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Machining Properties Evaluation of Copper and Graphite Electrodes in PMEDM of SKD61 Steel in Rough Machining

Banh Tien Long, Ngo Cuong, Nguyen Huu Phan, Pichai Janmanee

Abstract - Electrode materials have a great impact on the productivity and quality of electrical discharge machining (EDM). This study investigated the material removal rate (MRR) and surface quality after EDM using powder mixed dielectric fluid (PMEDM). The chemical composition of the surface which affected the tool wear rate (TWR) was evaluated. Titanium powder, copper (Cu) and graphite (Gr) electrodes were used. Results showed that mixing titanium powder in the oil dielectric fluid significantly affected MRR, TWR and the quality of the machined surface using EDM. Titanium powder mixed in the dielectric fluid increased MRR, decreased TWR, surface roughness (Ra) and thickness of the temperature-affected machined area. The chemical composition and the surface profile changed in a positive direction and the microscopic surface hardness increased. Results indicated that PMEDM is a viable method to improve the productivity, accuracy and surface quality in EDM.

Keysword: EDM; PMEDM; MRR; TWR; H13.

I. INTRODUCTION

The introduction of EDM has resolved many limitations of traditional manufacturing methods in the machining of conductive materials which were difficult or impossible before to work into complex shapes. EDM uses very large heat energy (10,000 to 12,000) °C generated from the discharge sparks to melt and evaporate the workpiece. EDM therefore overcomes the negative influences in traditional manufacturing methods, which include vibration, deformation and mechanical stresses requiring hard tools. However, EDM has lower productivity and electrode wear and great influence on machining accuracy. The principle of this manufacturing method is that the workpiece surface features formed after EDM are altered in comparison with the substrate. Normally, the surface machined layer has reduced mechanical properties with microscopic cracks of varying depth. The surface is also undulating giving a poor fit for the working surface of the machine parts. Before use the surfaces after EDM require extra or super fine machining.

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Therefore, many methods have been tested to improve the surface quality after EDM, such as polishing and grinding. Thus, if it is possible to simultaneously improve the productivity and surface quality defects, limit the surface erosion and reduce electrode wear, then this will reduce machining time and increase machining accuracy. Recent studies in EDM technology showed that the use of metal or alloy powder mixed in the dielectric fluid generated surface machining with reduced undulation and also significantly improved surface quality. The number and depth of the microscopic cracks decreased, the thickness of the heat-affected zone decreased, the microscopic surface hardness increased and the surface topography was good. [1] P. Pecas et al. (2003) used 10 micron silicon powder mixed with oil dielectric fluid (Castrol SE 180) at a concentration of 2 g/l for machining SKD61 steel using the EDM electrode method with Cu in different sizes. Results indicated that the silicon powder and cross-sectional area of the electrodes affected the value and structure of the undulating surface machining. The undulating surface values ranged from 0.09 to 0.57 µm with a machining area of 1 to 64 cm^2. [2] P. Pecas et al. (2008) studied the effect on the machining surface area of 1 to 64 cm^2 with surface roughness (Ra) and the characteristics of the SKD61 steel surface after EDM with 10 µm silicon powder mixed in the dielectric fluid. The results showed that the undulating surface, the thickness of the white layer and the depth of the undulations were related to the surface area of the machined surface and could be described by a mathematical equation. [3] K. Furutani et al. (2001) studied the increased strength of the AISI 1049 steel surface by coating a surface layer of titanium carbide (TiC) with the EDM method. The titanium powder, 36 µm size was mixed in the electrolyte solution medium oil (EDF-K) with Cu electrodes of 1 mm diameter. The results showed that a TiC layer with thickness 150 µm and hardness 1600HV was created on the surface of the billet. [4] J. Simao et al. (2003) improved of the quality of the SKD61 steel surface using electrode materials with WC/Co turning and Taguchi design. Results indicated that the actual hardness of the surface layer of the billet increased from 640HK (0025) to 1319HK (0025). [5] K. Furutani et al. (2009) investigated the conditions forming the TiC coating with hardness of 2000 HV on the AISI 1049 steel surface by means of PMEDM. [6] S. Kumara et al. (2012) demonstrated a method to create a tungsten carbide (WC) coating on the surface of the mould steel, such as OHNS, D2 and SKD61 through the PMEDM method.

The results showed that the hardness of the microstructure surface of the steel increased by 100 % compared with the base material and that it is feasible to improve the reliability of forging moulds and stamping. [7] K. Furutani et al. (2002) applied EDM to produce a molybdenum disulphide (MoS2) coating on steel bearing surfaces and the undulating surface machining improved. [8] K. Furutani (2003) created a TiC coating with a hardness of 1900 HV through the PMEDM method. The Ti powder with size smaller than 38 µm was used in a dielectric of mixed oil (EDF - K). [9] V.S.Ganachari et al. (2013) used the Taguchi method combined with the gray relational analysis (GRA) method to optimise some parameters of PMEDM technology. Aluminium (Al) and silicon carbide (SiC) powders were mixed in the dielectric fluid and the parameters of PMEDM technology were used to achieve the best quality surface machining. [10] Ved Parkash et al. (2013) mixed Cu powder with graphite powder in the dielectric fluid which significantly reduced the erosion of the electrodes. TWR with graphite powder declined compared to the Cu powder. The reduction of electrode erosion contributed to increased durability of the electrode and improved the machining accuracy. [11] Khalid Hussain Syed et al. (2013) used Al powder mixed in pure dielectric fluid water to machine mould steel W300 with EDM. They found that variable white layer thickness (WLT) on the surface of the billet did not decrease compared with machining without powder in the solution. When the amount of powder increased, the variable white layer thickness decreased. [12] B. Govindharajan et al. (2014) showed that mixed powder with Gr and Ni in the dielectric fluid using the EDM method increased the productivity of dissection materials (MRR), decreased TWR, and the precision machining and quality of the machined surface was enhanced. [13] Gurtej Singh et al. (2014) used Al powder mixed in the dielectric fluid at different concentrations to examine the changes in the SKD61 steel surface roughness after processing by EDM. Results showed that the addition of Al powder in the dielectric fluid reduced the surface roughness values and higher concentrations of the powder led to a decrease in the undulating surface values. [14] The authors studied the effect of tungsten powder mixed in the dielectric fluid in the EDM method on the OHNS steel surface quality after machining. Results showed that a large amount of tungsten powder (up to 2.89 % from 0.25 %) mixed in the dielectric fluid entered the machining surface and increased the hardness of the microscopic surface by 100 %. This increased the durability of the worn surface machining. [15] Vipin Kumar et al. (2014) showed that changes in the powder material and the size of the powder have a strong influence on MRR and Ra in EDM machining of EN31 steel. They expanded the influence of a variety of materials and their concentrations on the productivity and quality of surface machining. [16] M.A. Razak et al. (2015) compared the influence of the concentration and size of SiC powder mixed in the dielectric fluid on MRR, TWR and Ra in EDM. Compared with machining by EDM, the productivity and quality of surface machining in PMEDM increased with reduced machining time. [17] Bleys et al. (2006) attained an undulating surface of Ra less than 1µm with small sparks of energy and reversed polarity. In reverse polarity, the electrodes are affected by the heat generated from the sparks in a larger billet. [18] N. Mohri (1991) introduced the method of manufacturing the mould surface without using additional machining methods by hand (polishing, grinding, etc.). These research results showed that the quality of the machined surface was significantly improved using PMEDM. This study investigated the influence of the concentration of titanium powder mixed in the oil dielectric fluid on the quality of SKD61 steel surface after EDM. The characteristic elements of surface quality, such as MRR, TWR, Ra, the heat-affected zone thickness, hardness of the surface microstructure, chemical composition and surface profile were measured. The addition of the powder material mixed in the dielectric fluid and the effect of the electrode materials on the surface after EDM were also assessed.

II. EXPERIMENTAL PROCEDURE

The experiments were conducted using the electrical discharge machine model CNC-AG40L from Sodick, Inc. USA at The Central Laboratory of Thai Nguyen University of Technology. The material used for the workpiece was SKD61 (Japanese Industrial Standard) hot-die steel that is used extensively for hot-forged dies. The constituents of the steel, as determined by chemical analysis, were: 0.40 % C, 0.47 % Mn, 0.98 % Si, 0.14 % Ni, 4.90 % Cr, 0.83 % V, 1.15 % Mo, 0.016 % Co, 0.00012 % S, 0.018 % P, and the balance was Fe. The workpiece dimensions were 45 × 27 × 5 mm^3 (L x W x H). Before machining, the raw material had a microhardness of 490–547 HV. The tool materials selected were titanium and copper. The two electrodes had the shape shown in Figure 1. Copper and graphite have excellent electrical and thermal conductivity and both are major commercial materials. The powder material chosen was titanium at 45 µm grain size, shown in Figure 2. Titanium compounds have been applied extensively as materials for surface modification because of their hardness, abrasion resistance, high melting point and low coefficient of friction. The dielectric fluid used was HD-1. To avoid the wastage of kerosene oil, a small dielectric circulating system was designed as shown in Figure 3. A tank of size 330 mm × 180 mm × 187 mm was made of 3 mm thick mild steel with a capacity of 9 litres. The tank was installed in the EDM machine as shown in Figure 4. An air motor rotating at 100 rpm was used in the tank to prevent the particles settling. A micro pump (model A303 from China) was installed in the system for better circulation of the powder mixed dielectric fluid. To ensure constant reuse of the powder mixed dielectric fluid, magnets were used to separate the powder particles from the debris produced by the machining. These parameters for the experimental work were selected on the basis of results from previous research. Machining parameters are shown in Table 1. The following material parameters were studied during the course of this experiment: material removal rate, chemical composition, microstructure, surface hardness, surface roughness and surface appearance. Three readings were taken for each work specimen to compute the final, average measurement. Surface roughness was measured using a portable SJ-301 machine from Mitutoyo, Japan. A precision balance measured the weight of the workpiece and the electrode before and after the machining process (model vibra AJ-203 shinko max 200 g /d = 0.001 g, Japan). After EDM, the samples were cleaned and the cross-section of the die-sink surface machined. An optical microscope was used to study the change in the microstructure of the surface after EDM.

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The analysis was carried out on six samples using a scanning electron microscope (SEM, model JSM 6490, JEOL, Japan). The surfaces of the samples were cleaned prior to SEM analysis at three different magnifications: 100x, 500x and 1000x. To analyse the phase composition of the surfaces, selected workpieces were examined with an X-ray diffractometer (XRD) over a 2θ range from 5° to 85° using a model Axiovert 40MAT from Carl Zeiss, Germany. Microhardness was measured with a microhardness tester (model Indenta Met 1106) from Buehler, USA. The chemical compositions of the machined surfaces were analysed using energy-dispersive X-ray spectroscopy (EDS, model JSM – 6490LA, JEOL, Japan).

Figure 1. Electrodes used in this research

Figure 2. Titanium powder

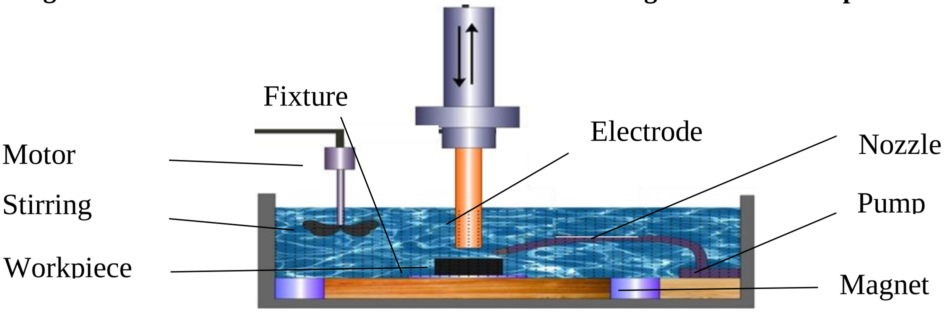

Figure 3. Schematic diagram the experimental setup

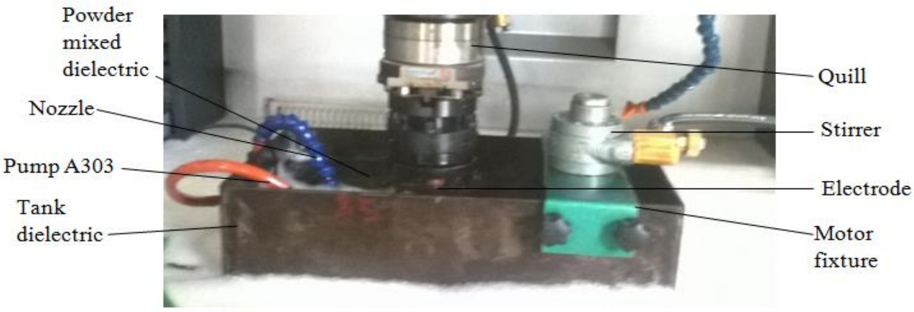

Figure 4. Experimental setup

Table 1. Machining conditions

Variable	Set-up	
Intensity of discharge(A)	15	
Pulse-on time(µs)	50	
Pulse-off time(µs)	85	
Dielectric	HD-1	
Polarity	Copper	Positive and negation (EDM process)
	Graphite	Positive (EDM process)
Machining time	15’	
Voltage of discharge (V)	150	
Tool material	Copper, Graphite (Ø25mm)	
Flushing	10 liters/min	
Powder	Titanium: - grain size 45µm. - concentration 0, 5, 10, 15, 20 g/l.	

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III. RESULTS AND ANALYSIS

3.1. Material removal rate (MRR)

Material dissection productivity is the most important parameter in roughing. It affects the machining time. Equation 1 was used to determine the MRR value:

$$MRR = \frac{W_i - W_f}{\rho_T . t} .1000 mm^3 / \min \quad (1)$$

Where

W_i – Initial weight of workpiece material (g)

W_f – Final weight of workpiece material (g)

t – Time period of trails in minutes (t = 15 min)

ρ_T – Density of workpiece material (ρ_T = 7.81g/cc)

Table 2. Results for material removal rate

Trial no	MRR (mm³/min)			Concetrations (g/l)
	Cu		Gr	
	+	-	+	
1	0.747	0.657	30.089	0
2	0.896	0.734	93.918	5
3	1.438	0.837	136.203	10
4	1.660	0.948	150.672	15
5	1.699	1.304	174.263	20

Table 2 shows that the graphite electrode produced maximum MRR followed by the positive polarity copper electrode. The lowest was the negative polarity copper electrode processed without powder mixed in the dielectric fluid. MRR using graphite electrodes was much higher than the copper electrodes. With no powder mixed in the dielectric fluid, the MRR using graphite electrodes was 40 times larger than the reverse polarity Cu and 45.8 times higher than the straight Cu. The conductive titanium powder mixed dielectric fluid increased the material dissection productivity. EDM with graphite powder mixed in the dielectric fluid increased MRR by 474.1 % at 20 g/l compared with no mixed powder. With powder mixed dielectric fluid, the MRR maximum of the graphite electrode increased compared with the copper electrode (20 g/l). It was 102.57 times higher than the reverse polarity Cu and 133.61 times higher than the straight Cu polarisation.

3.2 Machine surface roughness

The undulating surfaces were examined with the two types of electrode materials, Cu and Gr. Cu is often used to make crystal electrodes using both straight and reverse polarity. The results are shown in Figure 5.

With no powder mixed in the dielectric fluid, the undulating surface machining values using the Gr electrode were the largest, followed by Cu (+) with the smallest Cu (-). With powder the undulating surface topography was reduced. Increasing the power concentration decreased the Ra. The Ra reduction using graphite electrodes was larger than Cu. For reverse polarity, the effect of the powder was greater than with straight polarity.

Negative electrode polarisation gave reduced undulating surface values compared with positive polarity for both Cu and Gr. The smallest Ra (Ra_{min}) was 2.54 µm. Table 2 shows MRR and Ra values for positive electrode polarity with Ti powder mixed in the dielectric fluid at concentrations of 0 to 10 g/l. Gr electrodes gave more efficient machining. For improved surface machining quality, it is advisable to choose a negatively polarised copper cathode. The graph shows that the concentration of powder (0 to10) g/l has the most influence on Ra. Increasing the concentration of powder reduces the slope of the graph, thereby reducing the influence of the Ti powder on Ra.

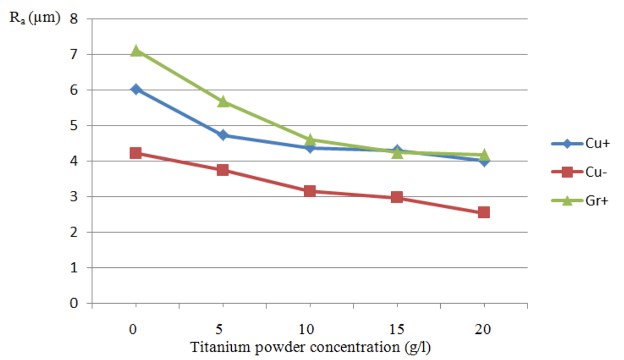

Figure 5. Variation of R_a with titanium powder concentrations

3.3 Topography of the machined surface

The machine surface is a collection of many craters (Figure 6). A larger number of craters were produced using copper electrodes than with graphite electrodes, both with and without powder mixing. The diameter and depth of the craters using graphite electrodes was larger than with copper. The negative polarity copper electrode showed larger diameter and depth of craters than with reverse polarity.

With powder mixed in the dielectric fluid the number of craters increased, while the diameter and depth decreased. Increasing the concentration of powder increased the number of craters, while the diameter and depth decreased. This resulted in increased surface smoothness. The shape at the mouth of the craters was curved with a radius r (Figure 7). This created a surface shape with reduced stress concentration at the top and bottom of the undulations, resulting in increased strength of the surface.

Cracks appeared on the microstructure surface after EDM. Mixing powder in the dielectric fluid reduced the microscopic cracks. Craters and microscopic cracks appear distributed on all surface machining. They create a detailed fatigue resistant profile surface with easy lubrication caused by the subtle cracks. This creates favourable conditions for the lubricant to be retained and kept on the machined surface, especially as detailed working conditions always require continuous lubrication. The highest surface quality was produced with straight copper electrodes.

More machining metal particles in a spherical shape appear in the surface as shown in Figure 7. This is because the molten metal and the solution evaporated are cooled down and adhere on the surface machining. The number of the particles on the surface appear more when machining without powder mixed in dielectric fluid and the number of the particles in the mixed powder and solvent decreases with the increasing of the concentration of powder. The metal particles will increase machining surface roughness.

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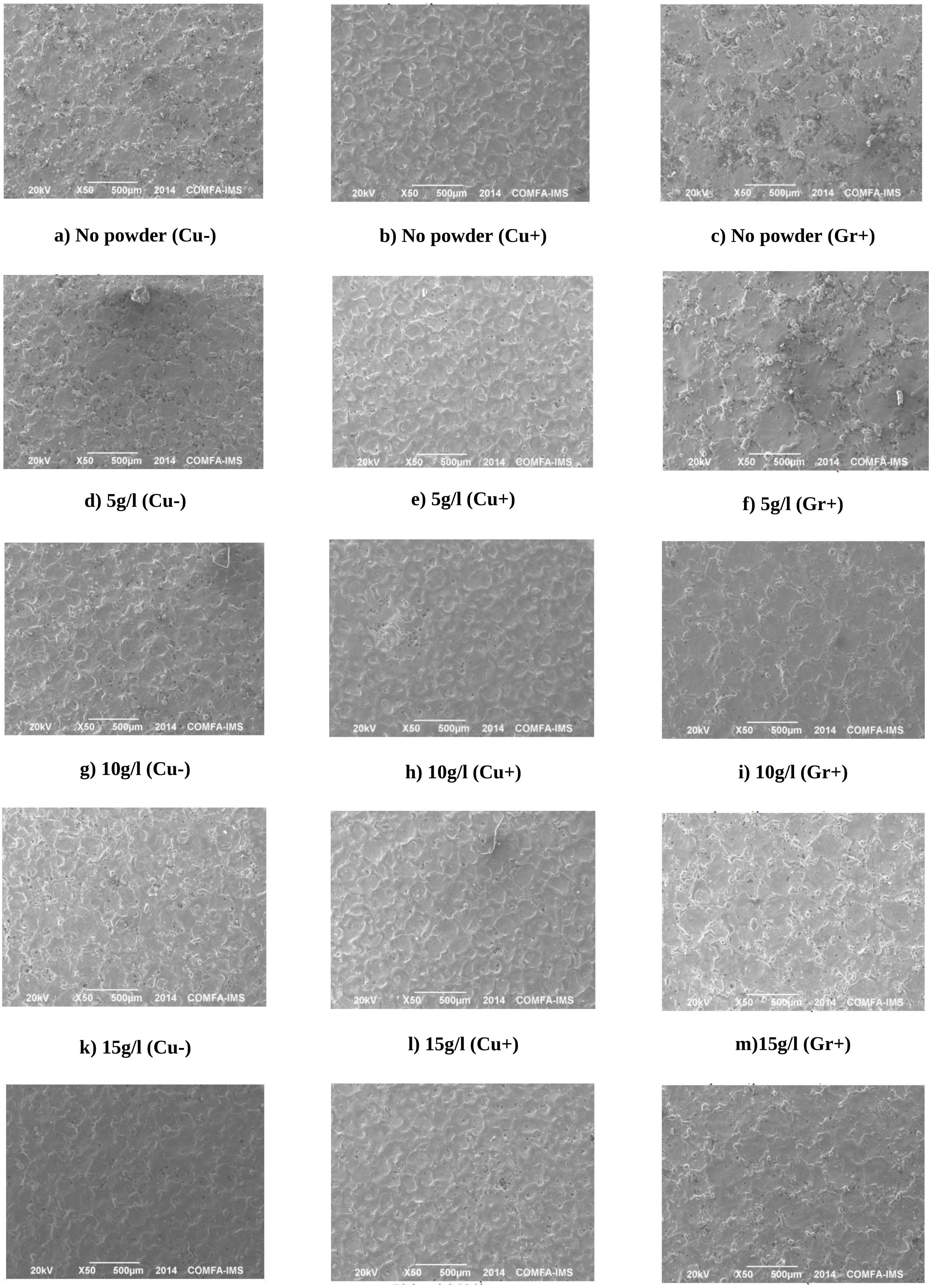


a) No powder (Cu-) b) No powder (Cu+) c) No powder (Gr+)

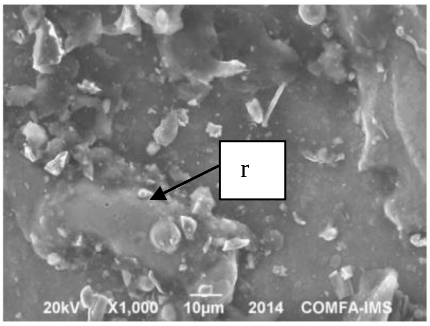
d) 5g/l (Cu-) e) 5g/l (Cu+) f) 5g/l (Gr+)

g) 10g/l (Cu-) h) 10g/l (Cu+) i) 10g/l (Gr+)

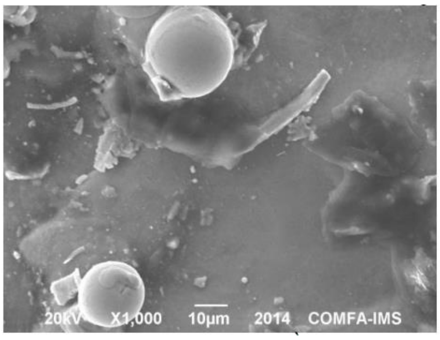
k) 15g/l (Cu-) l) 15g/l (Cu+) m)15g/l (Gr+)

n) 20g/l (Cu-) e) 20g/l (Cu+) p) 20g/l (Gr+)

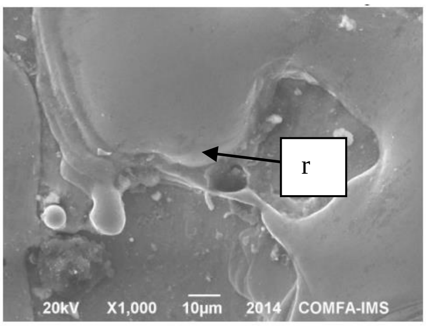
Figure 6. Topography of machined surface



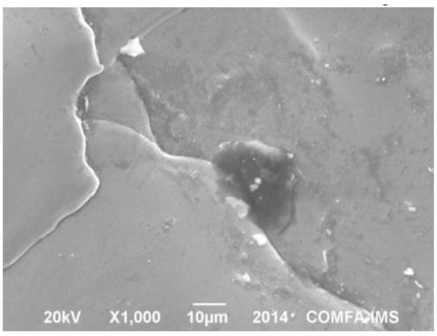
a) No powder (Gr+)



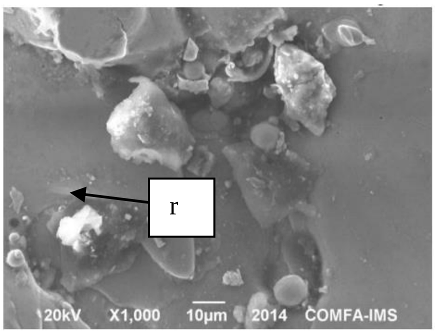
b) 5g/l (Gr+)



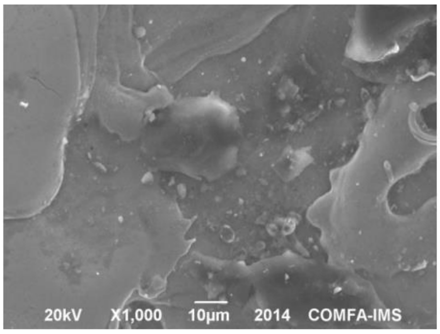
c) No powder (Cu-)



d) 5g/l (Cu-)



e) No powder (Cu+)



f) 5g/l (Cu+)

Figure 7. Microstructure of machine surface

3.4 Surface layer after EDM

The surface layer after EDM was divided into three classes: the white layer, the heat-affected layer and the substrate as shown in Figure 8. Both with and without powder mixed in the dielectric fluid and using graphite electrodes, the white and the heat-affected layers had greater impact than with the copper electrodes. Straight copper electrode polarity generated a thicker heat-affected layer than reverse polarity.

Figure 9 shows that the thickness of the layers decreased with powder in the dielectric fluid. The powder increased the number of sparks generated in a single pulse and reduced the thermal energy of each spark impacting on the machining surface. The white layer showed reduced thickness and more even distribution with powder mixed in the dielectric fluid. The sparks had uniform density over the entire surface with even thermal energy pulses on the surface of the material. With titanium powder mixed in the dielectric fluid the surface and white layers were stronger using copper electrodes than with graphite and fewer voids appeared inside the white layer. This negatively affected the workability of the surface of the material after EDM.

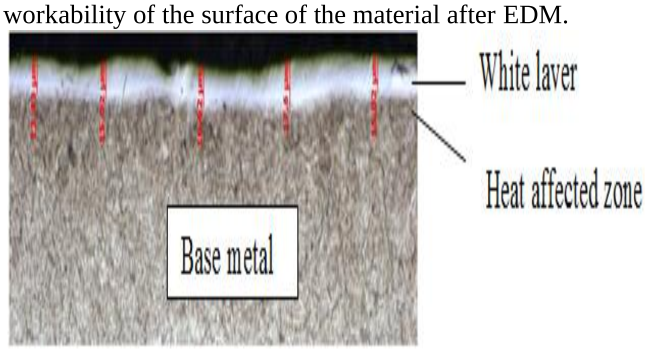


Figure 8. The different layers formed on the EDMed surface

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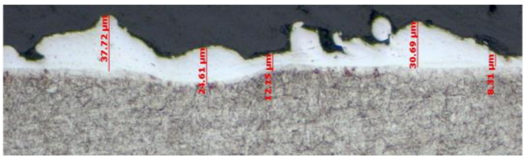
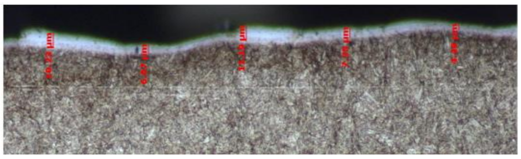
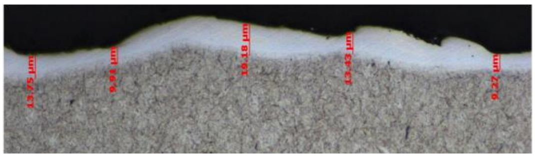


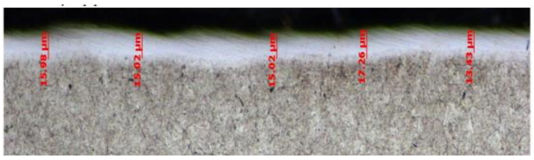
a) Gr+ No powder (t_{min}= 8.31 µm, t_{max}= 22.69µm)



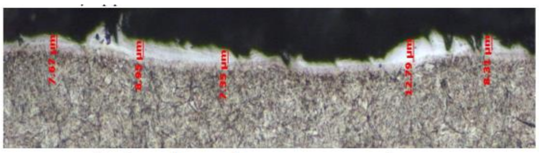
b) Gr+ 5g/l (t_{min}= 4.48 µm, t_{max}= 11.19 µm)



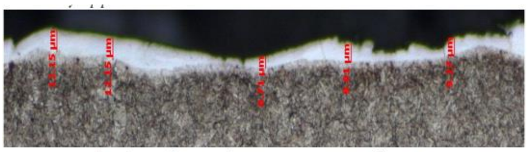
c) Cu- No powder (t_{min}= 9.27 µm, t_{max}= 19.18 µm)



d) Cu-5g/l (t_{min}= 13.43 µm, t_{max}= 17.26 µm)



e) Cu+ No powder (t_{min}= 7.67 µm, t_{max}= 12.79 µm)



f) Cu+ 5g/l (t_{min}= 6.71 µm,t_{max}= 12.15 µm)

Figure 9. Layers of machine surface after EDM

3.5 Chemical composition of the machined surface layer

Figure 10a shows that the percentage of carbon (C) in the surface after EDM increased, especially when using graphite electrodes. This can be explained by the cracking of carbon from the oil dielectric fluid and the eroded graphite electrode material entering the machining surface. The percentage of C in the surface using graphite electrodes with no powder showed a maximum of 36.99 %. The percentage of C in the surface layer decreased with powder mixed into the dielectric fluid as the reduced thermal energy of the sparks curtailed the cracking of the oil. However, there was no significant reduction in the carbon electrode with copper. This may indicate that the influence of the titanium powder on the oil dielectric fluid cracking was not great. EDM using graphite electrodes with titanium powder mixed in the dielectric fluid decreased the percentage of C in the surface layer with reduced electrode erosion. Increasing the concentration of titanium powder resulted in decreased carbon in the surface machined layer and the graphite electrode erosion reduced.

The surface after machining contained titanium (Figure 10b). This is because the titanium powder was melted by the sparks, it evaporated and entered the machining surface. A higher concentration of titanium powder increased titanium in the surface layer. EDM with a straight Cu electrode produced the highest titanium surface penetration. The titanium in the surface layer after EDM gave higher micro-hardness, corrosion resistance and abrasive strength. Figure 11 shows that EDM electrodes with titanium also lead to a significant amount of material entering the electrode surface machining (Ti = 1.58 %). However, titanium powder mixed in the dielectric fluid in EDM penetrate the machining surface to a larger extent with uniform distribution over the surface than EDM with titanium electrodes (Figure 12 a, b). Therefore, the use of titanium powder mixed in dielectric fluid leads to more even durability and hardness in the surface machining. However, Figure 13 shows that TiC did not form on the surface machining layer.

Figure 10c shows that EDM with Cu electrodes and reverse polarity without powder mixed in the dielectric fluid caused a greater amount of copper material to enter the machined surface than with straight polarity. This indicated that EDM with reverse polarity electrodes gave greater electrode wear than with positive polarity and affected the precision of the machining. The amount of copper material appearing in the surface layer reduced using a straight copper electrode. With reversed polarity, the slope of the graph indicated a greater influence from the titanium powder mixed in the dielectric fluid. The erosion of the Cu electrode decreased as the titanium powder concentration increased from 0 to 10 g/l.

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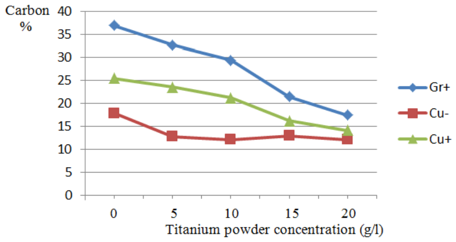
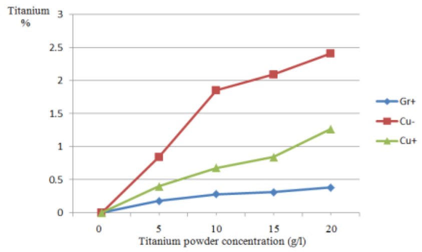
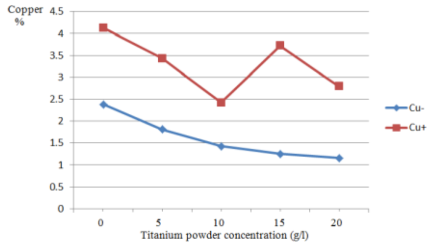


a) Graph %C



b) Graph %Ti



c) Graph %Cu

Figure 10. The permeability of carbon, titanium and copper into machine surface.

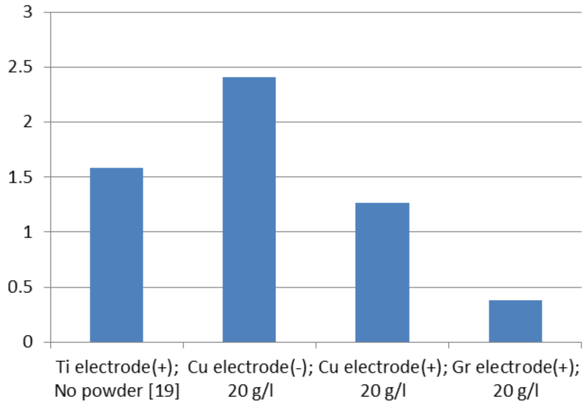
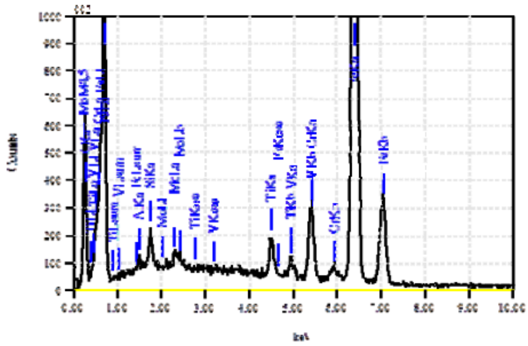
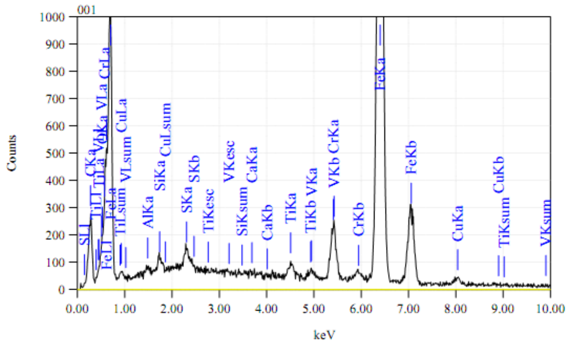


Figure 11. Titanium chemical in machine surface



a) Titanium Electrode [19]



b) With titanium powder (5g/l)

Figure 12. The distribution of titanium on the machine surface

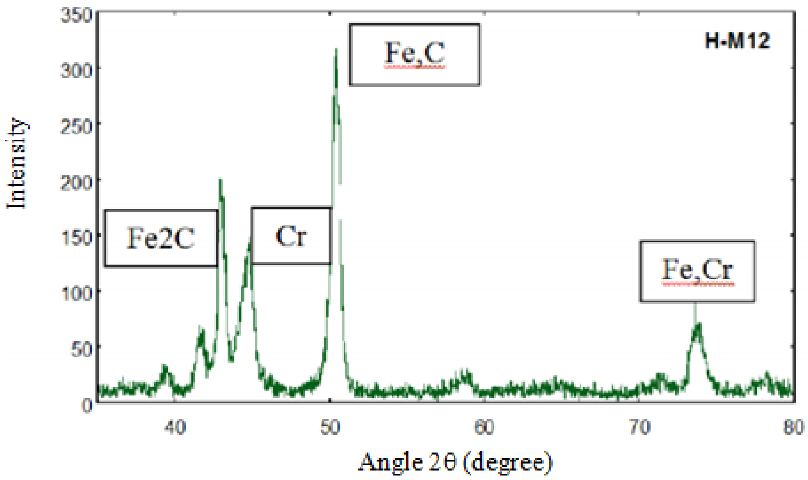


Fig. 13. XRD patterns of the machined SKD61 steel

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3.6 Microhardness of the machined surface

The microhardness of the mould steel surface after machining greatly influences efficiency and workability. Increased microhardness results in better corrosive and abrasive strength and reduces deformation. This increases the working life and accuracy of the mould.

Table 3 and Figure 14 show the microhardness of the lowest white layer as (502.0 to 549.3) HV. The microhardness of the base metal was higher and the microhardness of the heat affected zone (HAZ) was the highest (568.2 to 638.6) HV with no Ti powder. This shows that the white layer has inappropriate properties for the workability of SKD61 steel. The HAZ has good impact on the working conditions of the mould. Therefore, for precision moulds, it is preferable to remove the white layer to expose the HAZ.

When titanium powder was mixed in the dielectric fluid the white layer microhardness increased. The white layer has the highest microhardness of the three layers in the machined material. This is explained by the entry of titanium powder and carbon mixed in the dielectric fluid. With concentrations of titanium powder greater than 10 g/l, the slope of the graph reduced with no significant increase in machined surface microhardness. The highest microhardness of the white layer was 660.2 HV. The white layer had a porous microstructure and some microcracks appeared [20]. This increased the storage capacity of the lubricant on the work surface and the microhardness and the worklife of the mould increased, especially for work in conditions of wet friction lubrication.

Table 3. Micro-hardness of surface layers after PMEDM

Electrode materials	Polarity	Concentrations (g/l)	Micro hardness of surface layers (HV)		
			White layer	HAZ	Base metal
Cu	+	0	549.3	638.6	557.4
		5	610.3	609.4	561.9
		10	653.6	593.7	556.6
		15	655.3	598.7	526.7
		20	652.5	603.0	569.2
	-	0	526.4	568.2	560.7
		5	620.5	628.1	577.0
		10	651.3	579.4	556.6
		15	660.2	628.6	561.6
		20	662.0	623.9	564.9
Gr	+	0	502.0	591.0	554.7
		5	602.8	596.0	508.7
		10	624.3	575.6	540.1
		15	650.9	620.5	571.9
		20	653.7	598.2	581.6

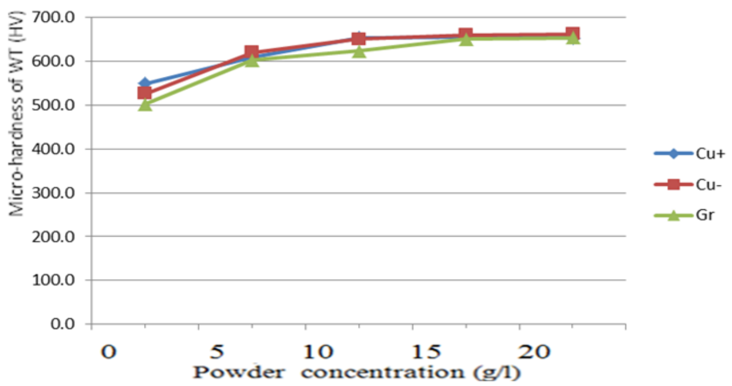

Figure 14. Powder concentration and micro-hardness at constant machining variables.

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IV. CONCLUSIONS

In rough machining by EDM, graphite electrode material produces better machining efficiency than copper. Reverse polarity gives higher productivity than straight polarity. Titanium powder mixed in the dielectric fluid at suitable concentration improves the dissection productivity of the material, increases surface quality and surface machining, and reduces electrode erosion. This improves productivity and accuracy, and also reduces machining time in parts manufacturing.

Titanium powder mixed in the dielectric fluid increases MRR; this is very beneficial for roughing. However, titanium has a high material cost and more research is required to find other suitable cheaper materials.

The SKD61 steel surface changes positively after EDM. Ra, HAZ and the number of microscopic cracks decrease. This reduces the cost of refined manufacturing methods, particularly in the machining of smaller surface holes.

The intrusion of titanium powder and carbon materials from the solvents and the electrode material into the surface layer of the billet changes the physical properties and chemical composition of the surface layer after EDM. A new research trend, using PMEDM and combining suitable electrode materials with powder materials (powders and electrode materials are titanium or tungsten) to improve the quality of the material surface has recently gained importance.

This study results showed improved machining capacity and surface quality. However, the study was carried out with rough surface machining of small sizes and simple shapes. This did not fully reflect the effect of machining by PMEDM in EDM. More studies using refined PMEDM and larger surface areas with complex shapes are required. The study was carried out with PMEDM to understand the mechanism of machining and how the interaction of the particles in the powder form sparks, especially relating to the uniformity of the powder particles in the solvent. The problems with modelling and optimising the machining parameters for the output conditions of this field are very limited. There is now a new research trend in PMEDM. Designing powder stirring systems and chip filters for industrial EDM machines is very complicated, especially the manufacturing of specialised PMEDM machines. This is a new research area which will greatly expand in the future.

REFERENCES

[1] P. Pecas, E. Henriques, *Influence of silicon powder-mixed dielectric on conventional electrical discharge machining*, International Journal of Machine Tools & Manufacture 43, 2003, P.1465–1471.

[2] P. Pecas and E. Henriques, *Effect of the powder concentration and dielectric flow in the surface morphology in electrical discharge machining with powder-mixed dielectric (PMD-EDM)*,International journal advance manufacturing technology, Vol. 37, (2008), P. 1120–1132

[3] K. Furutani, A. Sanetoa, H. Takezawaa, N. Mohri, H. Miyakeb, *Accretion of titanium carbide by electrical discharge machining with powder suspended in working fluid,* Precision Engineering Journal of the International Societies for Precision Engineering and Nanotechnology 25, 2001, P.138–144.

[4] J. Simao, H.G. Lee, D.K. Aspinwall, R.C. Dewes, E.M. Aspinwall, *Workpiece surface modification using electrical discharge machining,* International Journal of Machine Tools & Manufacture 43, 2003, P.121–128.

[5] K. Furutani, H. Sato, M. Suzuki, *Influence of electrical conditions on performance of electrical discharge machining with powder suspended in working oil for titanium carbide deposition process,* Int J Adv Manuf Technol, 2009.

[6] S. Kumara, U. Batra, *Surface modification of die steel materials by EDM method using tungsten powder-mixed dielectric*, Journal of Manufacturing Processes 14, 2012, P.35–40.

[7] K. Furutani, K. Shiraki, *Deposition of lubricant layer during finishing process by electrical discharge machining with molybdenum disulphide powder suspended in working fluid,* JSME/ASME International Conference on Materials and Processing, 2002, P. 468–473.

[8] K. Furutani (2003), *Electrical Conditions of Electrical Discharge Machining with Powder Suspended in Working Oil for Titanium Carbide Accretion Process*, Proceedings of International Conference on Precision Engineering (ICoPE03/04), 2004, P. 532–538, Singapore.

[9] V. S. Ganachari, M. V. Kavade, S. S. Mohite, *Effect of mixture of Al and SiC powder on surface rounghness in PMEDM using Taguchi method with GRA optimization,* Int. J. Adv. Engg. Res. Studies II, 2013, P. 04 – 07.

[10] V. Parkash, D. Kumar, *Effect of Powder Mixed Dielectric Medium on Tool Wear Rate in EDM, IJSR - International journal of scientific research*, Vol 2, Issue 2, 2013.

[11] K. H. Syed, P. Kuppan, *Studies on Recast-layer in EDM using Aluminium Powder Mixed Distilled Water Dielectric Fluid*, IJET, Vol 5, 2013, 1775-1780.

[12] B.Govindharajan, P.Meivel, C.Chelladurai, K.Avinaash, *Performance and Analysis of Nickel Mixed Kerosene*. *Servotherm in EDM of Monel 400TM*, Journal of Innovative Research and Solution (JIRAS)- A unit of UIIRS, Vol 1, No.1, 2014.

[13] G. Singh, P. Singh, G. Tejpal, B. Singh, effect of machining parameters on surface roughness of SKD61 steel in EDM process using powder mixed fluid, International Journal of Advanced Engineering Research and Studies,Vol. 2, 1, 2012, P148-150.

[14] K. N. Khedkar,T. P. Singh, S. V. Jatti, *Material migration and surface improvement of OHNS die steel material by EDM method using tungsten powder-mixed dielectric*, WSEAS Transactions on Applied & Theoretical Mechanics, Vol. 9, 2014.

[15] V. Kumar, Mr. Rajpal, M. Singh, *Experimental Study of Surface Parameters of EN31 on Powder Mixed EDM using Taguchi Methodology*, International Journal for Scientific Research & Development, Vol. 2, Issue 07, 2014.

[16] M. A. Razak, A. M. A. Rani, A. M. Nanimina, Improving EDM Efficiency with Silicon Carbide Powder-Mixed Dielectric Fluid, *International Journal of Materials, Mechanics and Manufacturing, Vol. 3, 1, 2015.*

[17] P. Bleys, J.-P. Kruth, B. Lauwers, B. Schacht, V. Balasubramanian, L. Froyen, J. Van Humbeeck, Surface and sub-surface quality of steel after EDM, Advanced engineering materials, Vol 8, 2, 2006, P.15-25.

[18] N. Mohri, N. Saito, M. Higashi, N. Kinoshita, *A New Process of Finish Machining on Free Surface by EDM Methods*, Annals of the CIRP, Vol. 40, 1991, P. .

[19] Banh Tien Long, Ngo Cuong and Nguyen Huu Phan, *Experimental Investigations of Hot Forging Die Surface Layer of Skd61 Steel in Die Sinking Electrical Discharge Machining*, Journal of Materials Science and Engineering B 4 (8) (2014) 226-231.

[20] L. C. Lee, L. C. Lim, V. Naryanan, V. C. Venkatesh, *Quantification of surface damage of tool steels after EDM*, International Journal of Machinery Tools &Manufacture, Vol 28, 1987, P. 359–372.

[21] B. T. Long, N. Cuong, N. H. Phan, N. D. Man, P. Janmanee, *Effects of Titanium Powder Concentrations during EDM Machining Efficiency Of Steel SKD61 Using Copper Electrode*, International Journal of Advance Foundation And Research In Science & Engineering (IJAFRSE), Volume 1, Issue 7, December 2014, P. 9 -18.

[22] B. T. Long, N. Cuong, N. H. Phan, *Study on surface material layer quality of SKD61 die sink in Electrical discharge machining using titanium electrode in oil dielectric fluid*, The 15th International Symposium on Eco-materials processing and Design - ISEPD2014.

[23] B. T. Long, N. Cuong, N. H. Phan, H. A. Toan, P. Janmanee, *Enhanced material removal rate and surface quality of SKD61 steel in electrical discharge machining with graphite electrode in rough machining*, International Journal of Scientific Engineering and Technology, Vol 4, 2, 2015, 103-108.

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