Engineering and Technology Journal
Journal homepage: engtechjournal.org

Effect of SiC-Cu Electrode on Material Removal Rate, Tool Wear and Surface Roughness in EDM Process

Yousif Q. Laibi[a*], **Saad K. Shather** [b]

[a] Production Engineering and Metallurgy Dept. Baghdad, Iraq. 71404@student.uotechnology.edu.iq

[b] Production Engineering and Metallurgy Dept. Baghdad, Iraq. drengsaad_k_sh@yahoo.com

*Corresponding author.

Submitted: 01/09/2019 Accepted: 03/11/2020 Published: 25/09/2020

KEYWORDS

EDM, SiC-Cu electrode, MRR, TWR, SR

ABSTRACT

Electrical discharge machining (EDM) is one of the most common non-traditional processes for the manufacture of high precision parts and complex shapes. The EDM process depends on the heat energy between the work material and the tool electrode. This study focused on the material removal rate (MRR), the surface roughness, and tool wear in a 304 stainless steel EDM. The composite electrode consisted of copper (Cu) and silicon carbide (SiC). The current effects imposed on the working material, as well as the pulses that change over time during the experiment. When the current used is (8, 5, 3, 2, 1.5) A, the pulse time used is (12, 25) µs and the size of the space used is (1) mm. Optimum surface roughness under a current of 1.5 A and the pulse time of 25 µs with a maximum MRR of 8 A and the pulse duration of 25 µs.

How to cite this article: Y. Q. Laibi, S. K. Shather, "Effect of SiC-Cu electrode on material removal rate, tool wear and surface roughness in EDM process" Engineering and Technology Journal Vol. 38, Part A, No. 09, pp. 1406-1413, 2020.

DOI: https://doi.org/10.30684/etj.v38i9A.552

1. Introduction

At a relatively high potential difference [1], discharge between the pair of parts and the electrodes. These discharges occur hundreds of thousands of times per second to maintain the removal of a material from surface in the region of the treatment interval [2]. Since EDM is not a mechanical process, the hardness, toughness, and strength of the part material do not necessarily affect the material removal rate (MRR). Therefore, a very hard or highly flexible material having a complicated and complicated shape and size can be processed by this method. Figure 1 shows the EDM machine. The machine can be used in many applications, such as forging, die casting, extrusion, injection molding and the production of large sheet metal Automotive body parts [3, 4]. In this regard, numerous particle compaction electrodes have been developed to improve treatment efficiency in the MRR, SR and TWR systems. Figure 1 shows the EDM machine.

Publishing rights belongs to University of Technology's Press, Baghdad, Iraq.

Figure: 1 EDM machine

On the other hand, the research shows that composite materials are the class of engineering materials identified as the combination of two or more the chemically insoluble stages [5]. The resulting material is beneficial for the ductility of a parent metal and the high strength, as well as for improving hardness and heat resistance of a material. These materials are increasingly used in the automotive and the aerospace industries because of their high strength to weight ratio and the desirable thermal performance [6]. Aluminum carbide (Al / SiC) is one of the most popular MMC composites and its application in the aerospace industry and the automotive industry has a good strength-to-weight ratio. In addition to being able to customize composite materials with unique features Compared to traditional materials. [7] Addition of a reinforcing agent to a metal or an alloy it is thought that it improves its performance while possibly limiting its processing capacity. Cutting traditional MMCs using conventional treatment methods is considered difficult; this is not practical because it results in significant tool wear and increased machining time. Therefore, the potential application of these materials is limited by a production cost. There are powder casting and the metallurgy routes for forming MMC components, but their versatility is greatly enhanced by improving their process ability. The growing demand for such sophisticated materials requires economical processing methods. EDM or spark erosion are widely used in the production of molds and molds [8, 9]

Amoljit Singh Gill, et al. [10] studied electrical discharge alloying (EDA) is used to modify the surface of high carbon steel by using composite electrode (Copper-Chromium Nickel) manufactured by powder metallurgy (PM) process. The effect of EDM parameters on micro hardness during the surface alloying is a studied Experimental results show the increase in micro hardness of a machined surface by 139.7% as a compared to base material. Additionally, the techniques like X-ray diffraction (XRD) and Energy Dispersive Spectroscopy (EDS) are used to analyze a change in composition of alloying elements and phases of a machined surface. It is concluded that the increase in micro hardness is due to a formation of the carbides containing chromium in alloyed layer. Rosso [11] discussed that metallic matrix compounds have a number of beneficial properties compared to homogeneous metals including higher specific strength, higher specific modulus, higher temperature resistance, better corrosion resistance, and lower coefficients of thermal expansion. Gangadhar et al. [12] investigated a performance of Cr / Cu based composite electrodes. The results showed that the use of such electrodes facilitated the formation of a modified surface layer on the workpiece after EDM, with remarkable anti-corrosion properties. The optimum mixing ratio, appropriate pressure, and appropriate processing parameters (e.g. polarity, peak current, and pulse duration) were used to investigate the effect of MRR, EWR, surface roughness, and reformulation layer thickness on the usability of these electrodes. According to the experimental results, a mixing ratio of Cu-0wt% Cr and a sintering pressure of 20 MPa obtained an excellent MRR. The aim of research is studying the influence of composite tool material (SiC-Cu) on surface roughness (Ra) and material removal rate (MRR) of the work piece and Tool wear ratio.

2. Experimental procedures

In this research anew investigation of composite tool material is made by powder metallurgy method to get better results such as metal removal rate (MRR), surface finish (SR) and electrode wear rate (TWR). The experimental procedure involves the following steps:

EDM machine

The experimental work was done on an EDM machine called CHMER of the Model (CM 323C), and this machine was designed by an advanced system called Computer-Aided Design (CAD) to ensure high automation precision and deformation-free performance, EDM machine specifications listed in Table 1.

Table 1: The CHMER EDM machine specification

Machine body	CM323C
Table size (W×D) (mm)	500×350
Table travel (X×Y) (mm)	300×200
Work tank size (W×D×H) (mm)	820×500×300
Ram travel (Z) (mm)	300
Max. weight of workpiece (kg)	500
Max. weight of electrode (kg)	60
Distance to the RAM (mm) platen to the work table	250×550
Outside dimensions (mm)	1200×1350×2250

I. Workpiece

the work piece is stainless steel 304.it's The most important, versatile and commonly used chromium steels and their products, shapes and surface treatments, shapes and surface treatments are far more than other products. It has glorious molding and fixing properties. The balanced primary solid solution structure of class 304 allows it to be subjected to deep drawing without intermediate quenching, making it an essential element for the production of non-contaminating adsorbed components such as sinks, hollow vessels and pans. Dominant. For these applications, special variants (deep drawing quality) are often used. Class 304 high speeds or laminated brake components for industrial, industrial and transport applications. The chemical composition and mechanical properties of 304 grade stainless steel is shown in the Table 2 and Table 3, respectively.

Table 2: Chemical composition for stainless steel 304

material	**Weight%**
C%	0.0303
Si%	0.405
Mn%	1.599
P%	0.041
S%	<.0005
Cr%	18.66
Mo%	0.347
Al%	<.001
Ni%	8.68
Cu%	0.565
V%	0.0723
W%	0.0455
Fe%	0.0455

Table 3: Mechanical properties of 304 grade stainless steel

Grade	304
Tensile strength (MPa) min	515
Yield strength 0.2% proof (MPa)min	205
Elongation (%in50mm) min	40
Rockwell B (HR B) max(hardness)	92
Brinell (HB) max(hardness)	201

II. Electrode

In this study, a composite electrode consisting of pure copper (Cu) and silicon carbide (SiC) was used,97% (Cu) was mixed with 3% (SiC) where mixed and placed in a mold and put pressure on the mold by 15 tons to produce an electrode with dimensions (80*10*10) mm. The reason in choosing composite electrode is to reduce the electrode wear ratio, improves the material removal rate and surface roughness

III. Electrode manufacturing

Electrodes were manufactured using metal powder technology by using a mold measuring (80 mm long, 10 mm wide and 10 mm thick). The electrode is made of pure copper and a percentage of silicon carbide (SiC-Cu) where the powder is mixed in the agreed proportions and placed inside the mold Then put it inside the hydraulic piston and shed a pressure of 15 tons for 2 minutes and then remove the pressure for the purpose of obtaining the appropriate electrode for the process of electrical discharge machining after completing the hydraulic press, the electrode was placed inside the furnaces for the centrifugation process. It was placed in the oven for eight hours at 700 ° C which represents 70% of the melting point of copper because the copper is the basic electrode material, the composite electrode is shown in Figure 2.

Figure 2: SiC_Cu electrode

IV. Machining Parameters

Two main parameters (cutting conditions) that have many effects on the cutting process. The first parameter is the current (A) and the second is pulse on time (μs). The cutting condition listed in Table 4.

Table 4: Cutting conditions

Current (A)	Pulse on time(μs)	Polar	Voltage (V)
8A	25	+	240
8A	12	+	240
5A	25	+	240
5A	12	+	240
3A	25	+	240
3A	12	+	240
2A	25	+	240
2A	12	+	240
1.5A	25	+	240
1.5A	12	+	240

V. Response variables analysis

MRR is the relation between the weight of the metal before and after removing from the workpiece divide by the time of the machining

MRR = (Wb – Wa)/t (g/ min) (1)

In this equation, Wb and Wa are the weights of the metal before and after the process of removing, t is the time. TWR is the relation between the magnitude weights of the electrode before machining and after removing to a machining time

TWR = (Wtb – Wta)/t (g/ min) (2)

In this equation, Wtb, and Wta are the magnitude weights of an electrode, before machining and after the process of machining and t is time.

3. Results and discussion

The obtained results presented in Table 5 the effect of different machining parameters on metal removal rate (MRR), surface finish (SR) and electrode wear rate (TWR)

Table 5: Results of the (SiC- Cu) electrode

Exp no.	Current (A)	Pulse on time (μs)	MRR (g/min)	TWR (g/ min)	SR (μm)
1	8	25	0.0367	0.00616	2.93
2	8	12	0.0320	0.00597	2.8
3	5	25	0.0120	0.00400	2.91
4	5	12	0.0120	0.00403	2.78
5	3	25	0.0016	0.00172	2.15
6	3	12	0.0014	0.00171	2.41
7	2	25	0.0010	0.00052	1.65
8	2	12	0.00104	0.000526	1.92
9	1.5	25	0.00065	0.0000497	1.38
10	1.5	12	0.000652	0.0000496	1.70

I. Results for material removal rate

From Figures 3 and 4, it was noted that the applied current and pulse on time has the significant highest effect on material removal rate, while the composite electrode and other parameters prove that effect on material removal rate. Where material removal rate increased by increasing the current and decreasing of pulse on time. It was a good result for the electrode compound compared to the copper electrode and gave unexpected results and proved that the current relationship is significant by removing the material. The reason is the increase in the discharge energy of the plasma channel and the longer period of converting this energy to electrodes, which leads to the creation of a high spark with a high temperature to melt and evaporate the material and form larger pits on the work piece, it is concluded in [13, 14].

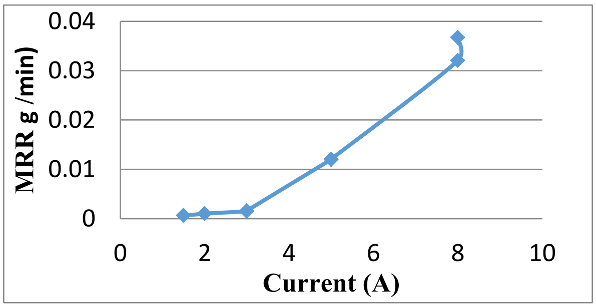

Figure 3: The relation between current and MRR

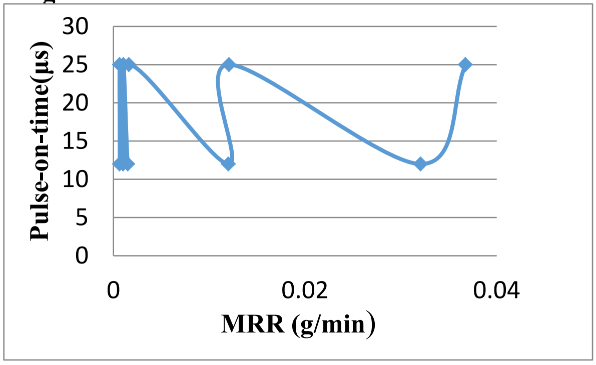

Figure 4: The relation between pulse on time and MRR

II.Results for tool wear rate

From Figures 5 and 6 it was noted that the tool wear rate is decreased in this experiment when we used compound electrode and that is better than pure electrode because of the high wear resistance and also the electrode wear increased when we raise the current, the minimum tool wear rate that we obtained is 0.00004961 when we used the current (1.5) A and (12) µs pulse on time and the maximum tool wear rate is 0.00616809 with current (8) A and 25 µs pulse on time. The reason is that the higher current will produce a stronger spark with higher energy and more heat will be generated and used to corrode more materials from the electrode tool as it is a concluded in Refs [15, 16].

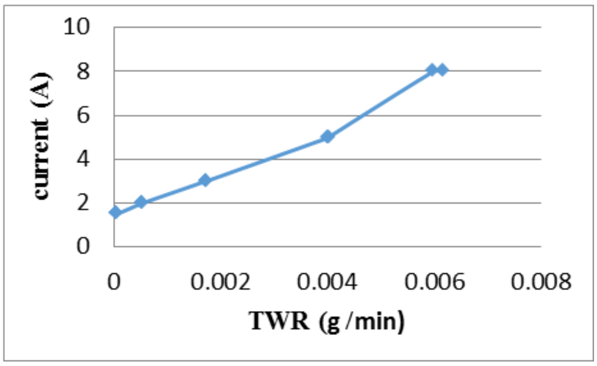

Figure 5: Relation between current and TWR

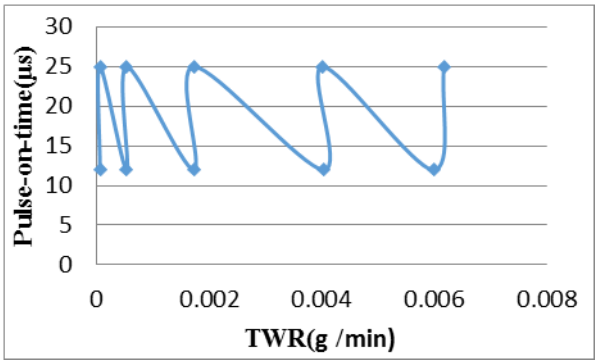

Figure 6: The relation between pulse on time and TWR

III. Results for surface roughness

Figure 7 and Figure 8 show variations in surface roughness with applied current and pulse on time. From Table 2, it appears that the highest surface roughness can be obtained is 2.93 µm at 8 A of the current and 25 µs pulse on time and the lowest surface roughness can be obtained is 1.38 µm at 1.5 A t and 12 µs current and pulse on time.

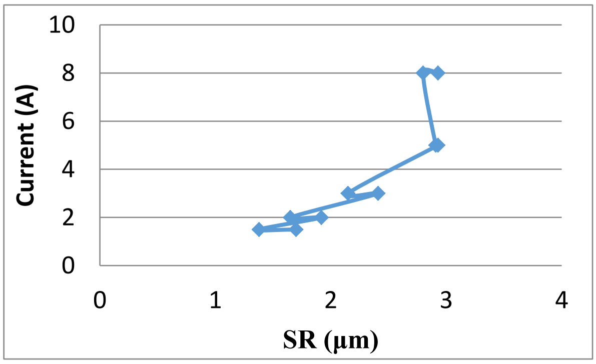

Figure 7: The relation between current and SR

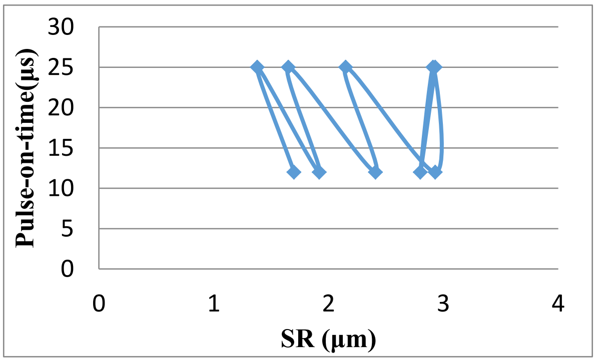

Figure 8: The relation between pulse on time and SR

4. Conclusions

The influence of machining parameters on performance specifications in an EDM process with Cu-SiC composite compact electrode was investigated using material removal rate and tool wear rate as the basic criteria. The following conclusions are obtained from the experiments

1. The experiments show that (MRR) is significantly influenced by the EDM discharge current and the pulse on time in addition to the interaction influence between the two. On the other side, all three factors have significant effect on the tool wear rate during the EDM of stainless steel with Cu-SiC composite electrode.

2. Both the current and pulse on time have a direct relationship with the MRR and TWR. Thus, the results increase with increasing current and on-time. The highest MRR obtained with the composite electrode is 0.0367 g/min with the current of 8 A and pulse duration of 25 µs. The highest TWR is 0.0061 g/min with the current of 8 A and the pulse duration of 25 µs.

3. Surface roughness is increased when used composite electrode and negative polarity. The positive polarity in a composite electrode to get better surface roughness. Should be used.

References

[1] S. Kalpakjian, and S. Schmid, “Manufacturing engineering and technology,” 5th ed., Pearson Prentice Hall, Singapore, 2006.

[2] M.P. Groover, “Fundamentals of modern manufacturing,” John Wiley & Sons, Inc., New York, 2007.

[3] Y.H. Liu, R.J. Ji, X.P. Li, L.L. Yu, H.F. Zhang, and Q.Y. Li, "Effect of machining fluid on the process performance of electric discharge milling of insulating Al2O3 ceramic," International Journal of Machine Tools and Manufacture, Vol. 48, pp. 1030-1035, 2008.

[4] H.I. Medellin, D.F. De Lange, J. Morale, and A. Flores, "Experimental study on electro discharge machining in water of d2 tool steel using two different electrode materials," Proceedings of Institution Mechanical Engineers, Part B: Journal of Engineering Manufacture, Vol. 223, pp.1423-1430, 2009.

[5] D.E. Dimla, N. Hopkinson, and H. Rothe, "Investigation of complex rapid EDM electrodes for rapid tooling applications," The International Journal of Advanced Manufacturing Technology, Vol. 23, pp. 249-255, 2004.

[6] B. Jha, K. Ram, and M. Rao, "An overview of technology and research in electrode design and manufacturing in sinking electrical discharge machining," Journal of Engineering Science and Technology Review, Vol. 4, pp. 118-130, 2011.

[7] P.K. Patowari, U.K. Mishra, P. Saha, and P.K. Mishra, "Surface modification of c40 steel using wc-cu p/m green compact electrodes in EDM," International Journal of Manufacturing Technology and Management, Vol. 21, pp. 83-98, 2010.

[8] M.P. Samuel, and P.K. Philip, "Power metallurgy tool electrodes for electrical discharge machining," International Journal of Machine Tools and Manufacture, Vol. 37, pp. 1625-1633, 1997.

[9] H. Tsai, B. Yan, and F. Huang, "EDM performance of Cr/Cu-based composite electrodes," International Journal of Machine Tools and Manufacture, Vol. 43, pp. 245-252, 2003.

[10] A. S. Gilla, and S. Kumarb, "Surface alloying by powder metallurgy tool electrode using EDM process," a, b Mechanical Engineering Dept., PEC University of Technology (Formerly Punjab Engineering College), 2015.

[11] A. Gangadhar, M.S. Shunmugam, and P.K. Philip, "Surface modification in electro discharge processing with a powder compact tool electrode wear," Elsevier, Wear, 143 (16): 45–55.1991. https://doi.org/10.1016/0043-1648(91)90084-8

[12] M. Rosso, "Ceramic and metal matrix composites: routes and properties," Journal of Materials Processing Technology, 175(6): 364-375, 2006.

[13] P. Malhotraand and A. Kohli, "Performance study of electrical discharge machining with h-11 tool steel using one variable at a time approach," International Journal for Science and Emerging, Vol. 12, pp.15-20, 2013.

[14] S. Jaspreet, S. Mukhtiar and S. Harpreet, "Optimization of machining parameters of electric discharge machining for 202 stainless steel," International Journal of Modern Engineering Research, Vol. 3, pp. 2166-2169, 2013.

[15] P. Malhotraand and A. Kohli, "Performance study of electrical discharge machining with h-11 tool steel using one variable at a time approach," International Journal for Science and Emerging, Vol. 12, pp.15-20, 2013.

[16] S. K. Majhi, T.K. Mishra, M.K. Pradhan and H. Soni, "Effect of machining parameters of AISI D2 tool steel on electro discharge machining," International Journal of Current Engineering and Technology, Vol. 4, 2014.