Performance of a Low Cost Tabletop Die Sinker Electric Discharge Machining [EDM] Unit

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Abstract: New developments in the field of material science have led to new engineering metallic materials, composite materials, and high tech ceramics, having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can readily be machined by spark erosion. The recent development of new materials that are hard and difficult-to-machine such as tool steels, composites, ceramics, super alloys, hast alloy, nitr alloy, waspalloy, nemonics, carbides, stainless steels, heat resistant steel, etc. being widely used in die and mould making industries, aerospace, aeronautics, and nuclear industries. Many of these materials also find applications in other industries owing to their high strength to weight ratio, hardness and heat resisting qualities. EDM has also made its presence felt in the new fields such as sports, medical and surgical instruments, optical, dental including automotive R&D areas. EDM technology is increasingly being used in tool, die and mould making industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) requiring high precision, complex shapes and high surface finish. Heat treated tool steels have proved to be extremely difficult-to-machine using traditional processes, due to rapid tool wear, low machining rates, inability to generate complex shapes and imparting better surface finish. EDM provides a easy solution. This present work provides an approach to make an EDM unit at reasonably low cost, and its performance.

Keywords: Sinker EDM, Die-electric media, Spark erosion.

THE SETUP:
The present paper deals with making a low cost setup of Sinker type EDM for general machining of hard materials like machining steels, ceramics, etc., using RC circuit with copper and graphite as tool material and kerosene as dielectric medium as shown in the Fig. 1. The performance and process capabilities of the developed setup are here under.

Fig. 1: Low Cost EDM Setup

Part List:
Stepper Motor, Controller, Pulse Generator Circuit, Power Supply, Basic Electrical Components(Wires, Capacitors Etc), Graphite Electrode/Copper Electrode, Electrolyte-Kerosene, Plastic Tank, Fuel Filter, Etc. With Cost Of Re 7,000/-.[$300]

The power supply must provide enough spark to the sparking gap for material removal. It must also monitor the electrical conditions at the sparking gap and direct the machine servo in advancing, retracting, or maintaining the position of the electrode, in reference to the work piece. The dielectric unit must provide the dielectric fluid to the machine submersing the work piece. In addition, the dielectric unit must send fluid to the dielectric gap for cooling purposes and to remove the EDM chip. The
dielectric unit includes a filtration system for cleaning the dielectric fluid. The machine tool is the focal point of the die-sinker.

**DEVELOPMENT OF POWER SUPPLY:**
A relaxation generator (R-C type) used as an power supply unit. The power supply unit used is quite simple. A VARIAC (Variable Auto Transformer) is used to adjust output voltage. In the power supply unit, rectification is normally achieved using a solid state diode. Diode has the property that will let the electron flow easily at one direction at proper biasing condition. Bridge rectifiers of 4 diodes are used to achieve full wave rectification. Two diodes will conduct during the negative cycle and the other two will conduct during the positive half cycle. Therefore bridge rectifier is used to convert AC to DC. This DC power supply is used to charge the capacitor connected in series to resistor. A filter capacitor provides smoothing of the DC voltage produced. A resistor allows the electrode to short to the work without blowing fuses, and also moderates the flow of current from the raw DC supply to the EDM capacitor and electrode.

The required circuit is connected and simulated by using the PSPICE software. The following is one such circuit.

![Fig.3: Circuit of Power System](image)

The current of 4.5amps was obtained in the simulation result. This circuit was then tested on the mild steel plate and the metal removal was observed on the work-piece surface. Thus this circuit was adopted.

**SIMULATION RESULT:**

![Fig.4: Charging and discharging with respect to time – for power circuit employed](image)

**RAM:**
The Electrode used in the EDM machine should follow the predictable linear path free from the errors like back lash.

The machine Ram designed by us consists of the following parts: 1. Drawer slide, 2. Lead Screw (1/4” -20”), 3. Coupling, 4. Stepper motor, 5. Aluminium column, 6. Electrode (Graphite and Copper)

The slide is actuated by the lead screw driven by the DC Stepper motor which is controlled by the 100:1 reduction gear box. The Lead Screw is UNC (Unified Coarse thread) 1/4 -20 in dimension. An appropriate nut of 3/8” dimension was made. This screw of longer length helps in reducing the back-lash.

The diagram shows the schematic of the RAM build. (From Bottom to Top) The insulated wooden block is used as an electrode holder. A metallic clamp is placed on the wooden block to hold the electrode firmly. The clamp can be connected to the power source. This block is mounted on the lower side of the slide. The next component is the mild steel block which carries the lead-screw nut. This block is mounted on the slide by Gas welding. Through this nut passes the lead screw, the other end of the screw is coupled to the motor shaft by a coupling made to size using mild steel cylindrical block. This coupling holds the screw and the shaft together without causing any relative motion between them.

This whole system is mounted on the aluminium “S” shaped frame as shown in the diagram and the picture. A (Dimension) plate is mounted on the Tub to carry the RAM. Two firm aluminium strips are used to support frame and stop the longitudinal motion caused by the motor vibration.

The whole system can be mounted on the milling machine table so that the machine remains flat and can be free from any other vibrations.

The followings are the different electrode materials which are used commonly in the industry: Graphite, Electrolytic oxygen free copper, Tellurium copper – 99% Cu + 0.5% tellurium, Brass.

For the present case copper and graphite electrodes are employed and their performance is observed for same workpiece. The properties of copper and graphite are presented below [6]

<table>
<thead>
<tr>
<th>S.No</th>
<th>Property</th>
<th>Copper</th>
<th>Graphite</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Density</td>
<td>9860 KG/M</td>
<td>(1.3-1.95) G/CM</td>
</tr>
<tr>
<td>2</td>
<td>Specific Heat (293 K)</td>
<td>0.383 KJ/KG.K</td>
<td>(710-830) J/KG.K</td>
</tr>
<tr>
<td>3</td>
<td>Thermal conductivity</td>
<td>394 W/M.K</td>
<td>(25-470) W/M.K</td>
</tr>
<tr>
<td>4</td>
<td>Electrical conductivity</td>
<td>100%</td>
<td>(90-100)%</td>
</tr>
<tr>
<td>5</td>
<td>Cross Sectional Area</td>
<td>82.7267mm² (d=10.217mm)</td>
<td>132.1049mm² (d=12.911mm)</td>
</tr>
</tbody>
</table>
PERFORMANCE WITH RESPECT TO POLARITY: COPPER AS ELECTRODE: Here we conducted the experiment by connecting both the polarities to the workpiece (MS) and the copper electrode of 10.217mm diameter. The picture shows the effect of the experiment on the workpiece and electrode. Silver colored portion on the workpiece shows the material removal. Darker portion on the electrode is carbon deposit.

The graphite Electrode was used as tool for removal.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Electrode</th>
<th>Polarity</th>
<th>Diameter (mm)</th>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Surface Roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Copper</td>
<td>-ve</td>
<td>15</td>
<td>4</td>
<td>48</td>
<td>0.03 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Copper</td>
<td>+ve</td>
<td>15</td>
<td>6</td>
<td>48</td>
<td>0.07 mm</td>
</tr>
</tbody>
</table>

OBSERVATIONS:
By connecting the straight polarity in the circuit we got the following observations:
1. Temperature change was almost negligible.
2. Lower value of current is observed.
3. Metal removal was even.

By connecting the negative polarity to the work piece and the positive to the Tool in the circuit we got the following observations: The temperature change was around 2°C, Observable carbon deposit was seen on crater. Color the kerosene changed drastically, Higher value of current was observed, Metal removal was uneven, Observable roughness was high.

GRAPHITE AS ELECTRODE: Here we conducted the experiment by connecting both the polarities to the workpiece (MS) and the graphite electrode of 12.911mm diameter. The picture shows the effect of the experiment on the workpiece and electrode. Silver colored portion on the workpiece shows the material removal. Darker portion on the electrode is carbon deposit.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Electrode</th>
<th>Polarity</th>
<th>Time (min)</th>
<th>Current (A)</th>
<th>Voltage (V)</th>
<th>Surface Roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Graphite</td>
<td>-ve</td>
<td>15</td>
<td>5</td>
<td>48</td>
<td>0.05 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Graphite</td>
<td>+ve</td>
<td>15</td>
<td>6</td>
<td>48</td>
<td>0.09 mm</td>
</tr>
</tbody>
</table>

The table shows the increase in the Roughness with increase in breakdown voltage.

TESTING WITH GRAPHITE TOOL:
The graphite Electrode was used as tool for this experiment:
The table shows the increase in the roughness value with increase in the breakdown voltage.

The depth of cut values increases like the trend shown with copper tool with increase in the voltage values. The results of work-piece surface roughness for copper and graphite tools at negative and positive polarity can be seen respectively in graphs. It is observed that negative graphite tool electrodes promoted higher roughness than copper tools for all the Discharge voltage values (40, 45, 50, 55 and 60).

TESTS BY VARYING CURRENT:
This experiment is conducted to evaluate the effect of the current on the cutting of the Electrical Discharge Machine.

TEST WITH COPPER TOOL(VARYING CURRENT):

The roughness value increases gradually with increase in the current value by using graphite electrode tool.

The Depth of cut increases with increase in the current value for the graphite tool.
MATERIAL REMOVAL RATE:

VARYING VOLTAGE:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Voltage</th>
<th>Copper Tool mm/Min</th>
<th>Graphite Tool mm/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40</td>
<td>2.5645</td>
<td>10.4362</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>4.8454</td>
<td>12.4178</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>5.6254</td>
<td>14.3994</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>6.9490</td>
<td>18.0983</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>8.3553</td>
<td>24.9678</td>
</tr>
</tbody>
</table>

VARYING CURRENT:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Current</th>
<th>Copper Tool mm/Min</th>
<th>Graphite Tool mm/Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>8.1072</td>
<td>13.6068</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>8.6035</td>
<td>17.7020</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>12.8226</td>
<td>23.2504</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>14.3117</td>
<td>26.1567</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>16.2971</td>
<td>29.0630</td>
</tr>
</tbody>
</table>

RESULTS & DISCUSSIONS:

ROUGHNESS:

VARYING VOLTAGE: Roughness increases with increase in the voltage for both copper and graphite tool, the possible reason for this can be increase in the power supplied per spark. Due to increase in spark power there is considerable increase in crater size which results in greater roughness.

VARYING CURRENT: Roughness values increases with increase in the current density. The increase in the current causes more sparks to generate causing increase in total roughness values. The same trend is observed in both the tool materials (Copper & Graphite).

DEPT OF CUT:

Varying Voltage: There is significant increase in the depth of cut value with increase in voltage with both the tool materials. The increase in voltage causes more discharge through the dielectric which causes the increase in material removal rate.

The material removed by the graphite tool is more compared to the Copper tool; this is the result of good electrical and thermal conductivity of the graphite tool compared to copper tool.

Varying Current: With the increase in operating current there is increase in the depth of cut of the work-piece. This is the result of increased current density causing more material removal from work surface.

MATERIAL REMOVAL RATE:

VARYING VOLTAGE: It’s been observed that the Material removal is more with increase in the operating voltage, this thing is verified by the increasing DOC.

VARYING CURRENT: The Material removal increases with the increase in the current value. The increase in the sparking is the reason for the increase in the material removal rate.

CONTROLLING OF DOC:

The Observed Values of MRR and Roughness suggests that controlling of Depth Of Cut can be effectively done by the controlling of the current, as the better surface finish is obtained in this case.

CONCLUSION:

The carried out experiments show that the time for machining and surface generated are almost equal to commercially available sinker machines. The performance of the Table Top Electric Discharge Machine using Copper and Graphite tools on the Mild Steel, HSS work-pieces has been investigated by varying important EDM variables such as Discharge Current, Discharge Voltage and Tool-Workpiece polarity. From the results of this work the following conclusions can be drawn:

- The machine was tested with change in the polarities of tool and work-piece and was concluded that the straight polarity gives better value of MRR and surface roughness.
- Copper tool with straight polarity gives better surface finish than the Graphite tool.
- The machine was tested with change in operating voltage and was found out that with the similar average current utilization; Copper tool gave better surface finish than the Graphite tool.
- Depth of cut for the Graphite tool was found to be more than Copper tool.
- The machine was tested with change in current density and was found that the roughness increases with the increase in the current density.
Copper was proved to be better material as tool because of the good surface finish compared to graphite tool.

Depth of cut was more for graphite tool with increase in the current density.

The Material removal rate for the Graphite tool is more than the Copper tool in any operating conditions.

The Current variation is better parameter for controlling Depth of Cut.

The present unit can be further improved by having PLC control for work fixtures, flushing systems,

REFERENCES