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CHARACTERISTICS OF ELECTRODE MATERIALS ON MACHINING PERFORMANCE OF TOOL STEEL SKD11 WITH EDM SHINKING

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ABSTRACT

Both qualitative and quantitative performance of EDM Shinking process depends not only on process parameters but also on the combination between electrode material and work piece material. This research experimented an EDM machining process uses a different type of electrode material such as cooper, aluminum, steel, brass, stainless steel, bronze and graphite to machine a workpiece of hardened tool steel SKD11. Parameters being analyzed in this research are not only the surface quality but also the material removal rate (MRR), the tool wear rate (TWR), the wear ratio (WR) which is defined as MRR/TWR. The result of the research shows that using different electrode material gives the surface roughness differences less than 3 µm e.g. for pulse current Ip=20A and Ignition voltage Uz=150V using the steel electrode and stainless steel electrode gives maximum Ra 9.63 µm and minimum Ra 6.90 µm respectively or between ISO N9 and N10. In the point of view of quantitative performance, the graphite and brass give the two highest MRR that is almost two times higher than the mild steel and stainless steel electrode. However the brass electrode has a tool wear rate 7.8 times higher than the steel electrode or 5.5 times higher than stainless steel electrode. Therefore it has the lowest wear ratio and even less than 1.0 for Ip=45A. The highest wear ratio is shown by stainless steel electrode with WR=5.23 and the lowest one is by brass electrode with WR=0.9. So, it means the brass electrode is eroded faster than the workpiece. In conclusion the application of the graphite and brass electrodes are normally used for roughing and stainless steel electrode is for finishing process.

Keywords: EDM shinking, surface roughness, electrode material, wear ratio, EDM performance.

INTRODUCTION

An EDM (Electrodischarge Machining) process is classified as modern machining process most commonly used in the industrial field for making mold and dies. Using EDM process of machining there is no contact between tool and workpiece, because the mechanism of material removal uses an erosion process due to electric sparks that come out from the gap between electrode as a tool and a workpiece. Therefore the EDM performance depends on the capacity of the sparks. Thus all parameter being used by EDM process is not only related directly to the electricity such as voltage and current but also to the physical properties of both electrode and workpiece.

LITERATURE REVIEW

Most researcher investigates the influence of process parameters on the characteristic of the machined workpiece to know both the surface finished to measure quality and the material removal rate to measure the quantity performance. The rate of material removal is highly influenced by the parameter of both arc on time and arc off time, but the surface roughness depends on the parameter of arc on time only [1]. The quality of surface finished of EDM process is also modeled and analyzed by simulation program during the parameters change [2]. The surface finished of EDM machined workpiece from Inconel 825 material is investigated using an APM (Atomic Forced Microscope) to find the parameters effects [4].

The effects of electric pulse parameters on the surface roughness, the metal removal rate and the electrode wear is also already investigated [9]. The characteristic of the micro EDM in the point of view of the material removal rate and the electrode wear rate depend on also the variation of the pulse power condition [10]. The research about the effects of the EDM process parameters on the air hardened steel of EN31 [8] and on the mild steel [7] as well as on maraging steel [3] has been done. Furthermore the effect of the EDM process parameters on the recast layers of the machined surface of workpiece is also already investigated [5].

In common, most researchers mentioned above investigate on the workpiece which is machined by EDM process, however there are only a few of them who have taken care of the electrode that is also a very important part to determine the process performance. The use of an electrode material from graphite, electrolytic copper and aluminum is to machine a workpiece of titanium alloy Ti-6Al-4V with an EDM shinking process [12]. The electrode from CuW, formed by powder metallurgical method, is also to perform for EDM shinking process [6]. Beside that the copper and brass electrode are used to machine a die steel of AISI D3 [13]. On the other hand, the electrode material from graphite, copper, copper tungsten (75% tungsten, 25% copper) are also developed to machine a stainless steel 316L and 17-4 PH with EDM process [11].

By the consideration of a little amount of research in the field of electrode material characteristic on the EDM performance, therefore this research has been chosen to be

done. Of course, the main goal of this research is to find a solution of how to increase the machining performance not only from the parameters effects but also from the electrode materials that play a big role to determine the EDM performance in both quality and productivity.

Workpiece and Electrode Specifications

The specification of workpiece and electrode for this research are listed below.

1. Workpiece from tool steel of JIS SKD11 with
   - Dimension: 160mm x 160mm x 15mm.
   - Specific gravity: 7.8 gr/cm^3.
   - Chemical compound: C 1.40-1.60%, Si 0.40% max, Mn 0.60%max, P 0.030% max, S 0.030% max, Cr 11-13%, Mo 0.80-1.20%, V 0.20-120%.
2. Electrode with dimension of ϕ20mm x 40mm. The electrode materials being investigated are copper, brass, bronze, aluminum, mild steel, stainless steel and graphite. The physical properties of the electrode materials are listed in Table-1.

Table-1. The list of electrode material and its physical properties.

Physical properties	Electrode material						
	Copper	Brass	Bronze	Aluminum	Steel	Stainless Steel	Graphite
Thermal conductivity, W/m.K	110	100	390	210	460	520	70
Melting point, °C	1083	927	913	660	1370	1450	3675
Specific gravity, gr/cm^3	8.9	8.55	8.5	2.75	7.86	8.05	1.77
Electrical resistant, Ωm	1.68E-8	7.1E-8	2.55E-7	2.82E-8	1.43E-7	6.9E-7	6.5E-6

EDM Machine

The EDM machine of Exeron 104E has specification:

- Dimension: 2860x1800x2510 (mm)
- Max. working space: X600, Y350, Z600 (mm)
- Dielectric fluid: Dielectrikum IME 82
- Max. current: 45 A
- Max. arc on time: 1600 µs.
- Max. arc off time: 1600 µs.

Instrumentation

- Mitutoyo Surftest 401 is used to measure the surface roughness of the machined surface of workpiece.
- Weight scale CHQ PS200 with 0.01 gram accuracy is used to weight both the workpiece and the electrode before and after machining process.
- Stopwatch with 0.01 second accuracy is used to measure the machining time.

METODOLOGY

The EDM shinking process is performed to machine the SKD11 workpiece until 1 mm depth and during the process the machining time is measured with a stopwatch. The volume V_m of the removed material of workpiece is calculated with formula

$$V_m = \frac{\pi d^2}{4} \cdot h \quad (1)$$

with d is a hole diameter and h is a shinking depth. Therefore, the material removal rate (*MRR*) is defined as the volume of the removed material divided by machining time t as follows:

$$MRR = \frac{V_m}{t} \quad (2)$$

The wear of the used electrode is measured with weight scale before and after the machining process and then the volume of the electrode wear is calculated with formula

$$V_e = \frac{M_1 - M_2}{\rho} \quad (3)$$

with M1 and M2 are the weight of electrode before and after machining respectively, ρ is a specific grafity of the electrode material.

For calculating the electrode wear rate (*EWR*) can be formulated as follows:

$$EWR = \frac{V_e}{t} \quad (4)$$

The wear ratio is defined as a ratio between the material removal rate of the workpiece and the electrode wear rate, so that is formulated by

$$WR = \frac{MRR}{EWR} \quad (5)$$

RESULTS

EDM Machining Process

The result of the EDM process both the workpiece and the electrode surface is shown visually in Figure-1. It is clearly different between the surface roughness which is machined by pulse current IP 20A and

IP 45A. A contrary to fact that the electrode surface roughness is only slightly different each other.

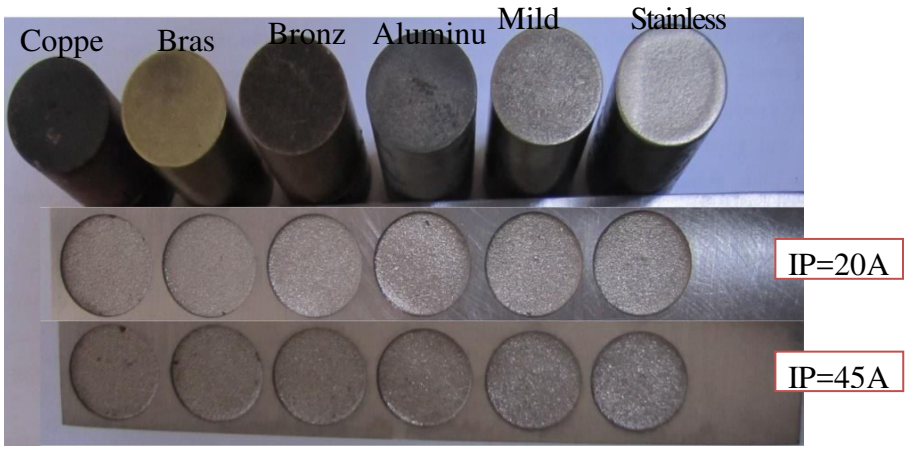

Figure-1. Result of the shinking EDM process for a workpiece of SKD 11 with pulse current IP 20A and 45A.

Measured Data

Table-2. Measured data from the workpiece and electrode.

Electrode Material	Pulse current IP	Machining time for 1 mm depth	MRR, mm^3/min	EWR mm^3/min	Wear ratio	Surface rough-ness, µm
Copper	20A	8'17"	38.43	12.24	3.14	7.15
	45A	4'12"	76.21	31.67	2.41	13.24
Brass	20A	5'51"	56.99	46.90	1.21	9.57
	45A	2'10"	149.52	165.86	0.90	14.35
Bronze	20A	7'26"	43.25	19.35	2.24	9.02
	45A	2'41"	130.29	81.59	1.60	14.05
Aluminum	20A	6'67"	47.08	32.76	1.44	8.9
	45A	2'54"	123.62	91.86	1.27	12.22
Mild Steel	20A	8'01"	39.20	7.84	5.0	9.63
	45A	4'33"	72.52	21.32	3.40	12.75
Stainless Steel	20A	8'09"	38.81	7.42	5.23	6.9
	45A	3'14"	100.00	29.72	3.36	11.57
Graphite	20A	5'42"	57.93	29.35	1.97	8.05
	45A	2'09"	150.24	113.09	1.33	11.52

Note: Parameters are set constant: Ignition current Iz=6A, Gap=40 µm, Ignition voltage Uz=150 Volt, Arc on time=16µs, Arc off time = 16µs.

DATA ANALYSIS AND DISCUSSIONS

In order to make much easier data analysis, it is better to change the measured data from Table-2 in the form of a visualized graphic.

Surface Roughness

The effect of the electrode materials on the surface roughness is shown in Figure-2. In this case, the machined workpiece roughness is only slightly influenced by the electrode materials. All the seven different electrode materials being investigated shows that the surface roughness differences of only ca. 3µm. In the contrary, the surface roughness even more depends on the applied pulse current, because the intensity of the electric sparks is increase from 20A up to 45A. So, it means that the sparks power also increases more than twice.

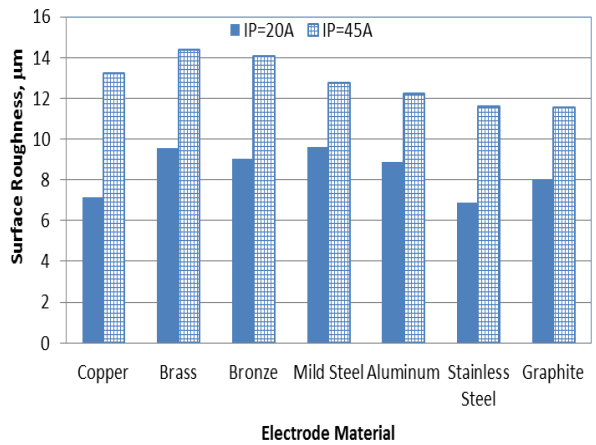

Figure-2. The surface roughness of a tool steel SKD11 machined by an EDM shinking with the difference type of electrode materials for the pulse current of 20A and 45A.

Material Removal Rate

The effect of the different type of electrode materials on the material removal rate from the tool steel SKD11 is shown in Figure-3. It is clearly shown in the figure-3 that the electrode material plays a big role in productivity especially for the applied high pulse current. The graphite and the brass electrode give a material removal rate almost twice or increase up to 100% higher compared to both the mild steel and the copper electrode for the pulse current of 45A, however for a lower pulse current (IP=20A) it increase only ca. 50%. It can be practically said that the productivity increase proportional to the pulse current. The first four electrode material that give a high material removal rate are brass, graphite, bronze and aluminum.

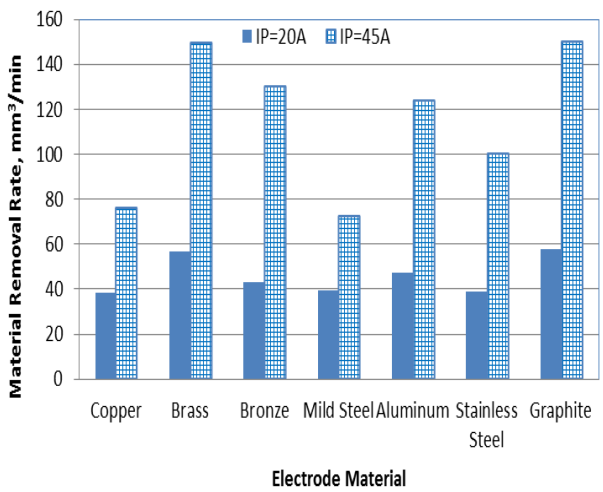

Figure-3. Material removal rate of the tool steel SKD11 machined by EDM shinking with the difference type of electrode materials for the pulse current 20A and 45A.

The reason why the material removal rate of the copper and the mild steel electrode have only the half of the brass and the graphite electrode is still a big question mark to reveal. Thus, much more researches must be done to find out the best solution.

Electrode Wear Rate

The difference type of electrode materials used to machine a workpiece of the tool steel SKD11 with an EDM shinking have also a difference electrode wear rate. It is clearly shown in Figure-4. The brass electrode has an extreme electrode wear rate especially for the high pulse current. For pulse current of 20A the brass wear rate is six times higher compared to both the mild steel and the stainless steel or about four times larger than the copper electrode. The brass electrode wear rate increase even more with increasing the pulse current. For pulse current 45A the brass wear rate circa 7.8 times higher than the steel and circa 5.5 times higher than both the copper and the stainless steel electrode. Whereas the physical properties such as thermal conductivity, specifik gravity, melting point as well as electric resistivity of the brass, the copper and the bronze are almost the same, but the each electrode has a much difference of the electrode wear rate. Therefore it should be more intensive to investigate the brass electrode.

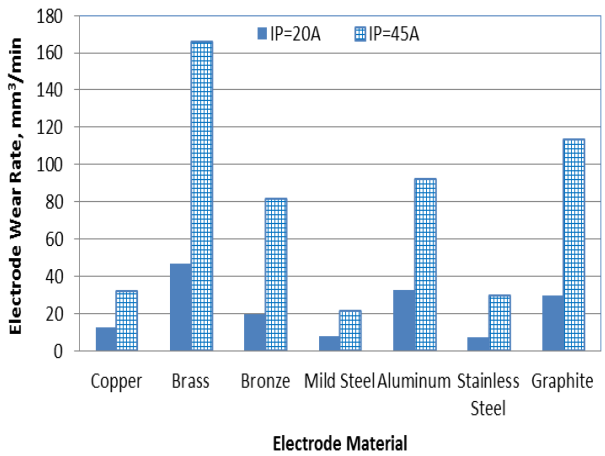

Figure-4. The wear rate of the difference type of electrode material used by an EDM shinking to machine a workpiece of a tool steel SKD11 with pulse current of IP 20A and 45A.

Wear Ratio

The higher wear ratio means the higher the material removal rate with the lower the electrode wear. The wear ratio for the seven difference electrode material used by the EDM to machine a workpiece of SKD11 is shown in Figure-5. It is clearly that the first two highest wear ratio are belongs to the stainless steel and the mild steel electrode. The each of them has wear ratio of 5.23 and 5.0 respectively for the pulse current of 20A as well as

3.36 and 3.4 respectively for the applied pulse current of 45A. On the contrary, the first two smallest wear ratio are belongs to the brass and the aluminum electrode with 1.21 and 1.44 respectively for the pulse current of 20A as well as 0.9 and 1.27 for the pulse current 45A. The wear ratio less than 1.0 means that the electrode wear rate is higher than the material removal rate. Of course, in this condition the electrode take highly effect to the accuracy of the machining process, because the electrode changes its dimension rapidly. In figure-5 is shown also the higher the pulse current, the lower is the wear ratio.

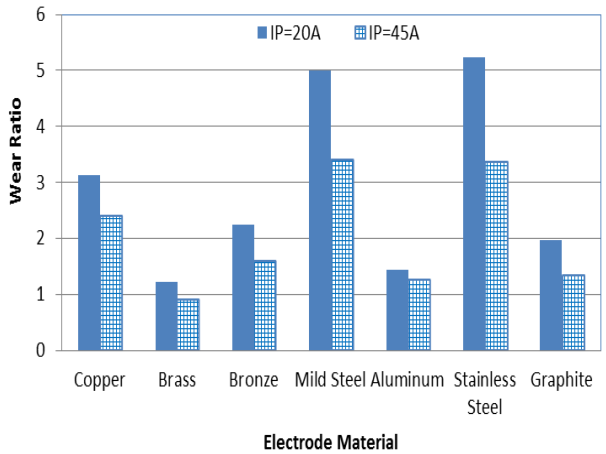

Figure-5. The wear ratio for the difference type of electrode materials for EDM shinking of a workpice SKD11.

CONCLUSIONS

From the analysis and discussion mentions above, it can be concluded that:

1. The electrode material take only a little effect on the surface quality of machined workpiece, but it plays a big role in productivity in the form of the material removal rate and the electrode wear rate.
2. The surface roughness is highly influenced by the applied pulse current.
3. The graphite and the brass electrode give the rate of material removal of the machined workpiece twice as much as both the mild steel and the stainless steel.
4. The brass electrode however give not only the highest the material removal rate but also the electrode wear rate, therefore it has the lowest wear ratio and even less than one.
5. The electrode wear rate of the brass reach as high as 7.8 times higher than the steel and 5.5 times higher than stainless steel.
6. The biggest wear ratio is belongs to the steel of 5.23 and the stainless steel of 5.0 for pulse current of 20A, whereas the smallest one is the brass of 0.9 and the aluminum of 1.27 for pulse current of 45A.
7. The higher pulse current the lower is the wear ratio.

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