Lapping of EDM-processed V-Groove array using three-dimensional tool motion

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Abstract

EDM process can produce various shapes that are impossible to produce with rotary tools. Therefore, it is used for machining metal molds. However, it is well known that the surface produced by EDM is rough and heat affected. The heat affected zone might shorten the life of the metal mold due to material change, residual stress, and micro cracks. Additionally, the rough topography of the metal mold surfaces might be reproduced on the product surfaces. With the aim of removing the heat affected zone and also improving the surface roughness, the authors developed a lapping machine, which finishes surfaces by applying various three-dimensional motions to a lapping tool in the presence of diamond compound. In this study, it is applied to the finishing of WEDM-processed V-groove array. It became clear that the lapping efficiency improves by applying a suitable lapping force and using a tool with slits.

1 Introduction

The plastic-molding of parts with precision teeth, e.g. gears and splines, are widely used in consumer products such as automobiles and office automation equipment. The metal mold to produce such a part is produced with the die sinking EDM (electrical discharge machining) or the WEDM (wire electric discharge machining), and the lapping process follows after that. As for the metal mold to which lapping is not performed after the EDM process, the mold life shortens due to the heat affected zone (HAZ) including microcracks formed by EDM. Moreover, the rough topography of the EDM-processed surfaces might be reproduced on the product surfaces, which deteriorates the performance as a mechanism element.

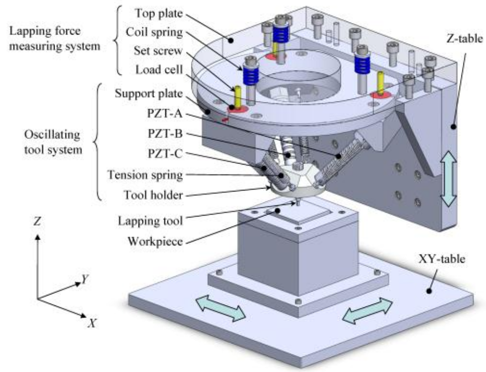


Figure 1: Developed lapping machine

Lapping of metal molds with teeth is performed manually in many cases. However, the demand for the automation of the lapping process is extremely high because the manual lapping requires time and skill. From such a background, the authors have developed a lapping machine [1], which finishes EDM-processed surfaces by applying various three-dimensional motions to a lapping tool in the presence of diamond compound.

In order to clarify the fundamental lapping performance of the developed lapping machine to a metal mold with teeth, the authors conducted the lapping experiment of a straight V-groove array formed by WEDM, using lapping tools with slits on their lapping faces.

2 Outline of lapping machine

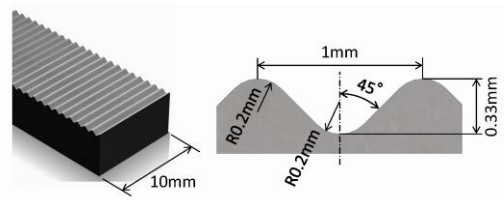
The developed lapping machine is shown in Figure 1. To aid the explanation, a right-handed rectangular coordinate system (*X*, *Y*, *Z*) is introduced as shown in this figure. The machine was composed of an oscillating tool system, a *Z* axis table which positions the oscillating tool system vertically, an XY-table which positions the workpiece horizontally, and a force sensor to measure the average lapping force.

Three multilayer piezoelectric transducers (PZTs) were installed between a PZT support plate and a tool holder with an appropriate preload. The three PZTs were arranged in rotational symmetry of a 120 degree angle with respect to the centre axis of the tool (*Z* axis). Here, the centre axis of PZT-C lied in the *YZ* plane. Each PZT axis formed a 45 degree angle with the XY plane.

3 Lapping experiment

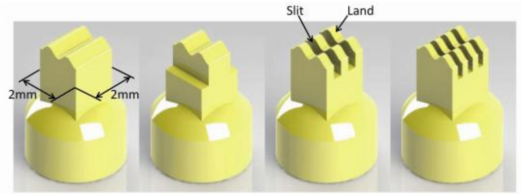
3.1 Lapping methods and conditions

Figure 2(a) shows the three-dimensional view of the workpiece, and Figure 2(b) shows the sectional view of the straight V-groove array formed on the workpiece by WEDM. The workpiece was made from cold worked tool steel (Daido Steel Co. Ltd., DC53). It was heat treated to increase the hardness. The average surface roughness (Ra) after WEDM was 0.7 – 0.9 µm.



(a) 3D-view (b) Sectional view of the V-groove

Figure 2: Workpiece



(a) Tool-A (b) Tool-B (c) Tool-C (d) Tool-D

Figure 3: Lapping tools

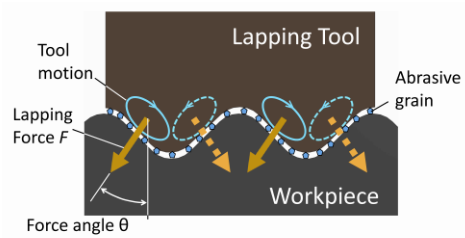
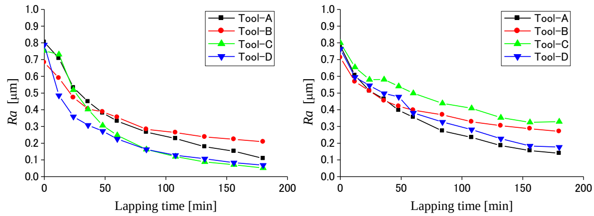


Figure 4: Lapping method

The lapping tool was made of an epoxy resin (ThreeBond Co Ltd., Base: 2023, Hardener: 2105C). For the lapping experiment, the tool end was machined so as to fit to the V-groove array geometry of the workpiece as shown in Figure 3. The tool slits are arranged in perpendicular to the V-groove direction. The depth of slits is 1 mm. Henceforth, the tool portion which comes in contact with the workpiece will be called “land”. Four kinds of tools were prepared as shown in Figure 3. The project area of the land part of Tool-A is 4.0 mm^2. On the other hand, that of Tool-B, Tool-C and Tool-D is the same, and is 2.4 mm^2.

Oil-based diamond compound (Engis Co Ltd., Hyprez OS Compound: 1-OS-47) was used. The compounds had average abrasive grain sizes of 1 µm.

The experiment procedure was as follows. First of all, the diamond compound is spread on the surface to be finished. Then, the lapping tool to which an elliptical motion of 100 Hz is applied is contacted to the workpiece surface at a constant force F as shown in Figure 4. The major axis of the elliptical tool motion is parallel to the inclined surface of the V-groove, and is 20 μm. The minor axis is 10 μm. The lapping force direction is defined by the force angle θ which is the angle between the negative Z direction and the lapping force direction. The workpiece table is reciprocated at a stroke of 8 mm and at a speed of 4 mm/min. The elliptical tool motion and the lapping force direction are changed when the work feed direction is changed.



(a) Lapping force: 4N (b) Lapping force: 6N

Figure 5: Change of R_a

3.2 Experimental results and discussion

Figure 5 shows the change of the average of R_a (average surface roughness) at the peaks and valleys of the V-groove array. In the case of F = 4 N and θ = 0°, the average of R_a at the peaks and valleys became small for Tool-C and Tool-D. In the same lapping condition, the amount of tool wear of Tool-C and Tool-D became larger than that of Tool-B. This means that the number of the abrasive grains between the lapping tool and the lapping surface increases in the case of the lapping tool with slits. On the other hand, in the case of F = 6 N, the amount of tool wear of Tool-C and Tool-D is almost the same as that of Tool-B. This means that abrasive grains become hard to enter between the lapping tool and the lapping surface, or they are embedded in the tool when too strong lapping force is applied. The inclined surface of the V-groove is finished well when θ = 15°, compared with when θ=0°. However, the valley portion is hard to be finished when θ = 15°.

4 Conclusions

It became clear that the lapping efficiency improves by applying a suitable lapping force and using a tool with slits.

Reference:

[1] M. Mizuno, T. Iyama, X. Zhang, N. Nishikawa: Development of a Three-Dimensional Tool Oscillation System for Finishing Metal Molds, Key Engineering Materials, Vols. 389-390, pp.302-307, 2008.