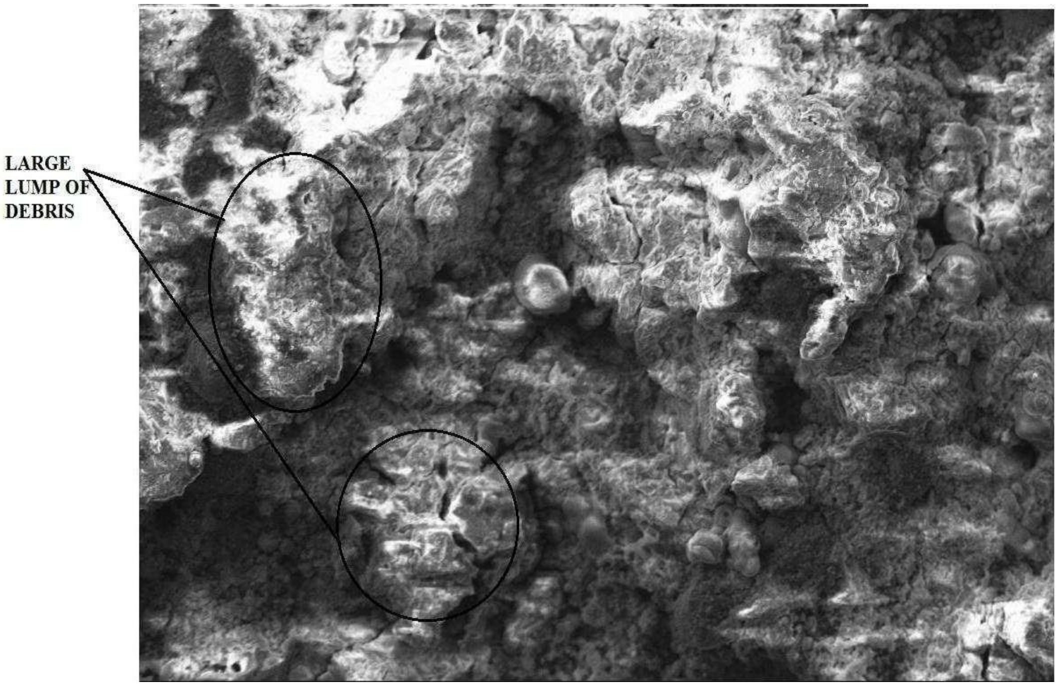
5.4 SURFACE MORPHOLOGY



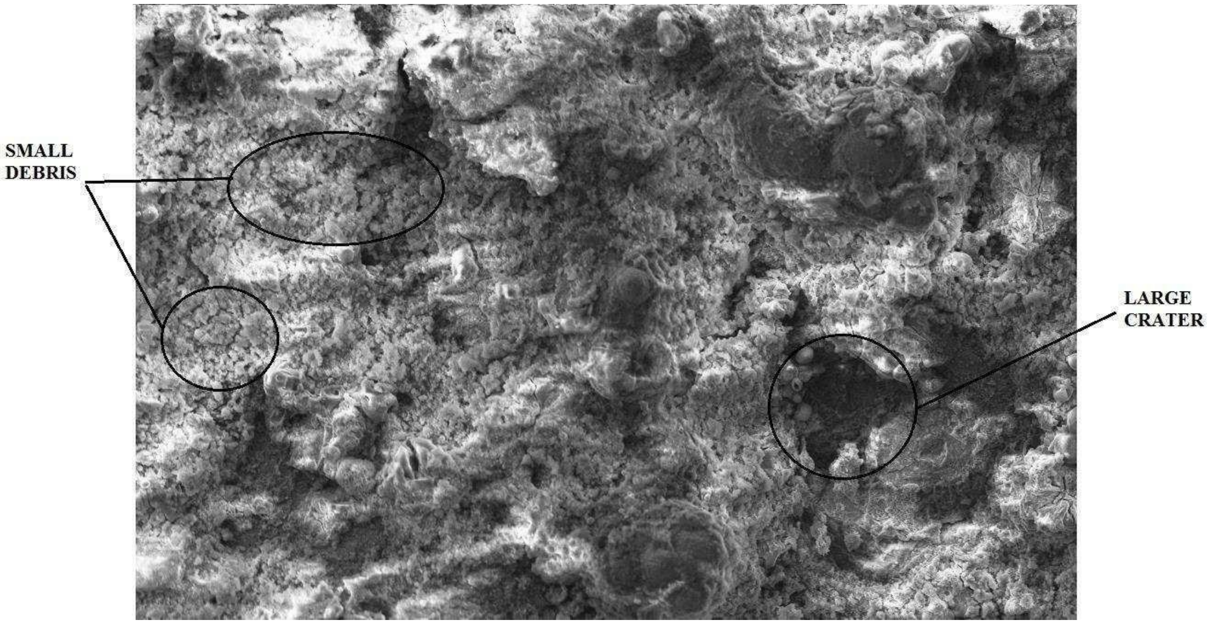
SEM photograph of Sample 1



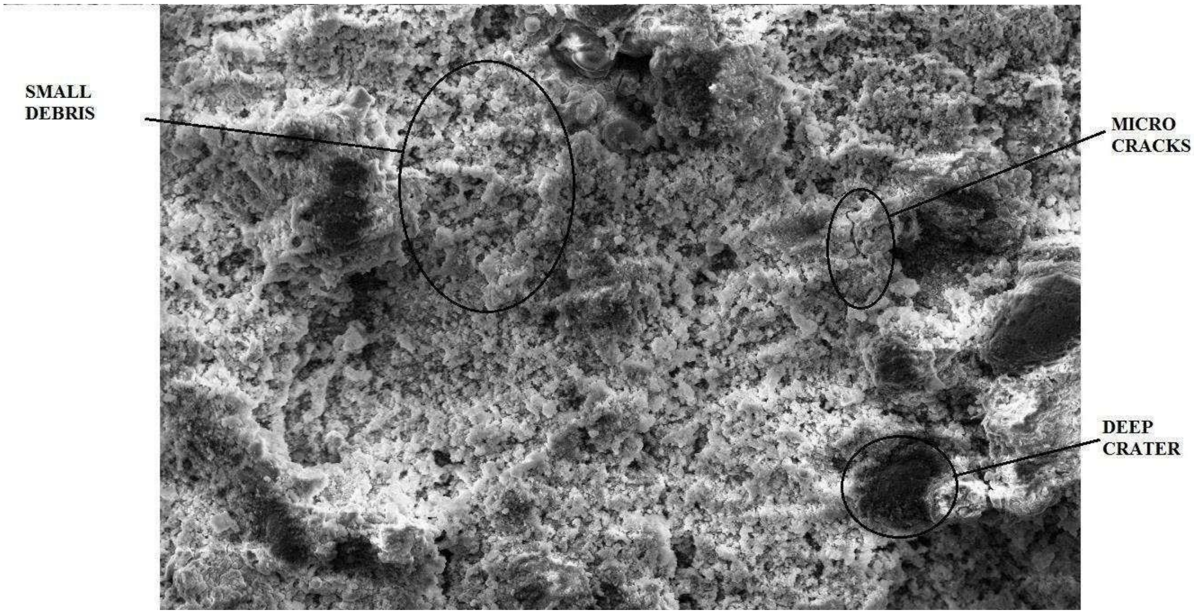
SEM photograph of Sample 2



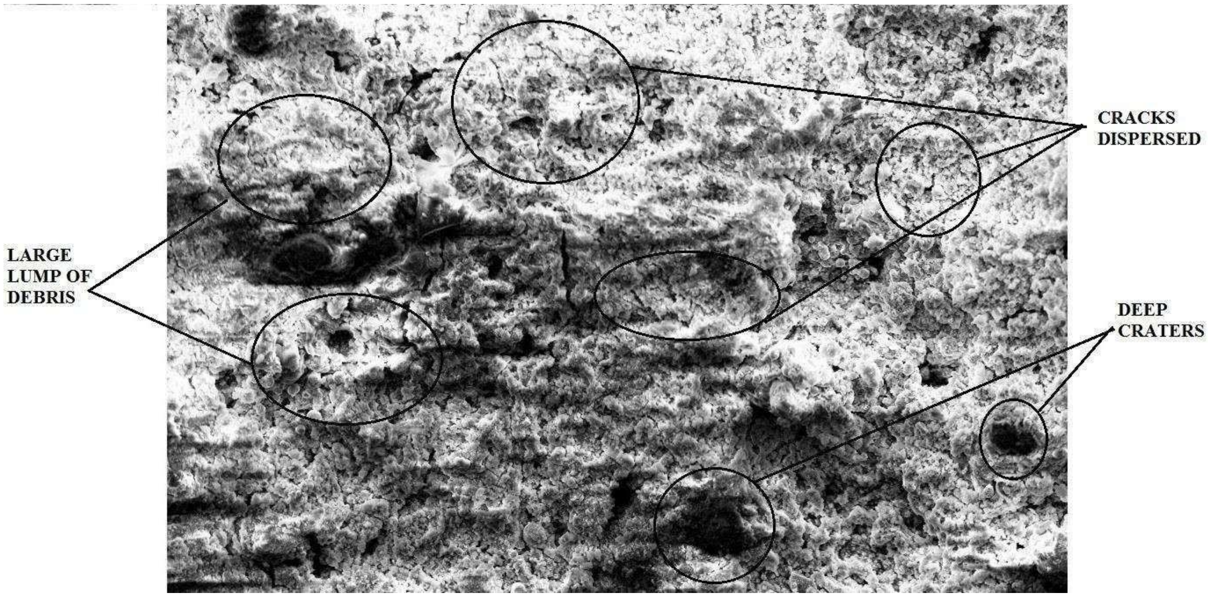
SEM photograph of Sample3



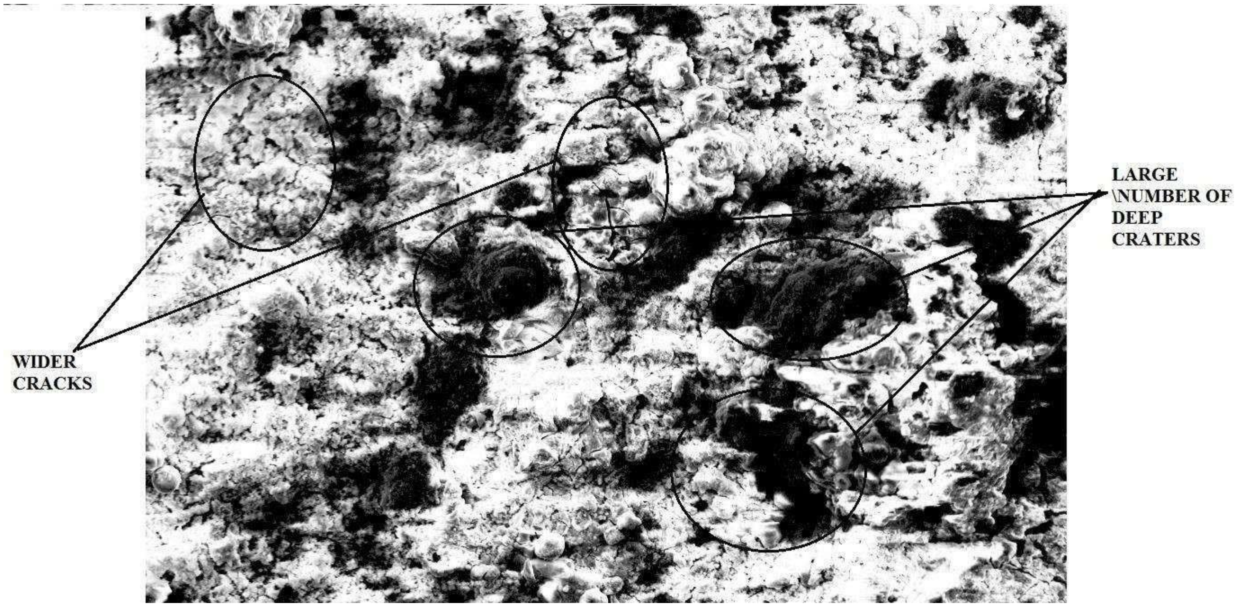
SEM photograph of Sample4



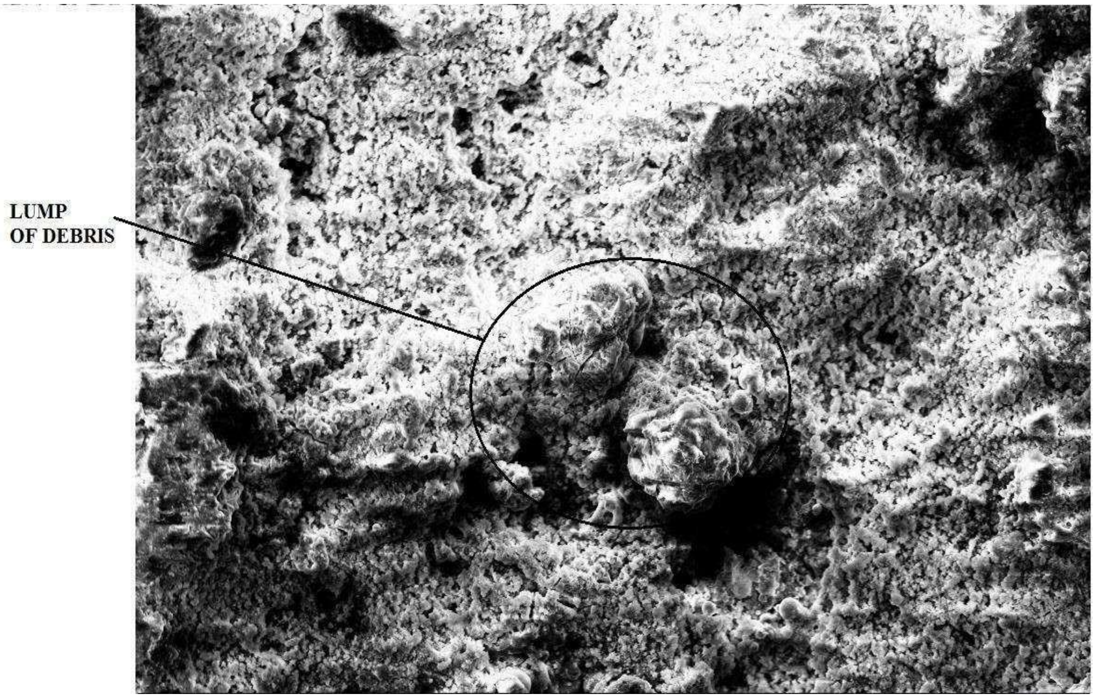
SEM photograph of Sample5



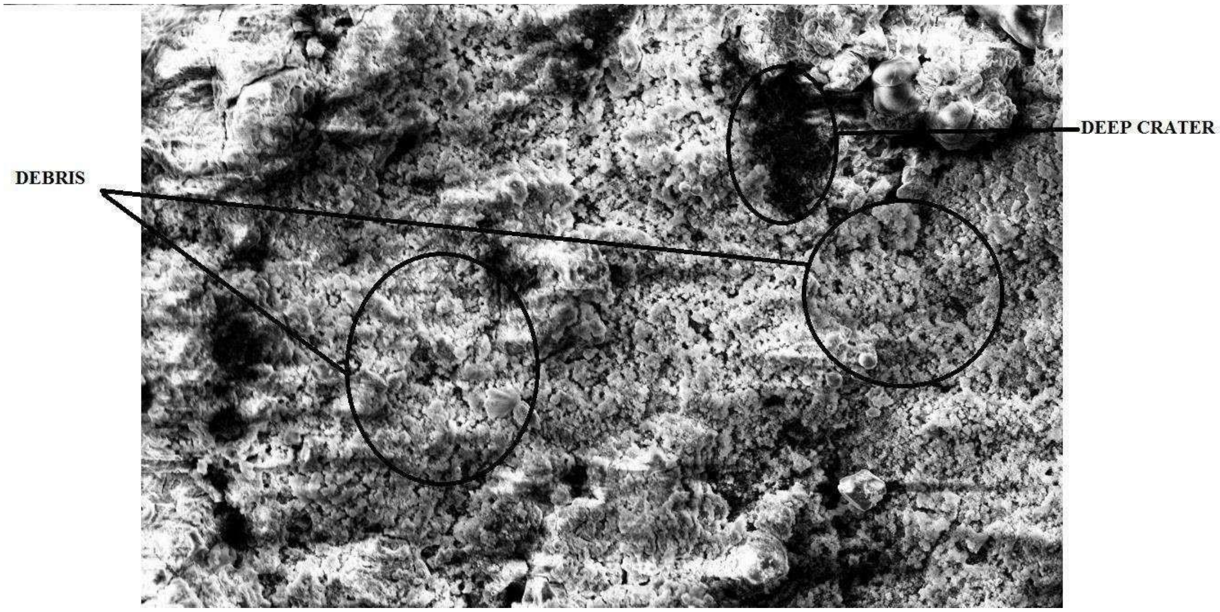
SEM photograph of Sample6



SEM photograph of Sample7



SEM photograph of Sample8



SEM photograph of Sample 9

The above SEM photo demonstrates the cavity created amid Wire-EDM machining of the work pieces. Since current was the most huge factor influencing both material expulsion rate (MRR) and the surface unpleasantness (SR), its seen that with low current the hole profundity is low which results is low surface harshness on the work piece and when the current is expanded, the hole profundity increments step by step as it appears in the SEM photo of Sample 9. Higher pinnacle current causes more regular splitting of dielectric atom so it is discovered that more successive soften blast in this manner results in poor surface wrap up.

The pictures of work pieces were expanded to 72X in order to consider the profundity of cavity caused by the flashes delivered amid the machining of the work piece on Wire-EDM.

The beat on time is the second most affecting element for the material expulsion rate (MRR) and slightest for surface unpleasantness (SR). Because of increment in the length of heartbeat, the profundity of hole is seen to be expanded. This is because of the way that bigger the term of heartbeat more serious will be the sparkles delivered for machining, and this will make the surface all the more unpleasant and will likewise create more material expulsionrate. It very1well may be seen in SEM pictures of test 1 and test 9, which show the profundity of cavity at most reduced and most astounding heartbeat on time.

The MRR increments with increment in hole voltage and after that it begins to diminish. This is because of increment in hole voltage result in higher release vitality per start due to huge ionization of dielectric between working hole. Surface unpleasantness additionally increments with hole voltage. As the release vitality increment, all the more unpleasant surface is delivered.

CHAPTER-6

CONCLUSION AND SCOPE FOR FUTURE WORK

6.1. CONCLUSION

This test think about depicted the advancement of info machining parameters in Wire- Electrical Discharge Machining of Die Steel D-3 with metal wire as terminal utilizing L9 symmetrical cluster of Taguchi technique. Components like Current, Pulse on time (Ton) and Wire Tension and their collaborations have been found to assume huge part in WEDM activity for expansion of MRR and minimization of Surface Roughness.

In light of above work following conclusions are made:

- With increment in the current, the MRR tends to increment at a high rate than beat on time and voltage. Pinnacle current is the most noteworthy factor for MRR.
- MRR at first increments with crest current however with additionally increment in its esteem MRR has a tendency to lessen. The explanation behind such conduct is that the garbage introduce between the terminal wire and the workpiece does not permit adequate sparks to strike the surface of work.
- MRR increments with increment in heartbeat on time yet at a slower pace when contrasted with that of current. The release vitality is higher at larger amounts of heartbeat on time accordingly we get higher material expulsion rate. For bring down heartbeat on time, the release vitality is lacking hence the material expulsion rate is low.
- With Wire Tension, at first the MRR tends to increment, however additionally increment in its esteem has a tendency to debase the MRR. Wire strain has relatively unimportant impact on MRR and is the minimum affecting parameters with a commitment of just 1.99%.
- All the three parameters demonstrate an expanding pattern with surface harshness i.e., with

increment in the levels of WEDM parameter, the surface unpleasantness of the machined surface increments.

- By expanding the current the surface unpleasantness increments and the surface complete corrupts. Rough surface is produced as we increment the current. Pinnacle current is the most critical factor having a commitment of 84.46%. As present expands, the start force increments and subsequently the surface debases more. The base surface harshness is seen at4A.
- With increment in beat on time and wire pressure the surface harshness increments however at an ease back pace when contrasted with current. The base surface unpleasantness was seen at 5 µsec beat on time and 300 wire pressure. The commitments of heartbeat on time and wire strain are 5.92% and 7.66%separately.

6.2 SCOPE FOR FUTURE WORK

The current study places a greater emphasis on failure detection and elimination.

- Follow-up research can be carried out to enhance the suggested monitoring system's ability to forecast and control surface integrity in real time.
- This type of device may also serve as an online inspection system for machined components.
- The P/M electrode's cross-sectional area can be employed in future experiments.
- Another dielectric medium can be utilized to investigate its effects and function in surface alteration.
- The effectiveness of such a model while cutting industrially relevant profiles such as fir tree slots may be investigated.
- Additional research can be done to determine the relationship between material attributes and discharge characteristics. To make the prediction model successful against numerous materials,

for example, the model must be retrained with a suitably big dataset created by examining several materials routinely processed by wire EDM.

- Instead of discrete incremental steps, the process control algorithm can be further extended to perform parameter adjustment as a function of RUL or any other relevant indication of failure severity.
- Other plastic mould steels for surface modification include corrosion-resistant steel (AISI 420, AISI 440B, AISI 630), pre-heat treated steel (P20), alloyed tool steel (D2, O1, H11, and H13), air hardening cold work die steel (A series), and water hardening die steel (W-series).
- Because arcing is an issue in all electric discharge machining processes, the suggested monitoring system may be applied to other types of EDMs.
- Flushing pressure can be changed to investigate its effect on surface properties.
- Machined surface wear measurement and corrosion testing can be used to forecast improvements in wear and corrosion behavior.

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"Investigation of Material Removal Rate, Surface Roughness and Surface Morphology in Wire-Electro Discharge Machining of Die Steel D3"

Ajay Kumar Singh[1], Dr. Shahnwaz Alam[2] , Dr. Mohd. Anas[3]

[1]*M.techStudent, Mechanical Engineering Dept, Integral University, Lucknow, UP India*
[2]*Associate Professor, Mechanical engineering Dept, Integral University, Lucknow, UP, India*
[3]*Associate Professor, Mechanical engineering Dept, Integral University, Lucknow, UP, India*

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Abstract - *Wire-EDM is a non-ordinary cutting procedure used machine materials with high hardness, affect obstruction and durability. It defeats the challenges looked by ordinary EDM as it machines with the assistance of a moving wire terminal. This examination is led on Wire-EDM for machining of Die Steel D3 with bass wire cathode in order to set up the connection between WEDM process parameters with material expulsion rate and surface unpleasantness. The examination uncovered that material expulsion rate and surface harshness were significantly impacted by the pinnacle current. Heartbeat on time was observed to be the second most overwhelming parameters for both execution measures while wire strain was the slightest commanding parameter for both execution measures.*

1. INTRODUCTION

Wire cut Electrical-Discharge Machining (Wire-EDM) is a variation of EDM which utilizes a thin wire (around 0.18mm) which fills in as the terminal. For the most part metal wires are normally utilized, which is nourished gradually through a wire reel into the material and the power releases through the wire cuts the work piece in type of sparkles. In Electrical-Discharge Machining (EDM) Wire Cut is typically performed in a shower of dielectric (ordinarily utilized is water). On the off chance that we watch the procedure under a magnifying instrument, the wire itself does not really interacts with the metal to be machined; the electrical releases in type of sparkles expel little measure of material and afterward enables the wire to movement through the workpiece. A release happen between the two nearest purposes of the anode and cathode, the extraordinary warmth is produced close to the zone liquefies and dissipates the materials in the starting zone.

Wire-EDM is a broadly acknowledged as a non-contact and non-traditional machining process utilized for creation of segments having unpredictable profiles. In wire EDM, the conductive materials are machined with a progression of electrical releases (known as sparkles) that are delivered between a precisely situated moving wire (the anode) and the work piece. High recurrence beat of AC or DC supply is released from the wire onto the work piece with a little start hole through the protected dielectric medium. WEDM process by and large includes the disintegration impact of discrete start releases between the device cathode in type of wire and work piece submerged in a liquid dielectric medium. WEDM is utilized for generation in aviation ventures while machining small scale gas turbine sharp edges and other electronic segments.

Wire electrical release machining (WEDM) is a warm material evacuation process that is prepared to do exactly machining parts with much hardness and complex structures, having sharp edges which are extremely hard to cut by the regular machining forms. WEDM is likewise a generally spread strategy utilized in enterprises for exactness machining for a wide range of conductive materials of any hardness. Wire-EDM machines have likewise embraced the beat creating circuit that utilizations bring down capacity to touch off and higher power for cutting. Since fine surface isn't accomplished as the vitality produced by the high-voltage sub-circuit is too high subsequently it isn't used for some activities.

As more current and more extraordinary materials are created, and more intricate shapes are introduced, customary machining tasks will keep on reaching their confinements and the expanded utilization of wire EDM in assembling will keep on growing at a quickened rate.

WEDM machining technique is usually used to cut hard metals that are unthinkable by other customary machining forms. It has been broadly utilized, particularly to cut confused shapes or fragile depressions that are hard to deliver with regular machining techniques. In any case, one basic confinement is that Wire-EDM just works with electrically conductive materials.

3.1 TAGUCHI METHOD

Taguchi has generated a methodology for the application of designing of experiments, which includes a practitioner's handbook. This methodology has taken the experiment design from the world of statistician and is applied fully into the world of manufacturing. This contribution have made the work much simpler by making the use of only fewer experimental designs, and providing a better understanding of the variations and the economic consequences of better quality engineering in the world of production. He introduced his approach using the experimental design for:

Designing the products and processes which are robust to environmental conditions;

Designing and developing products and processes which are robust to component variation;

To minimizing variation about a target value, this philosophy of Taguchi is applicable. He proposed that optimizing engineering process or product should be carried out in three step procedure, they are the design of system, parameter design and tolerance design. In system design the engineer applies scientific engineering knowledge to produce a basic functional prototype design. During the stage of product design stage, the selection of the work materials, components, parameter values etc. are involved. Since system design is an initial step, functional design may be far from optimum in terms of quality and cost.

The objective of parameter design is to optimize the setting of process parameter value for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. Also it is expected that the optimum level of process parameters obtained by the parameter design are insensitive to the varying environmental conditions and other noise factors. Hence the parameter design plays a key role in Taguchi approach for achieving high quality without increasing cost. To solve the problem, Taguchi approach utilizes a special design of orthogonal arrays for studying the entire parameter space using small number of experiments. Loss function is afterwards defined so as to find the deviation between the desired values and experimental values. The value of this loss function is then transformed into a signal-to-noise ratio. Basically there are three category of performance characteristic during the analysis of the signal to noise ratio, they are the lower-the-better, the nominal-the-better, and the higher-the–better. The S/N ratio for each level of process parameter is computer based on the S/N analysis. Larger S/N ratio basically are corresponding to the better performance characteristic and hence the optimal level of the process parameter is the level having the highest S/N and ANOVA analysis, the optimum process parameters can be predicted. Finally, a confirmation test experiment is conducted to verify the experimental optimal set of process parameters obtained from the parameter design. The Taguchi method is adopted to obtain optimal machining performance in the die sinking.

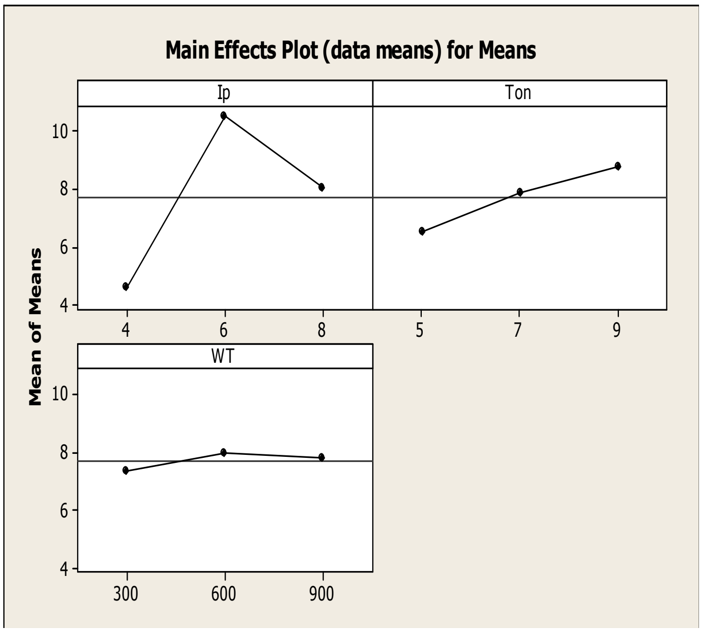
S.No.	**Parameters**	**Units**	**Level 1**	**Level 2**	**Level 3**
1	Current (Ip)	A	4	6	8
2	Pulse-on-time (Ton)	Msec	5	7	9
3	Wire Tension		300	600	900

: L9 Orthogonal Array

Exp. No	**Ip**	**Ton**	**WT**
1	4	5	300
2	4	7	600
3	4	9	900
4	6	5	600
5	6	7	900
6	6	9	300
7	8	5	900
8	8	7	300
9	8	9	600

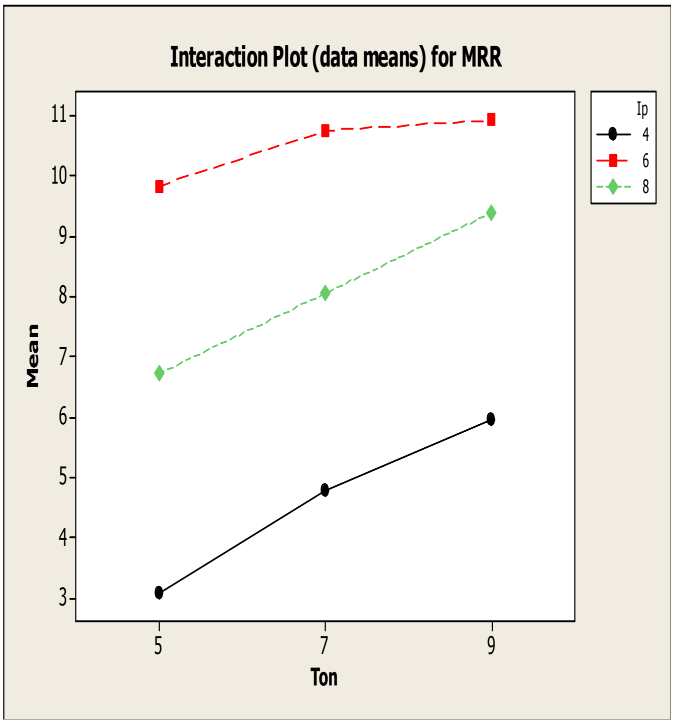
Calculation of Material Removal Rate

Exp. No	**Current**	**Pulse on Time**	**Wire Tension**	**Material Removal Rate (mm^3/min)**
1	4	5	300	3.079
2	4	7	600	4.775
3	4	9	900	5.940
4	6	5	600	9.830
5	6	7	900	10.748
6	6	9	300	10.928
7	8	5	900	6.715
8	8	7	300	8.050
9	8	9	600	9.390



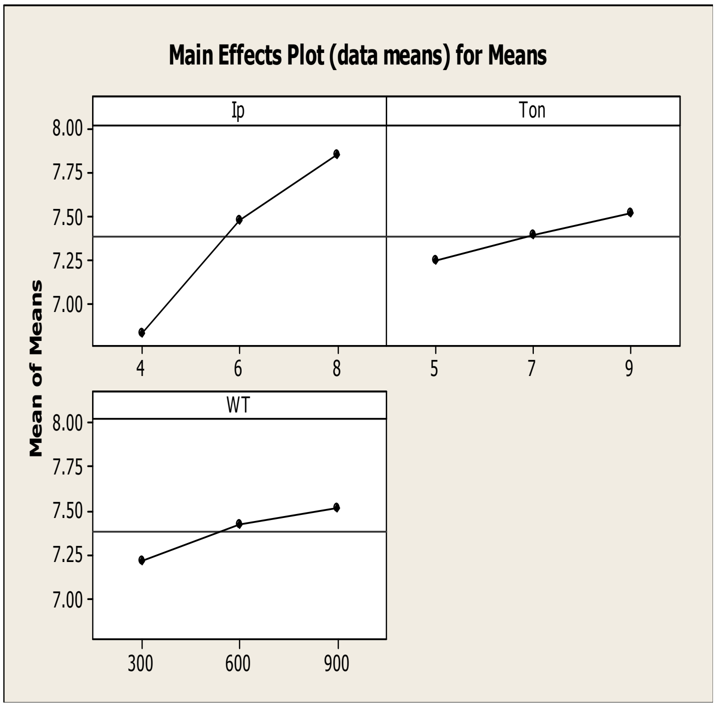
Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	52.789	26.395	160.10	86.25
Pulse on Time	2	7.424	3.712	22.51	12.13
Wire Tension	2	0.658	0.329	1.99	1.07
Error	2	0.330	0.165		0.53
Total	8	61.200			100%

Interaction plot between WEDM parameters and MRR



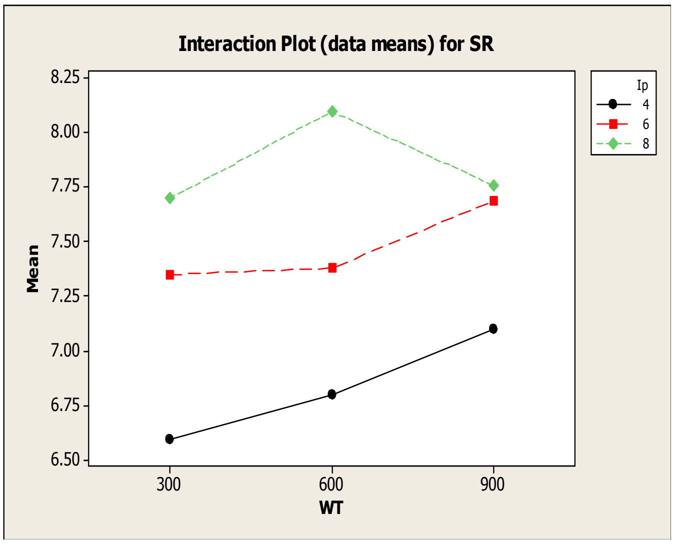
Calculation for Surface Roughness

Exp. No	Current	Pulse on Time	Wire Tension	Surface Roughness Ra(µm)
1	4	5	300	6.59
2	4	7	600	6.80
3	4	9	900	7.10
4	6	5	600	7.38
5	6	7	900	7.69
6	6	9	300	7.35
7	8	5	900	7.76
8	8	7	300	7.70
9	8	9	600	8.10



ANOVA of Surface Roughness

Source	DOF	SS	Adj MS	F Value	Contribution
Current	2	1.60549	0.80272	43.29	84.46
Pulse on Time	2	0.11262	0.05631	3.04	5.92
Wire Tension	2	0.14562	0.07281	3.93	7.66
Error	2	0.03709	0.01854		1.95
Total	8	1.90082			100%



CONCLUSION

- This test think about depicted the advancement of info machining parameters in Wire-Electrical Discharge Machining of Die Steel D-3 with metal wire as terminal utilizing L9 symmetrical cluster of Taguchi technique. Components like Current, Pulse on time (Ton) and Wire Tension and their collaborations have been found to assume huge part in WEDM activity for expansion of MRR and minimization of Surface Roughness.

- In light of above work following conclusions are made:

- With increment in the current, the MRR tends to increment at a high rate than beat on time and voltage. Pinnacle current is the most noteworthy factor for MRR.

- MRR at first increments with crest current however with additionally increment in its esteem MRR has a tendency to lessen. The explanation behind such conduct is that the garbage introduce between the terminal wire and the workpiece does not permit adequate spaks to strike the surface of work.

- MRR increments with increment in heartbeat on time yet at a slower pace when contrasted with that of current. The release vitality is higher at larger amounts of heartbeat on time accordingly we get higher material expulsion rate. For bring down heartbeat on time, the release vitality is lacking hence the material expulsion rate is low.

- With Wire Tension, at first the MRR tends to increment, however additionally increment in its esteem has a tendency to debase the MRR. Wire strain has relatively unimportant impact on MRR and is the minimum affecting parameters with a commitment of just 1.99%.

- All the three parameters demonstrate an expanding pattern with surface harshness i.e. with increment in the levels of WEDM parameter, the surface unpleasantness of the machined surface increments.

- By expanding the current the surface unpleasantness increments and the surface complete corrupts. Rough surface is produced as we increment the current. Pinnacle current is the most critical factor having a commitment of 84.46%. As present expands, the start force increments and subsequently the surface debases more. The base surface harshness is seen at 4A.

- With increment in beat on time and wire pressure the surface harshness increments however at an ease back pace when contrasted with current. The base surface unpleasantness was seen at 5 µsec beat on time and 300 wire pressure. The commitments of heartbeat on time and wire strain are 5.92% and 7.66% separately.

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