Micro-Pits on Biomaterial in Electrical Discharge Machining By Using Taguchi Method

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\textbf{Abstract:} - Electrical Discharge Machine widely used in the manufacturing industry, especially to generates small part or complicated product. This research has been conducted to determine capabilities of Electrical Discharge Machine Die Sinker (EDMDS) machining micro-pit on the biomaterials between stainless steel and Titanium. The significance of this study is to recognize EDM DS demanding for improvement or to enhance medical products. In this study Taguchi method is guide a series of experiments, and use to identify EDM DS parameter capabilities to machine pit depth 0.3mm on the titanium and stainless steel at current parameters, LT (1A and 3A). Meanwhile the Vgap were set at 55V and 65V. Based on Taguchi method statistically evaluated the experimental data and the regression of parameter. This paper showed the percentage of wear Electrode copper tungsten, percentage of depth machining pit and time spending during machine a pit. The pit model in biomaterials showed that exploring micro pit as new areas of improvement on the surface of biomaterials products.

\textbf{Key-Words:} - EDM DS, Biomaterial, Taguchi method, copper tungsten Electrode, Micro pit

\textbf{1 Introduction}

The use of Electrical Discharge Machine has been steadily growing. Formerly it was known as spark erosion that began early 1950. EDM die sinker EDM is used for the precision machining of medical parts, aerospace parts, and other highly specialized products. This study was conducted to examine the ability of Electrical discharge machine Die Sinker Machine (EDM DS) to produce pit (hole small / micro pit). At present, the study of the production pit on the materials used in the medical field is not widely available, compared to the manufacturing sector.

Many researchers have used the DS EDM applications in manufacturing and materials of high hardness to make a mold, die and so on [1][2][3][4]. Thus in the medical field now, resources need evolution on the surface of biomaterials and the end surface. Until now metal-based biomaterials has long been used with in the field of medicine as a safe and biocompatibility characteristics. A study by T. Hefti et al [5] found that resorption pits on bone quite familiar from native bone.

The existence of micro-pit approach in biomaterials may open new fields in other areas, such as in the automotive, medical and so on. Production of micro-sized pit may be helpful as oil reservoir, water or various types of fluid. The existence of fluid is bound to reduce friction on the surface. Therefore, to produce a uniform pit (uniform depth), the use of press machine, conventional lathe machine is limited on the type of machine tool and so on. Then, by use EDM DS surpassed these conventional machines[6]. EDM DS may able to machine a very hard material[7][8] (high HRC) material and can be molded as required with very minor defect (crack). With the concept working of EDM, material removal rate (MRR) in microns without severe damage to the surface (micro-crack) based on voltage and current parameter set.

In this experimental, the main goal is to machine a pit on the biomaterials. The success of this machining will assists researchers to determine the rate of decline electrode and also will plan the work for machining biomaterials. Electrode wear rate by using the machining process (EDM DS) will be
appeared. Many researchers carry out an experimental by using the Taguchi method\cite{9}\cite{10}\cite{11}\cite{12}\cite{13}\cite{14}. Therefore, the solution in this study will be presented and analysis by Taguchi method.

2 Experimental, Material and Procedure

There are two workpiece of biomaterial were used. There are titanium and stainless steel. These materials are used in products active implants and prosthesis of modern medicine. Material dimensions measuring on $30\text{mm} \times 10\text{mm} \times 8\text{mm}$ in this investigation. Fig 1a shows the position of the workpiece and electrode size $0.5\text{ mm}$ copper tungsten type selected. The electrode was choose cause of chemical and mechanical properties of the material better than copper, which is indulgent and cause high wear\cite{15}\cite{16}\cite{17}.

![Fig. 1a: Schematic of Electrode and the workpiece set up.](image)

![Fig 1b: Experimental set up and micro pits produced onto biomaterial surface.](image)

In this experiment there are two approaches was used to determine the percentage of Electrode wear and percentage reach into the pit as experimental. With the exact size prediction is very close to the size of Electrode as machined (pit or hole produced). Electrical Discharge Machine Die Sinker A50 shall have the ZNC was chosen because intelligent artificial features that seem to understand the needs of programmers or machine operators.

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 $x_0$, $y_0$, $z_0$. By using the coordinates of the x-axis, y-axis can determine the position of looking into the pit and the negative z axis ($-0.3\text{mm}$) in depth shown in fig 2.

After completing the first hole, Electrode manually lifted or moved on to another surface (Other axis $x_n$, $y_n$) and make new coordinates to get

<table>
<thead>
<tr>
<th>Table 1: Experimental condition</th>
</tr>
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<tbody>
<tr>
<td>Parameters</td>
</tr>
<tr>
<td>Current, $LT$</td>
</tr>
<tr>
<td>Diameter electrode,$\Omega$</td>
</tr>
<tr>
<td>QUP</td>
</tr>
<tr>
<td>QDon</td>
</tr>
<tr>
<td>Ton</td>
</tr>
<tr>
<td>Toff</td>
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<tr>
<td>Vgap</td>
</tr>
</tbody>
</table>
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.

This situation is only slightly different, to determine the extent of percentage on Electrode wear produced. In this experimental hole produced this micro-sized and only 0.3mm depth were set. At the beginning Electrode position touched on the first surface It is set up as the position xo, yo, zo. After that, the pit machining process is completed, the positions electrode should be transferred to another (P1, xn +1 / yn +1 / zo), where the position is held at level roughness, Ra and level (height of material, H = 10mm as fig 1). Lastly, the tungsten copper electrode brought touches on P1. Thus, Electrode wear reading displayed on the screen it will be recorded. In ascertaining the time or the pit hole produced. Researchers need only look on the screen display EDM DS and after reading time has been taken; it is reset for the timing of another pit. All of data have been shown in Table 2.

### 3 Taguchi Method

To ensure the experiment goes well, the design approach of experiment (DOE) is used. Based on software MINITAB 15 and this greatly simplifies the Taguchi method of research. In Taguchi method, the researcher chose two level designs with 3 numbers of factors, which consist of LT (A), Vgap (V) and material. On the details of which can be seen in Fig 3 (Taguchi design factor). For analysis, a mean and analysis of signal to noise (S/N), which is a metric designed by Taguchi to optimize the robustness of a product or process. In this study, there are two plots Designs of S / N ratio used. The S/N ratios for static designs are following equations:

Larger is better: to maximize the response, \[
S/N = -10(\log(\text{sum}(1/Y)/n)) \tag{1}
\]

Smaller is better: to minimize the response , \[
S/N = -10(\log(\text{sum}Y/n)) \tag{2}
\]

### 4 Results and Discussion

Based on Table 2 shows data *, there are three places. Individually, it can be said the shortest pit hole on a workpiece the material biomaterials with time at 1.11 minute and 3A current, Vgap at 55V (stainless steel). Electrode wear recorded at the lower rate of 1.6% during to machine pit on LT and Vgap (3A, 55V) respectively, for the stainless steel . However, the successful of the workpiece machined the pit by follow the actual depth achieved at the highest rate, 96.0% in the titanium the material with a relatively low electrode wear. Overall, it cans be said Electrode wear is below 10 % and more than 50% success of EDM DS machine produced the micro pit on the biomaterial.

#### Table 2: Result of experimental

<table>
<thead>
<tr>
<th>LT (A)</th>
<th>Vgap (V)</th>
<th>Material</th>
<th>% Electrode wear</th>
<th>Depth archive (%)</th>
<th>Time of machine (Minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>55</td>
<td>1</td>
<td>8.1</td>
<td>71.7</td>
<td>4.25</td>
</tr>
<tr>
<td>0.5</td>
<td>55</td>
<td>1</td>
<td>10.5</td>
<td>63.0</td>
<td>11.39</td>
</tr>
<tr>
<td>0.5</td>
<td>65</td>
<td>2</td>
<td>9.6</td>
<td>66.3</td>
<td>4.41</td>
</tr>
<tr>
<td>0.5</td>
<td>65</td>
<td>2</td>
<td>10.3</td>
<td>64.7</td>
<td>11.50</td>
</tr>
<tr>
<td>3</td>
<td>55</td>
<td>2</td>
<td>7.2</td>
<td>94.7</td>
<td>1.11*</td>
</tr>
<tr>
<td>3</td>
<td>55</td>
<td>2</td>
<td>1.6*</td>
<td>91.7</td>
<td>1.54</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
<td>1</td>
<td>7.1</td>
<td>77.0</td>
<td>1.16</td>
</tr>
<tr>
<td>3</td>
<td>65</td>
<td>1</td>
<td>1.8</td>
<td>96.0*</td>
<td>1.53</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>6.825</td>
<td>66.13</td>
<td>4.47</td>
</tr>
</tbody>
</table>

![Fig. 2 : Monitoring and machine programming in EDM.](image)

![Fig. 3: Taguchi design factor](image)
*excellent result

The S/N ratio can be used to measure the deviation of the performance characteristics from the preferred principles. The groups of performance characteristics in the analysis of the S/N ratio depend upon output parameters to be controlled. We authors have selected two categories between two materials which are as follows.

- The small is better for current set and Vgap to ensure low electrode wear, and
- The higher is better for current set and Vgap to ensure depth pit archive.

Fig.4a: Represented at 3.0A, material of titanium and at 55 V influent the electrode wear

Fig.4b: Represented an electrode wear at 0.5A, material of titanium and at 65 V influent the S/N value.

Fig.4c: Represented at 3.0A, material of titanium and at 55 V influent the machining times

Fig.4d: Represented machining times at 0.5A, material of titanium and at 55 V influent the S/N value.

Fig.4e: Represented at 3.0A, material of stainless steel and at 65 V influent the depth archive
5 Conclusion

Recently technology of Electrical Discharge Machining (EDM) has established technology for micro machining. From this study, the results obtained,

1) The use of EDM Die Sinker has well prospective and allowed discharging micro pit or hole for surface onto biomaterial. The need of micro pit in the surface of titanium and stainless steel is a new surface modification in biological systems (Osseointegration) on the biomaterial .

2) The used of copper tungsten electrode ,Ø0.5mm were successful to discharge/machine pit improved the surface onto biomaterial (Titanium and stainless steel).

3) Taguchi method statistically obtainable to evaluate the experimental data and the regression of parameters electrode wear, Time of machine and pit depth,0.3mm.

In the future study, researcher may use of other electrode and new parameter set for different current LT(A), Qdup, Qdon, Pon, Poff and Vgap to optimize performances in EDM DS.

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