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# Study on high efferent micro-deburring by large-area EB irradiation

Togo Shinonaga[1], Yasuaki Kimura[1], Akira Okada[1], Tomoaki Miyoshi[1]

[1]*Graduate School of Natural Science & Technology, Okayama University, 3-1-1 Tsushima-naka, Kita-ku, Okayama 700-8530, Japan*

*Email: shinonaga@okayama-u.ac.jp*

**Abstract**

A large-area Electron Beam (EB) irradiation method has been developed recently. High energy EB with uniform energy distribution can be obtained without focusing the beam and they can lead to instant melting or evaporating of metal surface. Previous works clarified that surface finishing and modification were possible for various materials, such as metal molds and biomaterials. On the other hand, it was also confirmed that convex corner tips on the workpiece was rounded due to preferential material removal at the tip by large-area EB irradiation. By using this phenomenon, we also reported that the micro burrs on SKD11 which were generated with EDM, were completely removed.

In this study, micro-deburring on magnetic and non-magnetic materials is investigated. High efficient micro-deburring is also tried by using magnetic block and thermal insulation plate. SKD11, Ni, Cu, Ti-6Al-4V and Al are used as magnetic and non-magnetic materials. Micro burrs whose height are about 40 µm, are generated at the edge of many holes machined by EDM drilling. Pulse duration $D_p$ and pulse frequency $f_p$ of large-area EB are fixed at 2 µs and 0.125Hz, respectively. The energy density $E_d$ and number of irradiation $N$ are varied in order to investigate the effects of $E_d$ and $N$ on deburring characteristics.

Burrs are completely removed on magnetic workpieces of SKD11 and Ni at $E_d$=15 J/cm$^2$ over $N$=30 shots, while complete removal of burrs is difficult for non-magnetic workpieces of Cu, Ti-6Al-4V and Al. When the magnetic block is placed under the Cu, complete removal of burrs on Cu is successfully done due to concentrating of EB. Moreover, removal ratio of burrs on Cu is increased by inserting the thermal insulation plate between Cu and magnetic block. These results suggest that high efficient micro-deburring can be done on any materials by using the magnetic block and insulation plate.

Keywords: Large-area EB irradiation, Deburring, Micro burr, Magnetic materials, Non-magnetic materials

## 1. Introduction

A large-area electron beam (EB) irradiation method developed recently, high energy EB can be obtained without focusing the beam. Then, large-area EB with uniform energy density distribution of 60mm in diameter can be used for instant melting and evaporating metal surface. It was clarified that the surface smoothing and surface modification of metal molds made of steel, cemented carbide and ceramics could be performed efficiently [1]. Furthermore, it was also reported that this surface finishing method could be applied to biomaterials, such as titanium alloy and stainless steel [2].

When the large-area EB is irradiated to a tip of convex shape, the material removal remarkably causes due to the EB concentration at the edge and heat accumulation. This phenomenon sometimes leads to the edge rounding. Our previous study showed high possibility of micro-deburring by the large-area EB irradiation due to the preferential material removal at the edge [3].

In this study, the reduction of micro burrs generated by resolidification of workpiece material in electrical discharge machining (EDM) was experimentally investigated. Then, batch micro-deburring by the large-area EB irradiation, in which many micro burrs were simultaneously removed, was discussed. In addition, micro-deburring characteristics with magnetic and non-magnetic materials were compared. Finally, high efficient micro-deburring was tried by using magnetic block and thermal insulation plate.

## 2. Micro-deburring of EDM micro burrs with different materials

Micro burr was generated at the edge of hole exit by EDM drilling using pipe copper electrode of 1.0mm in diameter. 25 small holes were arranged in 5×5 at a pitch of 1.5mm as shown in Fig. 1. Copper (Cu), titanium alloy (Ti-6Al-4V), aluminum (Al), nickel (Ni) and SKD11 (in JIS specification) plates were used as workpiece, and these sizes are 20mm length × 20mm width × 2.0mm thickness. The discharge currents in the EDM drilling were varied with the kind of workpiece material in order to obtain the same burr height of about 40µm at any materials.

SEM images of burr on different workpiece materials before and after EB irradiation at 30 shots are shown in Fig. 2. Burrs and much debris are generated by EDM drilling before EB irradiation. On the other hand, the burr hight is reduced on any materials after EB irradiaton. In the case of SKD11, burrs are completely removed after EB irradiaion at 30 shots. Although the burr heights are almost same with Cu, Ti-6Al-4V, Al and Ni,

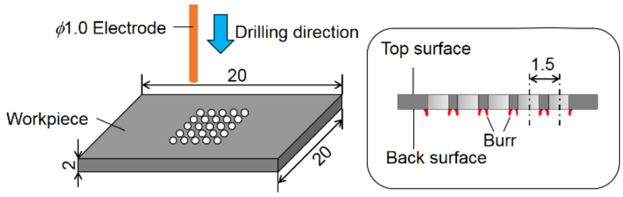


**Figure 1.** Burr generation by EDM drilling

the shapes of burrs are different with the type of workpiece materials. Moreover, EB irradiated surface around the burrs is smoothed after EB irradiation. Figure 3 shows variation of burr hight with number of EB shots. Initial burr hight is about 40µm at any materials. In the case of magnetic workpieces of SKD11 and Ni, burr can be removed completely by only 40 shots. On the other hand, reduction of burr hight is possible in the case of non-magnetic workpieces of Cu, Ti-6Al-4V and Al, while complete removal of burr was impossible.

During the large-area EB irradiation, the lines of magnetic force are generated by lower solenoid coils set on the outside of the chamber. In the case of magnetic material, the lines of magnetic force direct toward the workpiece. As a result, the electrons concentrate to the workpiece along the lines of magnetic force. Therefore, EB with higher energy density is irradiated, and complete removal of burrs is possible in the cases of Ni and SKD11.

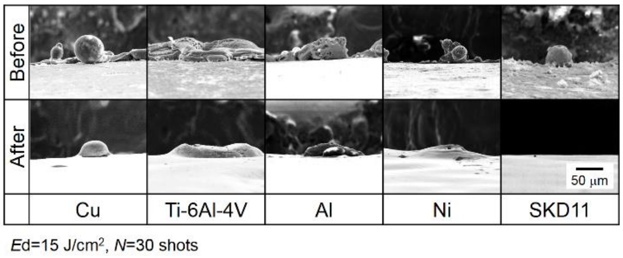


**Figure 2.** SEM images of burr before and after EB irradiation for various workpiece materials

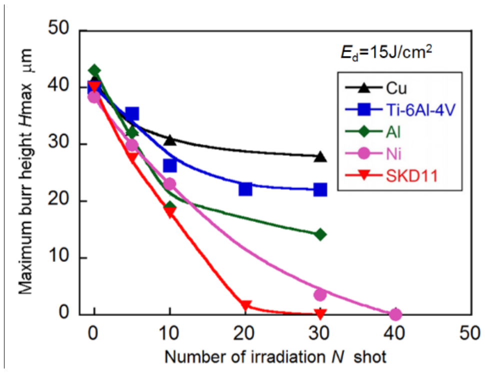


**Figure 3.** Variations of burr height with number of irradiation for various workpiece materials

## 3. High efferent micro-deburring

### 3.1. Micro-deburring with magnetic block

In the case of non-magnetic material, the EB diameter increases until the beam reaches workpiece surface, and energy densities are decreased on the workpiece surface as shown Fig. 4 (a). Then, new method of micro-deburring with EB is proposed by placing the magnetic block under the workpiece in order to realize high efficient micro-deburring for the non-magnetic material as shown in Fig. 4 (b). It is expected that electrons concentrate on the non-magnetic material since the lines of magnetic force direct toward the magnetic block under the workpiece.

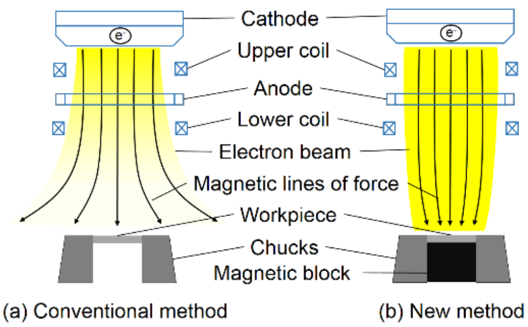


**Figure 4.** Proposal of new deburring method using magnetic block

SEM images of burrs for Cu before and after EB irradiation with conventional and new methods are shown in Fig. 5. Burrs cannot be completely removed with the conventional method at 30 shots as described above. However, complete removal of burrs is successfully done with the new method due to concentrating of EB on the Cu surface.

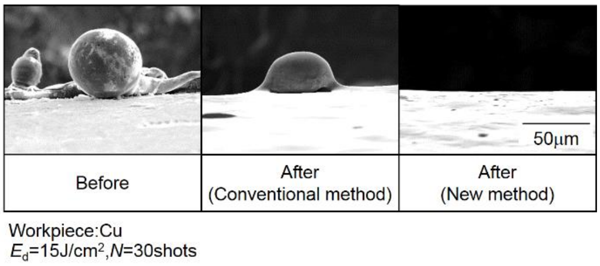


**Figure 5.** Comparison of burr after EB irradiation with and without magnetic block

### 3.2. Micro-deburring with thermal insulation plate

When the magnetic block is placed under the workpiece, it is considered that thermal diffusion is caused from the workpiece to the magnetic block. Therefore, it is expected that effect of micro-deburring is further improved by inserting the thermal insulation plate between Cu and magnetic block. Variation of burr height for Cu with thermal insulation plate is shown in Fig. 6. Burrs are completely removed at 30 shots by only using the magnetic block, while complete removal of burrs is done at 20 shots by using the thermal insulation plate. These results suggest that high efficient micro-deburring can be done on any materials by using the magnetic block and insulation plate.

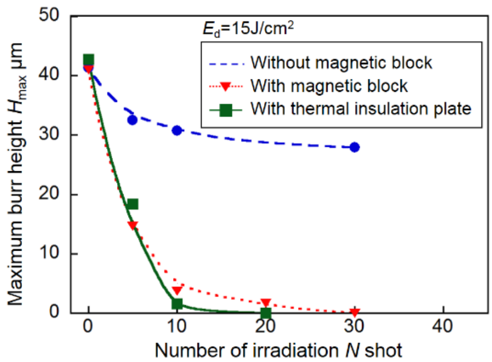


**Figure 6.** Effects of thermal insulation on burr reduction of Cu

## 4. Conclusion

1) Burrs of magnetic materials were completely removed by large-area EB irradiation at 40 shots.
2) Burrs of non-magnetic materials were completely removed by placing magnetic block under the workpiece.
3) Effect of micro-deburring was improved by inserting thermal insulation plate between magnetic block and workpiece due to reduction of thermal diffusion from the workpiece to the magnetic block.


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