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Machining Pits on the Curvature Surface Cup Using Spark Process

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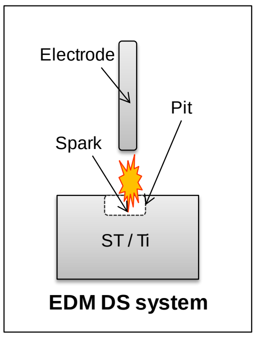
Graphical abstract



Abstract

In this study, investigations have been conducted using electrical discharge process (die-sinker) to obtain new surface in metal hip implant, which place pit on the surface of curvature cup. A circular array of pit in circle shape was successfully created on the surface of acetabular. There are 8 pits that have been embedded on the surface area of the acetabular by each diameter machine and the depths are 1.1 mm and 0.5 mm respectively. This new surface improvement will prolong the life span of the implant due to lubrication activities in hip tribology.

Keywords: Die-sinker; pit; curvature cup; surface modification

■1.0 INTRODUCTION

Metal hip replacement is alternatives to people with severe hip damage based on metal on metal (MoM) biomaterials. The most common problem with the MoM surgery is friction and hip dislocation acetabular happen. One of the significant current discussions on hip tribology to reduce the friction between the sliding contact curvature surface. Hip dislocation is a condition in which the implanted femoral head, or the ball, is no longer located inside the socket in the pelvis.

Hip artrosplasty is a treatment for people with severe hip disease. Hip replacement or hip implant is currently the most successful and reliable orthopaedic ope ration and has been reported to improve the patient severe from hip damage [1, 2]. Hip replacement or Total Hip Arthroplasty (THA) is a surgical procedure that replaces the hip joint with a prosthetic implant.

The total replacement of femoral hip joints with artificial joints, which consists of a ceramic ball head, steel or titanium stem and a cup (acetabular), has been successfully practiced for many years. Previous studies have shown that after the HR surgery, friction will contributed hip dislocation of acetabular cup from the ball socket [3-6].

The problem occurs after hip surgery discussed in this paper is the friction between contacting surfaces which will lead to hip dislocation. Hence, in order to increase the level of resistance and life span of the prosthesis, high-powered machine such as Electrical Discharge Machine Die-Sinker (EDM DS) is needed where it is obtainable to machine macro surface of the acetabular cup. Ginzel [7] was inferring that EDM suitable for highly accurate to machine sophisticated metal shaping. Other researchers [8-10] claimed that EDM may influence the material surface and make the surface roughness perfectly smooth.

Many researchers have been conducted using micro EDM for various applications. Liu *et al.* [11] shows that, micro EDM has the capabilities to fabricate small hole in nickel alloy which is used to prevent interference of the magnetic field. Furthermore, Yan *et al*. [12] used Electrical Discharge Machining to produce a circular micro-tool with high aspect ratios in borosilicate glass. Nowadays, EDM die-sinker is also used in precision machining especially for medical parts, aerospace parts, and other highly specialized products. Nikhil *et al.* [13] reported that die-sinker EDM is widely used for machining of hard material with high precision, high surface finish, and complex profiles. EDM also has advantages which it can reduce environmental pollution.

The focus of this study is to machine micro pits on the acetabular surface of THR using Electrical Discharge Machine Die-Sinker. Without a perforated surface inside the acetabular, after a decade it may cause patients with total hip arthroplasty or THR feel loosening friction and severe damage. For this purpose, a pit formation which also known as oil pockets, holes, dimples or cavities is machined for surface modification in THR.

■2.0 EXPERIMENTAL

2.1 EDM Setup

In this study for a successful machining pits, various parameters in EDM DS are considered such as current, diameter of electrode Ø, QD_{up} (length of retraction gap distance of electrode), QD_{on} (duration of machine head pulse discharge), T_{on} (discharge on time adjustment), T_{off} (off discharge time adjustment), V_{gap} (voltage during the EDM process). Detail of the parameter setting on this experiment is shown in Table 1. An electrode radius of 0.5 mm was selected for machining pits or holes of 0.5 mm depth on curvature cup workpieces.

Table 1 Experimental condition-EDM DS NEUAR A50

Parameters used	Value set
Current	0.5 A
Diameter electrode Ø	0.5 mm
QD_{up}	1 mm
QD_{on}	30 µs
T_{on}	0.50 µs
T_{off}	4 stages = 10 µs
V_{gap}	65 V

In the experiments, the aim is to determine the depth of the machined hole of biomaterial. Electrode initial step instructed touching the surface of workpiece. Once the position is set as the coordinate *x*o, *y*o, *z*o. By using the coordinates of the *x*-axis, *y*-axis can determine the position of looking into the pit and the negative *z*-axis (-0.5 mm) in depth shown in Figure 1.

Figure 1 Monitoring and machine programming in EDM

During the experiment, dielectric fluid Fuchs Ratax Edm was used. Electrode manually lifted or moved on to another surface (other axis *x*n, *y*n) and make new coordinates to get the latest *z*-axis position. When set at the new *z* position, electrode brought to the position coordinates of the first pit and lowered to touch the surface. With the determination of the percentage of first workpiece with pit depth on certain current and gap setting of v can be determined by looking at the screen and the machine next step is repeated to determine the depth of the other holes are machined.

2.2 Material and Method

The workpiece is a hip prosthesis model of curvature cup of ANSI 1045 which consists high chemical composition of Carbon (C, 0.40-0.45), Fe (0.98), Mn (0.60) and P (max, 0.5). Carbon steel generally has better edge and moderately strong but low ductility [14]. The size of curvature cup as workpiece has a round (Ø, 44 mm) and a curve in the center with a radius of 14 mm. Copper electrode was set to *z*-axis (position of the electrode) 1 mm from workpiece before machining for safety machining. Bhattacharyya *et al*. [15] stated that, copper as electrode material for the EDM experimental worked better in combination with carbon steel workpiece to other tool materials. Previous researchers have chosen copper, graphite, tungsten, brass and silver as the electrode [16-20]. For this study, the tool electrode is rod copper tungsten, with radius 0.5 mm of as shown in Figure 2a. The tip of the electrode shown in Figure 2b is a bit rough.

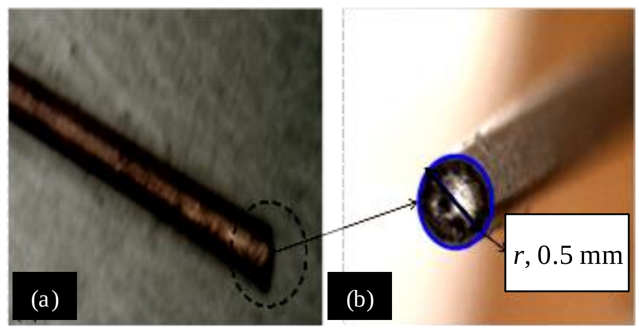


Figure 2 (a) Copper tungsten electrode (b) the tip of copper size 0.5 mm

Figure 3 portrays the experiment set up for machining micro pits on the surface of curvature cup. The curvature cup is round in shape and curve in the center. Electrode copper tungsten rod with composition (copper, 25%; tungsten, 75%) is used to machine 8 micro pits on the workpiece. During machining, electrode manually lifted or moved on to another surface (other axis *x*n, *y*n) and make new coordinates to get the latest *z* axis position. When set at the new *z* position, electrode brought to the position coordinates of the first pit and lowered to touch the surface. With the determination of the percentage of first workpiece with pit depth on certain current and gap setting of v can be determined by looking at the screen, and the machine next step is repeated to determine the depth of the other holes are machined.

The method for feeding EDM oil or dielectric is through flushing pipe and the workpiece is placed close to the magnetic table. In this experiment the pits were machined a circular arrangement. The Microscopy Image Analysis (MIA) has been used to capture the machined surface as well as measuring the surface diameter and area.

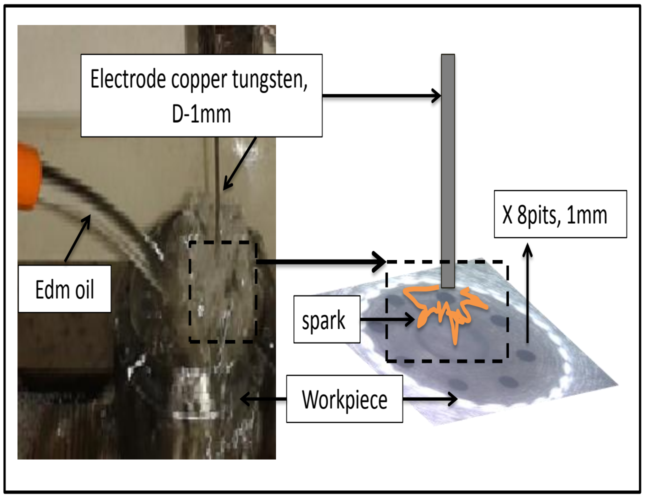


Figure 3 Experiment set up for machining pit on the acetabular (tool steel SKD 11)

3.0 RESULTS AND DISCUSSION

This study shows that the effect of current voltage of EDM that supplied on the copper tungsten electrode to machine pit. The influence of the current supplied to the copper tungsten electrode was very affected area and coarseness surface of the workpiece. The experiment is conducted by machining 8 oil reservoirs or pits on five samples of curvature cup, where the current setting is at 0.5 A. This is preferred to obtain an average diameter of micro pits machined of 1.105 mm and the depth is 4.895 mm.

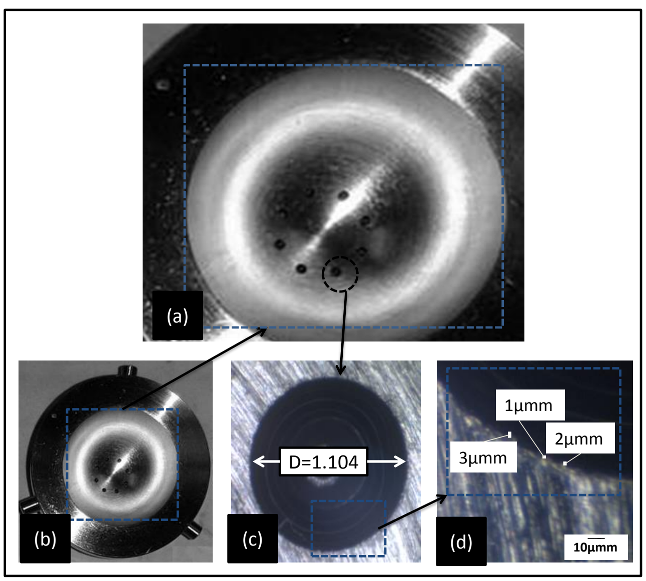


Figure 4 (a) Pits on the acetabular cup machined at current 0.5 A with 0.5 mm copper tungsten electrode (b) 8 pits after machine (c) Size of micro pit after machine (d) pit shape with no severe crack

The results of this experiment, show that each pit have been machined at 45^0 distances to each other in circular array (with radius of 4.258 mm). From Figure 4c and Table 2, it is observed that the diameter parameter of the pit is bigger than the diameter of copper electrode used. More debris is removed when high current is applied during discharge and it was affected due to the spark during machining as reported by Praveen [17]. In this experiment, the discharge current at 0.5 A it may effected to the residue area of workpiece or known as overcut. In EDM over cut will increase depends on high of current set, T_{on}, polarity and T_{off} [18].

Table 2 A set of data pit on machining current at 3.0 A

Sample	Diameter archive (mm)	Depth archive (mm)	Time of machine (min)
1	1.105	4.935*	29.25
2	1.104	4.890	30.29
3	1.108	4.930	32.07
4	1.104	4.835	32.06
5	1.105	4.890	30.50
Mean total	1.105	4.896	31.23

According to Ho *et al.* [21] and Guu [22] in EDM, more micro crack will appear with high current. From Table 2, set of data pit on machining current at 3.0 A were observed using Microscopy Image Analysis, and it is found that the shape round diameter is 1.104 mm in Figure 4c, total diameter mean from five samples is (1.105 mm) and the center looks smooth round as depicts in Figures 4c and 4d. From the data collected (Table 2), the successful of the workpiece machined the pit by follow the actual depth achieved at the highest rate*, 98.70%. Overall, it can be said time of machine to machine 8 pit is below 33 min and 100% successful of EDM DS machine produced the pit with radius ~ 1 mm on the curvature cup. However, the present tests shows micro crack was presence, represented by micro line length (1-3 mm) on the area surface of the acetabular cup. It can be concluded that, when current-voltage is increased, micro cracks become pronounce [23, 24].

4.0 CONCLUSION

Recent micro- and nano-technology in multi-engineering has improved the quality and the performance of equipments and machine. The EDM DS ZNC A50 has potential for modification to be used on machine prosthesis parts. This study has explored the capability of the electrical discharge machining die sinker to implanted pit on the curvature cup in THR by using 1.0 mm in diameter of copper tungsten electrode. The results obtained that 8 micropits were successfully machined on the model of curvature cup by using electrical discharge machining die sinker will act as oil reservoir. Thus, surface of acetabular cup with micropits allow lubrication activities, thus reducing friction and wear in THR.

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