Study the Effect of Electrode Wear Weight (EWW) in Electrical Discharge Machining (EDM)

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ABSTRACT

Electrical Discharge Machining (EDM) is one of the earliest non-conventional manufacturing processes based on thermo-electric energy which removing material from a part by electrical discharges between the tools called electrode and the part being machined in the dielectric fluid called work piece. One of the most important performance measures in electrical discharge machining (EDM) process are the electrode wear weight(EWW).

In the present work an experiments has been done to evaluate the rapidity of wear weight electrode of different material (Copper, Brass and Steel) under the same machining condition to analyze the effect of electrode material and the current on electrode wear weight.

Keywords : Electrical Discharge Machining (EDM) , Electrode Wear (EW) .

دراسة تأثير بلى الاقطاب الوزني (EWW) في عملية القطع بالشرارة الكهربائية (EDM)

الخلاصة

القطع بالشرارة الكهربائية (EDM) واحدة من عمليات التصنيع اللاتقليدية المبكرة تعتمد على الطاقة الكهروحرارية التي تزيل المادة بشرارات كهربائية تتولد بين أداة تدعى القطب والجزء المشغل الموضوع في سائل عازل والتي تدعى المشغولة.إن من أهم مقاييس الأداء للقطع بالشرارة الكهربائية (EDM) هي بلى القطب ألوزني (EWW).

يتضمن هدا البحث تجارب لتقييم سرعة بلى القطب ألوزني لأقطاب مصنعة من مواد مختلفة (نحاس, براص وفولاذ) تحت نفس ظروف التشغيل لدراسة تأثير تغيير مادة القطب على بلى القطب, كما تم تغيير التيار لكل قطب لتقييم تأثير كمية التيار على البلى ألوزني للقطب.

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INTRODUCTION

EDM is one of the most extensively used non-conventional material removal processes [1]. In this electro-thermal process metal removal by a series of rapidly reoccurring electrical discharges (sparks). The electrical energy from the spark is converted into thermal energy. The sparks occur in a gap between a tool and workpiece [2]. Both workpiece and tool electrode are submerged in a solution called dielectric [1]. Metal removal takes place as a result of the generation of extremely high temperatures generated by the high-intensity discharges that melt and evaporate the two electrodes [3].

During EDM, the main output parameters are the material removal rate (MRR), wear ratio (WR), electrode wear (EW), and job surface roughness (R_a). It is desirable to obtain the maximum MRR with minimum EW. Common electrode materials are graphite, brass, copper and copper-tungsten alloys [4].

Due to the high temperature of the sparks, not only work material is melted and vaporized, but the electrode material is also melted and vaporized, which is known as electrode wear (EW). The EW process is quite similar to the material removal mechanism as the electrode and the workpiece are considered as a set of electrodes in EDM. Due to this wear, electrodes lose their dimensions resulting in accuracy of the cavities formed [4]. Electrode wear (EW) is one of the major problems in EDM process. When electrode wear occurs, the required geometrical characteristics of the electrode will not be reproduced on the workpiece [5]. Unlike the mechanical milling process in which tool wear is very small and could be neglected in most cases, in contour EDM especially in rough machining, because of the erosive effect of discharging, wear of electrode is significant that could be up to several millimeters per minute. In the end machining process wear of electrode occurs at the end portion of the cylindrical electrode in both radial and axial directions. It is symmetrical because electrode is rotating. The wear in axial direction causes the electrode to become shorter while in radial direction the flat end of the cylindrical electrode becomes tapered, filleted or torus shapes. In roughing, layer-by-layer machining is a commonly used strategy. Electrode wear occurs in both axial and radial directions. If the cutting depth is not large, for example, smaller than 2 mm, the wear in both directions may reach a dynamic balance, i.e., both the edge and the bottom of the flat end of the electrode are worn away together continuously; the worn shape at the end looks nearly unchanged while wearing process is going on. Hence the real-time radial-wear compensation can thus be implemented on the electrode length, and the radial-wear compensation can be introduced by replacing the flat end of the electrode with a static torus or fillet geometry [6].

Electrode shape deformation and especially its random variations together with the volumetric wear ratio are the two main factors affecting the applicability of wear compensation methods. Variation of the electrode wear requires deep investigation as it determines the process capabilities and is used as a basis for applying the electrode wear compensation methods. Many electrode wear compensation methods have been studied and applied more or less successfully in research laboratories [7]. However, electrode wear occurs during EDM process leading to a lack of machining accuracy in the geometry of workpiece. To reduce the influence of the electrode wear, it is necessary either to feed electrode larger than the workpiece thickness in the case of making through-holes, or to prepare several electrodes for roughing and finishing in the present state of technology. For three-dimensional cavities, ED scanning or uniform wear method was applied by using small diameter electrode and forward-back tool path. However, tool life is still another concerned problem [8].

The wear ratio of the two most commonly used electrode materials, graphite and copper, requires the use of multiple electrodes in the production of each cavity, because the electrode wears away and loses its initial shape too quickly. Thus, the replacement of graphite and copper electrodes with electrodes made of materials which are more resistant to electric spark erosion would significantly improve the cost effectiveness of EDM tool production [9].

This study was focused on (current machining time and electrode material)have been studied through experiments, executed on EDM machine with a dielectric solution in the cutting laboratory of the metallurgy and production engineering department.

EXPERIMENTAL EQUIPMENT AND METHODS

The experiments include cutting 15 workpieces of stainless steel 304 with thickness (0.4)mm using three electrodes (Copper, Brass, and Steel) with diameters 3mm, 2.6mm and 5.5mm respectively(Five workpieces cut with each electrode) with different current to each electrode(10,15,20,25,30)A. The gap between the electrode and the workpiece are about 0.01 to 0.5 mm as shown in Figure (1). The chemical composition and mechanical properties of workpieces are shown in Tables (1, 2). The fixed machining conditions were summarized in Table (3).

The EDM machine was attached with a power supply current pulses during discharging. The polarity of tool-electrode was negative (-) and the polarity of workpiece was positive (+). A tap water used as a dielectric fluid due its high ability to transport high spark current between tool-electrode and workpiece. In particular, for better control of the environment, the dielectric fluid was kept in Pyrex (glass) container during each run of the experiments as shown in Figure (2).

The electrode wear weight (EWW) is being calculated using the formula [10]:

$$EWW\ (gm) = (W_1 - W_2) \qquad \text{……….. (1)}$$

Where:

W_1 = the electrode weight before machining.

W_2 = the electrode weight after machining.

The measurement is taken by using a weighing machine and the following equation is used to evaluate weight loss rate:

$$\text{Weight Loss Rate} = EWW/\ W1 \qquad \text{…………(2)}$$

RESULTS AND DISCUSSION

In this section, the results obtained from the EDM experiments using the electrodes made by copper, brass, and steel are discussed in comparison to varying currents (10, 15, 20, 25 and 30) A are shown in Figs. (3) and (4). According to these figures, an increase in the current causes an increase in the EWW and Weight Loss Rate (WLR). By the increase in current, the discharge energy of the plasma channel and the period of transferring of this energy into the electrodes increase. This phenomenon leads to the formation of a bigger molten material crater on the workpiece and electrodes. However, the plasma channel and the effect of thermal conductivity or melting point of electrodes (copper, brass and steel) in dispersing the thermal from the spark collision position increase by the increase in current.

Consequently, by the dispersing more heat from the spark stricken position and increasing the amount of heat transferred from the plasma channel to the electrodes, the plasma channels efficiency in removing molten material from the molten crater at the machining time decreases of tool made of copper, while the dimensions of the molten crater on the electrodes increases as shown in table (4).

Figure (5) show that weight loss rate of tool made of copper, brass and steel increase with augments of the electrode wear weight. Such results were expected as it is obvious that a higher current causes a stronger spark which results in more eroded material for both electrodes.

CONCLUSIONS

In this study, the influence of different EDM parameters (current, machining time and electrode material) in finishing stage on the electrode wear weight (EWW) as a result of application different electrode materials (copper, brass and steel) to a workpiece (stainless steel 304) has been investigated. The main conclusions which can be deduced from this research can be summarized as follows:

1- The results for the wear weight of electrode between (0.0083-0.0017) gm for copper electrode,(0.0060-0.0014) gm for brass electrode and (0.0043-0.0011) gm for steel electrode.

2- The electrode wear weight increases as the current increased.

3- The electrode wear weight increases with the increase in the electrical conductivity and decreases as the melting point of electrode material increased.

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Table (1) Chemical Composition (cast analysis) of Stainless Steel 304 Flat Products.

GRADES	AUSTENITIC	Name designation EN	X5CrNi 18-10
		EN Number designation	1.4301
		Designation AISI/ASTM	304
		C	≤0.07%
		Si	≤1,00%
		Mn	≤2,00%
		P max	0.045%
		S	≤0.015%
		N	≤0.11%
		Cr	17.50 to 19.50%
		Mo	0%
		Ni	8.00 to 10.50%

Table (2) Physical Properties of Stainless Steels 304 [10].

Physical Properties	Stainless Steel 304
Density (gm/cm^3)	8.03
Electrical Conductivity (×10^5/Ω cm)	11.6
Thermal Conductivity[W/(cm.K)]	0.162
Melting Point (K)	1644
Boiling Point (K)	1672

Table (3) The Fixed Machining Conditions.

Working Parameters	Description
Workpiece	steel 304 (0.4 mm thickness)
Shape of tool-electrode	Cylindrical bar (conical)
Tool-electrode polarity	Negative (-)
Work piece polarity	Positive (+)
Dielectric	tap water
Input voltage	380V (three phase)
Output voltage	70V (two phase)
Type of current	D.C Pulse current

Table (4) The Experiments Result.

Working Parameter		Current (A)	Machining time (min)	Weight of electrode (before machining) (gm)	Weight of electrode (after machining) (gm)	Electrode Wear Weight (gm)	Weight Loss Rate $\times 10^{-4}$
Copper electrode (3 mm diameter)	1st experimental	30	15	15.7450	15.7367	0.0083	5.2715
	2nd experimental	25	18	12.1763	12.1698	0.0065	5.3382
	3rd experimental	20	22	12.2160	12.2112	0.0048	3.9293
	4th experimental	15	25	12.1883	12.1857	0.0026	2.1332
	5th experimental	10	27	12.1812	12.1795	0.0017	1.3956
Brass electrode (2.6 mm diameter)	1st experimental	30	12	5.4113	5.4053	0.0060	11.0879
	2nd experimental	25	16	5.3839	5.3782	0.0057	10.5871
	3rd experimental	20	20	5.3579	5.3547	0.0032	5.9725
	4th experimental	15	25	5.0697	5.0675	0.0022	4.3395
	5th experimental	10	30	5.0550	5.0536	0.0014	2.7695
Steel electrode (5.5 mm diameter)	1st experimental	30	20	21.1660	21.1617	0.0043	2.0316
	2nd experimental	25	25	21.1003	21.0962	0.0041	1.9431
	3rd experimental	20	30	21.0950	21.0923	0.0027	1.2799
	4th experimental	15	35	21.1571	21.1555	0.0016	0.7565
	5th experimental	10	40	21.0200	21.0189	0.0011	0.5233

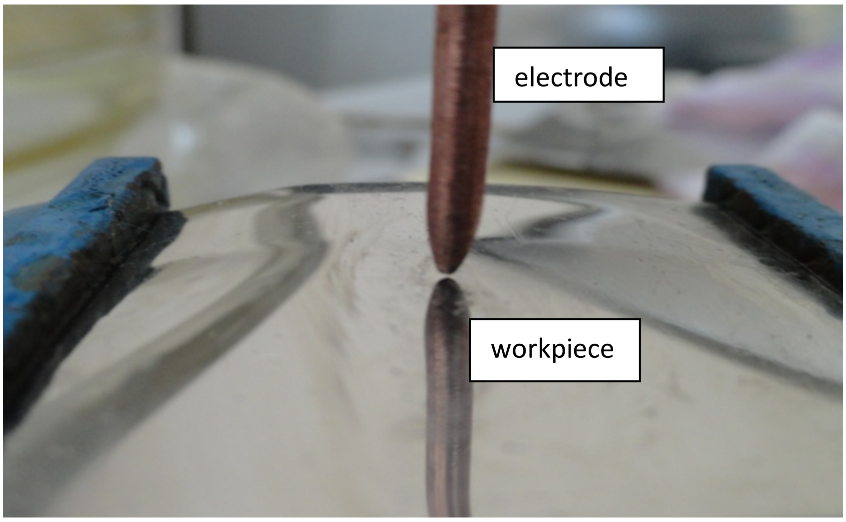

Figure (1) The gap between Electrode and workpiece of EDM operation.

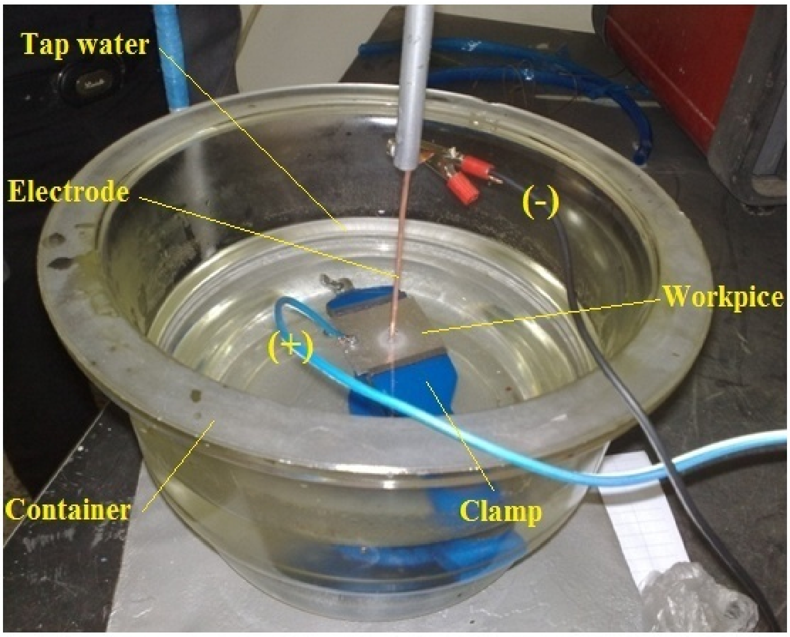

Figure (2) Material removal mechanism of EDM operation.

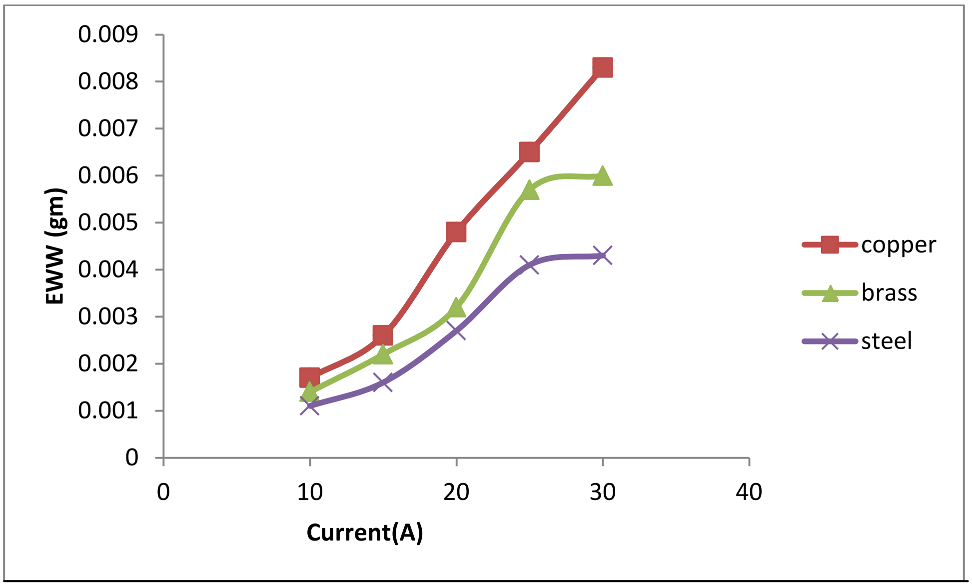

Figure (3) Effect of current on electrode wear weight of tool made of copper, brass and steel.

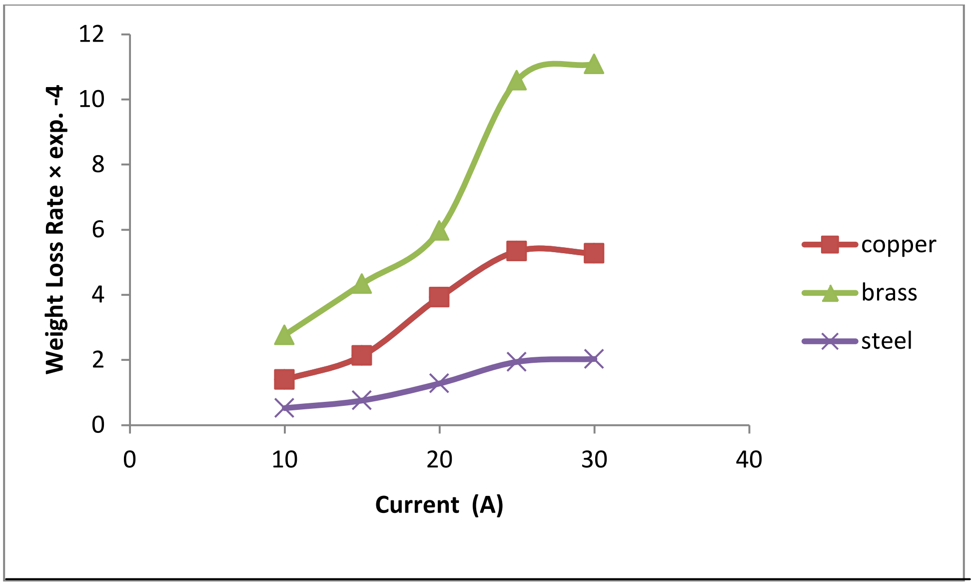

Figure (4) Effect of current on weight loss rate of tool made of copper, brass and steel.

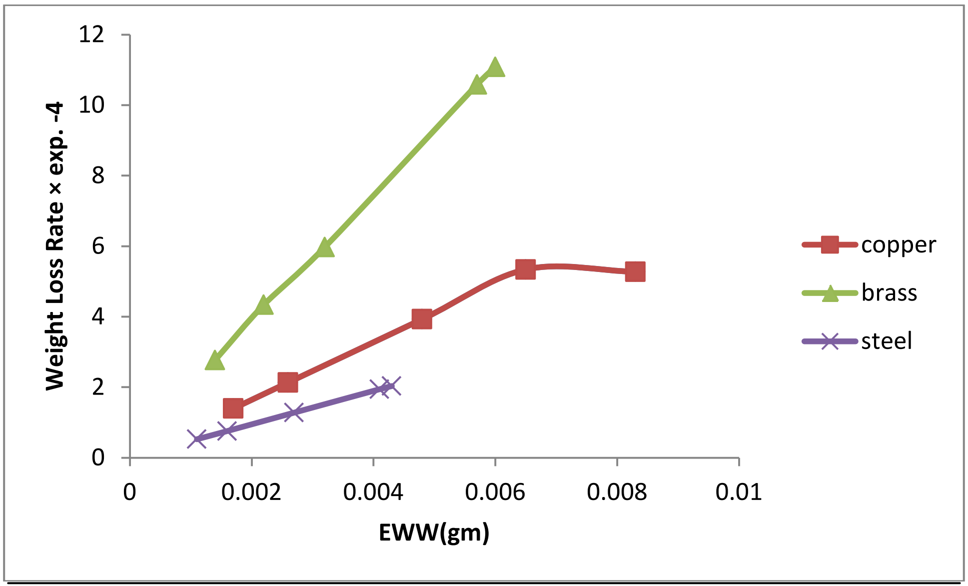

Figure (5) Effect of electrode wear weight on weight loss rate of tool made of copper, brass and steel.