International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 9 (2018) pp. 7076-7080

Enhancement of Machining Performance during Electrical Discharge Machining of Stainless Steel with Carbon Nanotube Powder Added Dielectric Fluid

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Abstract

Electrical discharge machining (EDM) is a nontraditional process of removing material from an electrically conductive work piece. It produces sparks to produce any desired shape cavity or geometry. The demand for good surface finish of a workpiece in EDM has developed a new method to improve surface condition where powder material is added to dielectric fluid during EDM. The present paper is on investigation of influence of carbon nanotube (CNT) powder addition to dielectric fluid on EDM performance. The effect of the addition of CNT is analyzed on MRR and surface roughness (Ra). The variable factors were pulse on time (Ton) and powder concentration. The addition of CNT powder has improved the surface roughness and MRR in comparison EDM without CNT addition. Lowest surface roughness obtained by the lowest Ton time of 6µs with the CNT powder concentration of 0.3 mg/L of 8.61µm compared to 9.97µm of no powder addition. Ton of 10µs has produced the highest surface roughness with no powder addition with the value of 30.38µm. The addition of 0.3mg/L powder addition and 10µs Ton enhanced the surface roughness to 29.40µm. The addition of CNT powder with the concentration of 0.3mg/L has also increased the MRR to the highest value of 0.4625g/min from 0.3503g/min without powder addition. The analysis of the result has shown that the MRR and surface finish improved due to CNT powder addition to dielectric.

Keywords: EDM, Carbon nanotube, Pulse on time, Surface roughness, MRR

INTRODUCTION

The die sinking EDM operates through the thermoelectric energy where it produces spark erosion for the shaping of geometries when submerging the workpiece and electrodes in dielectric fluid [1]. EDM is one of the machining techniques to remove materials irrespective of their hardness. EDM needs several components that are fundamental to its operations which are electrode, work piece materials, dielectric, and machining parameters [2]. The several commonly used dielectric fluids in EDM are oil, kerosene and distilled water where it is used to flush the molten material between the working components of the work piece and the electrode.

Many researchers are working on different powder materials added in dielectric fluid in EDM and investigating the outcomes produced. It was found that current and addition of CNT to dielectric fluid effect on surface roughness [3]. Several other machining parameters would affect the outcome when different variable applied in the machining. Also, it would affect the surface quality and machining performance such as tool wear rate (TWR) and material removal rate (MRR). It was reported that the addition of metallic powder in dielectric successfully decreased the surface roughness of Inconel 625 work piece [4] during RDM. The conductive powder particles enables the plasma channel to widen that results in less bubble trapped hence better surface finish is achieved.

Experiments were done by adding molybdenum (Mo) powder to the dielectric fluid with different particle sizes of 5 and 15 µm to the machine AISI H13 tool steel as the work piece [5]. Higher MRR and low electrode wear was reported by using powder added in dielectric fluid. Investigations were conducted with addition of manganese powder in the dielectric fluid to observe the changes happened to the work piece of OHNS die steel. Micro-hardness of the surface was improved due to addition of manganese. Significant changes were identified whereby the manganese and carbon percentage have been increased on the work surface which resulted in an improvement in micro hardness from 607 to 1,049.33 HV [6].

In the present work in variable parameters were pulse on time (Ton) and powder concentration. Other input parameters were kept constant. The output parameters were MRR and Surface roughness (Ra).

It was reported that the crucial quality of the products produced from EDM are the dimension, surface finish and the machining time. Some researchers have clarifies that the addition of powder into the dielectric fluid has successfully enhanced the MRR and the reduced surface finish. It was found that surface finished significantly affected by powder mixed concentration, current and pulse on time [7]. The micro hardness also affected by the increasing powder concentration, current and pulse on time. Different powder materials were used in the investigations like silicon, tungsten, and carbide. Experiments without the addition of powder material were also conducted which gave rough surface finish but the surface finished was improved by 50% with the concentration of 10mg/L. The presence of powder particles helped the distribution of the electrical discharge by bridging the discharge zone. This also controls the spark to be more uniform and increases the spark gap. The increasing of the spark gap reduces the force hitting the work piece that occurs in closer gap caused by the breakdown voltage resulting in the better surface finish on the surface of the work piece. The reduction of the impact force causes the small and shallow craters, therefore, better surface finish is produced. From the results obtained, it was said that the surface roughness increases as the current and pulse on time increases.

The volume of material removed from the work piece in one minute is called removal rate (MRR) which measured in gram per minute (g/min) [8]. The spark energy depends on current and voltage and heat absorption capacity of the work piece depends on pulse on time. MRR could be increased but it would affect the surface finish of the product. Higher MRR are obtained due to high current as the main parameter. In other words, a higher current would melt more material that this is due to the high energy of sparks.

Researchers investigated the effect of adding different powder materials into dielectric fluid and analyzed the outcomes. Different powder material possesses different material properties that would give different outcomes to the work piece. The dispersion of the powder initiates the distribution of the spark erosion which it increases MRR. Based on the results, aluminum powder achieved highest MRR compared to graphite and silicon powders. High concentration of powder is not desirable in EDM as is would be a disturbance accumulating and introduces electric arc.

METHODS

Materials

The workpiece material in this research work was austenitic stainless steel with the properties of stated in Table I. This type of stainless steel is most commonly used in the industries such as culinary, automotive bodies, and aircraft due to its easy forming, weldability, and thermal stability. The resistivity of corrosion of the material made it desirable for many applications. Copper and graphite are always said to be the common tool materials used in EDM. The electrode material used in the present work was Cu and its main properties are illustrated in Table II. In general powder addition to dielectric fluid EDM would give variety of outcomes accordingly to their properties. In the present study the material added to dielectric fluid was single walled carbon nanotube. Main properties of CNT were: specific gravity: 0.8 g/cm³; resistivity: 5-50 μΩ cm and thermal conductivity: 3000 W m⁻¹ K⁻¹.

Table I

PROPERTIES OF STAINLESS STEEL

Property	Value
Yield strength	30 ksi
Tensile strength	75 ksi
Percentage elongation	40%
Percentage reduction	60%
Hardness	187 HB

Table II

PROPERTIES OF TOOL ELECTRODE

Property	Cu
Chemical composition (%)	99.78
Electrical resistivity (μΩ m)	9
Melting point (°C)	1083
Density (g/cm^3)	8.96
Hardness (HB)	100

Experimental procedure

Experiments were conducted on the EDM die sinking type machine; Mitsubishi branded EX22, Model C11E FP60E. Square holes of 10mm x10mm were made on the work piece to a depth of 1 mm as shown in Figure 1. Machining was performed at current: 6 A and pulse off-time: (t_{off}): 9.0μs. Weight of the work piece was measured before and after each of the experiments. In order to keep the constant concentration of the CNT, the experiment was conducted in a steel container and the kerosene is flushed by separate air pressure around the container as shown in Figure 2. Surface roughness was measured using surface roughness measuring equipment Mitutoyo Surface test SJ-400. Experimental plan was done according to the software Design-Expert version 6.0.8. Design model indicates that there are 6 experiments to be conducted as shown in Table III.

Figure 1. Square hole on Stainless Steel

Figure 2. Usage of separate air pump in the container

Table III

MACHINING PARAMETERS

Parameters	Code	Level		
		I	II	III
Powder addition (mg/L)	A	0	0.3	-
Pulse On Time (μs)	B	6	7.5	10

RESULTS AND DISCUSSIONS

Experimental results are presented in Table IV. Figure 3 illustrates the effect of pulse on time and powder concentration on MRR. Effect of T_{on} on MRR is shown in Fig. 4. It can be observed that effect of powder concentration on MRR is very insignificant. However, increase in powder concentration results a little increase in MRR. Electrical discharges are broken down due to the presence of powders and results a uniform discharge of spark. As a result MRR increases a bit. But the effect of T_{on} on MRR is significant.

Table IV

EXPERIMENTAL RESULTS

t_{on} (μs)	Powder concentration (mg/L)	Machining Time	Surface roughness, R_a (μm)	MRR (g/min)
6		7min 45s	9.97	0.03785
7.5	No powder	3min 37s	15.08	0.1689
10		1min 55s	30.38	0.4265
6		11m 47s	8.61	0.0428
7.5	0.3	2m 3s	10.53	0.2029
10		1m 45s	29.40	0.3503

With increase in T_{on}, the workpiece gets a longer time to absorb heat energy. As a result more material is melted and vaporized and MRR is increased [9].

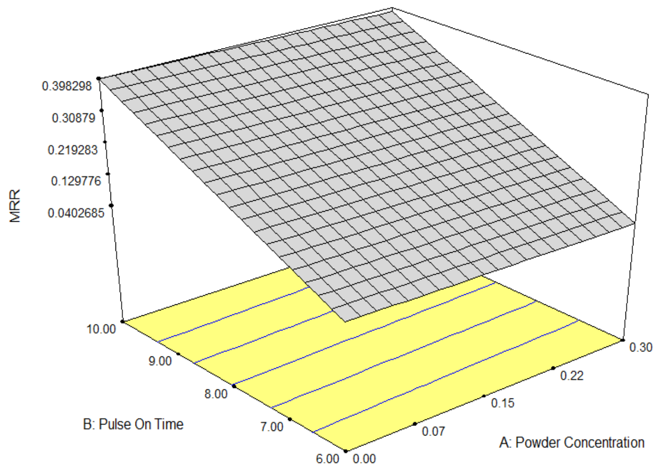

Figure 3. Effect of T_{on} on time and powder concentration on MRR

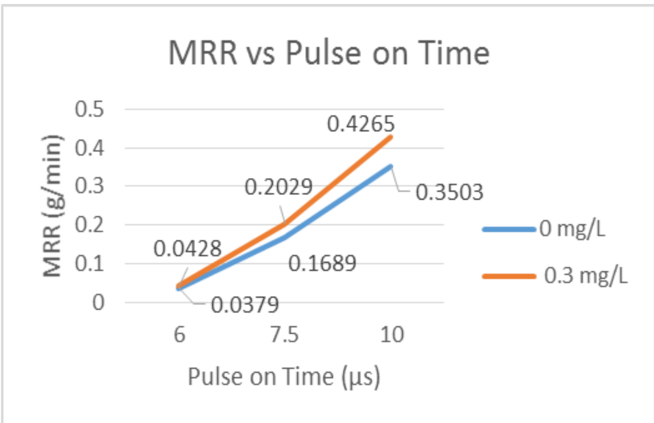

Figure 4. Relation of T_{on} on MRR

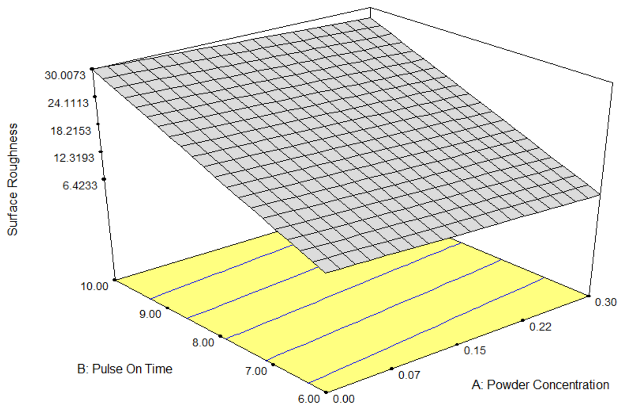

Figure 5. Effect of T_{on} on time and powder concentration on R_a

Effect of T_{on} and powder concentration on work surface roughness is shown in Figure 5 and Figure 6. It is to be noted that surface roughness is reduced as CNT powder concentration is increased.

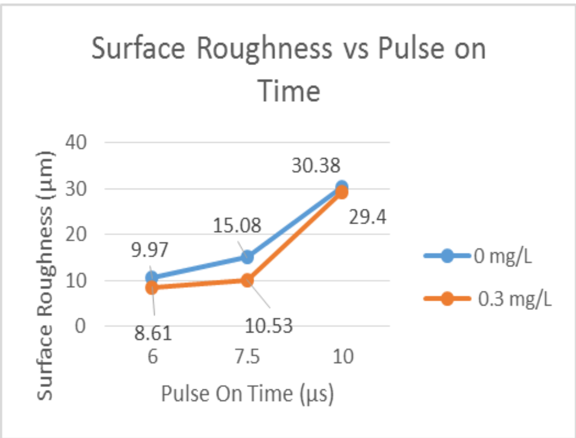

Figure 7. Relation of Surface roughness with pulse T_{on}

Due to the presence of CNT in the dielectric fluid the main spark is broken into small sparks and the heat energy is distributed more uniformly on the work surface. This results smoother work surface [10]. It can also be observed from Figure 4 that increase in T_{on} results rougher surface. When T_{on} is increased, workpiece gets more time to absorb heat energy. As a result the work surface is more stressed and a rougher surface is produced [11]. The smoothest surface (R_a 8.61µm) was produced with T_{on} of 6 µs and powder concentration of 0.3 mg/L.

CONCLUSION

The study of EDM has been conducted to analyze the effect of the addition of CNT on materials removal rate and work surface roughness. The results obtained showed that the addition of CNT in dielectric fluid has enhanced the MRR and produces better surface finish. The MRR increased from 0.0379g/min with no powder added to 0.0428g/min with powder addition of 0.3mg/L. Addition of CNT to dielectric fluid breaks the main spark into small discharges and the heat energy is distributed more uniformly. Hence MRR is increased. MRR also increases with increase in Ton. Due to increase in Ton the workpiece gets more time to absorb heat energy. Therefore, more material is melted and vaporized that increases MRR. The surface roughness also affected by powder concentration in dielectric fluid. The lowest surface roughness was obtained with the addition powder concentration of 0.3mg/L with the value of 8.61µm while no powder added results in higher surface roughness with the value of 9.97µm. As stated earlier, powder particles breaks the main spark into sparks and heat energy is uniformly distributed to the whole surface resulting a smoother surface. The highest value of surface roughness of 30.38µm is obtained when no powder added, but it reduced to 29.4µm when 0.3mg/L of CNT powder added.

ACKNOWLEDGEMENTS

The authors are grateful to Research Management Center, International Islamic University Malaysia (IIUM) for supporting the research work. Authors are also grateful to the colleagues and staff of MME Department, IIUM.

REFERENCES

[1] R.K. Garg, K.K. Singh, A. Sachdeva, V.S. Sharma, K. Ojha, S.Singh, Review of research work in sinking EDM and WEDM on metal matrix composite materials, *International Journal Advanced Manufacturing Technology*, Vol. 50, n. 1-5, pp. 611–624, 2010.

[2] N.M. Abbas, N. Yusoff, R.M. Wahab, Electrical Discharge Machining (EDM): Practices in Malaysian Industries and Possible Change towards Green Manufacturing, *Procedia Engineering*, Vol. 41, pp. 1684-1688, 2012.

[3] A.A. Khan, M.H. Hazza, E.Y. Adesta, N.F Mohd, Modeling the Effect of CNT Concentration in Dielectric Fluid on EDM Performance Using Neural Network. *2015 4th International Conference on Advanced Computer Science Applications and Technologies (ACSAT)*, doi:10.1109/acsat.2015.24, 2015.

[4] G. Talla, S. Gangopadhyay, C.K. Biswas, C. K. (2015). Effect of Powder-Suspended Dielectric on the EDM Characteristics of Inconel 625. *Journal of Materials Engineering and Performance*, Vol. 25, n. 2, pp. 704-717, 2015.

[5] F.L. Amorim, V.A. Dalcin, P. Soares, L.A. Mendes, (2016). Surface modification of tool steel by electrical discharge machining with molybdenum powder mixed in dielectric fluid. *The International Journal of Advanced Manufacturing Technology*, Vol. 91, n. 1-4, pp. 341-350, 2016.

[6] S. Kumar, R. Singh, T. Singh, B. Sethi, Surface modification by electrical discharge machining: A

review. Journal of Materials Processing Technology, Vol. 209, n. 8, pp. 3675-3687, 2009.

[7] A. Bhattacharya, A. Batish, N. Kumar, (2013). Surface characterization and material migration during surface modification of die steels with silicon, graphite and tungsten powder in EDM process. *Journal of Mechanical Science and Technology*, Vol. 27, n. 1, pp. 133-140, 2013.

[8] B.T. Long, N.H. Phan, C. Ngo, V.S. Jatti, (2016). Optimization of PMEDM Process Parameter for Maximizing Material Removal Rate by Taguchi's Method, *International Journal of Advanced Manufacturing Technology*, Vol. 87, n. 5-8, pp. 1929–1939, 2016.

[9] G.S. Brar, G. Mittal, Impact of Powder Metallurgy Electrode in Electric Discharge Machining of H-13 Steel, *Applied Mechanics and Materials*, Vol. *705*, pp. 34-38, 2014.

[10] M.R. Mhabgard, A.Gholipoor, H. Baseri, A Review on Recent Developments in Machining Methods Based on Electrical Discharge Phenomena. *International Journal of Advanced Manufacturing Technology*, Vol. 87, pp. 2081–20972016.

[11] H. Singh, A. Singh, (2012). Effect of Pulse On / Pulse Off Time On Machining Of AISI D3 Die Steel Using Copper and Brass Electrode In EDM, RESEARCH INVENTY: *International Journal of Engineering and Science*, Vol. 1, n. 9, pp. 19-22, 2012.