EXPERIMENTAL ANALYSIS FOR CRITICAL MACHINING PRAMETER OF DIE –SINKING EDM USING OF VARIOUS COMPOSITION OF Cu-W ELECTRODE

THESIS

Submitted in partial fulfillment of the
Requirement for the award of the
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By
Arvind Kumar Tiwari
Under the Guidance of

Mr. Jasvir Singh
Uid-14631

LOVELY PROFESSIONAL UNIVERSITY

PHAGWARA (DISTT. KAPURTHALA), PUNJAB

School of Mechanical (manufacturing) Engineering
Lovely Professional University
Punjab, India

Lovely Professional University
Phagwara, Punjab

CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled **"EXPERIMENTAL ANALYSIS FOR CRITICAL MACHINING PARAMETER OF DIE SINKING EDM USING VARIOUS COMPOSITION OF Cu-W ELECTRODE"**inpartialfulfillmentoftherequirementfortheawardofdegree of **Master of Technology** and submitted in Department of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, is an authentic record of my own work carried out during period from January 2014 to May 2015 under the supervision of Mr. Jasvir Singh**,** Assistant Professor, Department of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab.

The matter presented in this dissertation has not been submitted by Meany where for the award of any other degree or to any other institute. .

Date: …../…../……….. **(Arvind Kumar Tiwari)**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Date: …../…../………. **(Mr. Jasvir Singh)**

. Supervisor

The M. Tech Viva- Voce examination of Arvind Kumar Tiwari, has been held on …./…./………

Signature of Examiner

Signature of External Examiner

DECLARATION

I, Arvind Kumar Tiwari student of MASTER OF TCHNOLOGY (MANUFACTURING ENGINEERING) under Department of MECHANICAL ENGINEERING of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

Date- **Arvind Kumar Tiwari**

(11305392)

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Date **(Arvind Kumar Tiwari)**

Reg. No. 11305392

Abstract

Electrical discharge machining (EDM) is one of the non-conventional machining processes. EDM is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the workpiece to produce the finished part to the desired shap. EDM has become an important and cost-effective method of machining for extremely tough and brittle electrically conductive materials. It is widely used in the process of making moulds and dies and sections of complex geometry and intricate shapes.

The experimental work is done to optimize the EDM machining parameters using different composition of Cu-W electrode's (Cu30-W70, Cu25-W75 and Cu20-W80) on different specimens (ED11, AISI 4340 and W300) which are widely used for industrial applications in the manufacturing of dies. aircraft gear, various machines shaft .

The use of standard L9 orthogonal array, Minitab is done to investigate and optimize the EDM machining parameters .In this experiment input parameter are composition of electrode, specimen of different material and current , on the other side the output parameters are material removal rate, tool wear rate surface roughness.

In this experiment , the composition Cu25-W75 is found to be optimum at 04 ampere current on ED11 material . For this set of combination the MRR is high ,TWR is very less and surface finish is good.

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Chapter 1
Introduction

1.1 Development of Electrical Discharge Machine

EDM(EDM) is non conventional machining system. It is first time detected in 1970 ,by English scientist Priestley, recently during research it is developed to eliminate erosive effects on the electrical contact by soviet scientist Lazarenko . They decided to exploit the destructive effect of an electrical discharge and create controlled method of metal machining. The first they developed spark erosion machine in 1943, it know as Lazarenko circuit. It has been employed over many year in power supplies for EDM machine and an improved from is being many applications. In starting it use in industry to plastics moldings, die castings, forging of die. it started new evolution in material science and manufacturing technology have to start engineering material(metallic), composite material, ceramics, having superior thermal and mechanical properties with acceptable electrical and thermal conductivity, in order that work piece use be machined with the help of spark erosion which is produce with the help of electric current. In current time, EDM machine is a common procedure used in industries to get great accuracy in machining of conductive materials such as metallic alloys, metals, graphite even some ceramic materials that have hardness is so high. EDM is more and more used in die, mould and tool manufacturer industries, for machining of steels and complex material require high accuracy, complex shape and excellent surface finish. Conventional machining method is frequently based on the removal metallic engineering material using material of electrode(tool) which is harder compare to work-piece material and it is also economically. EDM is use to eroding effect of electrical spark on electrodes (tool and Work-piece).EDM is used a procedure of Material removal occurrence of electrical discharge in electrolyte. In EDM, tool theater vital task, it affects MRR and TWR. EDM normally used in die, mould production and tool making industries for machining of tool materials. The heat treated steels drop in material which is hardness is high these material group when using predictable machining procedure higher TWR is major disadvantage in EDM. The ratio of wear is known as the volume lost of material from the tool(electrode) which divided by specimen volume which is removed from the work-piece material, it depend on selection of tool (electrode) and work-piece materials used. If TWR is high then it means electrode is easy to wear which is not good for machining, it decrease the performance rate. The consequence of the experiment is support the thoughtfulness selection of tool in EDM for the advance machining in manufacturing industries and plant. The reason is each electrode materials have unique feature that gives dissimilar result. EDM has been developed step by step since several years to improve the MRR and decrees TWR, these are the significant aspect of procedure. In EDM, individuality which control the machining procedure. Most imperative MRR and TWR. This uniqueness taken into report when high-quality presentation is needed.

1.2 Introduction of Electrical Discharge Machine(EDM)

EDM is one of the non-terminal machining process .it remove material by erosion effect . in EDM machine spark is generated between electrode and specimen of material.

Generally it is use to making die and it performs hard material to remove. EDM could be machined multifaceted geometries in small batch production, even on shop. Specimen material to be machined by EDM should be electrically conductive.

1.3 Principal of EDM

EDM is compared with the conventional cutting method, this metal working technique use an electric erosion effect and it connotes breakdown of tool material add-on form electric discharge. Condition for create discharge is ionization of the dielectric that is splitting up of its molecules into ions and electrons .

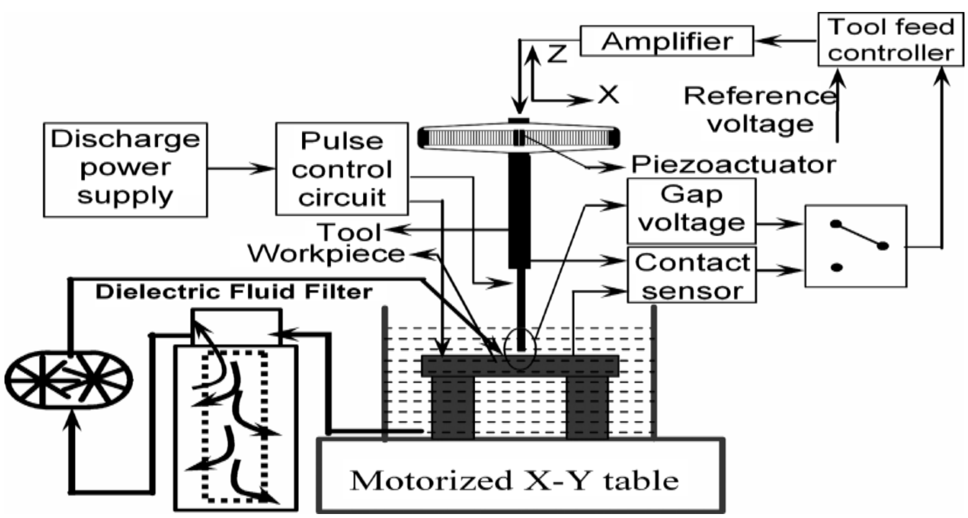

Figure 1.1 EDM Process Diagram

This diagram shows the die-sinking EDM machine in this machine we seen that in a tank there have a motorized table which move X-Y direction ,electrode is attaché with help of tool holder and this tank fill of die-electric fluid electrode move on Z-X direction. Tank is attaché die-electric fluid filter and in series it attach pump which are connect electric fluid nozzle it strike fluid on work piece. That system is controlled by controller; here we decide feed rate voltage gap current and another thing.

1.4 Die-Sinking EDM

Die-sinking EDM machine material removal affected by the use of non- stationary electric discharge which are separated from each other both spatially and temporally . in this process machine need average relative speed between electrode and wokpiece with penetration speed in work piece.

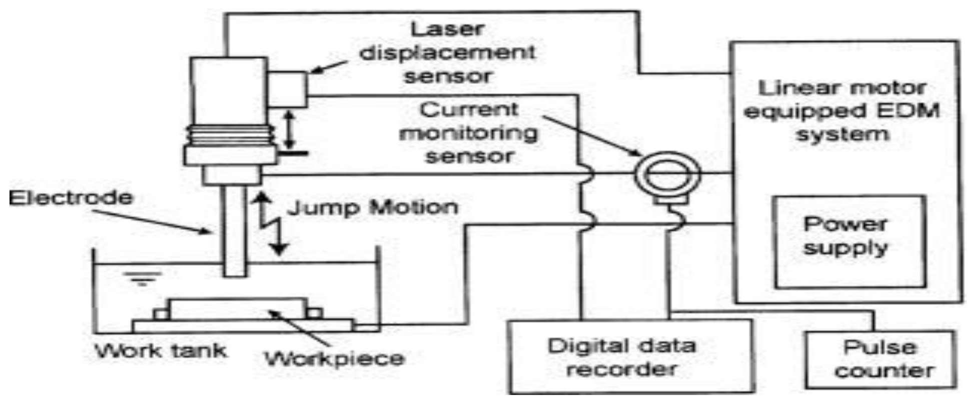

Figure1. 2 Die-sinking EDM Machine

1.5 Parameter of EDM

(a) **Spark on-time :** The period of instance (μs) time is used in per series use under the procedure.

(b) **Spark off-time:** The period of instance (μs) flanked by the spark time allow the molten metal to go hard and elect clean out of the arc gap.

(c) **Spark length (or gap):** spark length is distance between the workpiece and electrode throughout the procedure of EDM. It perhaps known as flash gap. Spark length can be maintained by servo scheme.

(d) **Current (Ip):** Current is deliberate in amp allowable to per cycle. Discharge current is directly relative to the MRR.

(e) **Voltage (V):** Potential that can be measure by volt it is also effect to the MRR per cycle.

(f) **Duty cycle (τ):** It is a relative of the on-time family member to the total cycle time. This Parameter is intended by in-between the punctual via whole cycle of time.

1.6 Characteristic of EDM electrode material

The characteristics of electrode materials are:

1. Tool material needs highly electrical conductivity

2. Tool material needs high thermal conductivity

3. Tool material needs higher density

4. Tool material needs high melting point

5. Tool material needs easy manufacturability.

6. Low Cost

Basics of these parameter we select the tool material

1.7 Design parameter

EDM design parameters

1. Workpiece MRR.

2. Electrode Tool wear rate

Machining parameter –

1. Electrical discharge of current (Ip)

2. EDM machine pulse on time (Ton)

Constant parameter-

1. Duty cycle

2. Voltage

3. Electrolyte fluid flushing pressure

4. Workpiece and electrode polarity

1.8 Advantage of EDM

- Complex shapes that would or else be hard to manufacture through customary cutting tools.
- Very durable material to have close tolerances.
- Small specimen where traditional cutting tools may harm the part from surplus cutting electrode pressure.
- There is no direct contact stuck between electrode and specimen. Consequently fragile sections and weedy materials can be machined with no any distortion.

- A high-quality surface finish can be obtained.

1.9 Limitation of EDM

Some of disadvantage of EDM take in:

- The sluggish rate of work piece material exclusion.
- Possible flames exposure linked by use of combustible electrolyte.
- The extra time as well as cost used for creating electrodes for ram of EDM.
- Producing sharp corners happening the specimen is hard due to tool wear.
- Specific power expenditure is elevated.
- Power expenditure is high.
- Tool wear occurs during machining.
- Electrically nonconductive material be able to machined only by means of precise set-up of the procedure

Chapter 2
Literature Review

In this chapter we explore the change rate of material removal rate, tool wear rate and surface roughness by use of copper – tungsten electrode. In this chapter we see that nature of electrode material in different condition, different material and process.

To improve the efficiency of Cu-W electrodperformed theyh had been performed they create different Cu-W electrode composition. To improve EDM efficiency like in 2001 Wong Y.S. et al [1] carried out the study of Material removal rate , tool wear rate and the surface roughness of Cu-W electrode for this experiment they use TiC specimen. To improve the performance of Cu-W electrode they use Ni and sinter with copper and tungsten . Effect of MRR ,TWR and surface roughness on specimen are

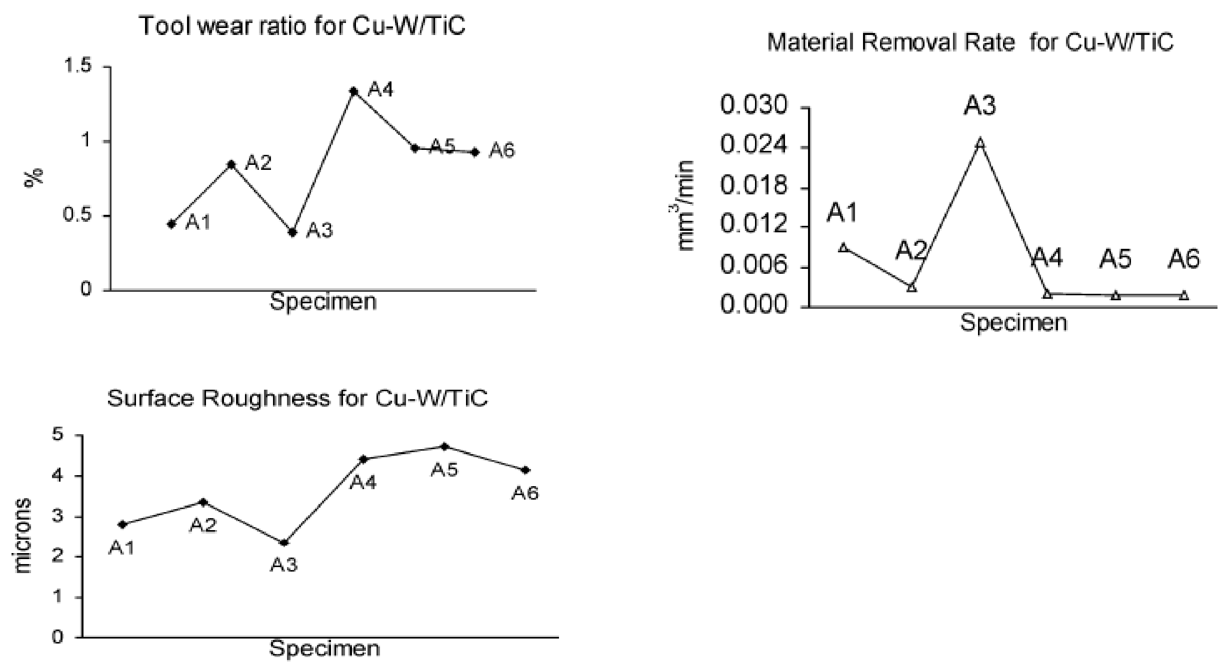

Figure 2.1 Behavior of output parameter CuW/TiC[1]

For this they study also the nature Cu-w electrode Composite .they find that if the relative density then electrodeomposition then electrode resistivity is lower.

Rozeneck et.al(2001)[2] worked on the electrical discharge machining process of metal matrix composites. Authors has studied the effects of peak current, pulse on time , pulse off time and the voltage on the surface roughness of metal matrix composite. The metal matrix composite chosen for study were AlSi-Mg/Sic and ALS7-Mg/AL2O3. They concluded that maximum cutting speed of ALSi-Mg/Sic was 3 times lower than the cutting speed of aluminum alloy whereas maximum cutting speed of ALSi-Mg/Al2o3 composites was 6.5 times lower than the cutting speed of aluminum alloy.

Singh and Maheshwar et al (2004)[3]shows that the input parameters such as current, pulse on time, and applied voltage influence the overcut. With the increase of current, the overcut increase but only up to a certain limit. Gap voltage also influence the overcut.

J.L Lin et. al (2005)[4] has worked on the grey-fuzzy logic analysis of optimization of the various parameters of electrical discharge machining composite alloy. Author has selected these parameters for study pulse on time, duty cycle and discharge current. The output Reponses were optimized material removal rate, tool wear rate and surface roughness. The concluded that grey fuzzy analysis helps to optimize the working condition by multiple process response. Author created a L18 orthogonal array for analysis. Fuzzy grey analysis performed a fuzzy reasoning of the multiple performance and helps to optimize the input variables and thus output response can be optimized to maximum performance.

After this CarvalhoJosé (2006)[5] Conducted experimental studied effect of Cu-W tool material composition on the electrical discharge machining. In the experiment the varying peak current are ie=0.5/1.0/2.0/3.0/4.0A0,Open voltage=280V and released voltage Ue=30V pulse length ti=3.2μs pulse gap to=3.2μs dielectric flushing pressure 40kPa and Cu20W80/Cu25W75/Cu30W70 electrode material with negative polarity stainless steel H13 as specimen material where hardness 53HRC.In the process workpiece and tool eroded throughout electrical liberation the relatively tool wear intended as material volume eroded from the tool per unit time divide eroded workpiece material. from this research they analyse the property of Cu-W electrode on different percentage .

Table 2.1 Copper Tungsten property table [5]

Property of electrode material	**Unit**	**Cu20-W80**	**Cu25-W75**	**Cu30-W70**
Density	g/cm3	15.4	14.7	14.1
Hardness Brinell		2,160	1940	720
HardnessRockwell		103	98	93
Heat capacity thermal	J/g-K	0.178	0.1920	0.208
Thermal conductivity	W/m-K	210	230	260
Solidus temperature	K	1,353	1353	1353
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Heat capacity	J/g-K	0.178	0.1920	0.208
Modulus of elasticity	GPa	214	234	226
Flexural modulus	GPa	1.17	1.03	0.89

Bradley .N (2007)[6] worked on the Response surface methodology which is consist of various statistical tool and mathematical models for the analysis of electrical discharge machining. The author emphasis that RSM basically consist of three different types first order, second order and three level factorial fractional design. A first order model is most significant for low order polynomial terms, furthermore it's very important model for analyzing a flat surface with or without tilted surface. The first order model has least squares. The lack of fit of first order equation takes place when the surface of the material is not plan. For second order equation, there are many designs are available. The most popular design is the central composite design. The experiment can be started from 2q factorial point and the center points and axial points can be generated. Author also concluded that when there are more than three surface points, it's very difficult to see surface in second order RSM.

Puertas et al.,(2007) [7] carried out results which showed that the intensity and pulse time factor are important factors in case of Surface Roughness .The duty cycle factor was not significant factor. In case of Tool Wear Rate, intensity factor was an important factor. The two important factors for MaterialRemoval Rate were the intensity, duty cycle and the pulse time..

Beri Naveen et al. (2007) [8]Taguchi approach applied to identification of import factor and measure output parameter selection of output prefer workpiece characteristic. during the experiment AISID2 steel use as workpiece and CuW(Cu30%-W70%) used as the electrode material and the parameters are electrode material ,current, duty cycle output parameter are MRR,TWR and surface roughness, to optimized these parameter applied L18 and did comparison to Cu electrode. In this experiment kerosene us as electrolyte here the best parameters for MRR is with Cu where current 10.5A0 duty cycle 0.66 and 0.7Kg/cm2flusing pressure.

Kwon Young-Sam et .al (2008) [9] studied Cu-W sintered electrode where percentage of copper they take 20 to 35 % and tungsten they take 65-70% manufacture through coating of Copper powder on tungsten electrode, and the electrode was homogenous, uniform and small scale with no pore, compare composition and size of electrode main parameter of this paper pulse on time, duty cycle, peck current, polarity.

Duarte José (2008)[10] studied the taguchi methodology for EDM process in this experiment black layer composition varies by a contact of EDM input parameters which affect the tool wear ratio (TWR), via an orthogonal array so as to provide a countermeasure to contacts be used. The study seeks the best possible levels of the EDM input parameters so as to create an improvement in TWR. Works demonstrate so as to the black layer composition be the manufactured goods of an contact of EDM input parameters with result on performance of EDM , as well as just not effect of EDM. The compositions of the black layer change the thermal conductivity of the outside of Cu-W electrode causative to TWR development

.Ganpatrao et al. (2010)[11] worked on the determination of Material Removal Rate of metal composite on wire electrical discharge machining. Authors suggested a optimized model for MRR based on response surface methodology. This model was based on thermal physical properties of the work piece, average gap and pulse on time.

Patowari Promod et al. (2010)[12] perfumed experiment on Artificial Nero Network(ANN) has been successfully applied for modify surface with W–Cu powder metallurgy sintered electrode in EDM. The optimized architecture of the ANN has been selected, trained and used for simulation. The simulated results from the ANN have been presented and discussed. On experiment copper tungsten electrode on C-40 grade carbon steel using prepared through powder metallurgy dense tool. In this paper the investigation the parameter sintering temperature ,pulse on time(ton) peak current(Ip) . They use to optimized L-16 orthogonal array and the ANOVA was done to study result of pertained process parameter. The basic parameter are

Table 2.2Paramete and Condition for [12]

Parameters	**Conditions**
Electrode composition	75%W–25%Cu
Compaction pressure	CP 120, 180, 240, and 300 MPa
Sintering temperature	ST 700°C and 900°C
Peak current, Ip	4, 8, 10, and 12 A
Pulse duration, Ton	19 to 386 μs in different steps
Polarity Electrode	(−)
Duty factor At lower Ton settings	50% and at higher Ton setting: 70%
Gap control and gap voltage Gap control is adjusted at average gap voltage around at	40–45 V
Processing time	5 min

Singh H. (2012)[13] proved that Depth of cut for EN-31 is better for copper then brass. Depth of cut increases with increase in pulsed current for both; depth of cut remains constant .In case of over cut, it is better for brass as compared with copper chromium. The best value of over cut was observed at current of 12A. The value of Hardness was also better for brass as compared with copper chromium. The value of maximum hardness was obtained at a current of 6A for copper chromium whereas 12A for brass. The tool wear rate was better for Copper as compared to brass. The maximum weight loss of electrode was at 12Amp for copper chromium and 7.5Amp for brass. Metal removal rate was better for copper chromium at all current values except at 6Amp. As compared to brass, maximum material removal rate was obtained at 12Amp for brass andcopper chromium.

Gopalakannan Subramanian et al. (2012)[14], conducted to investigate the effect of electrode materials on machining characteristics in EDM of corrosive resistant stainless steels 316 L and 17-4 PH. For 316 L and 17-4 PH work materials copper electrode gives the better MRR than graphite whereas the copper-tungsten yields the lowest MRR value. The MRR obtained by three electrodes in 17-4 PH is higher than 316 L because of its low hardness.

Prajapati B. Hitesh (2013)[15]worked on Material Removal Rate and Surface Roughness of electro discharge machining on EN19. Author has used three different types of electrodes graphite, copper and brass. A full factorial design was used for following parameters and levels –

Table 2.3 Factor and Level [15]

Factors	Level 1	Level 2	Level 3
Peak current	17	21	28
Pulse on time	45	55	65
Pulse off time	30	45	65

Author concluded that the most influential parameter was current and pulse on time for surface roughness. The material removal rate was poor for brass but the surface finish was better then copper and graphite. The graphite electrode give the maximum MRR at peak current 28 and 65 pulse on time.

Pradhan M. K (2013)[16] optimize various machining parameter for EDM process on AISI D2 steel and investigate response surface methodology with grey relation use to optimized machining parameter, it developed and recognized the mathematical model of EDM surface. It was studied pulse duration are most dominant factor to improve the surface finish and followed by duty factor, pulse current and voltage. The optimal cutting condition found that when duty factor is 80%,pulse duration 50µs and voltage 40V.

Manoharan Mehul et al.(2013)[17] electrode on EN-3 work metal. Basically in this paper they taking review s of author's, those who did work on EN-3 material and compare it and find optimum current value ,voltage value and relate the parameter and compare. In his investigation for higher MRR Cu electrode is superior where brass showed good surface finish and normal MRR,it found that the basis of controlling MRR and improving is most relies method this is due to stochastic nature of sparking phenomena .

Dewagonshilesh et al. (2014)[18] worked the EDM machining of AISI P20 tool steel. The tool electrode used for machining was graphite. For optimization of AISI P20 a new technique PCA grey analysis was used by the author. A L18orthogonal array based on taguchi design was created. The author concluded that for following parameter gives optimal cutting conditions Ip = 2A, Ton = 75 and Toff = 85.

Shashikant et al. (2014)[19] concluded that the optimum combination of pulse off time , discharge current , voltage and their interface for EN19 using RSM technique was Ton = 20 , Toff = 1400 , Ip = 10 amp , V = 20v . Under these condition copper gives maximum MRR and minimum Tool Wear rate.

Kumar surrender et. al (2014)[20] showed that Material Removal Rate for H-13 die tool steel increases with increase in the value of Pulse off time. The current was also an important factor. As the value of current increases, the material removal rate also increases. Author found that the value of MRR, decreases with increase in feed rate. The optimum value for MRR is 1.5456 mg/s for H-13 Die tool steel.

Habib (2014) [21]used optimization process, they use optimization of electrode to perform work on steel 2714 using EDM to optimization they use L27(3*4) orthogonal array .Main parameter are MRR, gap size and surface roughness and control parameter are Pulse on time

,Pulse off time ,Discharge current ,Average machining voltage he use Cu and graphite tool and using tuguchi approach he found that machining performance increase effectively using optimum

Chapter 3
Rationale

3.1 Problem Formulation

From the previous paper we studied, to improve the effectiveness we need to find electrode those have following properties-

1. Electrode have higher electrical conductivity
2. Electrode have lower tool wear rate
3. Electrode must be easy to manufacture
4. Electrode cost must be lower

To fill that parameter we need to find following questions answer, those questions are

1. Find the material or alloy those have higher electrical and thermal conductivity?
2. Find the material or alloy those have density is higher?
3. Analyses material or alloy manufacturing process and manufacturing cost?

That's why need a electrode those have electrical conductivity is higher and tool wear rate is lower to fill that aspect we find Cu-W electrode with the help of previous research papers. In Cu-W electrode have both properties. It's electrical conductivity is high by using of Copper and tool wear rate is lower by using of tungsten.

After the selection of material we need to find suitable percentage of Composition of Cu-W electrode. in generally in manufacturing industries are mainly uses 30-70, 25-75, 20-80 percentage composition of Cu and W . According the hardness of specimen material, operation and resultant surface finish of material is selection is also varied material removal rate and electrode deformation. The main problem is to a Cu-W electrode composition those who condition.

3.2Objective

According to problem the main objective of our research work is to optimized input and output parameters of different composition Cu-W electrode (30Cu-W70,25Cu-75W and 20Cu-W80) with the help of standard Taguchi L09 orthogonal array .

Table 3.1 Input and Output parameter

Input Parameter	**Output Parameter**
Composition of Electrode (30Cu-W70,25Cu-75W and 20Cu-W80)	Material Removal Rate(mm^3/min)
Specimen of Material (W300 die Steel ,AISI 4340,ED11)	Tool Wear Rate (mm^3/min)
Current	Surface Roughness(μm)

3.3 Methodology

To complete our research we followed the following steps

1. Selection of electrode material.
2. Preparation of Cu-W electrode those composition are 30Cu-W70, 25Cu-75W and 20Cu-W80.
3. Selection of Specimen material.
4. Perform the design of experiment and select Standard L09 orthogonal array.
5. Create experimental setup
6. Perform experiment
7. Take result
8. Optimization of Result
9. Analysis of the result according to desire output parameter and acceptance result.

These steps are shown in the following flowchart.

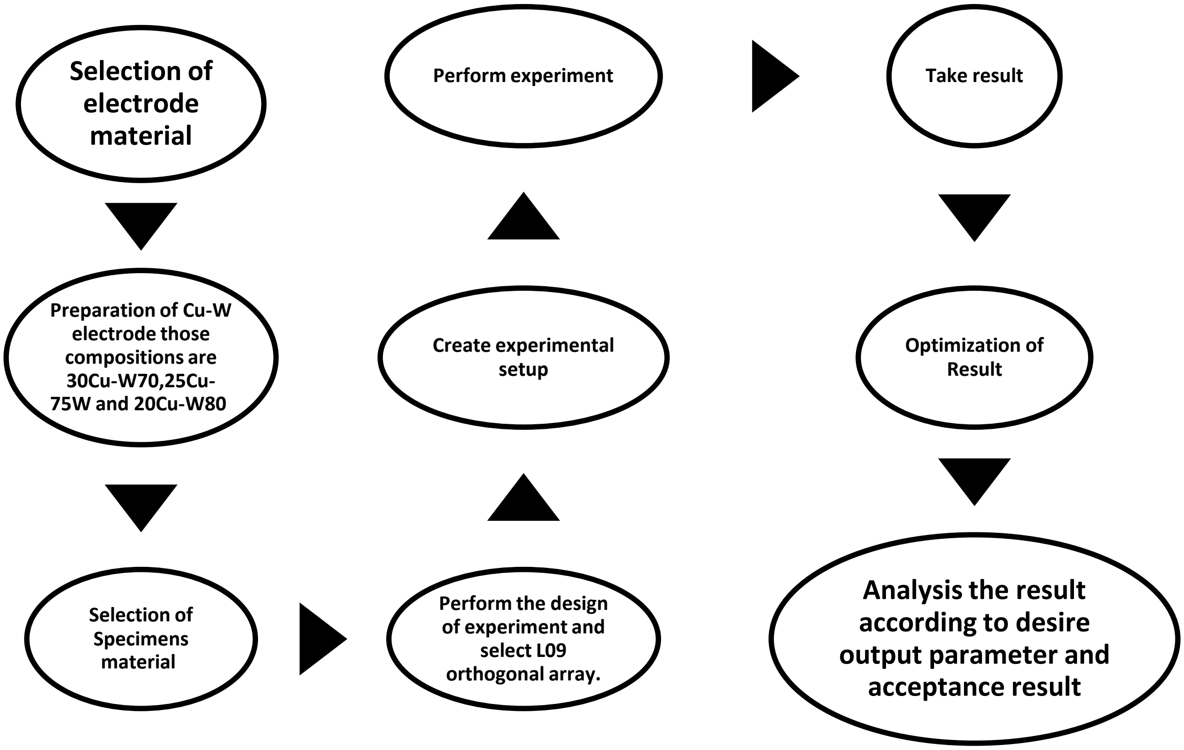

Figure 3.1Process Chart of Methodology

Chapter 4
Experimentation

In this chapter we discussed about experimentation and formulate the work of experiment . In this chapter we use L9 orthogonal array using Tuguchi design. This chapter includes experimental setup selection, Specimen of material selection ,Electrode selection, calculation of material removal rate, tool wear rate.

4.1 Experimental Setup

In this experiment, we conduct controller based three phase EDM Manufactured by Savita machine tool pvt. Ltd, where have surge tank volume 14*21. And electrolyte which we is Valcan company EDM oil and it consist of the following parameters-

- Die-electric fluid reservoir, pump and electrolyte circulation system.
- Power source and control unit
- Tank and tool holding device
- X and Y direction tool table
- Servo system for tool feeding of on EDM machine

Figure 4.1 Experimental Setup of Die sinking EDM

Figure 4.2 EDM Tool Holder

Figure 4.3 EDM machine controller

Figure 4.4 EDM filtration section

4.2Selection of Workpiece

EDM is capable of machining geometrically complex or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, carbides, heat resistant steels etc. For this experiment we selected three different materials : Specimens size: 10 mm length and 20mm diameter cylindrical block. Specimen materials ED11,W300 die steel and AISI 4340 steels use for the experiment .

4.1 Specimen of material and it's notation

Specimen of materials	Notation
ED11	A
W300	B
AISI 4340	C

AISI 4340- AISI 4340 is alloy steel. It contain Cr, Ni and Mo. Its density is 7.85g/cm^3 and melting point is 1427^{0}C and hardness, BHN 217.

Chemical Composition –

Table 4.2Chemical Composition for AISI4340

Element	**Fe**	**Ni**	**Cr**	**Mn**	**Co**	**Mo**	**Si**	**S**	**P**
Content %	95.195-96.33	1.65-2.0	0.7-0.9	0.6-0.8	0.37-0.43	0.2-0.3	0.15-0.30	0.04	0.035

Applications- AISI 4340 is use to manufacture power transmission gear and shat, air craft landing gear.

W300- W300 is containing high impact strength, tensile strength and outstanding hardenability with hardness as 52 HRC. Density is 7.18 g/cm^3.

Material composition –

Table 4.3 chemical composition for W300

Element	**Fe**	**C**	**Si**	**Mn**	**Cr**	**Mo**	**V**
Content %	91.42	0.38	1.10	0.40	5.00	1.30	0.40

Application- it is use to manufacture heavy duty tool, mandrels, dies, metal tube container and shaft.

ED 11- ED11 is HCHC cold work steel. It has fine carbide size and the grain size with high toughness. Density is 7.7 g/cm^3.

Material Composition-

Table 4.4 Chemical composition for ED11

Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Mo**	**V**
Content%	1.4-1.6	<0.4	<0.4	<0.030	<0.030	11.00-13.00	0.80-1.20	0.20-0.05

Applications - it is use to manufacture punch, immediate roller, mould, sharp wheel and Screw wheel and drawing die**.**

4.3Tool Design

In this experiment we use three copper tungsten electrodes those have percentage of copper and tungsten are Cu30-W70, Cu25-W75, Cu20-W80. In this experiment electrode diameter are 10mm and length 50mm. those copper- tungsten electrode are made of powder metallurgy technique. These tools electro-resistance at 20^{0}C are 4.41,4.51,4.71 in respective order.

4.4 Mechanism and Evaluation for MRR

Material Removal Rate (MRR) is rate of unit volume material removed in unit time form the specimen of material. In EDM machine spark in produced between electrode and specimen and effect of erosion material will remove. It unit are mm^3/ minute.

In mathematical term we call it ratio between difference of material and multiply time and density of material.

$$\frac{W_i - W_f}{T * \rho}$$

Where Wi= initial weight of material before experiment

Wf= final weight of material after experiment

t = time duration of experiment (30 min)

ρ = density of material

4.5Mechanism and Evaluation for TWR

Tool Wear Rate (TWR) is rate of tool wear in unit time. In EDM machine with the effect of erosion tool have wear of material. That cause tool weight and volume is decree.

In mathematical team it is the ratio between difference in material and the time duration of experiment.

$$\frac{W_{tb} - W_{ta}}{T}$$

Where Wtb =Weight of tool before experiment

Wta = Weight of tool after the experiment

T= Duration of time in experiment

4.6 Mechanism and Evaluation for Surface Roughness

Surface roughness is texture specimen material surface . it is measured in micro miter(µm).if the surface roughness value is higher it mean surface is rough and it is lower it mean surface is well finished. It is denoted form Ra it measured by portable surface roughness machine mitoyo sj201p.

Figure 4. 5 Surface roughness testing machine

4.7 Design of Experiment

Genchi Taguchi had developed statistical methods to improve the quality of manufacture good, this method known as Taguchi Method. Recently it applied on engineering, biotechnology, marketing, advertisement and some management.

Taguchi method is design to provide a efficient and potential method to improve designing a different manufacturing goods.

For this essential need we use MINITAB. It's providing dynamic and static response. It design of experiment analytical use independent variables in orthogonal array.

In this experiment we use L9 orthogonal array. Our experiment we have three factors those are Composition of Electrodes, Specimen of material and Current. In our design we have 3level and 3 factors.

Table 4.5 Input and Output Parameter

Input Parameter	Output parameter
Different Compositions (Cu & W) of electrode of material	Material removal rate (mm^3 /min)
Different specimens material used for EDM machining(AISI 4340,W300,ED11)	Tool wear rate(mm^3/min)
Current (I)	Surface Roughness (micro meter)

And we also have three level of each Parameter. These levels are -

Table 4.6 Input parameter and level

	Level 1	**Level 2**	**Level 3**
Composition of Electrode	Cu30-W70	Cu25-W75	Cu20-W80
Specimen of material	C	B	A
Current	4	8	12

With respect to these levels and parameter is design of experiment table are-

Table 4.7 Experimental L9 orthogonal array

Composition of Electrode	**Specimen of material**	**Current**
Cu30-W70	C	4
Cu30-W70	B	8
Cu30-W70	A	12
Cu-25-W75	C	8
Cu-25-W75	B	12
Cu-25-W75	A	4
Cu20-W80	C	12
Cu20-W80	B	4
Cu20-W80	A	8

Chapter 5
Result &Discussion

In this chapter we will discuss obtain result and optimize parameter. This chapter we study effect Material Removal Rate, Tool Wear Rate and Surface Roughness.

5.1 Material Removal Rate

After experiment we obtain material removal rate with respective material. in this section we analyses the material removal rate and get the main effective plot, Interaction plot ,regression plot and respond the behavior of factor.

The material removal rate are-

Table 5.1 Material Removal Rate Response

Composition of Electrode	Specimen of material	Current	Material Removal Rate			Mean	S/N Ratio
			M1	M2	M3		
Cu30-W70	C	4	3.8989	4.1453	4.1077	4.0506	12.1504
Cu30-W70	B	8	16.3466	15.5967	15.3649	15.7694	23.9563
Cu30-W70	A	12	20.6369	18.9809	20.5563	20.0580	26.0458
Cu-25-W75	C	8	15.3333	15.6838	15.9829	15.6667	23.8995
Cu-25-W75	B	12	13.9565	13.9163	13.9321	13.9350	22.8821
Cu-25-W75	A	4	4.1189	3.7367	4.4968	4.1175	12.2926
Cu20-W80	C	12	13.5470	13.5726	13.1624	13.4274	22.5598
Cu20-W80	B	4	6.3594	5.2070	5.7375	5.7680	15.2204
Cu20-W80	A	8	15.2675	15.5202	25.0531	18.6136	25.3966

It seen that MRR increase as the current increase throughout the entire range. In case we use different composition of electrode and different specimen of materials. In experiment changes of current and electrodes affect the MRR. To calculate the S/N Ratio for MRR we get approach larger is better .for this approach formula is

$$LB: \eta = -10 * \log[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{yi^2}]$$

η is S/N ratio which is calculated to observed value. yi is experimentally observed value and i^{th} equation

According to achieved material removal rate we get main effective plot to achieve plot response is mean of material removal rate.

Table 5.2 Selection MRR Level and it's relative factor

Level	Composition of Electrode	Specimen of material	Current
1	11.240	14.263	4.645
2	12.603	11.824	16.683
3	13.293	11.084	15.507
Delta	2.053	3.215	12.038
Rank	3	2	1

In main effective plot 30Cu-70W have higher MRR and lower MRR achieved in 25Cu-75W electrode. In ED11material shows higher MRR found comparatively W300 and AISI 4340. In current 8 amp showed higher MRR found.

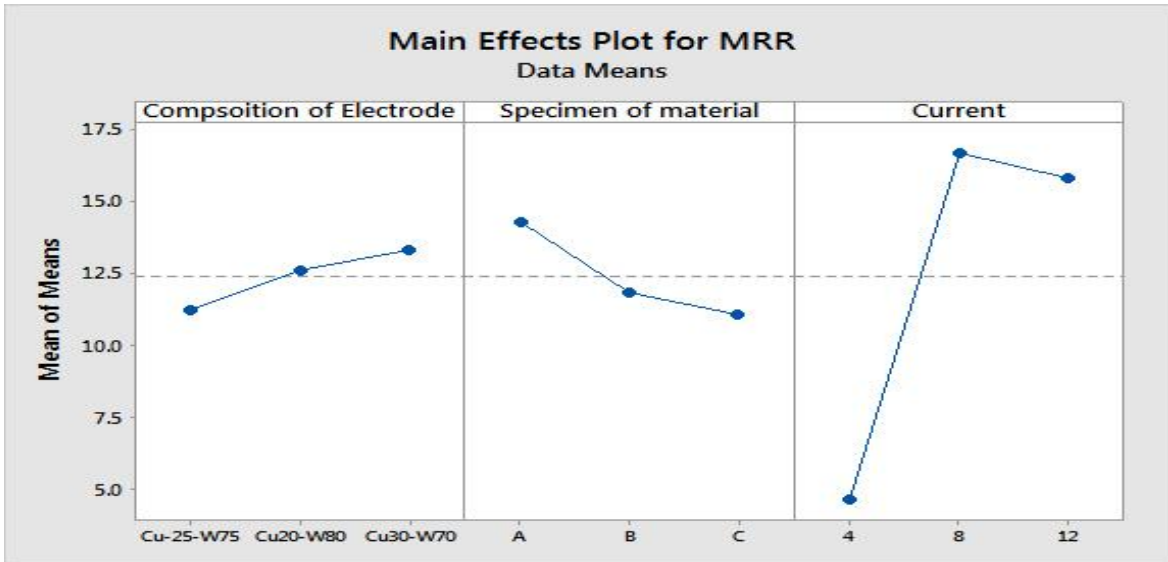

Figure 5.1 Main effective plot for MRR

Interaction plot of material removal rate (fig 5.2). this plot shows interaction between three input parameters taken in this experiment.

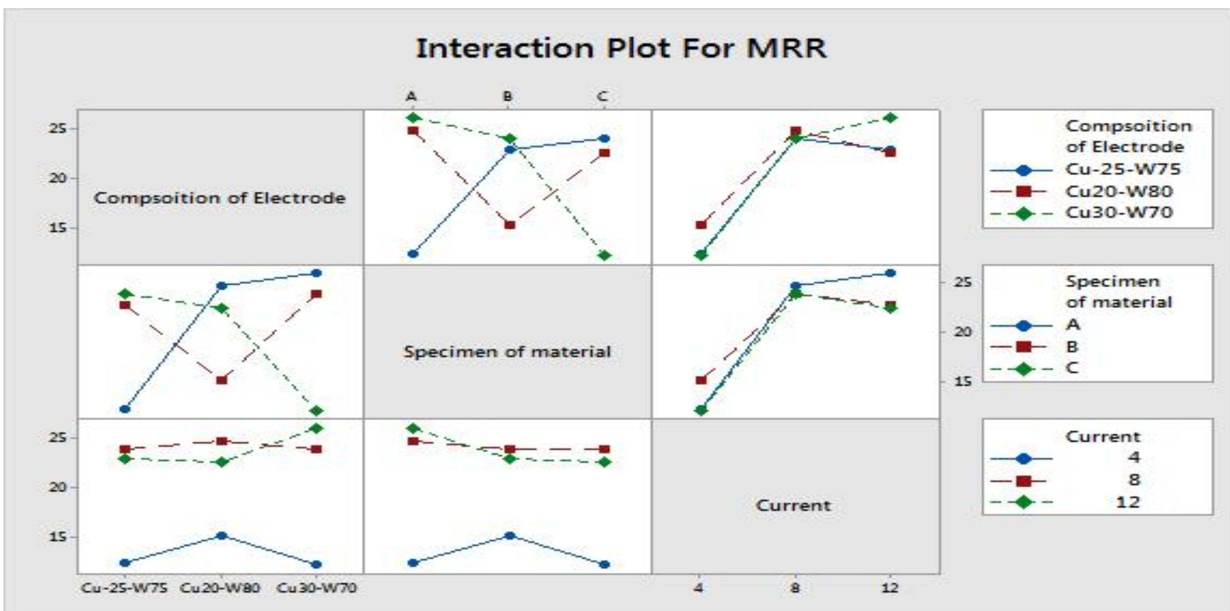

Figure 5.2 Interaction plot for MRR

Table 5.3 represent ANOVA table ,in this table it represent variable sources such as composition of electrode, specimen material, current and interaction between the factors . in ANOVA table sequentially in following columns Sum of Square, V(mean square), F (Variation),P(Probability) are calculated respectively.

Stander deviation, S=2.37609 and R^2 = 96.30 which indicate that model is capable of predicting higher accuracy and response.

ANOVA table is concluded with the all factor interaction and α=0.05.

5.3 Anova Table for MRR

	Sum of Square	V	F	% P
Composition of electrode	2.416242812	1.2081214	0.3148341	0.9698521
Specimen material	3.53855428	1.7692771	0.4610703	1.4203351
Current	235.5057234	117.75286	30.686171	94.529295
Error	7.674653177	3.8373266		3.0805177

Fig 5.3 represented that the residual plot for MRR. In this table most significant factors are composition of electrode, specimen of material and applied current.

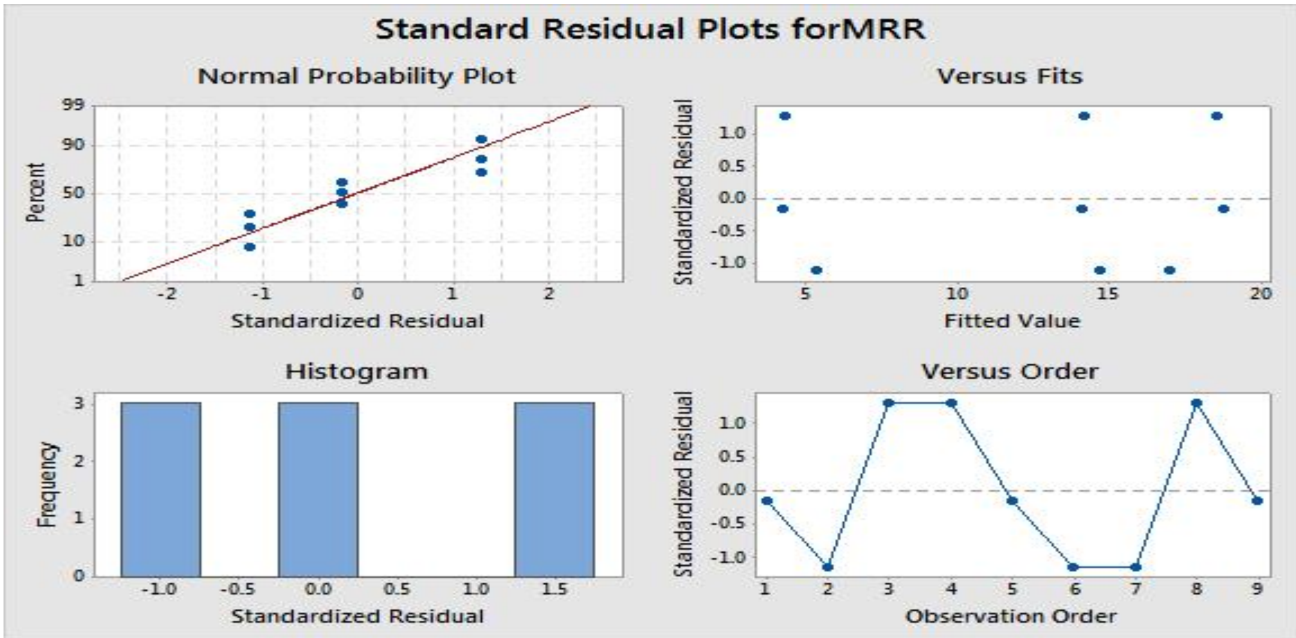

Figure 5.3 Standard Residual Graphs For MRR

The residual plot for material removal rate represent the layout of model. Layout of model is very necessary to check model get the acceptance of analysis or not. In interpretation of residual plot have following graphs.

a) Normal probability graph plot indicate the data is distributed normally and standardized residual plot it's lies between -2 to 2
b) Versus graph represent the variance is constant and a nonlinear relationship is exits as well as no out liner exits in these data.
c) Histogram chart shows that histogram of data desire skew shape .
d) Versus order graph shows the data's systematic effect .

In that analysis we performed the help of regression and regression equation are Regression Equation MEAN1 = 12.378 - 1.14 Composition of Electrode_Cu-25-W75

+ 0.22 Composition of Electrode_Cu20-W80 + 0.91 Composition of Electrode_Cu30-W70
+ 1.88 Specimen of material_A - 0.55 Specimen of material_B
- 1.33 Specimen of material_C - 7.73 Current_4 + 4.30 Current_8 + 3.43 Current_12

5.2 Tool Wear Rate

After experiment we obtain tool wear rate with respective material . in this section we analyses the material removal rate and get the main effective plot, Interaction plot ,regression plot and respond the behavior of factor.

The tool wear rates are

Table 5.4 Tool Wear Rate Response

Composition of Electrode	Specimen of material	Current	Tool Wear Rate			Mean	S/N Ratio
			W1	W2	W3		
Cu30-W70	C	4	**0**	**0**	**4.83E-02**	0.016100	31.09227
Cu30-W70	B	8	**7.44E-02**	**3.72E-02**	**7.44E-02**	0.062000	23.817368
Cu30-W70	A	12	**0.186012**	**7.44E-02**	**0.260417**	0.173604	14.438843
Cu-25-W75	C	8	**4.83E-02**	**5.25E-02**	**4.83E-02**	0.049700	26.067169
Cu-25-W75	B	12	**0.144928**	**0.217391**	**1.97E-01**	0.186440	14.480551

Cu-25-W75	A	4	**0**	**0**	**4.83E-02**	0.016100	31.090616
Cu20-W80	C	12	**0.16092**	**9.20E-02**	**0.183908**	0.145607	16.435093
Cu20-W80	B	4	**4.60E-02**	**0**	**4.60E-02**	0.030667	28.5101
Cu20-W80	A	8	**0**	**4.60E-02**	**4.60E-02**	0.030667	28.5101

It seen that TWR increase as the current increase throughout the entire range. In case we use different composition of electrode and different specimen of materials. In experiment changes of current and electrodes affect the TWR. To calculate the S/N Ratio for TWR we get approach smaller is better .for this approach formula is

$$LB: \eta = -10 * \log[\frac{1}{n}\sum_{i=1}^{n} yi^2]$$

η is S/N ratio which is calculated to observed value. yi is experimentally observed value and ith equation. According to achieved tool wear rate we get main effective plot to achieve plot response is mean of tool wear rate

Table 5.5 TWR response relative factor

Level	Composition of Electrode	Specimen of material	Current
1	23.88	24.68	30.23
2	24.48	22.27	26.13
3	23.12	24.53	15.12
Delta	1.37	2.41	15.11
Rank	3	2	1

According to data's we generate main effective plot. In following chart we have three section these section are Composition of electrode, Specimen of Material and Current.

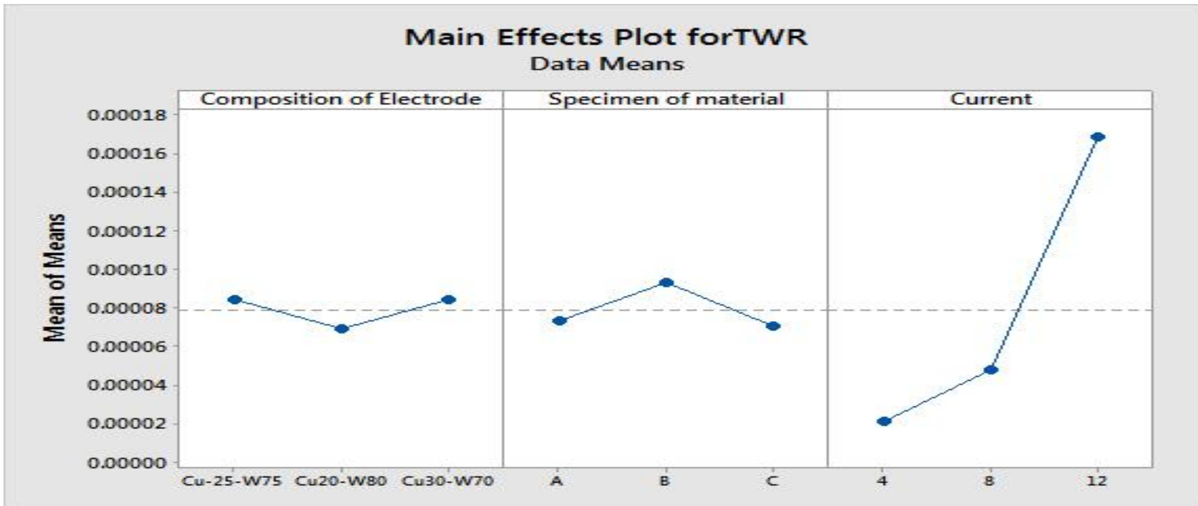

Figure 5.4 Main effective plot for TWR

Interaction plot of tool wear rate (fig 5.5). This plot shows interaction between three input factor taken in this experiment and it confirmed by ANOVA table.

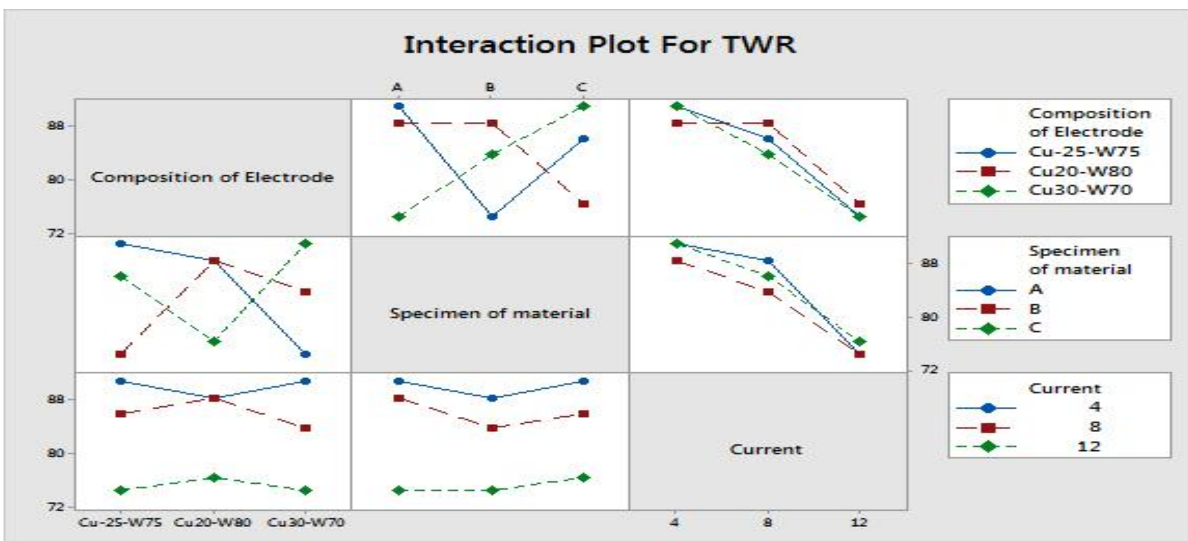

Figure 5.5 Interaction plot for TWR

Represent ANOVA table, in this table it represent variable sources such as composition of electrode, specimen material, current and interaction between the factors. In ANOVA table sequentially in following columns Sum of Square, V (mean square), F (Variation),P(Probability) are calculated respectively. Stander deviation S= 0.0089359, R^2= 99.59 which indicate that model is capable of predicting higher accuracy and response. ANOVA table is concluded with the all factor interaction and α=0.05.

Table 5.6 Anova table for TWR

	Sum of square	V	F	% P
Composition of electrode	2.823406889	1.411703444	0.6584085	0.7341926
Specimen of material	10.94999457	5.474997285	2.5535	2.8474127
Current	366.4978174	183.2489087	85.465994	95.303293
Error	4.288229751	2.144114876		1.1151019

Fig 5.6 represented that the residual plot for TWR. In this table most significant factors are composition of electrode, specimen of material and applied current. in residual plot.

The residual plot for material removal rate represent the layout of model. Layout of model is very necessary to check model get the acceptance of analysis or not. In interpretation of residual plot have following graphs.

a) Normal probability graph plot indicate the data is distributed normally and standardized residual plot it's lies between -2 to 2
b) Versus graph represent the variance is constant and a nonlinear relationship is exits as well as no out liner exits in these data.
c) Histogram char shows that histogram of data desire skew shape.
d) Versus order graph shows the data's systematic effect.

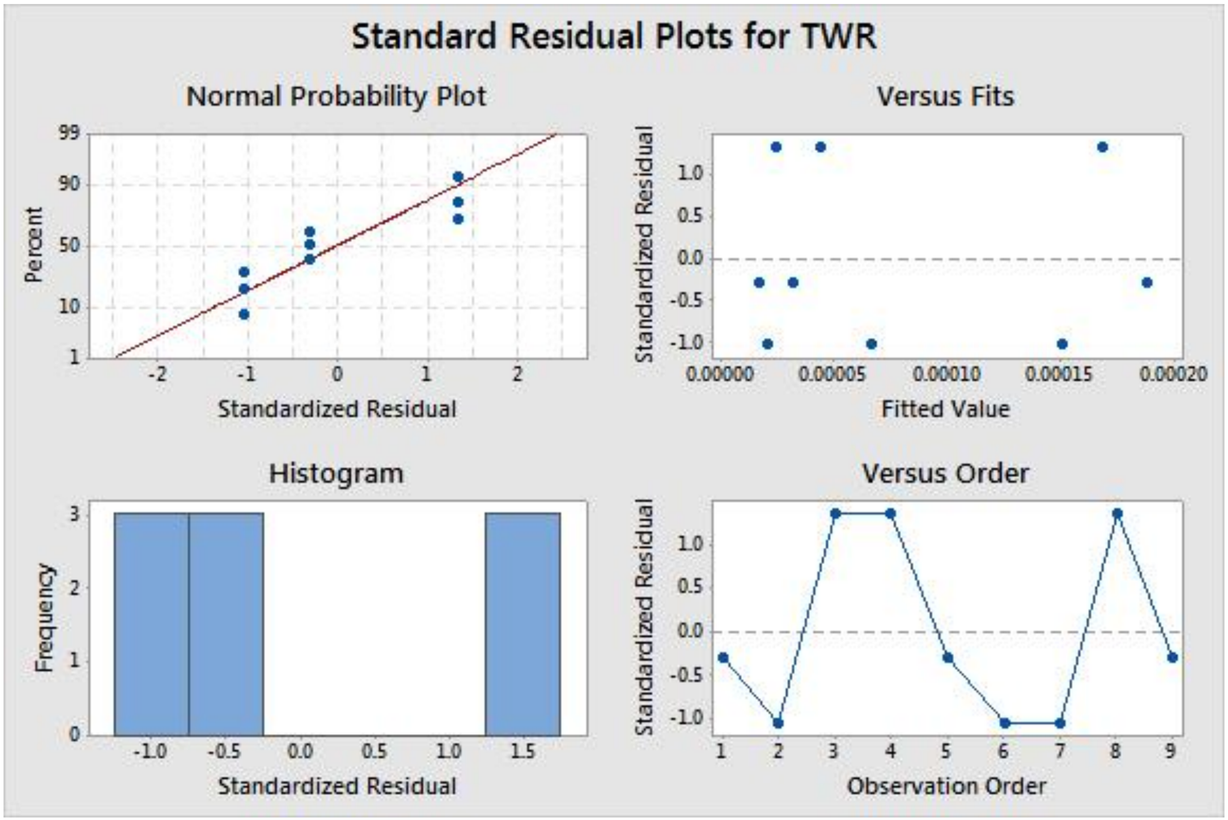

Figure 5.6 Standard residual plot for TWR

That analysis we performed the help of regression and regression equation are

Regression Equation-

MEAN2 = 0.07899 + 0.00509 Composition of Electrode_Cu-25-W75
- 0.01001 Composition of Electrode_Cu20-W80
+ 0.00491 Composition of Electrode_Cu30-W70 - 0.00553 Specimen of material A
+ 0.01405 Specimen of material - 0.00852 Specimen of material - 0.05803 Current_4
- 0.03153 Current_8 + 0.08956 Current_12

5.3 Surface Roughness

After experiment we obtain surface roughness with respective material. in this section we analyses the surface roughness and get the main effective plot, Interaction plot ,regression plot and respond the behavior of factor.

Surface Roughness is -

Table 5.7Surface Roughness Response

Composition of Electrode	Specimen of material	Current	Surface Roughness			Mean	S/N Ratio
			SF1	SF2	SF3		
Cu30-W70	C	4	3.140	3.136	3.16E+00	5.46867	-9.9533819
Cu30-W70	B	8	5.456	5.490	5.46E+00	7.77333	-14.757662
Cu30-W70	A	12	7.760	7.810	7.75E+00	5.48000	-17.812195
Cu-25-W75	C	8	5.540	5.490	5.41E+00	8.29667	-14.776026
Cu-25-W75	B	12	8.260	8.320	8.31E+00	3.28667	-18.378116
Cu-25-W75	A	4	3.230	3.320	3.31E+00	8.28667	-10.335765
Cu20-W80	C	12	8.300	8.290	8.27E+00	3.02667	-18.367607
Cu20-W80	B	4	3.040	3.030	3.01E+00	5.26667	-9.6193656
Cu20-W80	A	8	5.290	5.260	5.25E+00	5.46867	-14.430762

It seen that surface roughness increase as the current increase throughout the entire range. In case we use different composition of electrode and different specimen of materials. In experiment changes of current and electrodes affect the surface roughness. To calculate the S/N Ratio for surface roughness. we get approach Smaller is better .for this approach formula is

$$LB:\eta = -10 * \log[\frac{1}{n}\sum_{i=1}^{n} yi^2]$$

η is S/N ratio which is calculated to observed value. yi is experimentally observed value and i^{th} equation To achieved surface roughness we get main effective plot to achieve plot response is mean of surface roughness

Table 5.8 Surface Roughness Response

Level	Composition of Electrode	Specimen of material	Current
1	-14.497	-14.193	-9.970
2	-14.139	-14.252	-14.655
3	-14.174	-14.366	-18.186
Delta	0.357	0.173	8.216
Rank	3	2	1

According to data's we generate main effective plot. In following chart we have three sections these section are Composition of electrode, Specimen of Material and Current.

In main effective plot (fig5.7) found that the composition of electrodes and specimen of material showed the minor affect on surface roughness. In main effective plot current is most influent factor. Surface roughness is gradually increase as well as current.

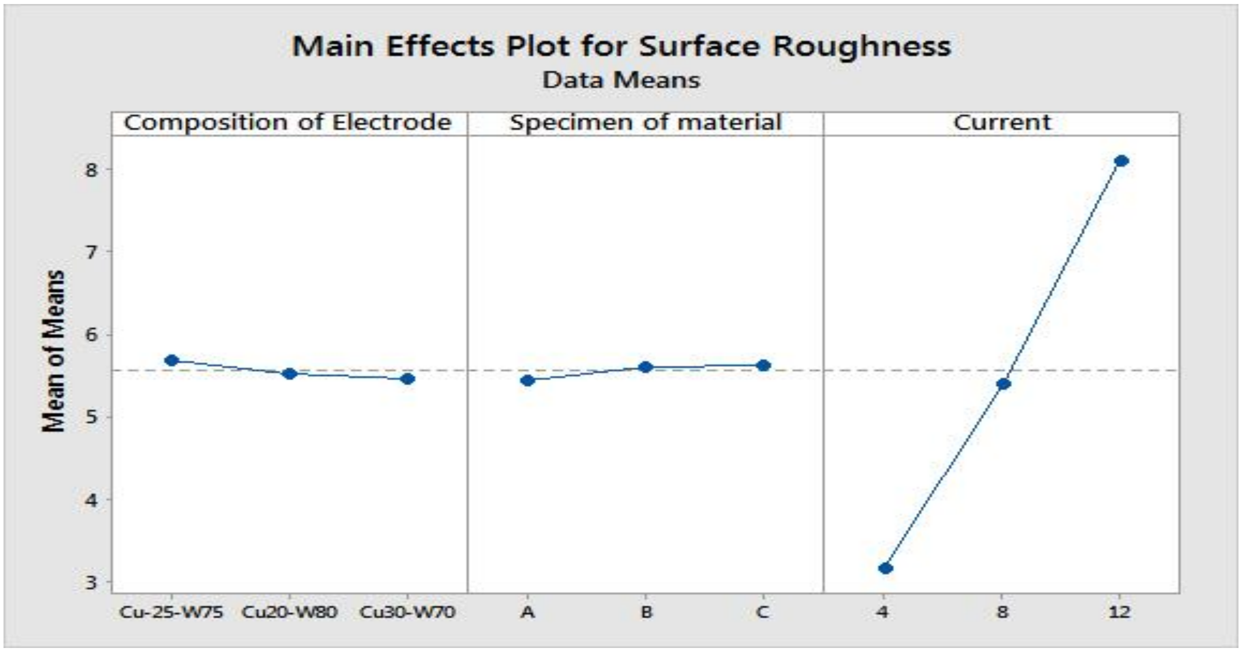

Figure 5.7 Main Effects Plot For Roughness

Interaction plot of surface roughness (fig5.8). This plot shows interaction between three input factor taken in this experiment and it confirmed by ANOVA table.

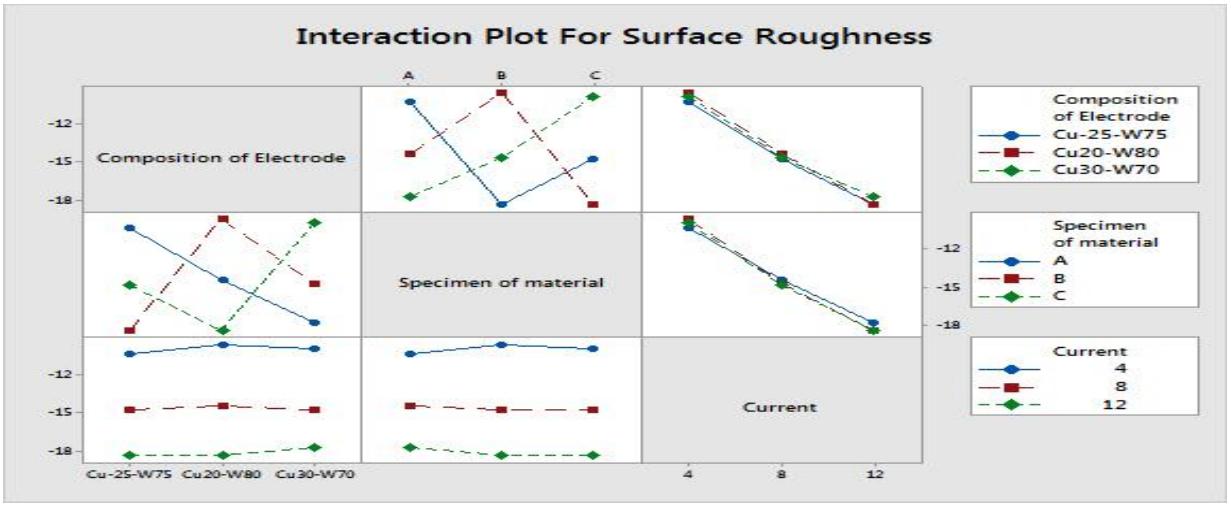

Figure 5.8 Interaction Plot For Surface Roughness

Represent ANOVA table, in this table it represent variable sources such as composition of electrode, specimen material, current and interaction between the factors. In ANOVA table sequentially in following columns Sum of Square, V (mean square), F (Variation), P (Probability) are calculated respectively.

Stander deviation S= 0.186701 R^2= 99.81 which indicate that model is capable of predicting higher accuracy and response.

ANOVA table is concluded with the all factor interaction and α=0.05

Table 5.9 ANOVA Table For Surface Roughness

	Sum of square	V	F	% P
Composition of electrode	0.232792423	0.116396212	0.8851117	0.2271729
Specimen of material	0.04629189	0.023145945	0.1760087	0.0451744
Current	101.9315738	50.96578692	387.55911	99.470992
Error	0.263009102	0.131504551		0.2566602

Represented that the residual plot for surface roughness. In this table most significant factors are composition of electrode, specimen of material and applied current. in residual plot

The residual plot for material removal rate represents the layout of model. Layout of model is very necessary to check model get the acceptance of analysis or not. In interpretation of residual plot have following graphs.

a) Normal probability graph plot indicate the data is distributed normally and standardized residual plot it's lies between -2 to 2
b) Versus graph represent the variance is constant and a nonlinear relationship is exits as well as no out liner exits in these data.
c) Histogram char shows that histogram of data desire skew shape.
d) Versus order graph shows the data's systematic effect.

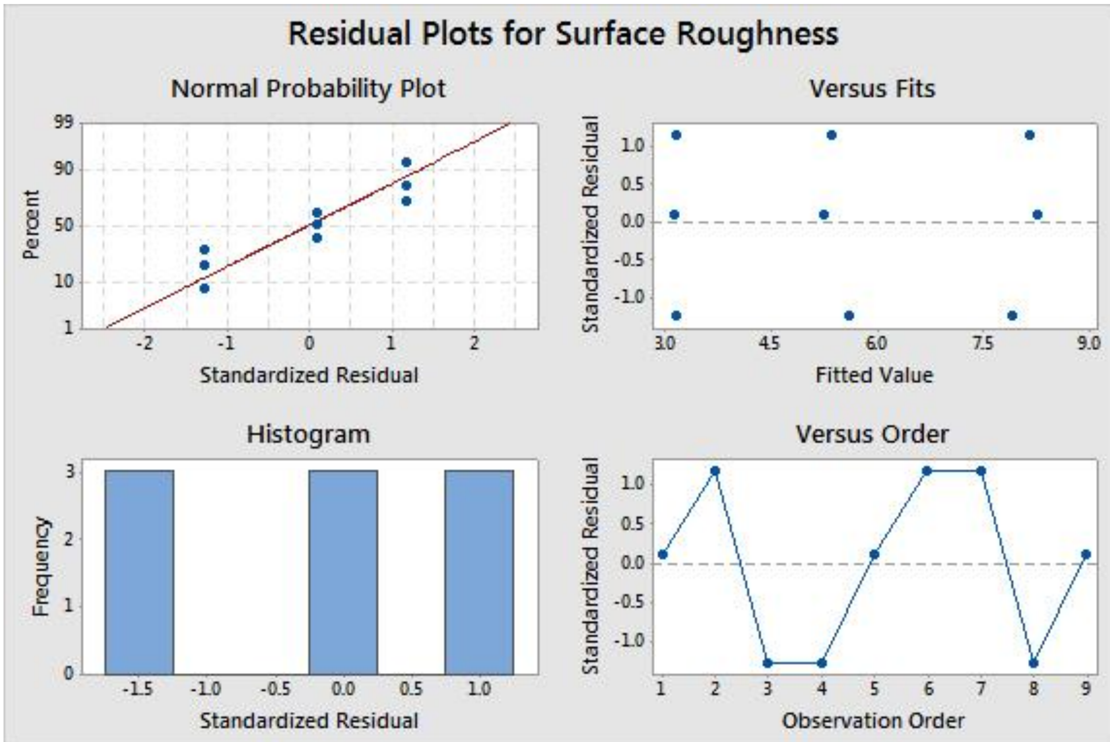

Figure 5.9 Residual Plot for Surface Roughness

That analysis we performed the help of regression and regression equation are

Regression Equation

SF1 = 5.5573 + 0.1193 Composition of Electrode_Cu-25-W75
- 0.0140 Composition of Electrode_Cu20-W80 - 0.1053 Composition of Electrode_Cu30-W70
- 0.1307 Specimen of material_A + 0.0280 Specimen of material_B
+ 0.1027 Specimen of material_C - 2.4207 Current_4 - 0.1287 Current_8
+ 2.5493 Current_12

5.4 Discussion

Experiment is done according to the Taguchi L9 orthogonal array by using of set of three copper- tungsten electrode were compotation of electrode is different . And we uses three specimen material.

To finding the result of Material Removal Rate ,Tool wear rate and the surface roughness. In this result current is most influence factor. Help of Minitab we find the predicted optimized condition these. In electrode composition is Cu-25-W75 specimen material A current 4 A.

Chapter 6
Conclusion

In this chapter we studied the effect of electrical discharge machining effect response MRR, TWR and surface roughness. On W300 die steel,AIS14340 and ED 11. And investigate for suitable electrode compositions 30Cu-W70, 25Cu-W75 and 20Cu-W80. In this experiment we use L9 orthogonal array based, design was performed for MINITAB software use for analysis the result and these results are partially validated experimentally.

1. As per experimentation done for the MRR, it can be stated that a current is most important influencing factor among other parameters. Since the MRR increase with the increase in current. From the main interaction plot and found that the 30Cu-70W composition of EDM electrode have higher MRR at 4,8,12 amp current in comparison to 25Cu-75W and 20Cu-80W electrodes.
2. During practical analysis for the TWR ,the important factor are discharge current, composition of electrode and specimen of material, to observe the experiment that have found in electrode 20Cu-W80 have lower rate of TWR on 4,8,12 amp current compare to 30Cu-70W,25Cu-75Welectrode .
3. Surface finish decrease when current increase, composition of electrode affect the surface finish, effect of surface finish rate was seen i.e. -14.497,-14.139, -14.174 respectively for 30Cu-70W,25Cu-75W and 20Cu-80W electrodes respectively .

Chapter 7
Appendix

In this Chapter we discus machine ,equipment and testing certificate which is use to conducting this experiment.

1. EDM machine which is using to conduct this experiment

Figure 7.1 Die-Sinking EDM machine

2. Weight measuring machine which capacity is 300 gram and its accuracy is 0.001 gram brand Shinko Denshi Co. Ltd Japan

Figure 7.2 Weight measuring machine

3.Surface roughness testing machine Mitutoyo sj207p

Figure 7.3 Surface roughness testing machine

4. Hardness testing machine Model:- AI-RAS, Sr.No:-163-2009/10, Make:- Arun Industries, Maharashtra, India

Figure 7.4 Hardness testing machine

5. Published Review paper

Arvind Kumar Tiwari Int. Journal of Engineering Research and Applications www.ijera.com
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RESEARCH ARTICLE OPEN ACCESS

Optimization of EDM Process of (Cu-W) EDM Electrodes on Different Progression

*Arvind Kumar Tiwari **Jasvir singh
*(Student, Department of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, India)
** (Faculty, Department of Mechanical Engineering, Lovely Professional University, Phagwara, Punjab, India)

Abstract –
The purpose of this research work is to determine the optimal cutting condition of EDM process of different work piece materials using different compositions of Cu-W tool Electrodes. The key cutting factors such as Discharge Current, Voltage, Pulse- On – Time, Duty Cycle, Spark Gap and flushing pressure will be optimized.
Keywords- Electrical Discharge Machining, MRR, SEM

I. INTRODUCTION

Electrical Discharge Machining (EDM) is a unconventional manufacturing process based on removal of material from a part by means of a series of repeated electrical sparks created by electric pulse generators at short intervals between a electrode tool and the part to be machined immersed in dielectric fluid [1]. At present, EDM is a widespread technique used in industry for high precision machining of all types of conductive materials such as metallic alloys, metals, graphite, composite materials or some ceramic material. The selection of optimized manufacturing conditions is one of the most important aspects to consider in the die-sinking electrical discharge machining (EDM) of conductive steel, as these conditions are the ones that are to determine such important characteristics: surface roughness, electrode wear (EW) and material removal rate (MRR). A study will be perform on the influence of the factors of peak current, pulse on time, interval time and power supply voltage. Design of experiments (DOE) technique to select the optimum machining conditions for machining .

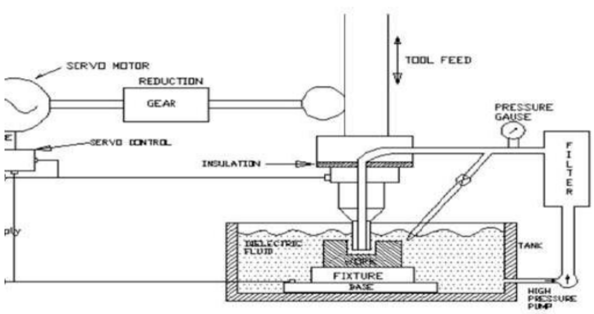


Fig1.pricipal of EDM

A. Mechanism And Evaluation of Material Removal Rate -

The MRR is defined as the ratio of the difference in weight of the work piece before and after machining to the density of the material and the machining time.

$$MRR = \frac{Wi - Wf}{T * \rho}$$

Where
Wi = initial weight before machining
Wf = final weight after machining
T = machining time
ρ is the density

B. Mechanism And Evaluation of Tool Removal Rate-

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time. it is written as –

$$\frac{Wtb - Wtb}{T}$$

Wtb = weight of tool before machining
Wta = weight of tool after machining
T =Machining time

C. Mechanism and Evaluation of Surface Roughness

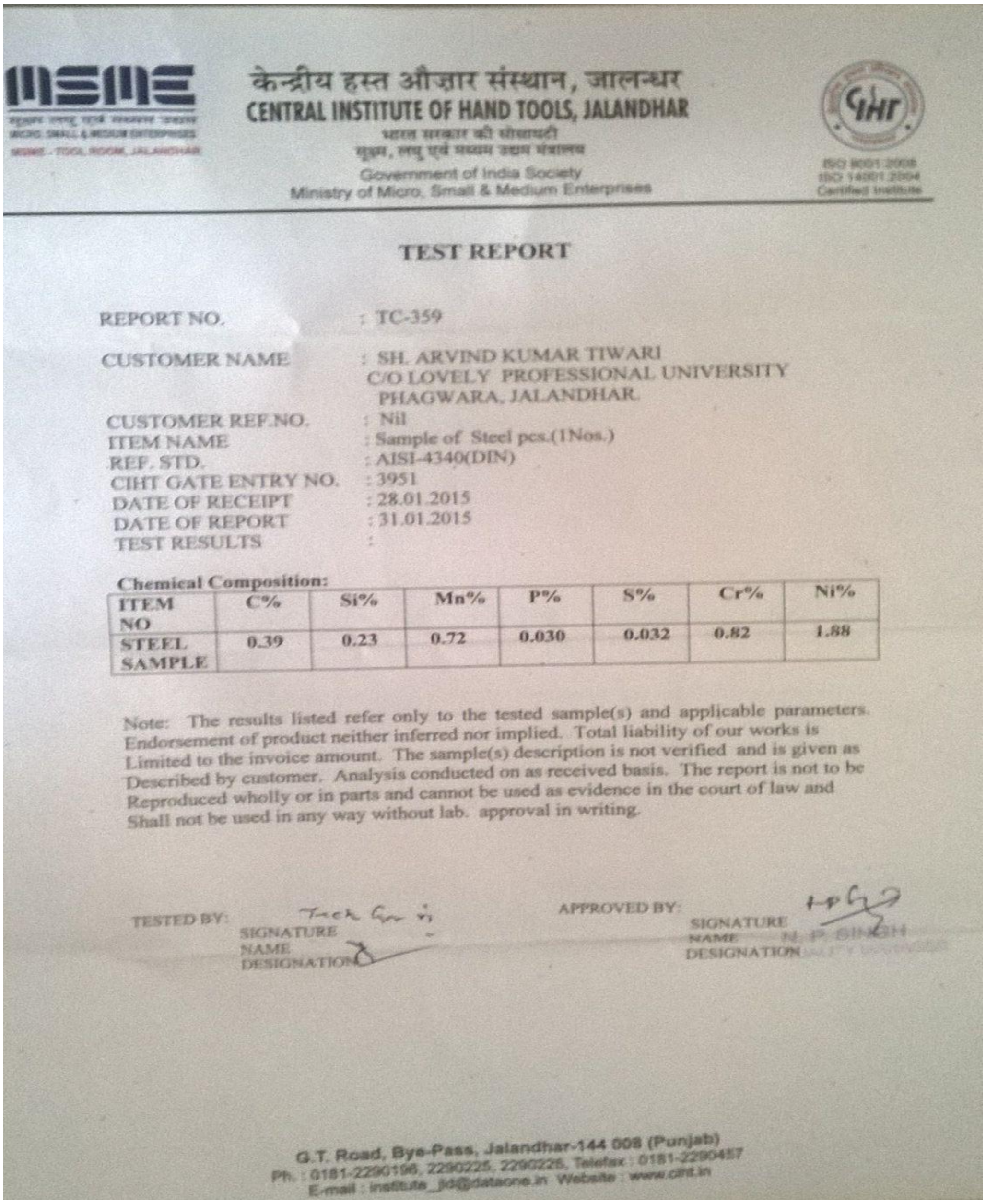
Surface Roughness is the measure of the texture of the surface. It is measured in µm. If the value is high then the surface is rough and if low then the surface is smooth. It is denoted by Ra.

D. Scanning Electron Microscope

A scanning Electron Microscope produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition.

Figure 7.5 Review paper

6.AISI4340 material testing report



केन्द्रीय हस्त औज़ार संस्थान, जालन्धर

CENTRAL INSTITUTE OF HAND TOOLS, JALANDHAR

Government of India Society

Ministry of Micro, Small & Medium Enterprises

ISO 9001:2008 ISO 14001:2004 Certified Institute

TEST REPORT

REPORT NO. : TC-359

CUSTOMER NAME : SH. ARVIND KUMAR TIWARI
C/O LOVELY PROFESSIONAL UNIVERSITY
PHAGWARA, JALANDHAR.

CUSTOMER REF.NO. : Nil
ITEM NAME : Sample of Steel pcs.(1Nos.)
REF. STD. : AISI-4340(DIN)
CIHT GATE ENTRY NO. : 3951
DATE OF RECEIPT : 28.01.2015
DATE OF REPORT : 31.01.2015
TEST RESULTS :

Chemical Composition:

ITEM NO	C%	Si%	Mn%	P%	S%	Cr%	Ni%
STEEL SAMPLE	0.39	0.23	0.72	0.030	0.032	0.82	1.88

Note: The results listed refer only to the tested sample(s) and applicable parameters. Endorsement of product neither inferred nor implied. Total liability of our works is Limited to the invoice amount. The sample(s) description is not verified and is given as Described by customer. Analysis conducted on as received basis. The report is not to be Reproduced wholly or in parts and cannot be used as evidence in the court of law and Shall not be used in any way without lab. approval in writing.

TESTED BY: SIGNATURE
NAME
DESIGNATION

APPROVED BY: SIGNATURE
NAME N. P. SINGH
DESIGNATION

G.T. Road, Bye-Pass, Jalandhar-144 008 (Punjab)
Ph. : 0181-2290196, 2290225, 2290226, Telefax : 0181-2290457
E-mail : institute_jld@dataone.in Website : www.ciht.in

Figure 7.6AISI 4340 testing Report

7.ED11 material testing report

केन्द्रीय हस्त औज़ार संस्थान, जालन्धर
CENTRAL INSTITUTE OF HAND TOOLS, JALANDHAR
भारत सरकार की सोसायटी
सूक्ष्म, लघु एवं मध्यम उद्यम मंत्रालय
Government of India Society
Ministry of Micro, Small & Medium Enterprises

MSME
सूक्ष्म लघु एवं मध्यम उद्यम
MICRO, SMALL & MEDIUM ENTERPRISES
MSME - TOOL ROOM, JALANDHAR

ISO 9001:2008
ISO 14001:2004
Certified Institute

TEST REPORT

REPORT NO. : TC-358

CUSTOMER NAME : SH. ARVIND KUMAR TIWARI
C/O LOVELY PROFESSIONAL UNIVERSITY
PHAGWARA, JALANDHAR.

CUSTOMER REF.NO. : Nil
ITEM NAME : Sample of Steel pcs.(1Nos.)
REF. STD. : ED-11
CIHT GATE ENTRY NO. : 3951
DATE OF RECEIPT : 28.01.2015
DATE OF REPORT : 31.01.2015
TEST RESULTS :

Chemical Composition:

ITEM NO	C%	Si%	Mn%	P%	S%	Cr%	V%
STEEL SAMPLE	1.52	0.32	0.36	0.021	0.023	12.36	0.32

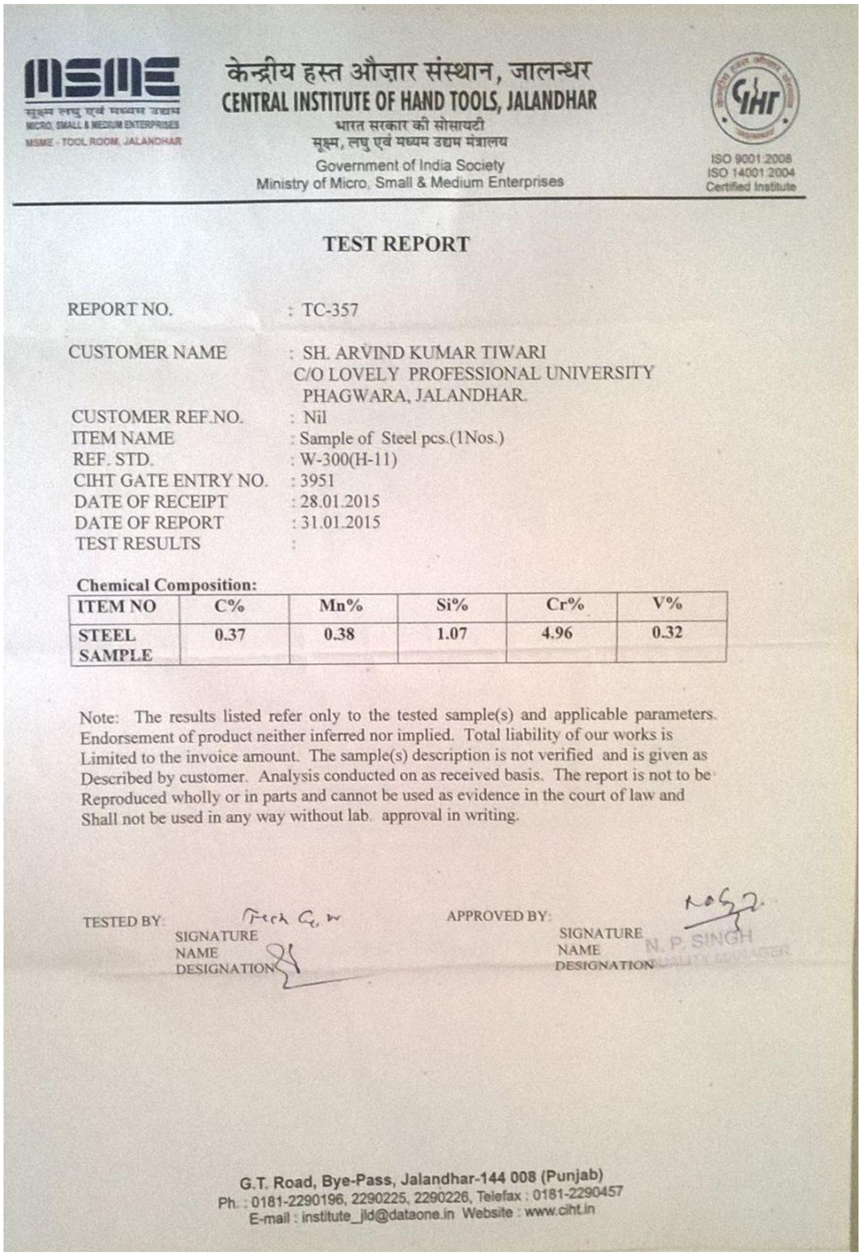
Note: The results listed refer only to the tested sample(s) and applicable parameters. Endorsement of product neither inferred nor implied. Total liability of our works is Limited to the invoice amount. The sample(s) description is not verified and is given as Described by customer. Analysis conducted on as received basis. The report is not to be Reproduced wholly or in parts and cannot be used as evidence in the court of law and Shall not be used in any way without lab. approval in writing.

TESTED BY:
SIGNATURE
NAME
DESIGNATION

APPROVED BY:
SIGNATURE
NAME N. P. SINGH
DESIGNATION QUALITY MANAGER

Figure 7.7 ED11 material testing report

8. W300 material testing report



केन्द्रीय हस्त औज़ार संस्थान, जालन्धर

CENTRAL INSTITUTE OF HAND TOOLS, JALANDHAR

भारत सरकार की सोसायटी

सूक्ष्म, लघु एवं मध्यम उद्यम मंत्रालय

Government of India Society

Ministry of Micro, Small & Medium Enterprises

MSME

सूक्ष्म लघु एवं मध्यम उद्यम

MICRO, SMALL & MEDIUM ENTERPRISES

MSME - TOOL ROOM, JALANDHAR

ISO 9001:2008

ISO 14001:2004

Certified Institute

TEST REPORT

REPORT NO. : TC-357

CUSTOMER NAME : SH. ARVIND KUMAR TIWARI
C/O LOVELY PROFESSIONAL UNIVERSITY
PHAGWARA, JALANDHAR.

CUSTOMER REF.NO. : Nil

ITEM NAME : Sample of Steel pcs.(1Nos.)

REF. STD. : W-300(H-11)

CIHT GATE ENTRY NO. : 3951

DATE OF RECEIPT : 28.01.2015

DATE OF REPORT : 31.01.2015

TEST RESULTS :

Chemical Composition:

ITEM NO	C%	Mn%	Si%	Cr%	V%
STEEL SAMPLE	0.37	0.38	1.07	4.96	0.32

Note: The results listed refer only to the tested sample(s) and applicable parameters. Endorsement of product neither inferred nor implied. Total liability of our works is Limited to the invoice amount. The sample(s) description is not verified and is given as Described by customer. Analysis conducted on as received basis. The report is not to be Reproduced wholly or in parts and cannot be used as evidence in the court of law and Shall not be used in any way without lab. approval in writing.

TESTED BY:
SIGNATURE
NAME
DESIGNATION

APPROVED BY:
SIGNATURE
NAME N. P. SINGH
DESIGNATION QUALITY MANAGER

G.T. Road, Bye-Pass, Jalandhar-144 008 (Punjab)
Ph. : 0181-2290196, 2290225, 2290226, Telefax : 0181-2290457
E-mail : institute_jld@dataone.in Website : www.ciht.in

Figure 7.8 W300 material testing report

References

1. M. Rozenek, J. Kozak, L. Dąbrowski, K. and Łubkowski. (2001). “Electrical discharge machining characteristics of metal matrix composites”, Journal of Materials Processing Technology. Vol 109, Pages 367–37015.
2. Tsai, H.C., Yan, B.H. and Huang, F.Y., (2003). "EDM performance of Cr/Cu-based composite electrodes". *International Journal of Machine Tools and Manufacture*, 43(3), pp245-252.
3. Puertas I. and Luis C.J. (2004), "A study of optimization of machining parameters for electrical discharge machining of boron carbide", *Materials and Manufacturing Process*, 19(6), pp1041-8888888888888888888881070,.
4. Ferreira José Carvalho(2004) “Study of die helical thread cavity surface finish by Cu-W with Planetary EDM” Int. J. Adv. Manufacturing Technology 34:1120–1132
5. J.L. Lin and C.L. Lin(2005) “grey-fuzzy logic for the optimization of the manufacturing process” Journal of Materials Processing Technology 160.
6. RiccardiB., Montanar Ri, Casadei M, Costanza G Filacchioni, G., Moriani A (2006)“Optimization and characterization of tungsten of thick coating on copper base alloy substance” Journal of Nuclear Materials 29–3,.
7. Daneshjou K. and Ahmadi M June (2006) “Optimizing the effective parameter of tungsten –copper composites” kdanesh jonrual .
8. Kwon Young-Sam, Chung Seong-Taek, Lee Seong , Noh Joon-Woong, Seong-Jin Park , Randall M. German(2007) “DEVELOPMENT OF THE HIGH PERFORMANCE W-CU ELECTRODE” Advances in Powder Metallurgy & Particulate Materials 664-953, 305-600, Korea- MS 39762-5405, USA. Nuran Bradley, M.E Thesis, “The Response Surface Methodology”, Department of Mathematical Sciences, Indiana University of South Bend, 2007
9. Beri Naveen, Maheshwari S, Sharma C., Kumar Anil (2007) “Performance Evaluation of Powder Metallurgy Electrode in Electrical Discharge Machining of AISI D2 Steel Using Taguchi Method” World Academy of Science, Engineering and Technology 02-24

10. Marafona José Duarte (2008)“Black layer affects of thermal conductivity of the surface of copper tungsten electrode” Int. J. Adv. Manufacturing Technology 42:482–488.
11. Saha S.K., and Choudhury S.K.,(2009)" Experimental Investigation and empirical modelling of the dry electric discharge machining process", *International Journal of Machine Tools and Manufacture*, 49(3-4), pp297-308
12. Hassan M. A., N. S. Mehat., S. Sharif, R. Daud., S. H. Tomadi, M. S. Reza.(2009)," Study of the Surface Integrity of AISI 4140 Steel in Wire Electrical Discharge Machining”. *Proceedings of the International MultiConference of Engineers and Computer Scientists VolIIIMECS* , Hong Kong.
13. DewanganS.K .(2010), "Experimental Investigation of Machining parameters for EDM usingU-shaped Electrode of AISI P20 tool steel", M-Tech Thesis *,http://ethesis.nitrkl.ac.in /2071 /1/ Thesis_EDM.pdf.*
14. Patowari Promod K. & Saha Partha & Mishra Prasanta K. (2010)“Tuguchi analysis of surface modification technique using Cu-W powder metallurgy sintered tool in EDM and characterization of deposited layer” ” Int. J. Adv. Manufacturing Technology 51:627–638
15. Iqbal AKM A., Khan A.A.(2011) ,“Optimization of process parameters on EDM milling ofstainless steel AISI 304”, *Advance Materials Research*, Vols. 264-265, pp 979-984.
16. Rao P.S., Kumar J.S, Reddy K., Reddy B.,(2011) "Fuzzy Modelling for Electrical Discharge Machining of AISI 304 Stainless Steel", *Journal of Applied Sciences Research*, 6 , pp1687-1700.
17. Beri Naveen, kumar Anil, MaheshwariS., Sharma C. (2011) “optimization of electrical discharge machine Cu-W powder metallurgy electrode using grey relation theory” Sharma/Int. J. Machining and Machinability of Materials 103–115
18. Poddar.A.(2012),"Experimental Investigation Of MRR, Surface Roughness And Overcut Of AISI 304 Stainless Steel In EDM",B-Tech Thesis,
19. Singh H.(2012) "Investigating the Effect of Copper Chromium and Aluminum Electrodes on EN-31 Die Steel on Electric Discharge Machine Using Positive Polarity", *Proceedings of the World Congress on Engineering Vol III* London, U.K

20. Pradhan M. K.(2012) "Estimating the effect of process parameters on MRR, TWR and radial overcut of EDMed AISI D2 tool steel by RSM and GRA coupled with PCA" Int J Adv Manufacturing Technology
21. Manoharan Mehul, Valera Abhi P., Trivedi Shrey M., Banker Kapil S (2013)"Material Removal Rate, Tool Wear Rate and Surface Roughness Analysis of EDM Process**"** International Journal for Scientific Research & Development 2321-0613.
22. Kumar Sanjeev, Batish Ajay, Singh Rupinder and Singh T. P.(2013) "A hybrid Taguchi-artificial neural network approach to predict surface roughness electric discharge machining of titanium alloys" Singh/Journal of Mechanical Science and Technology2831-2844.
23. Habib Sameh S.(2014) "Parameter optimization of electrical discharge machine process by using taguchi approach" academic journal 27-42.
24. Thirupathi.p (2014)"Optimization And Analysis Of Cu-W Tool Edm Process By Using Composite Materials" IOSR Journal of Mechanical and Civil Engineering 36-42
25. Chou Shih-Hsien , Wang A-Cheng (2014)"Investigating and removing the re-sticky debris on tungstencarbide in electrical discharge machining" Int J Adv Manuf Technol 71:1151–1158.
26. Muthuramalingam T., Mohan B.(2014)"Application of Taguchi-grey multi responses optimization on process parameters in electro erosion" Measurement Volume 58, December 2014, Pages 495–502,
27. Choudhary Sushil Kumar, Jadoun R.S.(2014) "Current Advanced Research Development of Electric Discharge Machining (EDM): A Review" International Journal of Research in Advent Technology, Vol.2, No.3, E-ISSN: 2321-9637,.
28. Sanghani C. R, Acharya G. D.(2014) " A Review of Research on Improvement and Optimization of Performance Measures for Electrical Discharge Machining" C. R. Sanghani et al Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 1(Version 2).

29. Dhar S., Purohit R., Saini N., Sharma A., Kumar G.H., Mathematical modelling of electric discharge machining of cast Al-4Cu-6Si alloy-10 wt.% SiCp composites, *Journal of Materials Processing Technology*, 194 ,pp24-29
30. Kumar S., Kundu S., Chaudhary R (2014) "Optimization of Process Parameter and Experimental Investigation of MRR on H-13 Die Tool Steel using EDM with Application of Taguchi Technique" *International Journal of Engineering and Management Research,* Volume-4, ISSN No.: 2250-0758
31. Shashikant, Roy A.K and Kumar K ., (2014) " Optimization of Machine Process Parameters on Overcut in EDM for EN19 Material using RSM", *International Journal of Current Engineering and Technology* ISSN 2277 - 4106

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