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# EFFECT OF PROCESS PARAMETERS ON MATERIAL REMOVAL RATE IN WIRE ELECTRICAL DISCHARGE MACHINING

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**ABSTRACT;** Technologically advanced industries demand for materials having higher hardness and wear resistance. These materials are difficult to machine using traditional methods. Hence,nontraditional methods such as electric discharge machining and wire electric discharge machining are applied. Wire EDM is capable of machining complex shapes in hard materials. The technology on which WEDM works is conventional electro discharge sparking phenomenon widely accepted and implemented for industrial application. Wire EDM has been employed for making dies, press tools and electrodes.In this project work, the effect of process parameters on material removal ratein WEDM like pulse on time, pulse off time and peak current has been investigated to reveal their impact on material removal rate of STAINLESS STEEL 304,ALUMINIUM and BRASS.During this work, it is tried to investigate the effect of one variable at a time.

The machine used for experimental work was electronica make wire EDM. Brass wire is used as electrode and deionized water is used as dielectric medium. The specimens of SS 304,ALUMINIUM and BRASS of required dimensions were prepared by milling. Number of experiments were conducted to find out the effect of input parameter on output parameter. The output parameter is material removal rate. The change in output parameter due to change in input parameter is measured every time. It is observed that the material removal rate increases with increase in pule on time and peak current, whiledecreases with increase in pulse off time

## 1. INTRODUCTION

Manufacturing industry is becoming even more conscious about time and quality with respect to the demand, efficiency, global acceptance and competence, also the need to use complicated and precise components having some special shape with high tolerances.

The conventical machining process, in spite of recent technical advancement, are inadequate to machine complex shapes in hard, high strength, temperature resistant alloys and die steels. Keeping these requirements into mind, a number of Non-traditional machining/unconventional machining processes have been developed. Nevertheless, such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods including Electrochemical machining, Ultrasonic machining, Electrical discharging machining (EDM) etc. are applied to machine such difficult to machine materials.

### ELECTRICAL DISCHARGE MACHINING

Electrical discharge machining is also known as spark machining, spark eroding, die sinking, wire burning or wire erosion, is a manufacturing process whereby a desired shape is obtained by using electrical discharges. Material is removed from the work piece by a series of rapidly recurring current discharges between two electrodes, separated by a dielectric liquid subject to an electric voltage. One of the electrodes is called the tool electrode or simply the “tool” or “electrode”, while the other is called the work piece electrode, or work piece, The process depends upon the tool and work piece not making actual contact.

## 2. LITERATURE REVIEW

Some selected resources papers have been discussed related the EDM and WEDM. The studies considered from these papers are mainly concerned with the WEDM parameters such as current, voltage, pulse on time, duty cycle etc., and how these effect the machining characteristics like MRR, SR etc.

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- Tarng et al. (1995) developed a model using neural network and simulated annealing algorithm in order to predict and optimize the surface roughness and cutting speed of WEDM process in machining of SUS-304 stainless steel materials.
- Liao et al. (1997) investigated WEDM parameters in machining of SKD11 alloy steel using Taguchi quality design method and analysis of variance (ANOVA). Using regression analysis mathematical models relating to the machining performance namely MRR, SR and gap width with various machining parameters were developed.
- Prohaszka et al. (1997) reported the requirements of wire electrode materials for improving WEDM performance. Three kind of wire material namely Mg, Sn and Zn were selected to perform the experiments. It was concluded that the materials used for the fabrication of wire electrodes must be characterized by a small work function and high melting and evaporation temperatures.
- Spedding and Wang (1997) attempted to model the cutting speed, surface roughness and surface waviness in wire EDM process through response-surface methodology and artificial neural networks (ANNs). The pulse-width, pulse duration, wire tension and injection set point were selected as input parameters. Multi Characteristics Optimization Techniques Application of Graph theory Machining of Tungsten Carbide composite Investigation and Modelling of WEDM parameters Literature Review 15
- Huang et al. (1999) investigated experimentally the effect of various machining parameters on gap width, surface roughness and depth of white layer on the machined workpiece (SKD11alloy steel). They adopted the feasible-direction non-linear programming method for determination of the optimal parameter settings.

## 3. METHODOLOGY

### 3.1 Selection Of Materials

The test materials used are SS 304,ALUMINIUM and BRASS and its composition is as shown in the table below

**Table 1: Composition of SS 304**

| Element | C | Mn | P | S | Si | Cr | Ni |
|---|---|---|---|---|---|---|---|
| % | 0.08 | 2.0 | 0.045 | 0.03 | 1.0 | 18.0 | 8.0 |

**Table 2: composition of BRASS**

| Element | Cu | Zn |
|---|---|---|
| % | 85 | 15 |

### 3.1.1 Mechanical Properties

The mechanical properties ofSS 304, ALUMINIUM and BRASS are given in below table.

**Table 3: Mechanical properties of SS 304,ALUMINIUM and BRASS**

| Mechanical Properties | BRASS | | SS 304 | | Al | |
|---|---|---|---|---|---|---|
| | Metric | Imperial | Metric | Imperial | metric | Imperial |
| Tensile strength | 36 Mpa | 52200 Psi | 505 Mpa | 73200 Psi | 150 Mpa | 21755 Psi |
| Yeild strength | 140 Mpa | 20300 Psi | 215 Mpa | 31200 Psi | 130 Mpa | 18855 Psi |
| Elongation break | 52 % | 52% | 70% | 70% | 7% | 7% |
| Poisson's ratio | 0.34 | 0.34 | 0.29 | 0.29 | 0.33 | 0.33 |
| Elastic modulus | 117 Gpa | 16969 Ksi | 193-200 Gpa | 28000 - 29000 Ksi | 70-80Gpa | 10153 - 11603 Ksi |

### 3.1.2 Thermal Properties

Thermal properties of SS 304, Al and BRASS are given in below table

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**Table 4: Thermal properties of SS 304,Al and BRASS**

| Thermal Properties | BRASS | | SS 304 | | Al | |
|---|---|---|---|---|---|---|
| | Metric | Imperial | Metric | Imperial | Metric | Imperial |
| Thermal Expansion (@20-300°C/68-572°F) (µm/m°C&µin/in°F ) | 20.8 | 11.6 | 17.8 | 30.5 | 21 | 13 |
| Thermal conductivity (@20°C/68°F) (W/mK& BTU in/hr ft²°F) | 123 | 854 | 16.2 | 112 | 150 | 1190 |

### 3.1.3 Physical Properties

The physical properties of SS 304, Al and BRASS are given in below table

**Table 5: Physical properties of SS 304, Al and BRASS**

| Physical Properties | BRASS | | SS 304 | | Al | |
|---|---|---|---|---|---|---|
| | Metric | Imperial | Metric | Imperial | Metric | Imperial |
| Density ($g/cm^3$& $lb/in^3$) | 8.39 | 0.303 | 8 | 0285 | 2.63 | 0.0939 |
| Melting Point | 904°C | 1660°F | 1400°C | 2550°F | 660°C | 1210°F |

### 3.2 Specimen preparation by Milling operation

Milling is the process of machiningusing rotary cutters to remove material by advancing a cutter into a workpiece. This may be done varying direction on one or several axes, cutter head speed, and pressure. Milling covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes for machining custom parts to precise tolerances.

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill). After the advent of computer numerical control (CNC) in the 1960s, milling machines evolved into machiningcenters: milling machines augmented by automatic tool changers, tool magazines or carousels, CNC capability, coolant systems, and enclosures. Milling centres are generally classified as vertical machiningcentre(VMCs) or horizontal machining centers (HMCs).

**Fig 10 : Milling machine**

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Fig 11: Specimens after Milling operation

**3.3Selection of process parameters**

the three process parameters are selected in WEDM. the selected process parameters are pulse on time (Ton), pulse off time (Toff) and peak current (IP).

Pulse On time (Ton): It is the duration of time expressed in micro seconds in which the peak current is ready to flow in every cycle. This is the time in which energy removes the metallic particles from the work piece.

Pulse Off time (Toff ): It is the period of time expressed in micro seconds between the two pulse on time. This time permits the melted particle to coagulate on to the work piece and to be wash away by flushing method of the arc gap.

Peak current (IP): The peak current is the maximum amount of current which output is capable of sourcing for brief periods of time. When a power supply or an electrical device is first turned on, high initial current flows into the load, starting at zero and rising until it reaches a peak value, known as the peak current.

**3.4Specifications of WEDM**

**Table 6: Specification of Spring cut CNC Wire EDM**

| WORK TABLE | |
|---|---|
| Design | Fixed column, moving table |
| Table size | 440 x 650 ×300 mm |
| **MAX.WORK PIECE DIMENSION** | |
| Max. work piece height | 200 mm |
| Max. work piece weight | 500 kg |
| Main table traverse (X,Y) | 300 x 400 mm |
| Aux. table traverse (U,V) | 80 x 80 mm |
| Wire electrode diameter | 0.25 mm (std.) 0.15 mm, 0.20 mm (opt.) |
| **PULSE GENERATOR** | |
| Pulse Generator | ELPULS-40 A DLX |
| CNC Controller | EMT 100W-5 |

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| | |
|---|---|
| Input power supply | 3 phase, AC, 415 V , 50 Hz |
| Connected load | 10 kVA |
| Average power consumption | 6 to 7 kVA |
| **DIELECTRIC SYSTEM** | |
| Dielectric Unit | DL 25 P |
| Dielectric fluid | Deionised water |
| Tank capacity | 250 Litters |

### 3.4.1 Wire cut machining process


**Fig 12: Wire cut EDM**

- The machine used for experimentation work was" spring cut" Electronica Make Wire EDM as shown in Figure.
- In wire electrical discharge machining (WEDM), also known as wire-cut EDM and wire cutting, a thin single-strand metal wire, usually brass, is fed through the workpiece, submerged in a tank of dielectric fluid, typically de-ionized water.
- Brass wire with 0.25mm diameter having tensile strength of 900N/mm2 was used as an electrode. De-ionized water was used as the dielectric medium.

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Fig 13: During cutting process

### 3.5 Wire EDM machining:

The heat treated test pieces were machined by wire EDM machine to obtain 20x20x5mm thickness test specimens were obtained. During machining, the input parameters considered are pulse on time, pulse off time, and servo voltage, peak current one at a time are considered to find out its effect on output parameter. The output parameter is surface roughness.

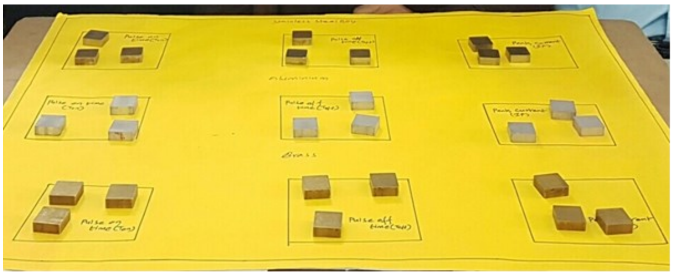

Fig 14: SS 304, BRASS and Al specimens

## 4. RESULTS AND DISCUSSION

In the present work while conducting the various experiments one factor experimental strategy was adopted as per this strategy only one input parameter is to be varied at a time and all other input parameter are kept to be constant. During this experimental works in all 27 experiments were conducted over three different types of pieces. The various experimental results observed are analysed and presented here.

### 4.1 EFFECT OF PULSE ON TIME (Ton)

In the first set of experiment pulse on time wasvaried from 110 units to 118 units in step of 4 units. All other parameters such as pulse off time, servovoltage, wire feed, peak current,and wire tension were kept constant. The variation inmaterial removal rate (MRR) due to variation in pulse ontime is tabulated in the Table7.

Table 7: Effect of Ton

| S.NO. | Pulse on time (Ton) (µs) | Material removal rate (MRR) ($mm^2$/min) | | |
|---|---|---|---|---|
| | | SS 304 | BRASS | Al |
| 1 | 110 | 2.413 | 5.509 | 3.506 |
| 2 | 114 | 3.411 | 5.81 | 4.528 |
| 3 | 118 | 4.522 | 6.215 | 5.425 |

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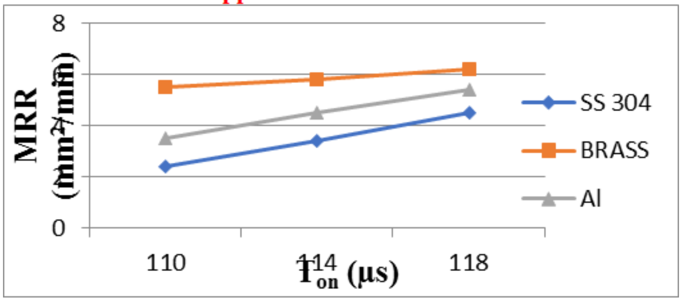



Graph 1

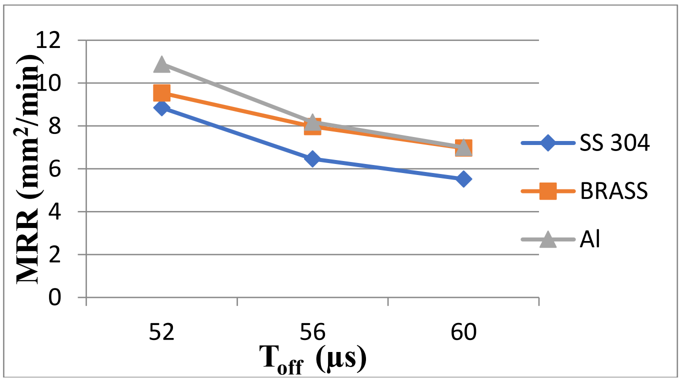
The graph shows that material removal rate increases with the increase in the pulse on time. So the pulse on time can be adjusted to get the desired material removal rate.

### 4.2 EFFECT OF PULSE OFF TIME (Toff)

In the second set of experiments pulse off time wasvaried from 52 units to 60 units in step of 4 units. All other parameters such as pulse on time, servovoltage, wire feed, peak current,and wire tension were kept constant. The variation inMRR due to variation in pulse off time is tabulated in the Table 8.

**Table 8: Effect of Toff**

| S.NO. | Pulse off time ($T_{off}$) (µs) | Material removal rate (MRR) ($mm^2$/min) | | |
|---|---|---|---|---|
| | | SS 304 | BRASS | Al |
| 1 | 52 | 8.849 | 9.541 | 10.89 |
| 2 | 56 | 6.468 | 7.98 | 8.176 |
| 3 | 60 | 5.521 | 6.968 | 7.002 |




Graph 2

The graph reveals that the material removal rate decreases with increase in the pulse off time. So the value of pulse off time can be selected in such a way that we get the desired material removal rate.

### 4.3 EFFECT OF PEAK CURRENT (IP)

#### 4.3.1 ON STAINLESS STEEL 304 MATERIAL

In the thirdset of experiment peak current wasvaried from 100 units to 160units in step of 30 units. All other parameters such as pulse off, pulse on time, wire feed, servo voltage ,and wire tension were kept constant. The variation inMRR due to variation in peak current is tabulated in the Table 9.

**Table 9: Effect of IP**

| S.NO. | Peak current (IP) (Amps) | Material removal rate (MRR) ($mm^2$/min) |
|---|---|---|
| 1 | 100 | 56.88 |
| 2 | 130 | 73.8 |
| 3 | 160 | 90.6 |

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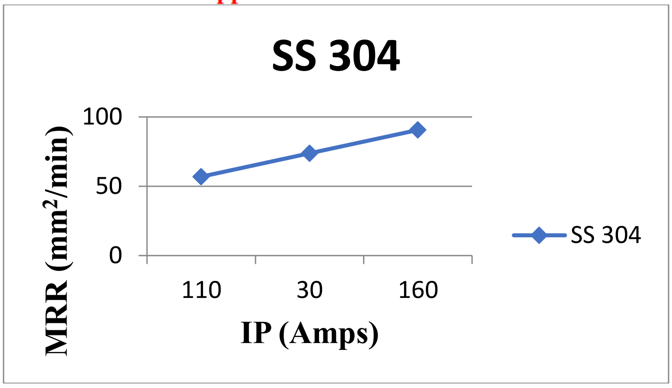


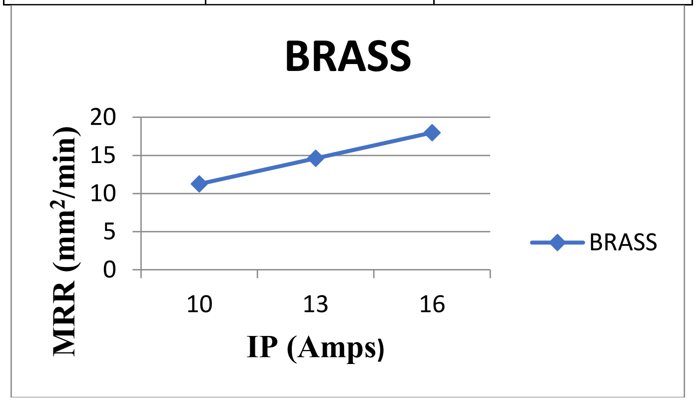

Graph 3

**4.3.2 ON BRASS MATERIAL**

In the fourth set of experiment peak current wasvaried from 10 units to 16units in step of 3 units. All other parameters such as pulse off, pulse on time, wire feed, servo voltage ,and wire tension were kept constant. The variation in MRR due to variation in peak current is tabulated in the Table10.

**Table 10: Effect of IP**

| S.NO. | Peak current (IP) (Amps) | Material removal rate (MRR) ($mm^2$/min) |
|---|---|---|
| 1 | 10 | 11.24 |
| 2 | 13 | 14.61 |
| 3 | 16 | 17.98 |




Graph 4

**4.3.3 ON ALUMINIUM MATERIAL**

In the fifth set of experiment peak current wasvaried from 3 units to 7units in step of 2 units. All other parameters such as pulse off, pulse on time, wire feed, servo voltage ,and wire tension were kept constant. The variation in MRR due to variation in peak current is tabulated in the Table11.

**Table 11: Effect of IP**

| S.NO. | Peak current (IP) (Amps) | Material removal rate (MRR) ($mm^2$/min) |
|---|---|---|
| 1 | 3 | 5.436 |
| 2 | 5 | 9.06 |
| 3 | 7 | 12.68 |

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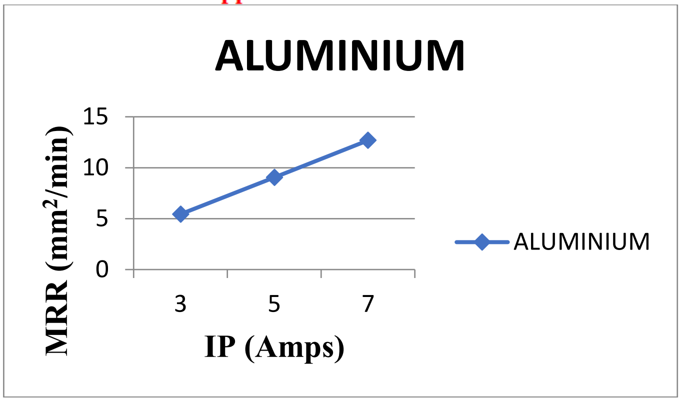


**Graph 5**

This graph shows that material removal rate increases with the increase in the peak current. So value of peak current should be high to obtain higher MRR.

## 5. CONCLUSION

On the basis of experimental work conducted and the result obtained the conclusions drawn are as follows:

- With increase in pulse on time, the material removal rate (MRR) increases in three types of pieces. the material removal rate is directly proportional to pulse on time (Ton).
- With increase in pulse off time, the material removal rate decreases in three types of pieces. the material removal rate is inversely proportional to pulse off time (Toff).
- With the increase in peak current,material removal rate increases in three types of pieces. the material removal rate is directly proportional to peak current (IP).
- As a overall concluding remark we can say that the material removal rate increases with pulse on time and peak current, while decreases with increase in pulse off time.

## 6. FUTURE SCOPE

- Need for finding optimal combination of parameters for different tool materials used for work materials.
- Responses like roundness, circularity, cylindricity, machining cost etc may be considered in further research.
- For the estimation of process parameters, the work being carried out can be compared by considering different methods such as multiple relation analyses, ANOVA or F-Test. Similarly comparison can be made between Taguchi analysis Fuzzy control or Orthogonal techniques

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