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EFFECT OF ELECTRICAL DISCHARGE FOR SURFACE CHARACTERISTIC INVESTIGATION IN WIRE ELECTRICAL DISCHARGE MACHINING OF COBALT CHROMIUM ALLOY

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ABSTRACT

Cobalt chromium alloys have attracted great interest. Cobalt chromium alloy processes excellent properties such as high strength, high corrosion resistance, and high biocompatibility. Therefore, the use of Cobalt Chromium is limited due to a cutting process. Non traditional equipments, such as wire electrical discharge machining (WEDM), are necessarily required for precise cuts and that is why, wire electrical discharge machining (WEDM) is preferred by most modern manufacturing industries. Despite high demand, the WEDM mechanism is relatively complex. Hence, the special trimming tool was introduced to maximize WEDM performance. The effect of process parameter variations peak current (IP) was determined by machining characteristics of CoCr alloys. Mechanism of material removal was correlated with machining conditions. Peak current process parameters were undertaken in this study. Results was that peak current was the dominant factor offering optimum responses in MRR, when the surface roughness (R_a), reduced.

KEYWORDS: *Wire Electric Discharge Machining (WEDM), Cobalt-Chromium (CoCr), Material Removal Rate, Surface Roughness (R_a), Peak Current (Ip)*

INTRODUCTION

Cobalt chromium (CoCr) alloy has been commonly used for an extensive range of applications, covering from engineering components like gas turbines to prosthetic and orthopedic implants (Mohd, 2016; Sreenivasa, 2013). Wire Electrical Discharge machine with electric arc can cut through the hardened work pieces or pieces that are difficult to process and also the workpieces that are difficult to cut. "Wire Electrical Discharge Machining" (W-EDM) is a process that uses the principle of electromagnetic induction by releasing the electric current through the electrode rods with a brass wire electrode. WEDM will simply cause the metal to evaporate, leaving little debris and providing a very accurate line. Each factor of discharge generates a lot of heat transfer of material.

Cobalt chromium alloy work piece was used in this study with the absence of carbide. Heat generated by carbide during the metal cutting process has great impact on the life time and surface integrity. Thus, the arc wire was used in cutting and milling machine (Mohd, 2016). This study aimed to investigate the optimal parameters for cutting cobalt chromium alloy and the performance of the WEDM process at different electrical discharge current. The influence of discharge current on surface quality and MRR was also studied

Material and Method

The experiments were carried out on Mitsubishi FA10S. The experimental setup is shown in figure 1. Cobalt chromium was used as work piece material for investigations. The chemical composition of cobalt chromium alloy % by weight is given in Table 1. And table 2 showed mechanical properties of CoCr alloy. The wire electrode was 0.25mm diameter brass. The main parameters follow the peak current.

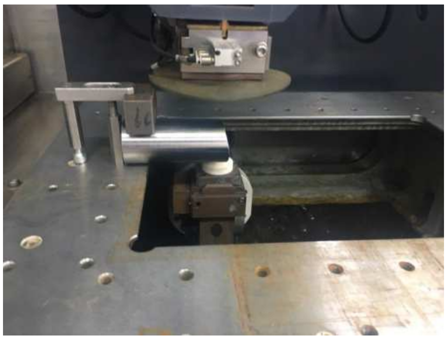

Figure 1: The Experimental Set Up

Table 1: Chemical Compositions of CoCr Alloy

Element	Content
Cobalt, Co	Balance
Chromium, Cr	28.5%
Molybdenum, Mo	6%
Nickel, Ni	0.25%
Iron, Fe	0.2%
Carbon, C	0.22%
Silicone, Si	0.7%
Manganese, Mn	0.5%
Nitrogen, N	0.15%
Tungsten, W	0.01%
Aluminium, Al	0.05%
Titanium, Ti	0.01%
Boron, B	0.006%

Table 2: Mechanical Properties of CoCr Alloy

Rockwell Hardness	34 HRC
Tensile Strength,	960 MPa
Tensile Strength, Yield	560 MPa

Table 3 presented machine conditions of the WEDM process. The surface roughness (Ra) of samples after machining by W-EDM was observed by optical microscope Olympus series OLS3000 LEXT Microscope. The OLS3000 uses a 405nm laser to obtain high resolution measurements. Lasers are used in microscopy to decrease the wave length of a light source, allowing for higher resolutions. Each test material was cleaned before scanning with the microscope, to avoid false measurements. Then, 5 point cross-section micrograph analysis was used to display the affected test materials area.

Table 3: Experimental Conditions of CoCr by WEDM Process

Parameters	Machine Value		
IP Current (A)	5	6	7
Wire feed rate (FA)	2.0	2.0	2.0
Wire Speed (m/s)	8	8	8
Wire Tension (g)	12	12	12
Voltage (V)	12	12	12
Liquid Rate (LQ)	12	12	12

RESULT AND DISCUSSIONS

This study aimed to investigate the optimal parameters for cutting cobalt chromium alloy and the performance of the W-EDM process at different electrical discharge current. The influence of discharge current on surface quality and MRR was also studied.

Material Removal Rate (MRR)

In this study, the effects of machining conditions on machining performance could be evaluated by MRR and surface quality.represented effect of discharge current on MRR. The results showed that the material removal rate significantly increased with the increasing of discharge current. The MRR can be obtained by the following equation (Arikatla and et al., 2017)

$$\text{MRR} = {}^{*}V_c \times H \times k \qquad \textbf{(1)}$$

$$^{*}\text{Vc} = 60 \times {}^{l}\!/_{t} \qquad \textbf{(2)}$$

Vc: the average feed in mm/min, H: The work piece thickness, k: Cutting width (offset) mm. l and t are the cutting length in millimeter and time second respectively. In WEDM the material removal erodes from the work piece by sequences of discrete spark between work piece and electrode immersed in the liquid dielectric (Sreenivasa Rao M, 2013). The electrical discharge generated high thermal energy which removes material by erosion, which is ejected and flush by the dielectric fluid. The effect of peak current with MRR on WEDM cutting is present in Figure.2 the effect of discharge current on MRR. It shows that the material removal rate is increased an it’s significantly affected by discharge current increase (Manna and et al., 2016; A. PRAMANIK, 2015).

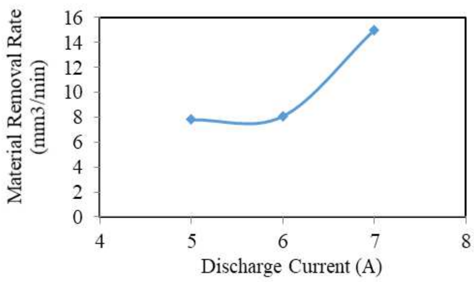

Figure 2: Relationship between MRR and Discharge Current

Surface Roughness

The temperature during the cutting by arc process was in 8,000 -12,000 degree Celsius. Therefore workpiece will be changing the surface roughness. An increase electrical current by arc process was found to result in rise smoothness of surface on high current.

Figure 3 showed the surface roughness of work pieces after WEDM process. 3 parameters were measured; mean surface roughness (Ra), a total height of roughness (Ry) and the maximum height of roughness profile (Rz) (Sreenivasa Rao M, 2013; A. PRAMANIK, 2015). It was found that the surface roughness increased with the increase of electrical current applied. This effect was due to the increase in bubble gas produced and thermal conductivity of the work piece. The rapid heat dissipation through the samples enhanced discharge energy produced. Hence, the progressive thermal erosion could be occurred and led to high surface roughness on the samples (Sreenivasa Rao M, 2013).

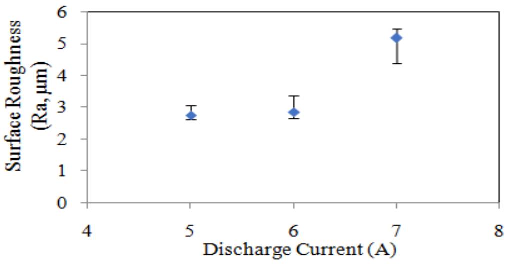

Figure 3: Surface Roughness Behavior with Electrical Current

Figure 4 shows SEM images of WEDM CoCr surface at various discharge currents. SEM images of the work pieces. The effect of the thermal erosion on the surface was shown in Figure.4, which indicated that rough surface condition occurred by the cooling of the brass wire electrode. The surface produced by the EDM process consisted of a multitude of small craters randomly.

These craters depend on mechanical properties of the material as well as on the discharge energy. The quality of surface mainly depended on the energy per spark. If the energy content was high, deeper craters would be occurred, leading to a poor surface (Li, L. And et al., 2013) the depth of the resulting craters usually represented the peak to maximum surface roughness. According to SEM images, the moderate valleys, craters, and surface cuts at discharge current 7 A (as shown in Figure.4d.) similar to the surface at discharge current = 5A (as shown in Figure.4b)

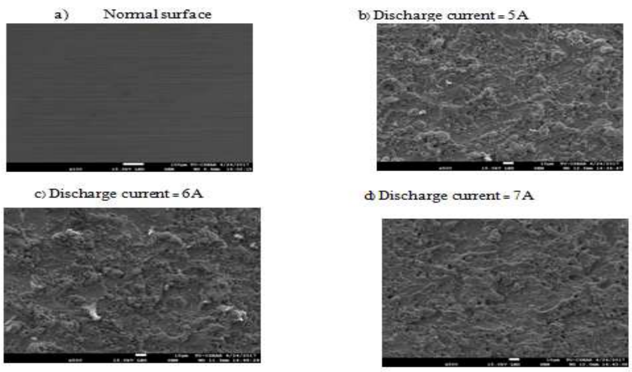

Figure 4: Shows SEM Images of WEDM CoCr

Hardness

Hardness testing was utilized to measure the hardness of surface work piece after WEDM process. The work piece was measured from the top of surface. The white layer was generated on the surface of the work piece in the three conditions of peak current. The bulk regions of the work pieces were tested. It was found that each work piece possessed an overall average hardness of 34 HRV. Next, the white layer of the material was tested at distances of 5–100μm by Vickers hardness testing method. The depth profile of hardness is shown in Figure.4 a comparison of micro hardness profile versus the discharge current of Wire-EDM processing.

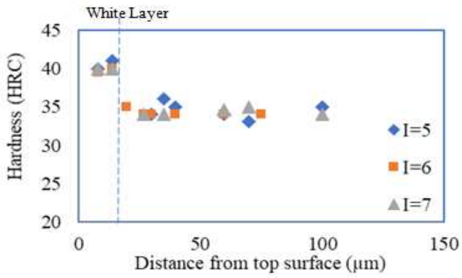

Figure 5: Micro Hardness Distributions below

Kerf Width

The kerf width was measured with digital camera microscope 600x the optical micrograph shown difference discharge current has been considering from the side of wire to the workpiece, erosion, as show in figure. 6 it observed the same optical camera it was found that the peak current increase, the kerf's width increase (Alias and et al., 2012) caused by the open circuit voltage and pulse duration high (Arikatla and et al., 2017) The kerf width increase for high current because of spark occurred from the side of workpiece

Figure 6: Digital Micrographs of the Kerfs Width as Peak Current 5-7A

Discharge Wave Form

The discharge energy of conventional WEDM at current of 5, 6, 7A. The discharge process is controlled by WEDM - CNC program. The spark occurred in a gap between the wire tool and material. If the gap between electrodes was too narrow, abnormal wave amplitude would be occurring (Lin, Y.-C. And et al., 2017)

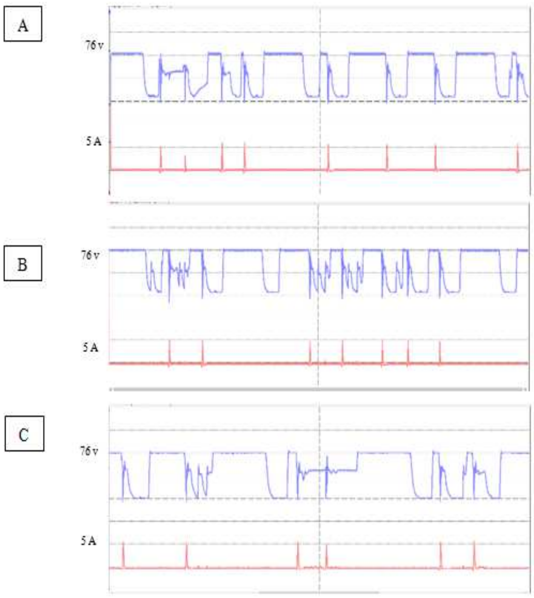

Figure: 7 Discharge Voltage Waveform of Conventional WEDM at 5-7A

The effects of discharge energy on surface roughness were presented in Figure.7, where abnormal discharge could be found. (Manna and et al., 2016)

CONCLUSIONS

The main conclusions from this study can be summarized as follows:

- An increase in high discharge current could cause an increase in MRR, showing that the high energy will be applied to energy during this period. MRR raising and surface finish will increase.
- The roughness of surface increased when the electrical discharge increased, because the thermal conductivity allowed a rapid dissipation of the heat through the sample instead of being concentrated on the surface, causing larger discharge energy on the surface and producing deep melting and larger craters which induced surface roughness on the work piece.

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