Comparison of Different Electrodes Used in EDM for En31 Work Piece

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Abstract: EDM stand for Electrical Discharge Machine which was developed in late 1940s which has now become the most important technologies in manufacturing industries. It is used for many complex 3D shapes can be machined using a simple shaped tool electrode. Now a days Electrical discharge machine (EDM) technology is increasingly being used in tool, die and mould making industries, for machining of heat treated tool steels and advanced materials requiring high precision, complex shapes and high surface finish. Electrical discharge machining (EDM) actually is a process of utilizing the removal phenomenon of electrical-discharge in dielectric. Therefore, the electrode plays an important role, which affects the material removal rate and the tool wear rate.

Key words: EDM, Electrode, Dielectric fluid, MRR, EWR.

INTRODUCTION

This paper shows the comparison between different electrode used in EDM for work piece En31. The high rate of tool wear is one of the main problems in electrical discharge machine (EDM). If the rate of tool wear is high means that the material is easy to wear and not good for machining performance. The significant of this study is to promote the consideration of electrode selection in electrical discharge machine (EDM) machine for advance machining in the manufacturing industries. In the machining of EDM, there are a few characteristics which influence the machining process. Most important are the performance is needed. The case studies of this project are to determine the best material removal rate (MRR) and electrode wear ratio (EWR) from different selection materials.

WORKING PRINCIPLE OF EDM

The working principle of EDM process is based on the thermoelectric energy. This energy is created between a work piece and an electrode submerged in a dielectric fluid with the passage of electric current. The work piece and the electrode are separated by a specific small gap called Spark gap. Pulsed arc discharges occur in this gap filled with an insulating medium, preferably a Dielectric liquid like hydrocarbon oil or de-ionized (de-mineralized) water.

The working principle of EDM is shown in Fig. 1. This technique has been developed in the late 1940s. The electrode moves toward the work piece reducing the spark gap so that the applied Voltage is high enough to ionize the dielectric fluid. Short duration discharges are generated in a liquid dielectric gap, which separates electrode and work piece. The material is removed from tool and work piece with the erosive effect of the electrical discharges. The dielectric fluid serves the purpose to concentrate the discharge energy into a channel of very small cross sectional areas. It also cools the two electrodes, andFlushes away the products of machining from the gap.

The electrical resistance of the dielectric influences the discharge energy and the time of spark initiation. Low resistance results in early discharge. If resistance is large, the capacitor will attain a higher charge value before initiation of discharge. A servo system is employed which compares the gap voltage with a reference value and to ensure that the electrode moves at a proper rate to maintain the right spark gap, and also to retract the electrode if short-circuiting occurs. When the measured average gap voltage is higher than that of the servo reference voltage, preset by the operator, the feed speed increases. Thus short circuits caused by debris particles and humps of discharge a crater are avoided. Also quick changes in the working surface area, when tool shapes are complicated, does not result in hazardous machining.
MATERIAL SELECTION

Material selection is the most important to this experiment because different materials have different working parameters based on their properties. The right selection of the machining material is the most important aspect to take into consideration in processes related to the EDM.

FIGURE 3: EDM MACHINE
ELECTRODE MATERIAL

Before run the experiment, the electrode and work piece is cut regarding their dimension. The electrode copper aluminium and brass needs to be cut its diameter same for all same dimension. This picture refers all the material dimension that should cut and shape.

![Electrode Materials](image)

FIGURE 4: ELECTRODE MATERIAL

EXPERIMENT PROCEDURE

Experiment will conducted with positive polarity of electrode. The electrode aluminium is taken. The diameter of electrode is measured with a micrometer.

Make sure its dimension is according to specification.

An initial mass of electrode mass value and the work piece mass value is measured with Precisa balance machine.

The work material (tool steel) was mounted on the T-slot table and positioned at the desire place and clamped. The electrode was clamped on the V-block, and its alignment was checked with the help of the try square.

Set the parameters of the experiment regarding table 1.1

A time of cut of 30 (min) was set for the machining of all work materials. Finally, switches ‘ON’ for operating the desire discharge current values.

After machining operation, the electrode was taken out and weight again on balance machine. Also take the mass value of work piece after machining.

The same experiment was repeated with other different electrode materials. This experiment is done by 9 times. The data will take and the average data calculated. This is to make sure the data more accurate.

DATA COLLECTION ON EDM

Table 1.1: Data collection for MRR and EWR

<table>
<thead>
<tr>
<th>EXP</th>
<th>ELECTRODE</th>
<th>CURRENT (I)</th>
<th>VOLTAGE (V)</th>
<th>Ton</th>
<th>MASS ELECTRODE BEFORE (g)</th>
<th>MASS ELECTRODE AFTER (g)</th>
<th>MASS (W/P)BEFORE (g)</th>
<th>MASS (W/P)AFTER (g)</th>
<th>TIME (min)</th>
<th>MRR (%)</th>
<th>EWR (%)</th>
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<td>MASS (W/P) BEFORE (g)</td>
<td>MASS (W/P) AFTER (g)</td>
<td>MR (%)</td>
<td>EWR (%)</td>
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<th>EXP</th>
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<th>VOLTAGE (V)</th>
<th>TIME</th>
<th>MASS ELECTRODE BEFORE (g)</th>
<th>MASS ELECTRODE AFTER (g)</th>
<th>MASS (W/P) BEFORE (g)</th>
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<td>265.82</td>
<td>261.98</td>
<td>0.06</td>
<td>85.46</td>
</tr>
</tbody>
</table>

Table 1.2: Data collection

Table 1.3: Data collection
From table 1.1 we can see the total number of experiment and its data result. Overall for experiment, the total time is taken to finish the machining is 4 hours 30 minutes. This time is just the time of machining process and not including the time set-up for the experiment. This experiment looks fairly suitable for the limits of scope project due to the lack of time. In other words, more experiment can be done if there is no limited time and more accurate result can be obtained. But, this experiment is quite accurate because the experiment had done nine times. Hence, the data from the table 1.1 can be used and analyze. The experiment is done with three electrode material which is copper aluminium and brass. Every electrode is running experiment by nine times. Means every electrode done machining a work piece (En31) and overall the number of electrodes and tool steels is 27 each.

From the table 1.2 also we can easily find the less mass of electrode material which aluminium. Aluminium is less in weight due to its properties followed by brass and copper. But, this only the machining data that cannot be make as conclusion. So, this data need to analyzed first in order to meet the objective of this project by calculation.

From table 1.3 we can see the time taken, current, voltage, mass of work piece and electrode EWR and MRR for the brass material electrode compare with other electrode materials like copper and aluminium.

Data Collection of Material Removal Rate (MRR)

The material removal rate (MRR) of the work piece measured by dividing the weight of work piece before and after machining (found by weighing method using balance) against the machining time that was achieved. The data from the experiment is collect and put into table 1.1, 1.2 and 1.3 in order to analyze the material removal rate (MRR). The table 1.1 is showing about experiment with copper electrode material and its data. The data is including the mass value of work piece (En31) before and after, and also the time taken to complete machining each experiment. The mass of work piece before and after is analyzed and then the different mass is obtained by minus the mass of work piece before against mass of work piece after. Then, we can know the different mass of the work piece that had been machining by using t

Calculation of Material Removal Rate (MRR)

In above table MRR has been calculated by the following formula which has been shown below. Although other ways of measuring material removal rate (MRR) and electrode wear ratio (EWR) do exist, in this work the material removal rate and electrode wear values have been calculated by the weight difference of the sample and electrode before and after undergoing the electric discharge machine (EDM) process. The present work highlights the development of mathematical solution to calculate the electric discharge machine (EDM) machining parameters such as: mass of electrode, pulse duration and voltage on the metal removal rate, wear ratio and surface roughness. This work has been established based on the mathematical equation. The material removal rate (MRR) of the work piece was measured by dividing the weight of work piece before and after machining against the machining time that was achieved. The material removal rate (MRR) is expressed as the work piece removal rate (WRR) under a period of machining time in minute (T),

\[
\text{MRR (g/min)} = \frac{\text{WRR}}{T}
\]

Where’s

\[
\text{WRR} = \text{Work Piece Removal Rate (g),} \quad T = \text{time (minutes)}
\]

The material removal rate (MRR) is calculate and can be refers to the table 1.1 copper electrode.

Calculation for average MRR

The average material removal rate (MRR) that calculated can be seeing in the table 1.4. Each machining using the selected electrode has their value of material removal rate (MRR) for the nine experiments. From that table also we can also calculate the average of material removal rate (MRR) each machining using different electrode material. With that value, we can know the total average of material removal rate (MRR) if we using the selected electrode material in the machining process. By the way, the machining using copper material as an electrode give the highest average of material removal rate (MRR), followed by aluminium and brass.
Table 1.4

<table>
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<th>Electrode</th>
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<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
<th>9th</th>
<th>Average MRR (g/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>0.0126</td>
<td>0.0093</td>
<td>0.0050</td>
<td>0.1666</td>
<td>0.1666</td>
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<tr>
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</table>

Graph For Material Removal Rate (MRR)

Regarding to the table 1.4, the graph for the material removal rate (MRR) can be plot. The value of all nine experiments using selected electrodes material is transfer into graph to make the analyzed more clearly and easy. Figure 5 show about the material removal rate (MRR) when machining of three electrode material; brass, copper and aluminium. By this graph also we can see the highest of material removal rate (MRR) when doing machining using the copper as an electrode material compared to others electrode material. These mean every experiment or machining process that using copper material as electrode will give the higher material removal rate (MRR) compared to brass and aluminium electrode.

![Graph for MRR](image)

Figure 5: Graph for MRR

Figure 5 show the average of material removal rate (MRR) graph after the machining process of En31 work piece using different electrode materials. From this graph it shows that machining electric discharge machine (EDM) using electrode material of copper give higher average material removal rate (MRR) than using electrode brass or aluminium. From is graph also, we can determine the best electrode for machining electric discharge machine (EDM) is copper. These prove from the higher value average of material removal rate (MRR) from graph from figure 5For material removal rate (MRR) in machining process electric discharge machine (EDM) the proper selection for electrode material is copper. The next choice should be aluminium due to fairly good value material removal rate (MRR). But the brass electrode showed very poor value of material removal rate (MRR) compare to others electrode material.

**CALCULATION OF ELECTRODE WEAR RATIO (EWR)**

Electrode wear occurs during electric discharge machine (EDM) process leading to a lack of machining accuracy in the geometry of work piece. In industries or engineering, electrode wear also known as electrode wear ratio (EWR). Due to important of this characteristic against the machining process, the analyzed for optimize the performance is necessary

**The Formula of Electrode Wear Ratio (EWR)**

Therefore, studying the electrode wear and related significant factors would be effective to enhance the machining productivity and process reliability. The electrode wear ratio (EWR) is define by the ratio of the electrode wear weight (EWW) to the work piece removal weight (WRW) and usually expressed as a percentage,

\[
\text{EWR} \text{ (%) } = \left( \frac{\text{EWW}}{\text{WRW}} \right) \times 100
\]
Where; s

EWW = Electrode Wear Weight
WRW = Work Piece Removal Weight

**Calculate Electrode Wear Ratio (EWR)**

In this paper, the data from the experiment is collect in table 1.1, 1.2 and 1.3 in order to analyze the electrode wear ratio (EWR). The data of copper electrode before and after is taken and also same with their work piece (En31). Then, the different mass of copper electrode is calculated by minus the mass before experiment against mass after experiment. The different mass value of this calculation is called electrode wear weight (EWW). Meanwhile, the different mass of work piece also calculated. The mass of work piece after experiment then will minus by the mass of work piece before the experiment to get the different masses. This different mass is called work piece removal weight (WRW).

The formula of electrode wear rate (EWR) is:

\[
EWR = \frac{EWW}{WRW}
\]

Where;
EWW = Electrode Wear Weight
WRW = Work Piece Removal Weight

The electrode wear ratio (EWR) can be obtained by divide the value of electrode wear weight (EWW) against the value of work piece removal weight (WRW). We also use the same method to calculated electrode wear ratio (EWR) in every experiment. Means, each experiment from 1\textsuperscript{st} to 9\textsuperscript{th} have its own value of electrode wear ratio (EWR). The value of the electrode wear ratio (EWR) when machining electric discharge machine (EDM) using copper electrode now can be determine. All the value of electrode wear ratio (EWR) can be analyzed.

Table 1.1,1.2,1.3 shows the data collection of the experiment machining En31 using electric discharge machine (EDM) with copper, aluminium an brass electrode. The data of copper electrode before and after is taken and also same with their work piece (En31). Then, the different mass of brass electrode is calculated by minus the mass before experiment against mass after experiment. The different mass value of this calculation is called electrode wear weight (EWW). Meanwhile, the different mass of work piece also calculated. The mass of work piece after experiment then will minus by the mass of work piece before the experiment to get the different masses. This different mass is called work piece removal weight (WRW).

The electrode wear ratio (EWR) can be obtained by divide the value of electrode wear weight (EWW) against the value of work piece removal weight (WRW). We also use the same method to calculated electrode wear ratio (EWR) in every experiment. Means, each experiment from 1\textsuperscript{st} to 9\textsuperscript{th} have its own value of electrode wear ratio (EWR). All the (EWR) value then can be analyze and discuss. The value of the electrode wear ratio (EWR) when machining electric discharge machine (EDM) using brass electrode now can be determine. All the value of electrode wear ratio (EWR) had been kept in and get from the table 1.1,1.2,1.3.

![Graph for EWR](image-url)
Table 1.5 shows the data collection of the experiment for average EWR machining work piece using electric discharge machine (EDM) with brass electrode. The data of aluminium electrode before and after is taken and also same with their work piece (En31l). Then, the different mass of brass electrode is calculated by minus the mass before experiment against mass after experiment. The different mass value of this calculation is called electrode wear weight (EWR). Meanwhile, the different mass of work piece also calculated. The mass of tool steel after experiment then will minus by the mass of tool steel before the experiment to get the different masses. This different mass is called work piece removal weight (WRW).

### Table 1.5: Calculations of average EWR

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<th>3rd</th>
<th>4th</th>
<th>5th</th>
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</table>

**DISCUSSION OF MATERIAL REMOVAL RATE (MRR) AND ELECTRODE WEAR RATIO (EWR)**

In industries, the production rate is a part that they consider most. The production rate is a rate or time taken to do a process in making product. If the production rate is slow, the profit flow is also slow. But if the production rate is high, the more profit can gain. To increase the production rate, we need to increase the material removal rate (MRR). When the material removal rate (MRR) is higher, the production also run faster. The high rate of tool wear is one of the main problems in electric discharge machine (EDM). Actually, the wear ratio defined as the volume of metal lost from the tool divided by the volume of metal removed from the work material, varies with the tool and work materials used. If the rate of tool wear is high means that the material is easy to wear and not good for machining performance. In industries, the wear ratio is an important thing because it will cost the production. They are trying to optimize this factor to make sure no waste occur and reduce the purchasing the material with high wear.

**ELECTRIC DISCHARGE MACHINE (EDM) CAPABILITIES**

There are a lot of benefits when using electrical discharge machine (EDM) for machining. This is due to its capabilities and advantage of EDM. To summarize, these are the electric discharge machine (EDM) capabilities compare to other method.

- Material of any hardness can be cut.
- High accuracy and good surface finish are possible.
- Not any type of cutting forces involved.

**ELECTRIC DISCHARGE MACHINE (EDM) LIMITATIONS**

But, when using electric discharge machine (EDM). There are some limitations also during machining of any material. These are electric discharge machine (EDM) limitation.

- It is limited to electrically conductive materials.
- Slow process, when good surface finish and high accuracy are required.
- Dielectric fluid vapour may be dangerous.

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