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Low Current Discharge Machining for Micro-Dimples on Hip Implant

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Abstract

The hip joint plays a vital role in enabling human daily mobility. One of the main issues that determines the longevity of Metal-on-metal (MoM) hip implants is wear rate. In order to improve lubrication and reducing friction, surface texturing has been widely adopted as a design alternative in implant manufacturing. Electrical Discharge Machining (EDM) with a low current discharge generated by the flyback power supply was employed in this research to machine the micro dimples on hip implant which offers high precision and eliminates burr formation on the surface. The low current discharge with optimize EDM parameters such as V_{OC}, I_{Gap}, T_{on} and T_{off}, demonstrating a significant influence on performance measures including surface roughness (SR) as well as material removal rate which make it suitable for biomedical applications. Moreover, with steady discharge duration, all micro-dimples are nearly consistent and sharp with required size of diameter.

Keywords: EDM; implant; discharge

Introduction

Hip joint is one of the most important joint in human body that help in our daily movement. It composed of a femoral stem (thigh bone) with a femoral head on top of it. The femoral head articulates against the acetabular cup in the acetabulum [1]. The femoral head and the acetabular cup are coated by a cartilage that lubricates their movement and facilitate the articulation. Hard on hard materials such as Metal-on-Metal (implant) have been introduced to replace the damage hip joint. Wear rate and friction are known as the major concerns for determining the lifespan of MoM hip implant. 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]. Due to stamping and drilling process in conventional machining technique, the 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. 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 (10-50 µm). Before the striking of the spark, the power supply operated at no load condition as the output sees an open circuit. The power supply then sees a negative resistance until the voltage drops to the working gap which is normally ranges from 10-25 V [3]. 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.

Materials and Methods

The EDM power supply for this study is implemented using a Flyback converter to provide a low current discharge [4, 5]. This novel study is to highlight the design of power supply which can stabilize the voltage during open circuit condition as well as during discharge condition which in turn ensure stable energy levels provided to the gap during machining process. This power supply will be applied between the electrode and workpiece (acetabular cup) for machining micro-dimples. The machined micro-dimples are expected to improve surface quality as well as consistency of material being removed. A Lab scale Die-sinking Micro-EDM, Figure 1 has been developed for micro machining by researcher at Universiti Teknologi Malaysia [6]. This machine is energized by a flyback power generator that supply the low current discharge suitable for machining micro dimples.

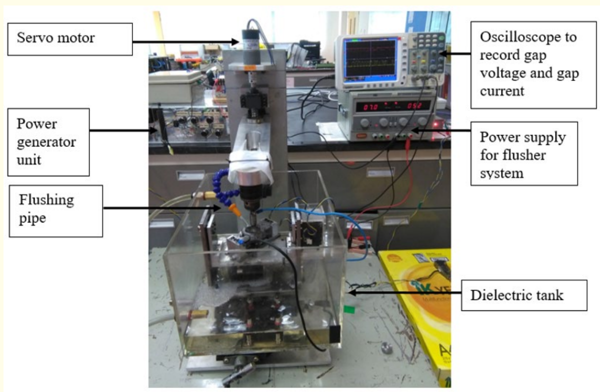

Figure 1: Lab scale of Micro-EDM system.

Machining tests were carried out with two assumptions: (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 with materials alloy tool steel (high carbon, high chromium). The size of workpiece has a hemisphere shape with diameter 44 mm and a curve in the center with radius of 14mm. The tool electrode material used in this study was pure high steel electrode with diameter of 500µm. During the machining process, EDM oil 99 was used. Various parameters in EDM Die sinker were considered such as discharge current (0.5 - 1.0 A), discharge on time (T_{on}, 60 µs), discharge off time (T_{off}, 30 µs) and open circuit voltage (V_{oc}, 100 V).

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 acetabular cup was hold using a workpiece holder which can rotate the position of acetabular cup according to micro-dimple position. Figure 2 illustrated the position as well as its distance from each other. The micro-dimples were divided into two different location namely lower position (8 number of micro-dimples), upper position (12 number of micro-dimples).

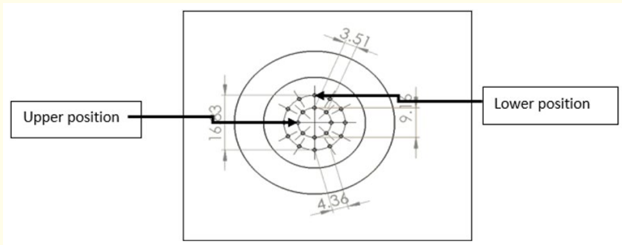

Figure 2: Dimple position and distance for each micro-dimple.

Results and Discussion

Figure 3 illustrates the gap voltage, V_{gap} and gap current, I_{gap} when Flyback power supply is applied. The gap voltage is plotted in upper graph whilst the corresponding gap current is plotted in lower graph. After a short dielectric breakdown period, the voltage applied between the electrode and workpiece drops to the working voltage which is 15 V and the duration for the discharge to occur is labelled as wear period. At this point discharge current starts to flow through the gap, which is represented by the gap current, I_{gap} waveform (lower graph).

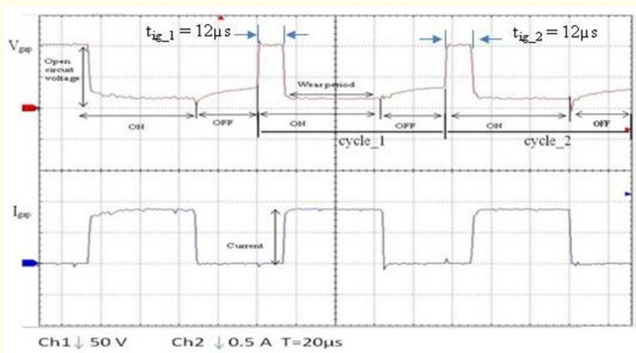

Figure 3: Gap voltage and gap current for flyback power supply.

The ignition time (t_{ig_1} and t_{ig_2}) is 12 µs which is similar for two subsequent cycles (cycle_1 and cycle_2). It is important to keep the ignition time constant in order for normal discharge to happen. When ignition time is kept constant, the duration for discharge will also constant since the ON time is fixed. This will maintain the same quality of roughness for each machined dimple. Meanwhile, a series of gap voltage (V_{gap}) and gap current (I_{gap}) waveform when Flyback power supply is applied in Micro-EDM are depicted in Figure 4. Eight numbers of discharge duration (D1 to D8) are captured by digital oscilloscope, later to be measured and evaluated.

Figure 4 shows eight discharge duration when Flyback power supply is applied. The discharge started with 55 µs in first discharge (D2), followed by slightly increase in second discharge (D2) with 60 µs. However the third discharge (D3) and forth discharge (D4) show a reduction of discharge duration before it increase again in fifth discharge (D5). The discharge duration is equal for sixth discharge (D6) with 50 µs before it shows an increment in seventh discharge (D7) and last discharge (D8) with 60 µs.

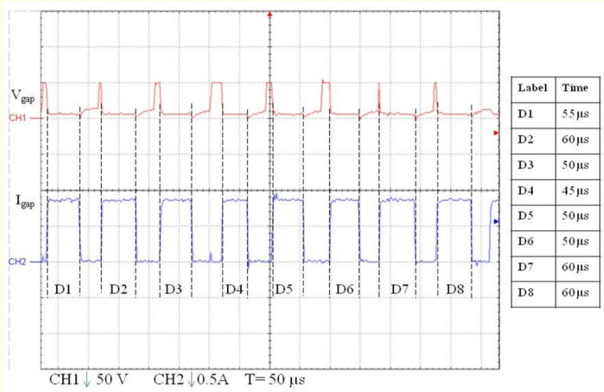

Figure 4: EDM gap voltage and gap current profile using Flyback power supply.

Flyback power supply provide less different (15 µs) of discharge duration with the lowest discharge duration is 45 µs and the highest discharge duration is 60 µs. Figure 5 shows discharge duration is more consistent when Flyback power supply is applied with the highest percentage error is 25%. It is found that MRR is consistent when discharge time is nearly consistent for every discharge process. Longer duration for discharge also increased the MRR which reduce time consumption for machining micro-dimples on hip implant.

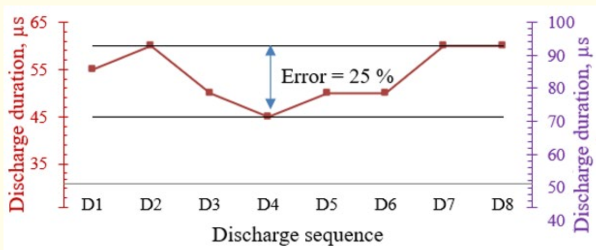

Figure 5: Comparison of discharge error profile for Flyback power supply and Linear power supply.

Conclusion

The low current discharge by the Flyback power supply was successfully applied the micro- EDM system for machining the hips implant. It provides consistent discharge duration, T_{on} and T_{off} with 25% percentage error. A short discharge duration between 45 µs and 60 µs is found to be optimum for MRR with reduce time consumption for machining micro-dimples on hip implant. A clear observation from image processing show that all micro-dimples are nearly consistent and sharp with required size of diameter. This revealed that low current discharge by the Flyback power supply is efficient to be applied for machining micro-dimples.

Acknowledgements

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