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A New Approach for the Analysis of Electric Discharge Machine Using Different Electrode Materials

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Abstract: **Electrical Discharge Machine (EDM) is now become the most important accepted technologies in manufacturing industries since many complex 3D shapes can be machined using a simple shaped tool electrode. This is due to material removal rate (MRR) characteristic. Less MRR needs more time for machining process and become waste and not goods for production. Decrease accuracy of the product because influence of the electrode wear ratio (EWR) characteristic. The accuracy of the product occurs maybe because the EWR is high or MRR is not suitable. Furthermore, electrode wear imposes high costs on manufacturers to substitute the eroded complicated electrodes by new ones for die making. In order to increase the machining efficiency, erosion of the work piece must be maximized and that of the electrode minimized in EDM process. Therefore, studying the electrode wear and related significant factors would be effective to enhance the machining productivity and process reliability. In this present study the proper electrode material for Machining tool steels work pieces using EDM. When the best electrode can be determine, it would lead to better process Performance in EDM. To archive this, the Characteristic of machining must be determined because the higher MRR and less EWR will lead to better performance.**

1. INTRODUCTION

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. EDM is a widespread technique used in industry for high precision. Machining of all types of conductive materials such as: metals, metallic alloys, graphite, or even some ceramic materials, of hardness. EDM technology is increasingly being used in tool, die and Mold making industries, for machining of heat treated tool steels and advanced Materials .Traditional machining technique is often based on the material removal using tool material harder than the work material and is unable to machine them economically. EDM is based on the eroding effect of an electric spark on both the electrodes used. 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. The heat treated tool steels material falls in the difficult-to-cut material group when using conventional machining process. The high rate of tool wear is one of the main problems in EDM. 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. The significant of this study is to promote the consideration of electrode Selection in EDM machine for advance machining in the manufacturing industries. This is because every electrode materials have their own characteristic that lead to different result due to its properties. EDM has been analyzed since several years in order to improve the material removal rate and the wear ratio, which are the most critical aspects of the process. In the machining of EDM, there are a few characteristics which influence the machining process. Most important are MRR and EWR. These characteristics should be taken into account when good machining performance is needed. The case studies of this project are to determine the best MRR and EWR from different selection materials. This would lead to the better process and product finishing. In other words, if we can determine the best MRR and EWR, the best performance of machining for EDM can be archived. However, the machining characteristics of EDM remain unclear, especially in regard to the total energy of discharge pulses and tool electrode wear, since the energy is not only used to machine the work piece, But also degrades the tool electrode . Hence, some investigation needs to do to find the best electrode for best performance in machining using EDM.

2. PROBLEM STATEMENT

In EDM improper choose of the electrode Material may cause of poor machining rate or performance. This is due to MRR characteristic. Less MRR needs more time for machining process and become waste and not goods for production. The second problem is it will decrease the accuracy of the product because influence of the EWR characteristic. The accuracy of the product occurs maybe because the EWR is high or MRR is not suitable. Furthermore, electrode wear imposes high costs on manufacturers to substitute the eroded complicated electrodes by new ones for die making. In order to increase the machining efficiency, erosion of the work piece must be maximized and that of the electrode minimized in EDM process. Therefore, studying the electrode wear and related significant factors would be effective to enhance the machining productivity and process reliability.

3. ELECTRIC DISCHARGE MACHINE CAPABILITIES

There are a lot of benefits when using EDM when machining. This is due to its capabilities and advantage.

- Material of any hardness can be cut
- High accuracy and good surface finish are possible
- No cutting forces involved
- Holes completed in one pass

4. ELECTRIC DISCHARGE MACHINE LIMITATIONS

- Limited to electrically conductive materials
- Slow process, particularly if good surface finish and high accuracy are required
- Dielectric vapor can be dangerous
- Heat Affected Zone (HAZ) near cutting edges
- Die sinking tool life is limited.

5. MACHINING PARAMETER SELECTION

EWR is important Electrode tool wear Also used as a parameter to measure the ease of machining in the EDM processes, because the total energy of discharge pulses is not only used to machine the work piece, but also degrades the tool electrode. Another important parameter is MRR. This two characteristic EWR and MRR is a major influence resulting the machining performance. Any grade of steel that can be used for a tool. The term tool steel as applied in the steel industry is a grade of steel characterized by high hardness and resistance to abrasion coupled in many instances with resistance to softening at elevated temperatures. These properties are attained with high carbon and high alloy contents and the steel is usually melted in electric furnaces to assure cleanliness and homogeneity of the product. Among the numerous parameters affecting the EDM performance, the dielectric fluid has a very important role. The physical properties of the fluid influence the breakdown voltage and the ignition delay. The debris concentration in the fluid modifies these parameters, decreasing the dielectric strength by many orders of magnitude. But this parameter is neglect due to limitation of scope of studies. Electrical characteristics also affect the result of machining performance. High pulsed current and pulse time provide low surface finish quality. However, this Combination would increase material removal rate and reduce machining cost. As a result, this combination (high pulsed current and pulse time) should be used for rough machining step of EDM process. Rough and finish machining steps require different level of machine power. For rough EDM application, the machine power should be one-fourth of the produced power with 16A of current, 6s of pulse time and 3s of pulse pause time. Finish machining should be carried out at one-half level of power at 8A of current as well as 6s of pulse time and 3 s of pulse pause time

6. MACHINING PERFORMANCE EVALUATION

MRR, surface roughness (SR), and EWR are used to evaluate machining performance. The MRR increased when electrodes were used with positive polarity in all cases of semi-sintered electrodes. In the case of the copper electrode, EDM cannot be used when positive polarity was selected, due to no conductive layer being generated. The highest MRR and minimal wear were obtained using EDM-C3 with positive polarity. The copper electrode gave the highest electrode wear ratio. The results of electrode wear ratio relate to melting point; materials with higher melting points wear less. However, the wear ratio is inversely proportional to the MRR result. The lower MRR, the electrode must spend more time to achieve machining. The positive polarity gives better MRR than negative polarity. This result is same as for EDM on a conductive material. This can be explained by the fact that positive polarity gives better machining by causing a higher MRR under higher discharge energy. The MRR is expressed as the WRW under a period of machining time in minute (T), which is:

MRR (g/min) = WRR/T

The EDM process is spark erosion method. EDM has a high capability of machining the accurate cavities of dies and mould. Electrode wear occurs during EDM process leading to a lack of machining accuracy in the geometry of work piece. Electrode wear imposes high costs on manufacturers to substitute the eroded complicated electrodes by new ones for die making. In order to increase the machining efficiency, erosion of the work piece must be maximized and that of the electrode minimized in EDM process Therefore, studying the electrode wear and related significant factors would be effective to enhance the machining productivity and process reliability. EWR is define by the ratio of the EWW to the WRW and usually expressed as a percentage.

EWR (%) = [EWW/WRW] ×100

7. MATERIAL SELECTION

Material selection is the most important to this experiment because different Materials have different working parameters based of their properties. The right Selection of the machining material is the most important aspect to take into Consideration in processes related to the EDM. From the observation and discussion with partner and supervisor, the electrode material that has been selected is Aluminum and cooper while the tools steels as their work pieces.

8. ELECTRODES

The important factors in selecting aluminum, brass and cooper are their high Strength-to-weight ratio, resistance to corrosion by many chemicals, high thermal and electrical conductivity, non-toxicity, reflectivity, appearance and ease of formability and of Mach inability. The principal uses of aluminum and its alloys, in decreasing order of consumption, are containers and packaging (aluminum cans and foil), building and other types of construction, transportation(aircraft, automobiles and aerospace), electrical applications (as an economical and nonmagnetic electrical conductor) and portable tools Copper is a chemical element with the symbol Cu (Latin: cuprum) and atomic number 29. It is a ductile metal with excellent electrical conductivity. It is used as a heat conductor, an electrical conductor, as a building material and as a constituent of various metal alloys. Copper is malleable and ductile, a good conductor of heat, a good conductor of electricity.

9. DATA COLLECTION

The data that will be taken:
1) Machining time, t
2) Mass of work piece before and after, g
3) Work pieces removal rate (WRR), g
4) Electrode wear weight (EWR), g

10. ANALYZED METHOD

The present work highlights the development of mathematical solution to calculate the 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 (1).

The MRR of the work piece was 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. After completion of each machining process, the work piece was blown by compressed air using air gun to ensure no debris and dielectrics were present. A precise balance (Precise 92SM – 202A DR) was used to measure the 23 weight of the work piece required. Similar procedure for measuring the weight of work piece was used to determine the weight of the electrode before and after machining. The equation (2) will use for determine the EWR value:

$$MRR\ (g/min) = WRR/T \ldots\ldots\ldots\ldots \quad (1)$$

$$EWR\ (\%) = [EWW/WRW] \times 100 \ldots\ldots\ldots \quad (2)$$

The higher material removal rate in the EDM machine, the better is the machining performance. While, the lower electrode wear ratio in the EDM machine is the better and accurate performance characteristic. Due to the result, the best electrode material for EDM machining process can be determined.

11. RESULTS AND DISCUSSIONS

Discuss the results obtained throughout the experimental research analysis on the MRR and EWR after a period of machining process.

Table 4.

EXP	ELECTRODE	MASS ELECTRODE BEFORE (g)	MASS ELECTRODE AFTER (g)	MASS W/P BEFORE (g)	MASS W/P AFTER (g)	TIME
1	copper	11.2121	11.2082	143.4450	143.1936	25m 20s
2	copper	11.1217	11.1143	142.8812	142.6335	25m 33s
3	aluminum	10.5560	10.3952	143.000	142.9462	18m 58s

From above table 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 13 hours 24 minutes and 3 second. 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 five times. Hence, the data from the table can be used and analyze. The experiment is done with three electrode material which is copper and aluminum. Every electrode is running experiment by five times. Means every electrode done machining a work piece (tool steel) and overalls the number of electrodes and tool steels is 15 each. If we think again, more time are spend and waste on set up the material than machining because every experiment needs another electrode and work piece. But finally, the experiment done successfully and the data have been collected. The data collections that are taken are the mass of electrode before and after, mass of Work piece before and after and time taken of every experiment. Aluminum is less in weight due to its properties Followed copper.

12. ANALYSIS OF MATERIAL REMOVAL RATE

There are many factor need to be consider during operating the machine to make sure the results produce are in good condition and increase productivity. The most important factor in making the production run faster is the time taken for machining product. The time taken for machining can be express in term of MRR.

13. CALCULATION OF MATERIAL REMOVAL RATE

The present work highlights the development of mathematical solution to calculate the 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 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 MRR is expressed as the WRR under a period of machining time in minute (T).

MRR (g/min) = WRR/T
Where;
WRR = Work Piece Removal Rate (g)
T = time (minutes)

Table 2.

Electrode	1st	2nd	Average MRR (g/min)
Copper	0.00998	0.00978	0. 00988
Aluminum	0.00289	0.00475	0.003805

Each machining using the selected electrode has their value of MRR for the five experiments. From that table we can calculate the average of MRR each machining using different electrode material. With that value, we can know the total average of MRR. If we use the selected electrode material in the machining process. Copper material electrode give the highest average of MRR followed by aluminum.

14. GRAPH FOR MATERIAL REMOVAL RATE

The graph of MRR can be plot. The value of all five experiments using selected electrodes material is transfer into graph to make the analyzed more clearly and easy. By this graph also we can see the highest of 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 MRR compared to brass and aluminum electrode. The graph from figure has proved.

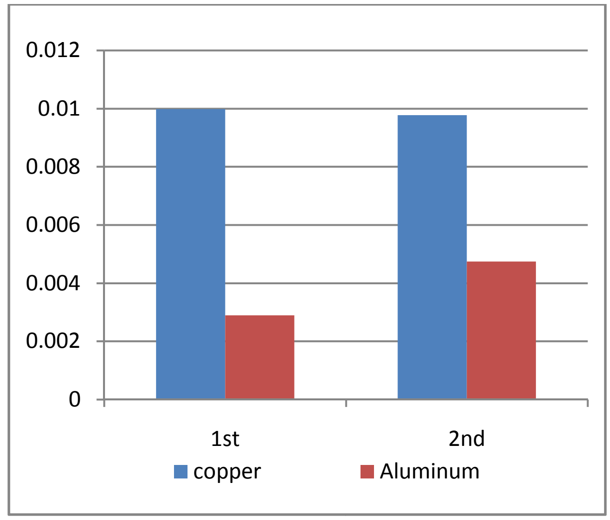

Fig 1 . Graph of MRR

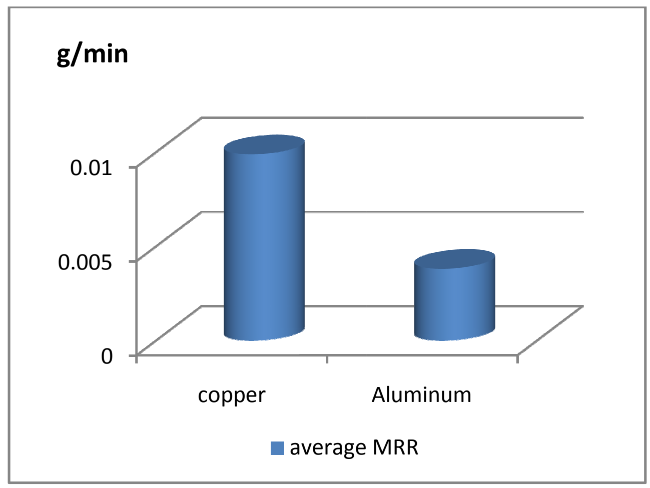

Fig.2 Graph of Average MRR

15. ANALYSIS OF ELECTRODE WEAR RATIO

Electrode wear imposes high costs on manufacturers to substitute the eroded complicated electrodes by new ones for die making. In order to increase the machining efficiency, erosion of the work piece must be maximized and that of the electrode minimized in EDM process. Electrode wear and related significant factors would be effective to enhance the machining productivity and process reliability. Furthermore, in EDM improper selection of material as electrode when machining process is running will decrease the accuracy of the product because influence of the EWR characteristic. 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.

16. FORMULA OF ELECTRODE WEAR RATIO

The EWR is define by the ratio of the EWW to the WRW and expressed as a percentage,

EWR (%) = [EWW/WRW] ×100
Where;
EWW = Electrode Wear Weight
WRW = Work Piece Removal Weight

Table 3. EWR BY USING COPPER ELECTRODE

copper	1st	2nd
EWW	0.0136	0.0074
WRW	0.257	0.2499
EWR	0.0529	0.030

Table 4. EWR BY USING COPPER ELECTRODE

Aluminum	1st	2nd
EWW	0.0317	0.0254
WRW	0.1181	0.131
EWR	0.2684	0.1938

17. GRAPHS FOR ELECTRODE WEAR RATIO

Regarding to the table, the graph for the EWR can be plot. The value of all five experiments using selected electrodes material is transfer into graph to make the analyzed more clearly and easy. By this graph also we can see the lowest EWR. These mean every experiment or machining process that using copper material as electrode will give the less EWR compared to brass and aluminum electrode. The graph from figure has proved. Figure show the average of EWR. From this graph it shows that machining EDM using electrode material of copper less average EWR than using electrode aluminum. These prove from the less value average of EWR from graph. The next choice should be aluminum due to average value EWR.

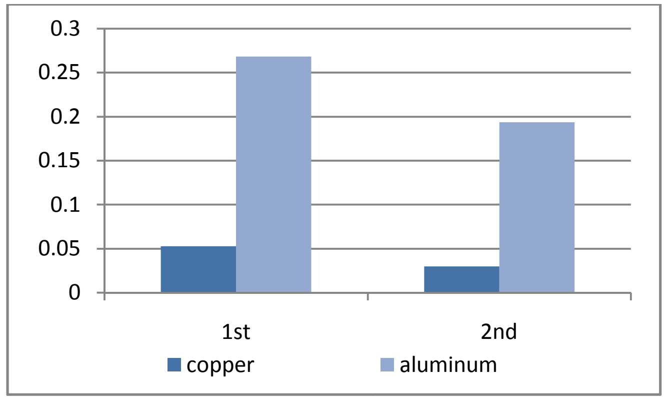

Fig. 3 Graph of EWR

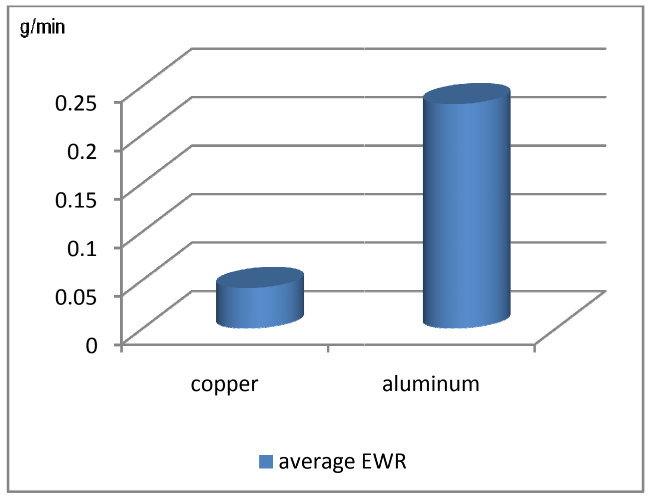

Fig.4 Graph of Average EWR

18. FINAL RESULTS

After the experiment machining tool steel with EDM using different electrode material the final result is obtained. This result obtained from the calculation of MRR and EWR. We can determine the average value of MRR and EWR for all electrode material. Higher MRR is using electrode copper followed by aluminum while for EWR the higher value is come from material aluminum followed by copper.