Flyback Converter of Electrical Discharge Machining Power Supply: Application to Surface Texturing

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Abstract: - Electrical Discharge Machining, EDM is one of non-conventional machining process that is currently applied for surface texturing. Power supply is one of the components in EDM that control process parameters which will directly influence the machining condition as well as Material Removal Rate (MRR). In this study, Flyback converter has been proposed as the new power supply. An experimental studies were conducted to verify the performance of Flyback converter by machining twenty micro-dimples in circular arrangement on metallic acetabular cup. Material removal are calculated by weighing the workpiece before and after machining. The results show a consistent value of material removal when Flyback converter is applied compared to Linear power supply. Therefore, Flyback converter is highly recommendation to be used as EDM power supply.

Key-Words: - Flyback, Electrical discharge machining, surface, texturing

1 Introduction

Surface texturing technique was previously used on golf ball surfaces to improve their aerodynamic characteristic. Numerical studies on surface texturing have indicated micro-texture may significantly affect the tribological performance of contact surface and improved lubrication performance [1]. However, there are few experimental studies on surface texturing in the metallic hip implant, especially in surface dimpling. This approach of surface texturing by applying micro-dimples on the metallic acetabular help to promote in reservation and distribution of lubricant between the contact surfaces thus give better tribological performance [2]. There are many surface texture technologies used such as CNC micro drilling, Solid State Laser, Abrasive waterjet and Electrical Discharge Machining (EDM). Due to stamping and drilling process in conventional machining technique, micro-dimples may suffer from micro cracks. Non-contact process which is the characteristic of EDM would be the best solution to replace drilling and stamping process. While considering the micro-dimples quality, EDM is suggested since it results in no burr formation. Since EDM process is of stochastic nature, it requires a lot of improvements on it especially while considering machining of micro-dimples on metallic acetabular cup. Most of the literatures have discussed about relating of machining parameters to improve performance measures [3], modelling and optimization of the process variables [4,5], and monitoring and control of the sparking process [6]. It has been observed that less attention has been given for enhancing electrical process parameters of EDM process in terms of controlling the process variable such as voltage and current. Material Removal Rate (MRR) is the most dominant performance measure in this study since it affects the quality of micro-dimples in term of consistency of material being removed for each micro-dimple.

MRR is defined as the volume of material removed per minutes. Material removal in EDM is realized by thermal action of electrical discharge between the tool and the workpiece, which are connected to a DC power supply. The discharge energy released by this power supply is responsible for melting small quantity of material of both electrode and workpiece. This power supply generates high enough voltage to breakdown the dielectric at a very small gap (10-50μm). Before the striking of the spark, the power supply operated at no load condition as the output sees an open circuit. The EDM servo system then adjusts the position of the electrode to breakdown the dielectric. The power supply then sees a negative resistance until the voltage drops to the working gap which is normally ranges from 10-25 V. The current is maintained during this time until the pulse is terminated. The process is repeated at the next cycle. With the working principle stated, enhancing the power supply design that meets the EDM system working principle is necessary.

The conventional power supplies applied in EDM are typically traditional Linear converter, which is act as current source. The major problems of this power supply include bulky volume and low efficiency. In order to solve these problems, resonant-switching power converter is introduced. However, the drawback is when the load resistor of the resonant tank is in high impedance state, the output voltage of the resonant tank is fairly high. Buck based topology is preferred for implementing the power supply [7], however due to desirable of low output power for EDM application, Flyback converter is suggested. Several studies implementing Flyback converter only discuss on the design of the power supply without conducting proper experiments on EDM system to proof the efficiency of the proposed designed [8,9].

Therefore, this study provides an intensive knowledge of using Flyback converter in EDM system. Experimental results of using Flyback converter comparing with Linear converter are provided by machining micro-dimples on metallic acetabular cup. The consistency of MRR for each micro-dimples machined on metallic acetabular cup of hip implant then evaluated. Since concern on surface texturing to the hip implant has been rising, this study provided a significance idea on surface texturing by embedded the acetabular cup with micro-dimples.

2 Methodology

This section discusses the steps taken for machining micro-dimples, measuring the MRR and observing the surface quality. Firstly, machining tests were carried out using two types of power supply, modified Flyback converter and Linear converter. Two assumptions were made: (a) temperature and pressure of dielectric fluid were assumed to be constant; (b) current consumption was constant throughout the experiments. The workpiece is a hip implant model of curvature cup. The workpiece is a hemisphere shape with diameter 44 mm and a curve in the center with radius of 14 mm. The tool electrode material used in this study was pure tungsten with diameter of 1000μm. During the machining process, the acetabular cup was sprayed with EDM oil 99 using a flushing pipe. The flushing process helps to remove the particles or any debris inside the micro-dimples. The acetabular cup was hold using a workpiece holder which can rotate the position of acetabular cup according to micro-dimple position. The system as illustrated in Fig. 1 is based on Swing-Rotate configuration where the position of the dimples is set using dedicated Graphical User Interface (GUI) software. The computer will convert the angular value set to commands in order to set the servo to the corresponded angular value [10].

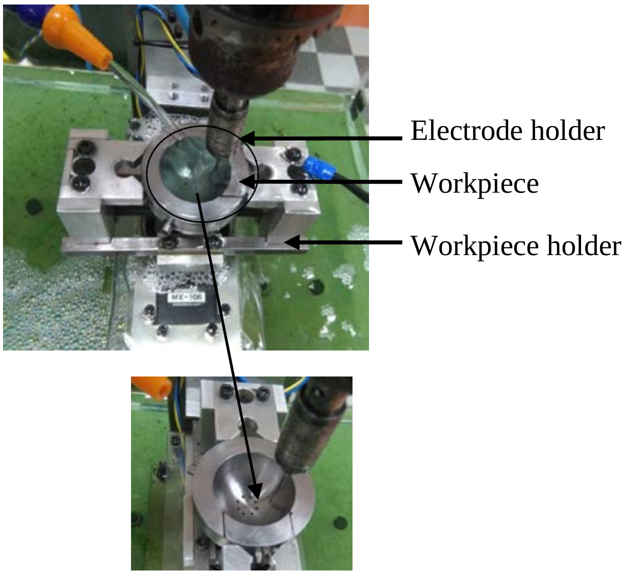

Fig. 1 Novel workpiece positioning system mounted on EDM tank

A set of micro-dimples were machined on the acetabular cup where the diameter of the micro-dimple was the same as the diameter of the electrode. The metallic acetabular cup was textured with circular shape dimples with diameter 1000 μm in a circular arrangement. In details, the arrangement was divided into two categories. First, eight micro dimples (single circular pattern in lower position) and second twenty micro-dimples (two circular pattern in lower and upper position). An angular value of 45° is set from each micro-dimple for lower position while an angular value of 30° is set from each micro-dimple for upper position as shown in Fig.2.

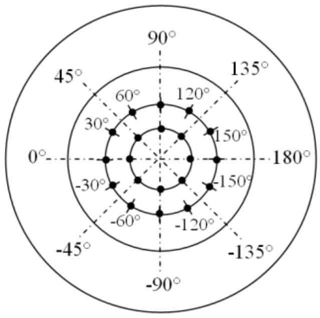

Fig. 2 Position of micro-dimples

Material Removal Rate (MRR) is considered as the performance measurement to evaluate the performance of both power supplies. MRR is defined as weight of material removed during machining period in minutes. For measuring material removal rate, Shimadzu ATX224 weight balance was used. Moreover, to obtain image surface quality a high resolution microscope was used.

MRR was obtained based on the calculation of the ratio of mass loss per maching per effective machining time. Equivalent equation is described in Equation (1)

$$MRR = \frac{(W_b - W_a)x\ 1000}{t} \qquad (1)$$

Where MRR is the material removal rate (mg/min), W_b is the average weight of workpiece before machining (g), W_a is the average weight of workpiece after machining (g) and t is the time of machining (min).

3 Results and Discussion

3.1 Micro-Dimple Image Observation

Fig. 2 depicts two different images of micro-dimples machined using Linear power supply. The size of electrode used is 1000 µm and the machining time is set to 210 minutes. The diameter of micro-dimples varies where first dimple was 1115.77 µm (Fig. 2(a)) while second dimple was 1094.46 µm (Fig. 2(b)). From visual inspection, the diameter for each dimples is uneven and can only be determined by taking average measurement.

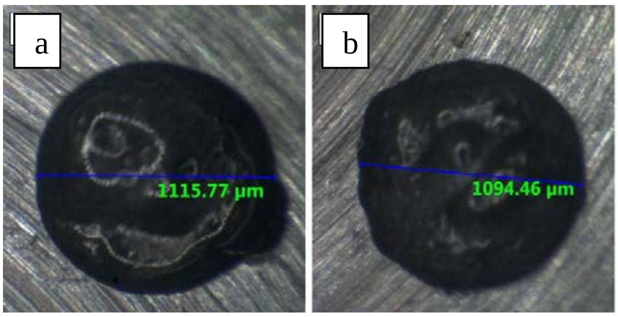

Fig.2 Close up image of micro-dimples machined using Linear power supply

Fig. 3 depicts two different images of micro-dimples machined using Flyback power supply. The size of electrode used is 1000 µm and the machining time is set to 210 minutes. The diameter of micro-dimples varies where first dimple was 1047.51 µm (Fig. 3(a)) and second dimple was 1043.74 µm (Fig. 3(b)). A clear observation can be made where all micro-dimples are nearly consistent and sharp with required size of diameter. This revealed that Flyback power supply is more efficient to be applied for machining micro-dimples. Thus, Flyback power supply is proposed to be used when size consistency is the main objective during micro-dimples production.

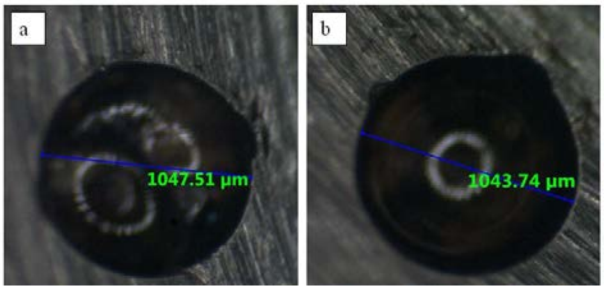

Fig.3 Close up image of micro-dimples machined using Linear power supply

3.2 Material Removal Rate Results Analysis

Fig. 4 illustrates the material removal of each micro-dimple machined using Linear power supply and Flyback power supply for Mild Steel workpiece material. A machining time of 150 minutes is set for machining each micro-dimples (total 1200 minutes). The weight of workpiece before and after machining of micro-dimples in lower circular position as well as their differences is presented and MRR is calculated accordingly. The highest weight of material removed when Linear power supply used is 8.2 mg while highest weight of material removed when Flyback power supply used also 8.2 mg

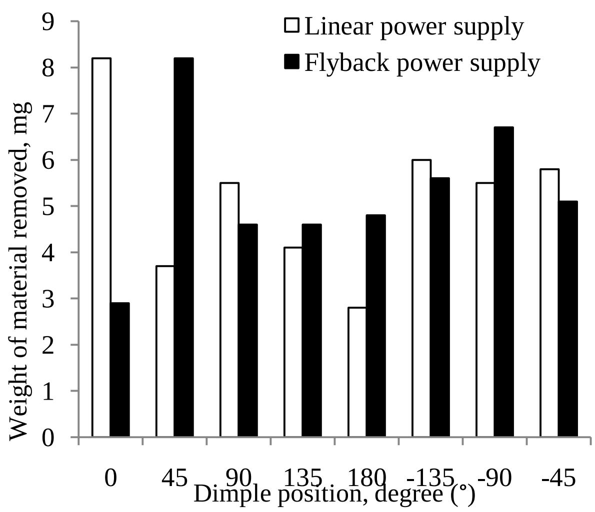

Fig.4 Material removal for Mild Steel workpiece material and Tungsten electrode in lower position.

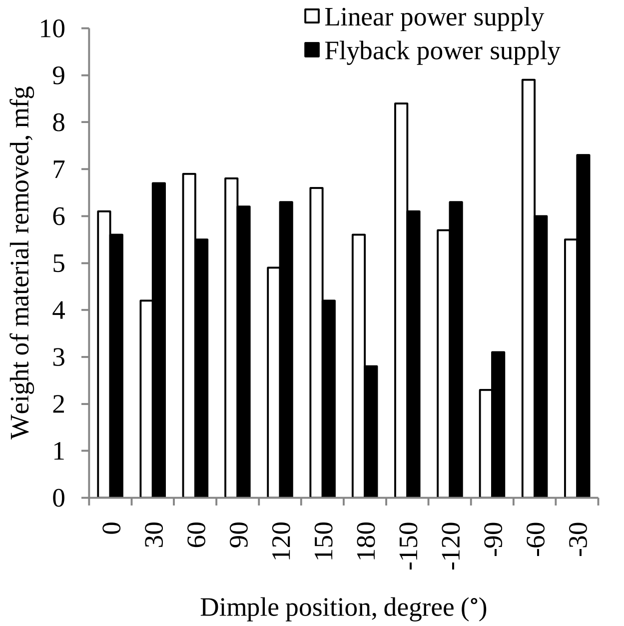

Fig.5 Material removal for Mild Steel workpiece material and Tungsten electrode in upper position

The weight of material removed for micro-dimples in upper circular position is presented in Figure 5. The highest weight of material removed when Linear power supply used is 8.9 mg while the highest weight of material removed when Flyback power supply used is 7.3 mg. Higher material removal is obtained (8.9 mg and 8.4 mg) when Linear power supply is used due to uncontrollable discharge process that lead to unpredictable material removal.

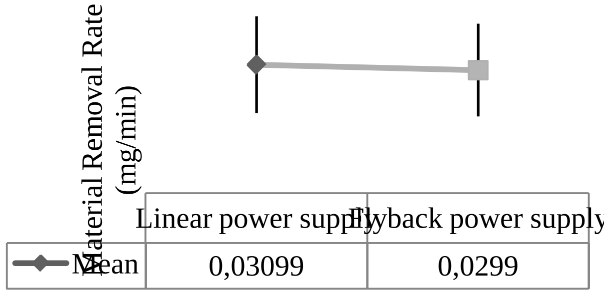

Fig. 6 Mean for both power supply with their respective standard deviation

An average value of 0.03099 mg/min MRR is obtained for Linear power supply while 0.0299 mg/min MRR is obtained for Flyback power supply From the graph, standard deviation from the mean MRR to the measured MRR for Flyback power supply is 0.00940 and 0.00981 for Linear power supply. From the analysis, Flyback power supply provides higher consistency of MRR compared to Linear power supply due to its lower deviation value. Higher consistency of MRR when using Flyback converter shows that the machining condition are more stable as it able to remove the material nearly consistent for each micro-dimples.

4 Conclusion

The development of Flyback power supply and Linear power supply was performed in order to investigate the material removal rate of micro-dimples. A comparison study was conducted and all results obtained was evaluated. The experimental studies of machining micro-dimples using alloy tool steel and mild steel workpiece were presented in tabular and graphical form. Analysis of the results show that Flyback power supply improved the performance of Micro-EDM in term of material removal which avoiding the need for large development costs in term of money and time. In conclusion, the research has performed an improvement of MRR to the existing EDM machining by applying another power supply to the system. Consistency in MRR is an idea where time for machining can be predicted and minimized.

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