A PROJECT REVIEW

ON

# PERFORMANCE OF COPPER AND COPPER TUNGSTEN ELECTRODES WITH DIFFERENT DIELECTRICS USING TAGUCHI BASED TOPSIS

*Under the guidance of*

**Dr. A.NEELAKANTESWARA RAO**

ASSOCIATE PROFESSOR

*Submitted By*

P.RAMESHBABU

ME093115

MANUFACTURING ENGINEERING

# INTRODUCTION

❖Electro Discharge Machining (EDM) is a traditional machining technology and is one of the most efficient technologies for fabricating components.

❖EDM is the most widely and successfully used method for machining difficult to machine materials like super alloys and titanium alloys.

❖Titanium and its alloys have many attractive properties, including a high specific strength, excellent corrosion resistance and cryogenic properties.

❖Titanium alloy, which is a difficult-to-machine material, can be machined effectively by EDM.

# LITERATURE REVIEW

- Biing Hwa Yan , Hsien Chung Tsai (2005), **S**tudy investigates the influence of the machining characteristics on pure titanium metals using EDM with the addition of urea into distilled water.
- Anand Pandey et. Al (2010), Explained Present manufacturing industries are facing challenges from these advanced materials viz. super alloys.
- LUO Yong et.al (2007), Described about Three different nitrogen ion doses were implanted into a Ti6Al4V alloy to improve its mechanical surface properties
- I.Puertas, C.J.Luis,(2003), worked on study on the machining parameters optimization of electrical discharge machining.
- F. Hosseinzadeh Lotfi et al [2009], the aim of this paper is to extend the TOPSIS method for decision-making problems with Fuzzy data.

# OBJECTIVE OF PRESENT WORK

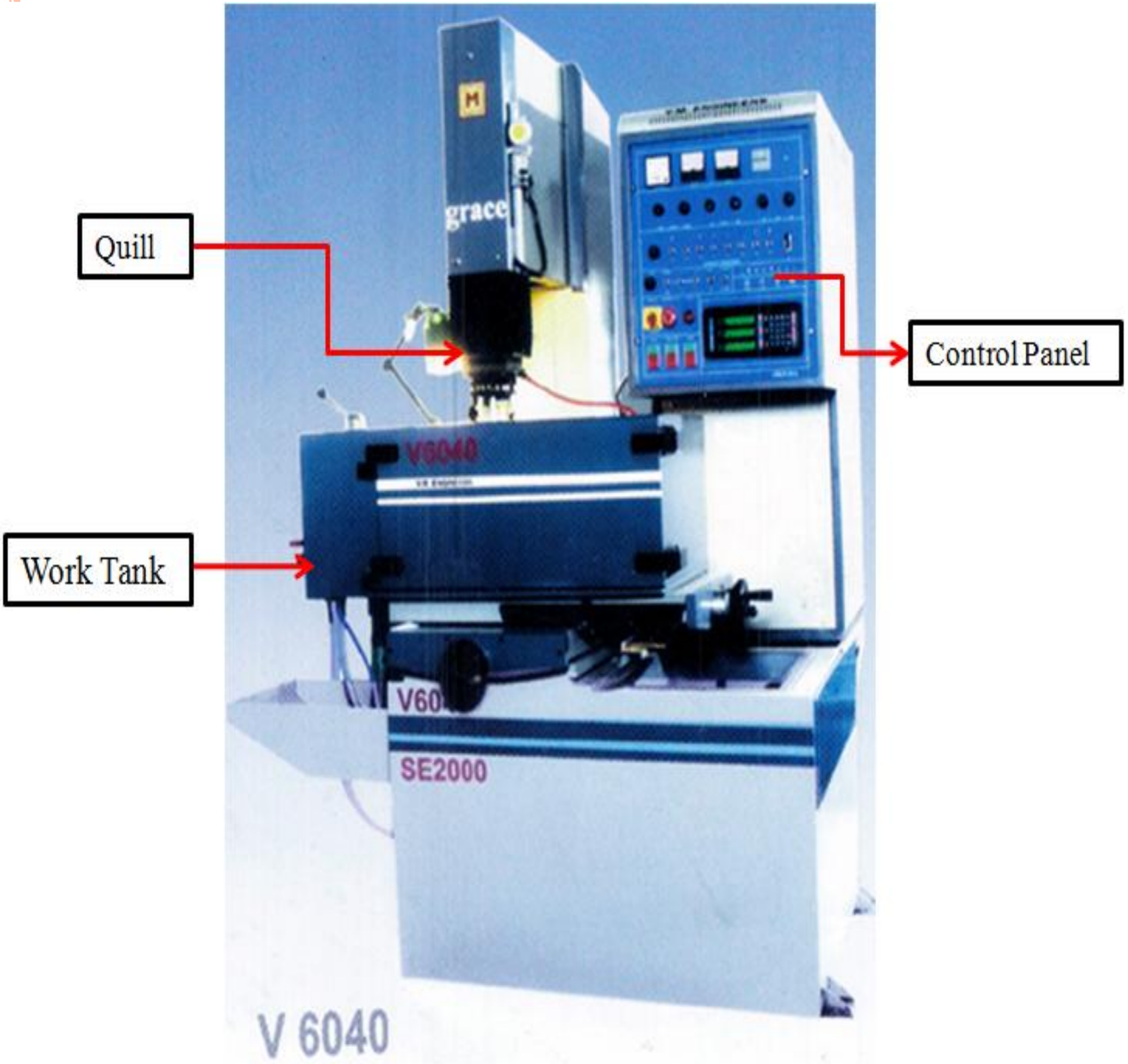
- To investigate the performance of copper and copper tungsten as electrodes in EDM characteristics of Titanium alloy [Ti–6Al–4V] using kerosene, distilled water and urea solution as the dielectrics.
- To attain higher Material removal rate, lower Electrode wear rate, while machining Titanium alloy [Ti–6Al–4V] using copper tungsten as electrode with different dielectrics.

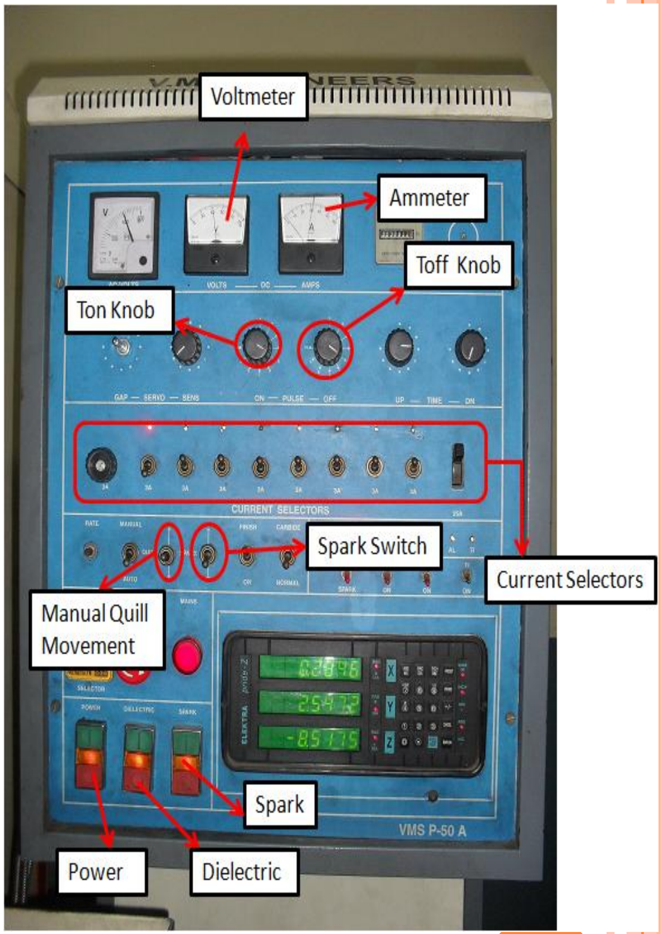
# DETAILS OF THE WORK

## MACHINE TOOL DETAILS

| SPECIFICATIONS OF MACHINE TOOL (EDM V 6040) | UNITS | V 6040 |
|---|---|---|
| TABLE DIMENSION | MM | 600 x 400 |
| WORK TANK DIMENSION | MM | 900 x 550 x 375 |
| X TRAVEL | MM | 400 |
| Y TRAVEL | MM | 275 |
| Z TRAVEL | MM | 220 |
| BACK SLIDE TRAVEL | MM | 200 |
| MAX. TABLE LOADING | KGS | 600 |
| DI-ELECTRIC CAPACITY | LTS | 300 |
| NORMAL CURRENT | AMPS | 50 |
| SPECIFICATIONS OF POWER SUPPLY | UNITS | P50 |
| MAX. CURRENT | AMPS | 50 |
| MAX. OPEN CKT. VOLTAGE | VOLTS | 75-80 |
| MATERIAL CU | $MM^3/MIN$ | 300 |
| REMOVAL RATE GR | | 350 |
| SURFACE FINISH | CLA MICRON | 0.8 |
| POWER CONSUMPTION | KW | 3 |
| PULSE ON/OFF TIME | | IN 10 STEPS |

# PHOTOGRAPH VIEW OF EXPERIMENTAL SETUP



# WORK MATERIAL

## Titanium Alloy [Ti–6Al–4V]

### Composition

| | |
|---|---|
| C | <0.08% |
| Fe | <0.25% |
| $N_2$ | <0.05% |
| $O_2$ | <0.2% |
| Al | 5.5-6.76% |
| V | 3.5-4.5% |
| $H_2$(sheet) | <0.015% |
| $H_2$(bar) | <0.0125% |
| $H_2$(billet) | <0.01% |
| Ti | Balance |

### Mechanical properties

| | | |
|---|---|---|
| Tensile Strength MPa (ksi) | 897 (130) | 1000 (145) |
| 0.2% Proof Stress MPa (ksi) | 828 (120) | 910 (132) |
| Elongation Over 2 Inches % | 10 | 18 |
| Reduction in Area % | 20 | |
| Elastic Modulus GPa (Msi) | | 114 (17) |
| Hardness Rockwell C | | 36 |
| Specified Radius <0.070 in x Thickness | | 4.5 |
| Specified Radius >0.070 in x Thickness | | 5.0 |
| Welded Radius x Thickness | 6 | |
| Charpy, V-Notch Impact J (ft.lbf) | | 24 (18) |

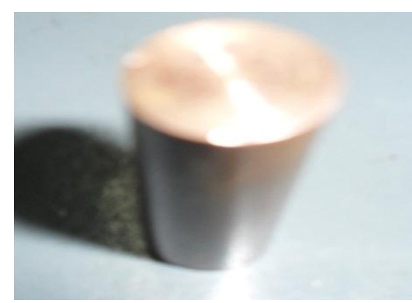
### Applications

- Aerospace industry
- Biomechanical
- Marine applications
- Chemical industry
- Petrochemical
- Body Jewelers
- Sports Equipment

### Work piece

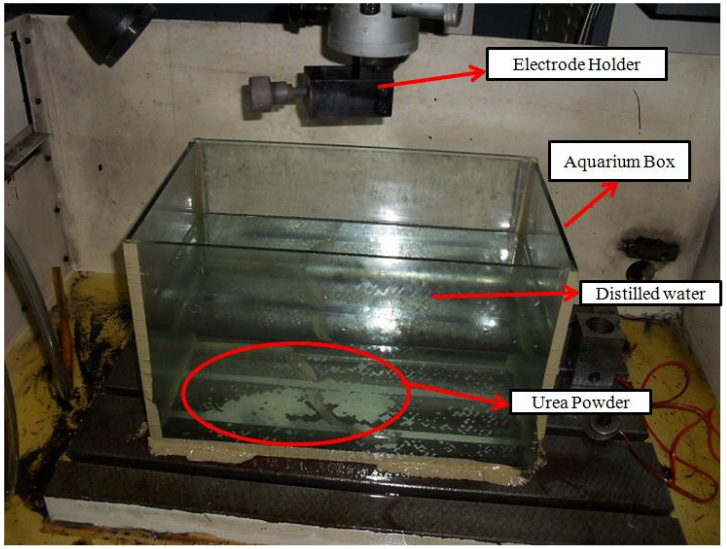
### Copper electrode

### Copper tungsten electrode



# Preparation of Dielectric

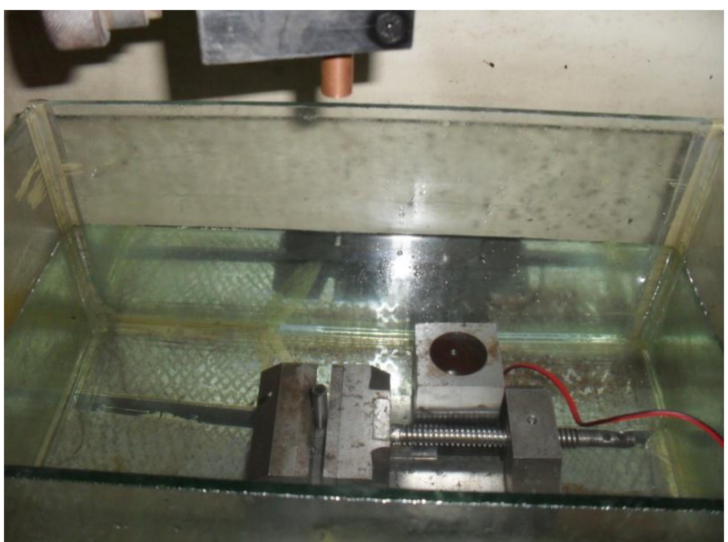
- Urea solution is prepared of concentration 10 grams urea powder in 1 liter of distilled water.




## Urea Properties

| | |
|---|---|
| Molar mass | 60.06 g mol−1 |
| Appearance | White solid |
| Density | 1.32 g/cm3 |
| Melting point | 133–135 C |
| Solubility in water | 51,8 g/100 ml (20 C) |

- Distilled water



## Distilled water Properties

| | |
|---|---|
| Density ( 1000 Kg/m$^3$) | 1 |
| Viscosity (Pa-s) | 1.79*10e-3 |
| Kinematic Viscosity (m$^2$/s) | 1.79*10e-6 |
| Temperature | 0 |

# Taguchi Design Of Experiments Process Steps

- Genichi Taguchi, a Japanese engineer, has developed the Taguchi method for the application of design of experiment.
- Taguchi methods is the method used for the optimization of experimental designs for performance quality and cost.
- Taguchi parameter design can optimize the performance characteristics through the settings of design parameters and reduce the sensitivity of the system performance to sources of variation.

## Steps followed by the taguchi method

1. Problem identification
2. Objectives of the project work
3. Selecting Quantity characteristics
4. Selecting the process parameters that may influence quantity characteristics

# CONTD..

5. Identifying Control factors

**Control factors**

Peak current(Amps)
Ton(Micro secs)
Gap voltage(Volts)
Electrode
Dielectric

**Noise factors**

Environmental (Room) conditions
Homogeneity of work or tool material
Tool and Machine Tool Rigidity
Tool & Work Material

6. Selecting levels for control factors

| Control factors | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Electrode | CU | CU+W | |
| Dielectric | Kerosene | Distilled water | Urea solution |
| Peak current(Amp) | 3 | 5 | 7 |
| Ton(Micro secs) | 50 | 100 | 200 |
| Gap voltage(Volts) | 35 | 40 | 45 |

7. Selecting Orthogonal Array and Assign Factors

Here we have five factors and three levels for each factor so L18 Mixed Orthogonal array can be selected and factors are assigned.

Contd..

8. Conducting Tests as per trials in Orthogonal Array

9. Analyze the results of experimentation trials

10. Conduct confirmation Experiment

# Experimental Design

Mixed level $L_{18}$

| SL.No | A | B | C | | | D | E | |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 |
| 4 | 1 | 2 | 1 | 1 | 2 | 2 | 3 | 3 |
| 5 | 1 | 2 | 2 | 2 | 3 | 3 | 1 | 1 |
| 6 | 1 | 2 | 3 | 3 | 1 | 1 | 2 | 2 |
| 7 | 1 | 3 | 1 | 2 | 1 | 3 | 2 | 3 |
| 8 | 1 | 3 | 2 | 3 | 2 | 1 | 3 | 1 |
| 9 | 1 | 3 | 3 | 1 | 3 | 2 | 1 | 2 |
| 10 | 2 | 1 | 1 | 3 | 3 | 2 | 2 | 1 |
| 11 | 2 | 1 | 2 | 1 | 1 | 3 | 3 | 2 |
| 12 | 2 | 1 | 3 | 2 | 2 | 1 | 1 | 3 |
| 13 | 2 | 2 | 1 | 2 | 3 | 1 | 3 | 2 |
| 14 | 2 | 2 | 2 | 3 | 1 | 2 | 1 | 3 |
| 15 | 2 | 2 | 3 | 1 | 2 | 3 | 2 | 1 |
| 16 | 2 | 3 | 1 | 3 | 2 | 3 | 1 | 2 |
| 17 | 2 | 3 | 2 | 1 | 3 | 1 | 2 | 3 |
| 18 | 2 | 3 | 3 | 2 | 1 | 2 | 3 | 1 |

Factors were assigned in A,B,C,D,E column means

A-Electrode, B-Dielectric, C-Peak current, D-Ton, E-Gap voltage

| Sl. No | Electrode | Dielectric | Peak current(Amps) | Ton(Mic.sec) | Gap voltage(Volt) |
|---|---|---|---|---|---|
| 1 | CU | K | 3 | 50 | 35 |
| 2 | CU | K | 5 | 100 | 40 |
| 3 | CU | K | 7 | 200 | 45 |
| 4 | CU | D | 3 | 100 | 45 |
| 5 | CU | D | 5 | 200 | 35 |
| 6 | CU | D | 7 | 50 | 40 |
| 7 | CU | U | 3 | 200 | 40 |
| 8 | CU | U | 5 | 50 | 45 |
| 9 | CU | U | 7 | 100 | 35 |
| 10 | CU+W | K | 3 | 100 | 40 |
| 11 | CU+W | K | 5 | 200 | 45 |
| 12 | CU+W | K | 7 | 50 | 35 |
| 13 | CU+W | D | 3 | 50 | 45 |
| 14 | CU+W | D | 5 | 100 | 35 |
| 15 | CU+W | D | 7 | 200 | 40 |
| 16 | CU+W | U | 3 | 200 | 35 |
| 17 | CU+W | U | 5 | 50 | 40 |
| 18 | CU+W | U | 7 | 100 | 45 |

## Conducting the Experiments

- In this step the experiment was conducted for the five Process Parameters using the *L*9 orthogonal array.
- In this study experiments were conducted in two halves. First 9 experiments Copper was taken as electrode and for other 9 experiments copper Tungsten was taken.

# RESULTS AND DISCUSSION

## COPPER[CU] MRR AND EWR [$L_9$]

| Dielectric | Peak current | Ton | Gap voltage | MRR | EWR |
|---|---|---|---|---|---|
| K | 3 | 50 | 35 | 0.8 | 0.6 |
| K | 5 | 100 | 40 | 1 | 1 |
| K | 7 | 200 | 45 | 2 | 3 |
| D | 3 | 100 | 45 | 6 | 4 |
| D | 5 | 200 | 35 | 8 | 5 |
| D | 7 | 50 | 40 | 12 | 7 |
| U | 3 | 200 | 40 | 7 | 6 |
| U | 5 | 50 | 45 | 9 | 7 |
| U | 7 | 100 | 35 | 15 | 8 |

## COPPER TUNGSTEN [CU+W] MRR AND EWR [$L_9$]

| Dielectric | Peak current | Ton | Gap voltage | MRR | EWR |
|---|---|---|---|---|---|
| K | 3 | 100 | 40 | 3 | 1 |
| K | 5 | 200 | 45 | 4 | 2 |
| K | 7 | 50 | 35 | 8 | 4 |
| D | 3 | 50 | 45 | 3 | 4 |
| D | 5 | 100 | 35 | 6 | 5 |
| D | 7 | 200 | 40 | 14 | 6 |
| U | 3 | 200 | 35 | 8 | 5 |
| U | 5 | 50 | 40 | 6 | 6 |
| U | 7 | 100 | 45 | 18 | 7 |

## CU&CU+W MRR, EWR [$L_{18}$]

| Sl. No | Electrode | Dielectric | Peak current | Ton | Gap voltage | MRR | EWR |
|---|---|---|---|---|---|---|---|
| 1 | CU | K | 3 | 50 | 35 | 0.8 | 0.6 |
| 2 | CU | K | 5 | 100 | 40 | 1 | 1 |
| 3 | CU | K | 7 | 200 | 45 | 2 | 3 |
| 4 | CU | D | 3 | 100 | 45 | 6 | 4 |
| 5 | CU | D | 5 | 200 | 35 | 8 | 5 |
| 6 | CU | D | 7 | 50 | 40 | 12 | 7 |
| 7 | CU | U | 3 | 200 | 40 | 7 | 6 |
| 8 | CU | U | 5 | 50 | 45 | 9 | 7 |
| 9 | CU | U | 7 | 100 | 35 | 15 | 8 |
| 10 | CU+W | K | 3 | 100 | 40 | 3 | 1 |
| 11 | CU+W | K | 5 | 200 | 45 | 4 | 2 |
| 12 | CU+W | K | 7 | 50 | 35 | 8 | 4 |
| 13 | CU+W | D | 3 | 50 | 45 | 3 | 4 |
| 14 | CU+W | D | 5 | 100 | 35 | 6 | 5 |
| 15 | CU+W | D | 7 | 200 | 40 | 14 | 6 |
| 16 | CU+W | U | 3 | 200 | 35 | 8 | 5 |
| 17 | CU+W | U | 5 | 50 | 40 | 6 | 6 |
| 18 | CU+W | U | 7 | 100 | 45 | 18 | 7 |

# Analyzing the experiment results

Contd..

- In this step the result of the Experiment are studied using following two steps.

    1. Analysis of Means

    2. Analysis of variance (ANOVA)

- Based on the results of the Mean and ANOVA analyses, optimal settings of the control parameters for MRR and EWR are obtained.

## Analysis of Means

Mean A, 1= (MRR1+MRR2+MRR3) / 3

Mean B, 1= (MRR4+MRR5+MRR6) / 3

Mean C, 1= (MRR7+MRR8+MRR9) / 3

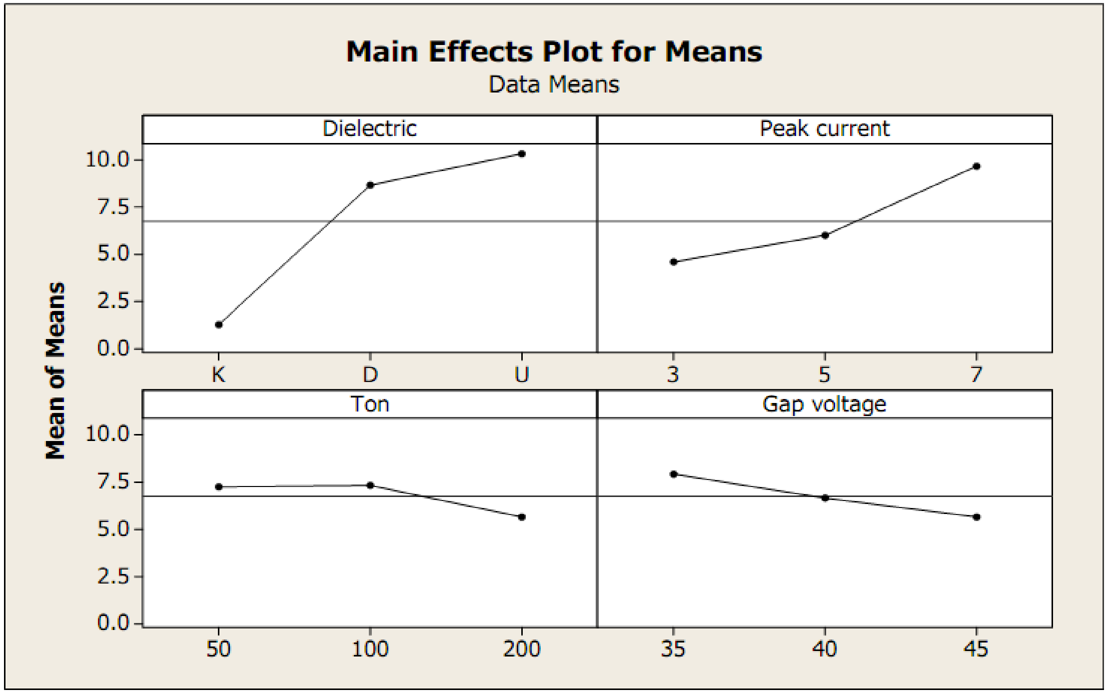
## Mean Response table for CU MRR

| Level | Dielectric | Peak current | Ton | Gap voltage |
|---|---|---|---|---|
| 1 | 1.267 | 4.600 | 7.267 | 7.933 |
| 2 | 8.667 | 6.000 | 7.333 | 6.667 |
| 3 | 10.333 | 9.667 | 5.667 | 5.667 |
| Delta | 9.067 | 5.067 | 1.667 | 2.267 |
| Rank | 1 | 2 | 4 | 3 |

Optimum process parameters: **A3, B3, C2, D1**

- Dielectric = Urea solution
- Peak current = 7 Amps
- Ton = 100 Micro seconds
- Gap voltage = 35 Volts

## Mean Response graph for CU MRR Vs Control Parameters



## Mean Response table for CU EWR

| Level | Dielectric | Peak current | Ton | Gap voltage |
|---|---|---|---|---|
| 1 | 1.533 | 3.533 | 4.333 | 4.533 |
| 2 | 5.333 | 4.333 | 4.867 | 4.667 |
| 3 | 7.000 | 6.000 | 4.667 | 4.867 |
| Delta | 5.467 | 2.467 | 0.533 | 0.133 |
| Rank | 1 | 2 | 3 | 4 |

Optimum process parameters: **A1, B1, C1, D1**

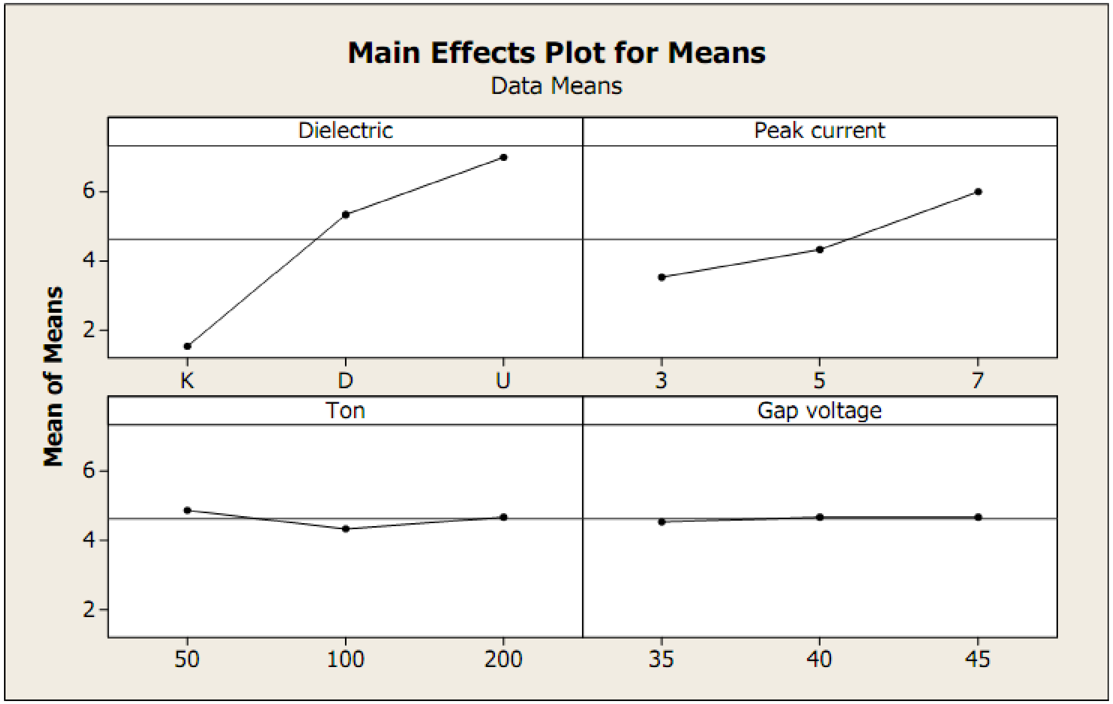
Dielectric = Kerosene

Peak current = 3 Amps

Ton = 50 Micro seconds

Gap voltage = 35 Volts

## Mean Response graph for CU EWR Vs Control Parameters



## Mean Response table for CU+W MRR

| Level | Dielectric | Peak current | Ton | Gap voltage |
|---|---|---|---|---|
| 1 | 5.000 | 4.667 | 5.667 | 7.333 |
| 2 | 7.667 | 5.333 | 9.000 | 7.667 |
| 3 | 10.667 | 13.333 | 8.667 | 8.333 |
| Delta | 5.667 | 8.667 | 3.333 | 1 |
| Rank | 2 | 1 | 3 | 4 |

Optimum process parameters: **A3, B3, C2, D3**

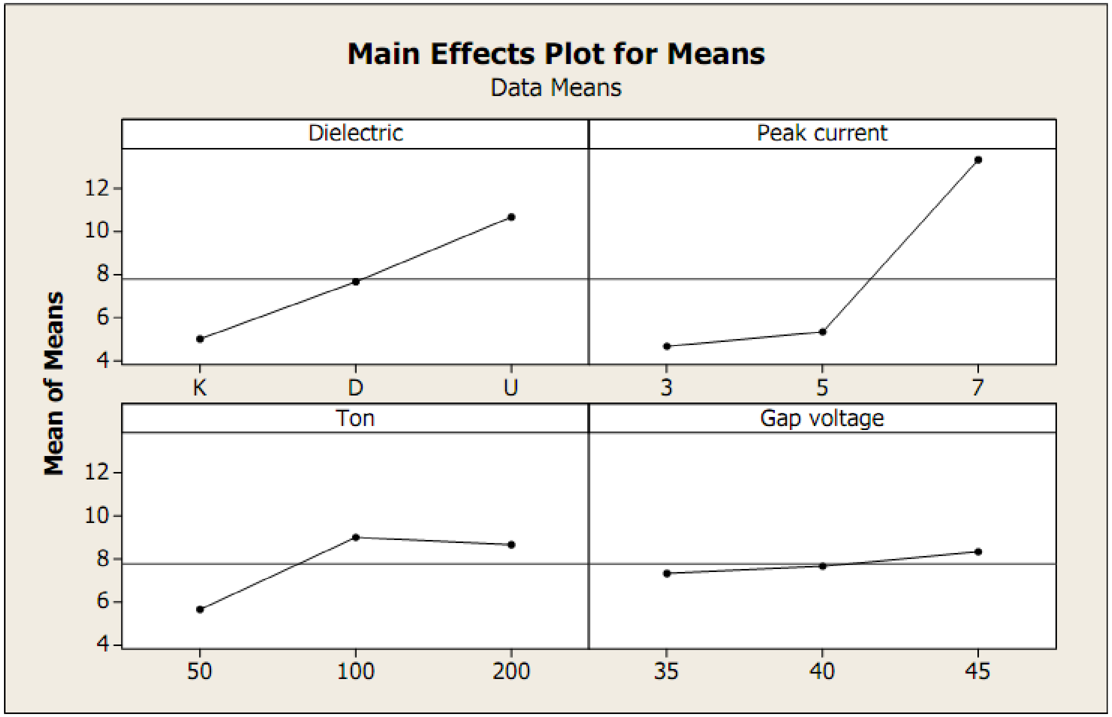
Dielectric = Urea solution

Peak current = 7 Amps

Ton = 100 Micro seconds

Gap voltage = 45 Volts

## Mean Response graph for CU+W MRR Vs Control Parameters



## Mean Response table for CU+W EWR

| Level | Dielectric | Peak current | Ton | Gap voltage |
|---|---|---|---|---|
| 1 | 2.333 | 3.333 | 4.667 | 4.667 |
| 2 | 5.000 | 4.333 | 4.333 | 4.333 |
| 3 | 6.000 | 5.667 | 4.334 | 4.345 |
| Delta | 3.667 | 2.333 | 0.333 | 0.333 |
| Rank | 1 | 2 | 3.5 | 3.5 |

Optimum process parameters: **A1, B1, C2, D2**

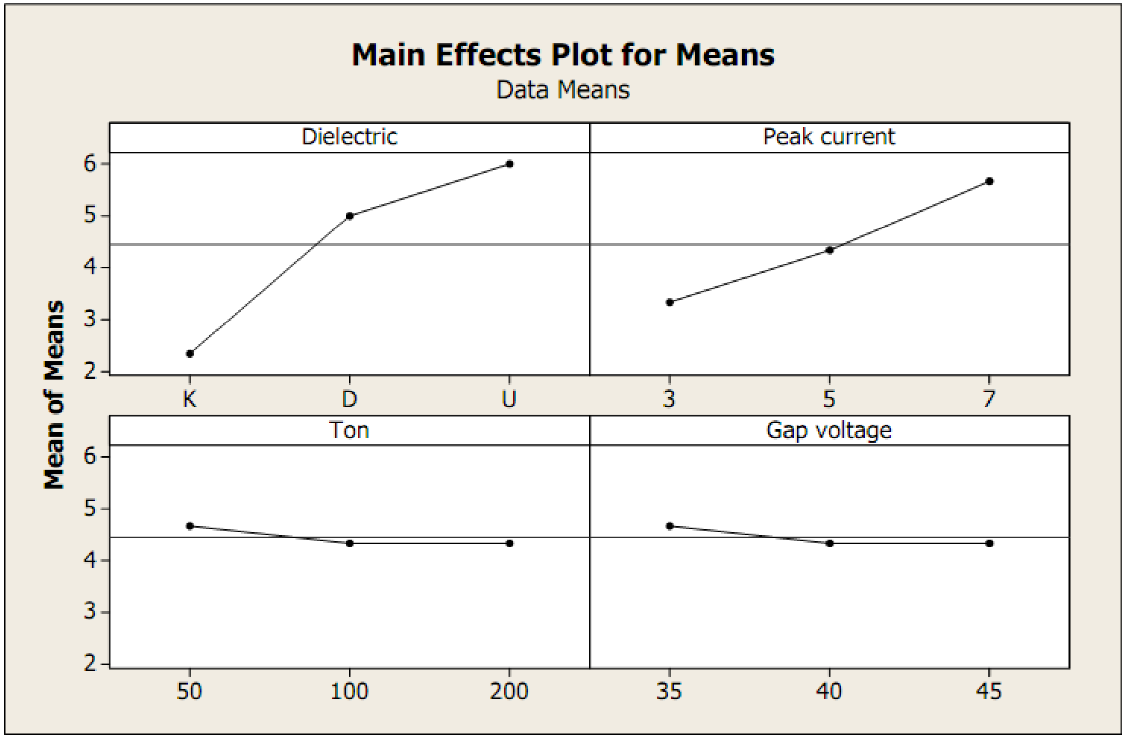
Dielectric = Kerosene

Peak current = 3 Amps

Ton = 50 Micro seconds

Gap voltage = 40 Volts

## Mean Response graph for CU+W EWR Vs Control Parameters



## Mean Response table for CU&CU+W MRR

| Level | Electrode | Dielectric | Peak current | Ton | Gap voltage |
|---|---|---|---|---|---|
| 1 | 6.756 | 3.133 | 4.633 | 6.467 | 7.000 |
| 2 | 7.778 | 8.167 | 5.667 | 8.167 | 7.167 |
| 3 | | 10.500 | 11.500 | 7.167 | 7.633 |
| Delta | | 7.367 | 6.867 | 1.7 | 0.633 |
| Rank | 4 | 1 | 2 | 3 | 5 |

Optimum process parameters:

**A2, B3, C3,D2,E3**

Electrode = Copper Tungsten (CU+W)

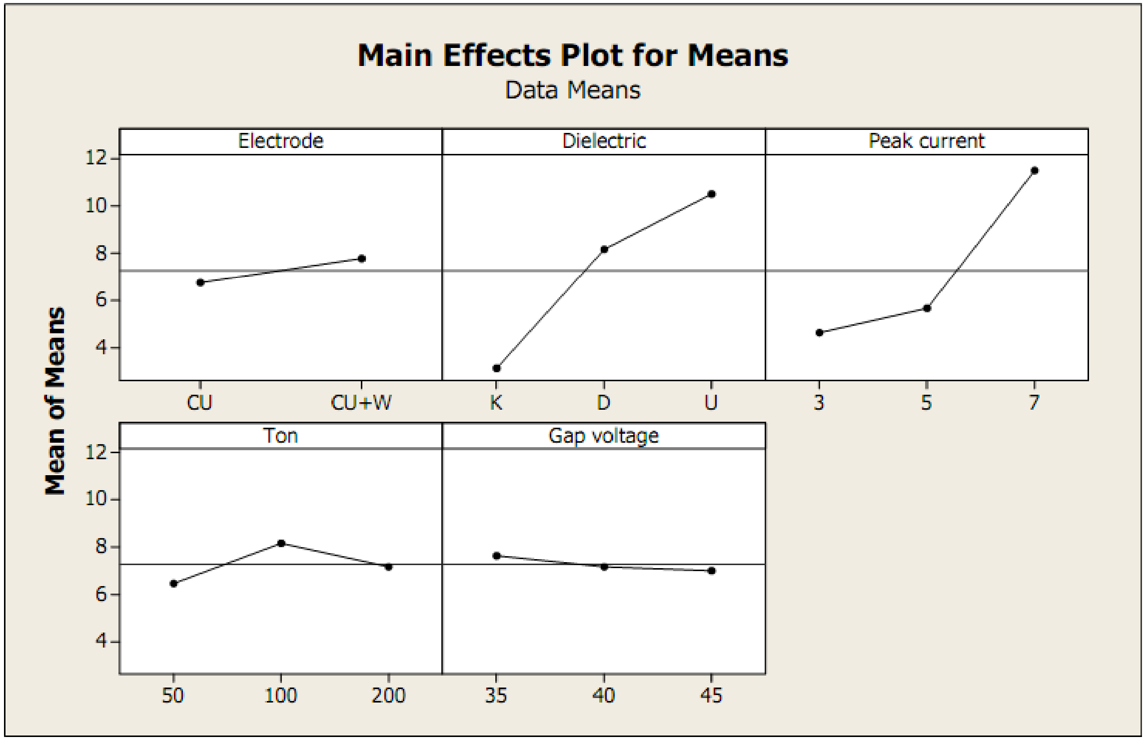
Dielectric = Urea solution

Peak current = 7 Amps

Ton = 100 Micro seconds

Gap voltage = 45 Volts

## Mean Response graph for CU&CU+W MRR Vs Control Parameters



# Mean Response table for CU&CU+W EWR

Contd..

| Level | Electrode | Dielectric | Peak current | Ton | Gap voltage |
|---|---|---|---|---|---|
| 1 | 4.622 | **1.933** | **3.433** | 4.767 | 4.60 |
| 2 | **4.444** | 5.167 | 4.333 | **4.333** | **4.500** |
| 3 | | 6.500 | 5.833 | 4.500 | 4.550 |
| Delta | | 4.567 | 2.40 | 0.433 | 0.1 |
| Rank | 4 | 1 | 2 | 3 | 5 |

Optimum process parameters:

**A2, B1, C1,D2,E2**

Electrode = Copper Tungsten (CU+W)

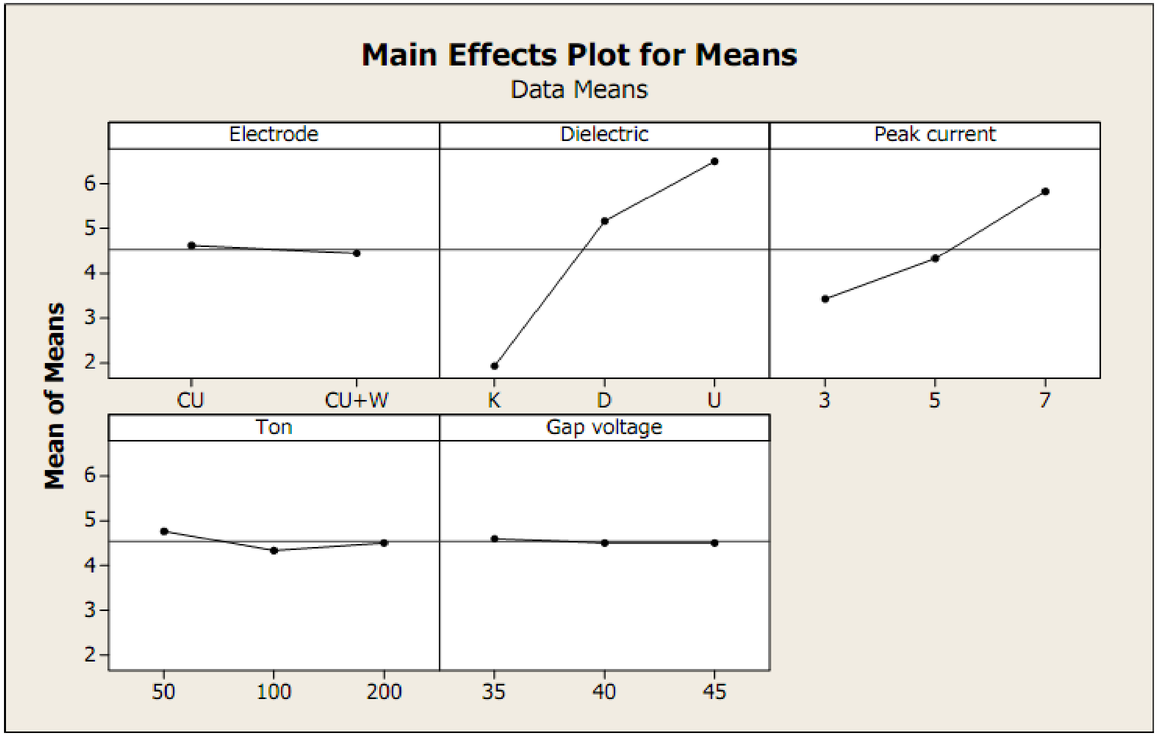
Dielectric = Kerosene

Peak current = 3 Amps

Ton = 100 Micro seconds

Gap voltage = 40 Volts

# Mean Response graph for CU&CU+W EWR Vs Control Parameters



# ANALYSIS OF VARIANCE

➢ The purpose of the analysis of variance (ANOVA) is to investigate which design parameters significantly affect the quality characteristic.

➢ To calculated the sum of the squares, mean squares and contributions by each of the design parameters from response table.

➢ First, Average calculated as:

Average ($n_m$) = (MRR1+MRR2+MRR3+MRR4+MRR5+MRR6+MRR7+MRR8+MRR9)/9

Total Sum of Squares ($S_T$) = $\sum_{i=1}^{9}(MRR)$

Sum of squares due to the mean ($S_m$) = $n*(n_m)^2$

Sum of squares due to factors ($S_A$) = $n_{A1}*A_1^2 + n_{A2}*A_2^2 + n_{A3}*A_3^2 - S_m$

Degree of freedom (DOF) = no of levels – 1

Mean sum of squares ($M_{Qa}$) = $S_A$ / DOF

% Contribution (P) = $S_A / S_t$ where $S_t = S_T - S_m$

# Results of the ANOVA for CU

## MRR

| Symbol | Process parameters | DOF | Sum of squares | Mean squares | Contribution (%) |
|---|---|---|---|---|---|
| A | Dielectric | 2 | 140.41 | 70.205 | 72.16 |
| B | Peak current | 2 | 41.77 | 20.885 | 21.46 |
| C | Ton | 2 | 6.03 | 3.015 | 3.09 |
| D | Gap voltage | 2 | 8.42 | 4.21 | 4.32 |
| Error | | 0 | - | - | - |
| St | | 8 | 194.58 | - | - |
| Mean | | | 410.06 | - | - |
| ST | | | 604.64 | - | - |

## EWR

| Symbol | Process parameters | DOF | Sum of squares | Mean squares | Contribution (%) |
|---|---|---|---|---|---|
| A | Dielectric | 2 | 47.77 | 23.885 | 83.41 |
| B | Peak current | 2 | 9.68 | 4.84 | 16.90 |
| C | Ton | 2 | 0.64 | 0.32 | 1.11 |
| D | Gap voltage | 2 | 5.96 | 2.98 | 10.40 |
| Error | | 0 | - | - | - |
| St | | 8 | 57.27 | - | - |
| Mean | | | 192.09 | - | - |
| ST | | | 249.36 | - | - |

# Results of the ANOVA for CU+W

## MRR

| Symbol | Process parameters | DOF | Sum of squares | Mean squares | Contribution (%) |
|---|---|---|---|---|---|
| A | Dielectric | 2 | 47.28 | 23.64 | 22.46 |
| B | Peak Current | 2 | 139.22 | 69.61 | 66.53 |
| C | Ton | 2 | 53.27 | 26.63 | 25.45 |
| D | Gap Voltage | 2 | 1.23 | 0.61 | 0.50 |
| Error | | 0 | - | - | - |
| St | | 8 | 209.25 | - | - |
| Mean | | | 544.75 | - | - |
| ST | | | 754 | - | - |

## EWR

| Symbol | Process parameters | DOF | Sum of squares | Mean squares | Contribution (%) |
|---|---|---|---|---|---|
| A | Dielectric | 2 | 21.55 | 10.77 | 71.28 |
| B | Peak Current | 2 | 8.22 | 4.11 | 27.19 |
| C | Ton | 2 | 0.22 | 0.11 | 0.72 |
| D | Gap Voltage | 2 | 0.22 | 0.11 | 0.72 |
| Error | | 0 | - | - | - |
| St | | 8 | 30.23 | - | - |
| Mean | | | 177.77 | - | - |
| ST | | | 208 | - | - |

# Results of the ANOVA for CU & CU+W

## MRR

| Symbol | Process Parameters | DOF | Sum of squares | Mean squares | Contribution (%) |
|---|---|---|---|---|---|
| A | Electrode | 1 | 6.53 | 6.53 | 1.59 |
| B | Dielectric | 2 | 171.86 | 85.93 | 41.92 |
| C | Peak Current | 2 | 166.24 | 83.12 | 40.55 |
| D | Ton | 2 | 10.59 | 5.29 | 2.58 |
| E | Gap Voltage | 2 | 3.04 | 1.52 | 0.74 |
| Error | | 8 | - | - | - |
| St | | 17 | 409.91 | - | - |
| Mean | | | 948.73 | - | - |
| ST | | | 1358.64 | - | - |

## EWR

| Symbol | Process Parameters | DOF | Sum of squares | Mean squares | Contribution (%) |
|---|---|---|---|---|---|
| A | Electrode | 1 | 0.63 | 0.63 | 0.72 |
| B | Dielectric | 2 | 66.73 | 10.77 | 75.83 |
| C | Peak Current | 2 | 18.13 | 4.11 | 20.60 |
| D | Ton | 2 | 1.12 | 0.11 | 1.27 |
| E | Gap Voltage | 2 | 0.59 | 0.11 | 0.6 |
| Error | | 8 | - | - | - |
| St | | 17 | 87.99 | - | - |
| Mean | | | 369.37 | - | - |
| ST | | | 457.36 | - | - |

# TOPSIS METHOD

- TOPSIS (Technique for order preference by similarity to an ideal solution) considers the distances to the ideal solution and negative ideal solution regarding each alternative and selects the most relative closeness to the ideal solution as the best alternative.

**Step 1** Decision matrix

$$D = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} F_1 & F_2 & \cdots & F_n \end{array} \\ \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} \end{array}$$

**Step 2** Normalized Decision matrix $r_{ij} = f_{ij} / \left( \sum_{j=1}^{n} f_{ij}^2 \right)^{1/2}$

**Step 3** Weighted Normalized Decision matrix $v_{ij} = w_{ij}\, r_{ij}$

**Step 4** Positive Ideal Solution

$$V^+ = \{v_1^+, \ldots, v_n^+\} = \{(Max\, v_{ij} \mid j \in J), (Min\, v_{ij} \mid j \in J')\}$$

Negative Ideal Solution

$$V^+ = \{v_1^-, \ldots, v_n^-\} = \{(Min\, v_{ij} \mid j \in J), (Max\, v_{ij} \mid j \in J')\}$$

**Step 5** Separation measure of each alternative from the PIS

$$D_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2} \ , \ i = 1, \ldots, m$$

Separation measure of each alternative from the NIS

$$D_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2} \ , \ i = 1, \ldots, m$$

**Step 6** Relative closeness of the alternative Ai with respect to PIS

$$\overline{C}_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

- Where the index value of Ci lies between 0 and 1.
- The larger the index value, the better the performance of the Alternatives.

# Contd..

## Decision Matrix [CU]

| Dielectric | Peak current | Ton | Gap voltage | MRR | EWR |
|---|---|---|---|---|---|
| K | 3 | 50 | 35 | 0.8 | 0.6 |
| K | 5 | 100 | 40 | 1 | 1 |
| K | 7 | 200 | 45 | 2 | 3 |
| D | 3 | 100 | 45 | 6 | 4 |
| D | 5 | 200 | 35 | 8 | 5 |
| D | 7 | 50 | 40 | 12 | 7 |
| U | 3 | 200 | 40 | 7 | 6 |
| U | 5 | 50 | 45 | 9 | 7 |
| U | 7 | 100 | 35 | 15 | 8 |

## Normalized decision matrix [CU]

| Dielectric | Peak current | Ton | Gap voltage | MRR | EWR |
|---|---|---|---|---|---|
| K | 0.190117 | 0.125988 | 0.290159 | 0.032534 | 0.037996 |
| K | 0.316862 | 0.251976 | 0.331611 | 0.040668 | 0.063327 |
| K | 0.443607 | 0.503953 | 0.373062 | 0.081336 | 0.18998 |
| D | 0.190117 | 0.251976 | 0.373062 | 0.244007 | 0.253307 |
| D | 0.316862 | 0.503953 | 0.290159 | 0.325343 | 0.316633 |
| D | 0.443607 | 0.125988 | 0.331611 | 0.488015 | 0.443287 |
| U | 0.190117 | 0.503953 | 0.331611 | 0.284675 | 0.37996 |
| U | 0.316862 | 0.125988 | 0.373062 | 0.366011 | 0.443287 |
| U | 0.443607 | 0.251976 | 0.290159 | 0.610018 | 0.506613 |

## Weighted normalized decision matrix [CU]

| Dielectric | Peak current | Ton | Gap voltage | MRR | EWR |
|---|---|---|---|---|---|
| K | 0.057035 | 0.025198 | 0.023213 | 0.013014 | 0.00076 |
| K | 0.095059 | 0.050395 | 0.026529 | 0.016267 | 0.001267 |
| K | 0.133082 | 0.100791 | 0.029845 | 0.032534 | 0.0038 |
| D | 0.057035 | 0.050395 | 0.029845 | 0.097603 | 0.005066 |
| D | 0.095059 | 0.100791 | 0.023213 | 0.130137 | 0.006333 |
| D | 0.133082 | 0.025198 | 0.026529 | 0.195206 | 0.008866 |
| U | 0.057035 | 0.100791 | 0.026529 | 0.11387 | 0.007599 |
| U | 0.095059 | 0.025198 | 0.029845 | 0.146404 | 0.008866 |

## Relative closeness to the ideal solution for [CU]

| Electrode | Dielectric | Relative closeness |
|---|---|---|
| CU | K | 0 |
| CU | K | 0.162387 |
| CU | K | 0.3405 |
| CU | D | 0.339274 |
| CU | D | 0.545878 |
| CU | D | 0.686975 |
| CU | U | 0.455757 |
| CU | U | 0.518482 |
| **CU** | **U** | **0.827988** |

## Relative closeness to the ideal solution for [CU+W]

| Electrode | Dielectric | Relative closeness |
|---|---|---|
| CU+W | K | 0.096866 |
| CU+W | K | 0.293256 |
| CU+W | K | 0.39076 |
| CU+W | D | 0.031159 |
| CU+W | D | 0.254256 |
| CU+W | D | 0.767725 |
| CU+W | U | 0.389904 |
| CU+W | U | 0.231264 |
| **CU+W** | **U** | **0.822157** |

## Relative closeness to the ideal solution for [CU]& [CU+W]

| Electrode | Dielectric | Relative closeness |
|---|---|---|
| CU | K | 0 |
| CU | K | 0.145782 |
| CU | K | 0.30744 |
| CU | D | 0.290238 |
| CU | D | 0.468076 |
| CU | D | 0.612224 |
| CU | U | 0.396697 |
| CU | U | 0.448818 |
| CU | U | 0.772134 |
| CU+W | K | 0.145694 |
| CU+W | K | 0.309963 |
| CU+W | K | 0.439323 |
| CU+W | D | 0.120195 |
| CU+W | D | 0.320988 |
| CU+W | D | 0.788453 |
| CU+W | U | 0.438708 |
| CU+W | U | 0.304493 |
| **CU+W** | **U** | **0.845587** |

Topsis Analysis are summarized as follows:

| Sl.No | Array of Experiments | Best Alternative |
|---|---|---|
| 1 | Copper $L_9$ [1-9] | Urea solution |
| 2 | Copper Tungsten [9-18] | Urea solution |
| 3 | Copper & Copper Tungsten [1-18] | Copper Tungsten and Urea solution |

# CONCLUSION

On the basis of experimental results, the EDM characteristics of Titanium alloy [Ti–6Al–4V] were examined using kerosene, distilled water and urea solution as the dielectrics and Copper and copper Tungsten as electrodes.

- Copper Tungsten electrode gives better MRR while copper performed for lower EWR.
- Urea solution gives better MRR and kerosene is preferred for lower EWR.
- By applying TOPSIS Urea solution and Copper Tungsten electrode gives better results among other alternatives.

# REFERENCES


1.Biing Hwa Yan , Hsien Chung Tsai, Fuang Yuan Huang, The effect in EDM of a dielectric of a urea solution in water on modifying the surface of titanium, International Journal of Machine Tools & Manufacture 45 (2005), 194–200.

2. Lin, Y.C., Yan, B.H., Chang, Y.S., 2000. Machining characteristics of titanium alloy (Ti–6Al–4V) using a combination process of EDM with USM. J. Mater. Process. Technol. 104, 171–177. Material Property Data, Matweb, 2007.

3. M. Toren, Y. Zvirin, Y. Winograd, Melting and evaporation phenomena during electrical erosion, Journal of Heat Transfer 1989; 576–581.

4. Hascalik, A., Caydas, U., 2007, Electrical discharge machining of titanium alloy (Ti–6Al–4V), Applied Surface Science, 253:9007-9016.

5. Boothroyd, G.; Winston, A.K. (1989): Non-conventional machining processes, in Fundamentals of Machining and Machine Tools, Marcel Dekker, Inc, New York, 491.

6. Marafona J, Wykes C (2000) A new method of optimizingmaterial removal rate using EDM with copper-tungsten electrodes. Int J Mach & Manuf 40:153–164.

7. C.J. Luis, I. Puertas, G. Villa, Material removal rate and electrodewear study on the EDM of silicon carbide, Journal of MaterialsProcessing Technology 164–165 (2005) 889–896.

8. Jahanshahloo, G.R., Junior, H.V., Hosseinzadeh Lotfi, F., Akbarian, D., 2007, A new DEA ranking system based on changing the reference set, European Journal of Operational Research. 181, 331-337.

9. G.Taguchi (1990) Introduction to Quality Engineering, Asian Produc-tivity Organization, Tokyo.

10. F. Hosseinzadeh Lotfi, T. Allahviranloo, M. Alimardani Jondabeh, and N. A. Kiani, A New Method for Complex Decision Making Based on TOPSIS for Complex Decision Making Problems with Fuzzy Data, Applied Mathematical Sciences, Vol. 1, 2007, no. 60, 2981 – 2987.

# THANK YOU