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# Optimization of Machining Parameters in EDM Using SS 317 by Factorial Design

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**Abstract: Electric Discharge Machining (EDM) is an electro-thermal non-traditional machining process having a widespread applications in automotive, aviation, miniaturized scale frameworks industries etc. EDM process is governed by thermoelectric vitality between anode (workpiece) and cathode (tool wire). EDM shoulders a fantastic part in the improvement of practical things with more dependable quality affirmation. Enhancing the material removal rate, surface finish and diminishing the tool wear rate and dimensional variation were paid exceptional attention in EDM. Generally copper, brass and graphite are utilized as tool (cathode) materials. In this experimental research work, SS 317 grade steel is machined in EDM by varying input factors and optimized the process using Full factorial method. Copper and brass electrodes were utilized as tool material on SS 317 steel which is oil hardened, non-shrinking steel. These steels are used for fine parts such as taps, hand reamers, milling cutters, engraving tools and intricate press tools which cannot be machined easily after hardening.**

**Keywords: Brass electrode, Copper electrode, Electrical discharge machining, Metal removal rate, SS 317, Tool wear rate.**

## I. Introduction

Wire Electrical Discharge Machining (WEDM) is a predominant non-traditional process where the spark delivered by the consistent current flow between the conductive electrodes to dissolve the target work material by erosion. The controlled disintegration of the material happens along the way (i.e. wire travel route). Because of the disintegration, material is expelled in extremely littler volumes which keeps up the high precision of parts machined. Servo mechanism maintains a gap of about 0.01 to 0.02mm between the electrode and the workpiece, preventing them from coming into contact with each other. The Heat Affected Zone (HAZ) is additionally less in contrast with traditional machining methods. The dielectric medium helps to divert the dissolved material, act as an insulator till breakdown voltage reached and keep the wire cool. The adaptability in controlling a few parameters on wire EDM is a preferential decision over some other machining process. It is easy and quite simple to machine materials with differing levels of hardness, surface wrap up.

Stainless steels are known as high-alloy steels. They comprise around 4-30% of chromium. They are grouped into martensitic, austenitic, and ferritic steels based on their crystalline structure. Stainless Steel 317 is modified from 316 stainless steel to possess high corrosion resistance and strength. Stainless Steel 317 is harder than 304 stainless steel. It is recommended to utilize chip breakers. Hardenability of this alloy will be diminished during constant feeds and low speeds. Primarily it found its utilization in paper pulping industry, textiles and chemical handling equipment.

## II. Experimental Setup and Machining

Experiments were performed using SPARKONIX S50 model Electrical Discharge Machine. Fig. 1 depicts the schematic experimental setup. Kerosene was used as a dielectric fluid in this experimental machining. The detailed specification of the EDM machine is given in the Table I below. In our investigation, Stainless Steel 317 material is used as a target material and its chemical composition is shown in the below Table II. Some of the important material properties are shown in Table III. Copper and brass electrodes of 6mm diameter were used as an electrode to erode a work piece of Stainless Steel 317 material to calculate Metal Removal Rate (MRR) and Electrode Wear Rate (EWR). The work piece material Stainless Steel 317, which is also known as oil hardened non-shrinking steel. Dimensions of this steel are designed and accurately calculated in compliance with high industry standards.


Fig. 1: Experimental Setup of SPARKONIX S50 EDM

TABLE I: SPECIFICATION OF EDM MACHINE

| Specification | Unit |
|---|---|
| Table size | 600x400 mm |
| Longitudinal and cross travel | 350x250 mm |
| Servo head vertical travel | 250 mm |
| Max. workpiece weight | 500 kg |
| Tank capacity | 240 liters |
| Control Variables | Voltage, Current, pulse time |

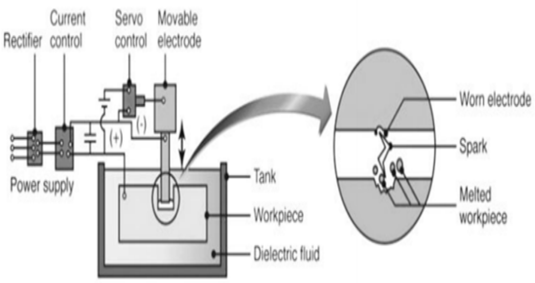


Fig. 2: Schematic Representation of EDM Process

### *A. SS 317 Steel*

Stainless Steel 317 grade can be hot worked using all common hot working procedures. It is heated at 1149-1260°C. It should not be heated below 927°C. Post-work annealing can be done to retain the corrosion resistance property. It has excellent corrosion resistance in a wide range of chemicals, especially in acidic chloride environments such as those encountered in pulp and paper mills. Chemical composition of 317 is shown in the Table II below. Table III shows some important properties of 317 steel.

TABLE II: CHEMICAL COMPOSITION OF SS 317 STEEL

| Element | Composition (%) |
|---|---|
| Fe | 60.92 |
| Cr | 18.56 |
| Ni | 12.83 |
| Mo | 3.49 |
| Mn | 2.37 |
| Si | 1.28 |
| C | 0.08 |
| P | 0.045 |
| S | 0.03 |

TABLE III: PROMINENT PROPERTIES OF SS 317 STEEL

| Properties | Value |
|---|---|
| Density | 8 g/cm$^3$ |
| Melting point | 1370°C |
| Tensile strength | 619 MPa |
| Yield strength | 274 MPa |
| Elastic modulus | 193 GPa |
| Hardness | 85 HRC |

### *B. Copper Electrode*

It is one of the most widely used nonferrous metals in industry. Copper is soft and ductile that is difficult to machine and also it has an almost unlimited capacity to be cold-worked. Furthermore, it is highly resistant to corrosion in diverse environments including ambient atmosphere, sea water and some industrial chemicals. The mechanical and corrosion resistance properties can be improved by alloying. Table IV portrays the copper electrode properties.

TABLE IV: PROPERTIES OF COPPER ELECTRODE

| Physical properties | Value |
|---|---|
| Density [g/cm$^3$] | 8.78 |
| Electrical Conductivity [(Ω-m) -1 x10 8] | 1.68 |
| Thermal Conductivity [W/m – K] | 401 |
| Coefficient of thermal expansion [×10-6 (1/°C)] | 16.5 |
| Melting Temperature [°C] | 1084 |

### *C. Brass Electrode*

Brass is a binary alloy composed of copper and zinc and is valued for its workability, hardness, corrosion resistance and attractive appearance. It is utilized for making musical instruments, firearm cartridge casing, radiators, architectural trim, pipes and tubing, screws, and decorative items. Properties of the brass electrode was portrayed in the Table V below.

TABLE V: PROPERTIES OF BRASS ELECTRODE

| Physical properties | Value |
|---|---|
| Density [g/cm$^3$] | 8.47 |
| Electrical Conductivity [(Ω-m) -1 x10 8] | 6.3 |
| Thermal Conductivity [W/m – K] | 109 |
| Coefficient of thermal expansion [×10-6 (1/°C)] | 20 |
| Melting Temperature [°C] | 924 |

### *D. Machining Factors*

The input factors selected for this experimental study was pulse-on time, pulse-off time and current. Voltage (50v), dielectric jet flushing. Polarity, dielectric medium (kerosene) remains unchanged throughout the experimental study. The factors with suitable levels for machining SS 317 steel were tabulated in the Table VI below. The standard order resembles a typical serial number while run order represents the order in which the experiments has to be carried out for better results and interactions.

TABLE VI: INPUT FACTORS WITH LEVELS

| Standard Order | Run Order | Pulse on | Pulse off | Current |
|---|---|---|---|---|
| 1 | 8 | 300 | 50 | 14 |
| 2 | 6 | 300 | 70 | 14 |
| 3 | 2 | 500 | 50 | 14 |
| 4 | 7 | 500 | 70 | 14 |
| 5 | 1 | 300 | 50 | 12 |
| 6 | 5 | 300 | 70 | 12 |
| 7 | 4 | 500 | 50 | 12 |
| 8 | 3 | 500 | 70 | 12 |

### *E. Output Responses*

Irrespective of the electrode material, dielectric fluid performance of EDM is generally measured by the Metal Removal Rate (MRR) and Electrode Wear Rate (EWR), surface roughness or finish. In this experimental study MRR and EWR is taken into account. The equation for calculating the MRR and EWR are specified in the equations 1 and 2 below,

MRR = (WB-WA) / TM (g/min) (Eqn. 1)

Where,

WB = Weight of workpiece before machining (g)

WA = Weight of workpiece after machining (g)

TM = Time taken for machining (min)

EWR = (EB-EA) / TM (g/min) (Eqn. 2)

EB = Weight of electrode before machining (g)

EA = Weight of electrode after machining (g)

TM = Time taken for machining (min)

## III. RESULTS AND DISCUSSION

Eight experiments were performed on Stainless Steel 317 by using copper & brass tool electrode separately. At the end of each experimental machining calculations were done for MRR and EWR. The variations of all the four output parameters are plotted against the variable input parameters. Table VII depicts the metal removal rate for different input factor combination using copper electrode. It is found that pulse-on 300µm, pulse-off 50µm and current 14A gives the maximum MRR while pulse-on 300µm, pulse-off 70µm and current 12A gives the minimum MRR.

TABLE VII: EXPERIMENTAL MRR OF COPPER ELECTRODE

| Standard Order | $W_B$ | $W_A$ | $T_M$ | MRR |
|---|---|---|---|---|
| 1 | 288.92 | 288.68 | 207 | 0.00115 |
| 2 | 289.4 | 289.16 | 365 | 0.00065 |
| 3 | 290.36 | 290.12 | 216 | 0.00111 |
| 4 | 289.16 | 288.92 | 229 | 0.00104 |
| 5 | 290.6 | 290.36 | 416 | 0.00057 |
| 6 | 289.64 | 289.4 | 480 | 0.0005 |
| 7 | 289.88 | 289.64 | 247 | 0.00097 |
| 8 | 290.12 | 289.88 | 280 | 0.00085 |

Electrode Wear Rate (EWR) is portrayed in the Table VIII for each parameter combination when copper electrode is used as EDM tool. The fourth set of factors contribute higher electrode wear rate (pulse-on 500µm, pulse-off 70µm and current 14A) whereas the fifth set of factors gives lower electrode wear rate (pulse-on 300µm, pulse-off 50µm and current 12A).

TABLE VIII: EXPERIMENTAL EWR OF COPPER ELECTRODE

| Standard Order | $E_B$ | $E_A$ | $T_M$ | EWR |
|---|---|---|---|---|
| 1 | 24.31 | 24.25 | 207 | 0.00029 |
| 2 | 24.42 | 24.37 | 365 | 0.00013 |
| 3 | 24.58 | 24.53 | 216 | 0.000231 |
| 4 | 24.37 | 24.31 | 229 | 0.000262 |
| 5 | 24.61 | 24.58 | 416 | 0.00007 |
| 6 | 24.46 | 24.42 | 480 | 0.000083 |

| | | | | |
|---|---|---|---|---|
| 7 | 24.49 | 24.46 | 247 | 0.000121 |
| 8 | 24.53 | 24.49 | 280 | 0.000142 |

Experimental MRR results using brass electrode were depicted in the Table IX below. Higher MRR is obtained in the first set of input factors (pulse-on 300µm, pulse-off 50µm and current 14A). Minimum MRR is achieved from the sixth input factor (pulse-on 300µm, pulse-off 70µm and current 12A).

Table IX: Experimental MRR of Brass Electrode

| Standard Order | $W_B$ | $W_A$ | $T_M$ | MMR |
|---|---|---|---|---|
| 1 | 287 | 286.76 | 840 | 0.00028 |
| 2 | 287.48 | 287.24 | 1200 | 0.00020 |
| 3 | 288.44 | 288.2 | 1029 | 0.00023 |
| 4 | 287.24 | 287 | 955 | 0.00024 |
| 5 | 288.68 | 288.44 | 1370 | 0.00017 |
| 6 | 287.72 | 287.48 | 1657 | 0.00014 |
| 7 | 287.96 | 287.72 | 1140 | 0.00022 |
| 8 | 288.2 | 287.96 | 1152 | 0.00021 |

Experimental EWR from brass electrode were shown in the Table X below. Less electrode wear is found in eighth input factor set (pulse-on 500µm, pulse-off 70µm and current 12A). Higher amount of wear is contributed by third set of input with pulse-on 500µm, pulse-off 50µm and current 14A.

Table X: Experimental EWR of Brass Electrode

| Standard Order | $E_B$ | $E_A$ | $T_M$ | EWR |
|---|---|---|---|---|
| 1 | 10.78 | 8.91 | 840 | 0.00222 |
| 2 | 14.78 | 12.31 | 1200 | 0.00205 |
| 3 | 14.7 | 12.11 | 1029 | 0.00251 |
| 4 | 12.31 | 10.78 | 955 | 0.0016 |
| 5 | 17.41 | 14.7 | 1370 | 0.00197 |
| 6 | 12.61 | 14.78 | 1657 | 0.002 |
| 7 | 10.47 | 12.61 | 1140 | 0.001423 |
| 8 | 12.11 | 10.47 | 1152 | 0.001142 |

## IV. Conclusion

SS 317 grade steel was successfully machined in EDM using copper and brass electrodes. MRR and EWR was calculated from the experimental results such as weight of electrode, workpiece before and after machining and time taken for machining. Higher metal removal rate was found in the first set of input factors with pulse-on 300µm, pulse-off 50µm and current 14A for both electrodes. Similarly lower metal removal rate was achieved with pulse-on 300µm, pulse-off 70µm and current 12A for both electrodes. From the above experimental results we can conclude that both copper and brass electrode exhibits similar characteristics in machining SS 317 steel by EDM.

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