A STUDY ON MACHINING CHARACTERISTICS FOR COMPOSITION 3-DIMENSIONAL SHAPE USING PULSE ELECTROCHEMICAL MACHINING: OPTICAL MICROSCOPIC, NON-CONTACT 3D MEASUREMENT STUDY OF SURFACE ANALYSES

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Abstract - As the level of precision increases gradually in the area of processing technology, interests in precise and complicated image processing increase as well particularly in the area of MEMS-related micro machinery and processing method development. However, technologies develop complementarily. While researches on processing technology for 3D micro structures are conducted actively, processing aspects involve problems. For instance, 3D image processing involves the remaining deformation layer after micro electric-discharge machining. Micro electro-chemical machining itself is superior in terms of surface roughness improvement, but its form accuracy is not as great as that of micro electric-discharge machining. The present study aims to examine the relevance between pulse electro-chemical machining variables and the processing state and to verify the potential of micro-precision image processing by measuring and inspecting the surface condition and image of electro-chemically machined specimens.

Index Terms - 3-Dimensional shape, Pulse electrochemical machining, Machining depth, applied voltage,

I. INTRODUCTION

As the demand for micro machining in the areas of electricity, electronics, and mechanics increases, countries with advance technology have already focused their researches on ultra fine and ultra-precise machining of knowledge information products with high added values in preparation for the knowledge-based age. It is sought to improve the performance, price competitiveness, and economic utilization of energy and resources by minimizing the size of products.

In general, problems of present mechanical processing method are thermal deformation and burr arising after processing. More-over, external chemical processing method needs much time, and also appears processing problems due to a series of several steps. It requires a special processing technology for respective purposes, particularly for surface quality, which cannot be achieved by using traditional mechanical polishing. In the traditional mechanical polishing method, even though surface condition is good after polishing, there still remains very slight polish mark and deformed layer. ECM and EP has been processed using DC current in the early days, but recently, pulse electrochemical machining(PECM), which can continue past, increases the accuracy of the shape and makes a better surface condition using pulse cur-rent than surface condition using DC current has been researched.[1] Therefore, PECM has seen a resurgence of industrial interest within the last decade, due to its many advantages, such as no tool wear, stress-free and smooth surfaces, and the ability to machine complex shape products by different materials, regardless of their hardness and high strength, high tension, or whether they are heat-resistant materials. In this study, the possibility of pulse electrochemical machining is investigated by surface analysis of processed Invar prior to pulse electrochemical machining.[2]

II. MECHANISM OF PULSE ELECTROCHEMICAL MACHINING

Traditional machining which performs with tool contact to workpiece is difficult to apply the machine parts which need to consider functional characteristics before mechanical or structural characteristics such as micro-structure for micro machines. Pulse electrochemical machining, one of non-traditional machining technique without contact between tool and workpiece can be used to achieve a desired workpiece surface and shape by dissolving the metal workpiece with an electrochemical reactions. Pulse electrochemical machining can machine difficult-to-cut materials which has characteristics such as high hardness, strength, tension, and heat resistant. And it can achieve micro-complex shapes without distortion, scratches, burrs, and stress. This pulse electrochemical machining method can be applied in industry for cutting, de burring, drilling, and shaping the workpiece. It provides an effective alternative for manufacturing a wide rage of components such as aircraft turbine parts surgical implants, bearing cages, molds and dies, and even micro-components.

Fig. 1 shows the principle of micro electrochemical. The workpiece and the electrode which used as tool are in electrolyte. The workpiece is contacted to anode and electrode is contacted to cathode in electrolyte. And than the electrical power is supplied, the electrical and chemical reaction between workpiece, electrode and electrolyte is occurred. The electron moves through a negative-flow of electricity. So, the surface of workpiece which contact to anode accepts electrons and the electrode which contact to cathode gives electrons. In other words, the oxidation-deoxidation process is occurred between anode and cathode. The speed and shape of electro-chemical reaction can be controlled through regulating the electrolyte and electrical power. Electro-chemical reaction is the oxidation-deoxidation process, and this oxidation process makes oxides which is a cause of corrosion of workpiece.

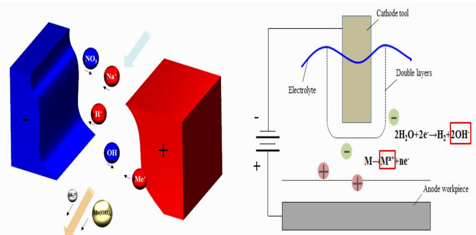


Fig.1 The principle of electrochemical machining

III. EXPERIMENTAL DETAILS

Fig. 2 shows the electrode (cathode and anode) cyclic voltammeter equipment used for the laboratory PECM experiments. PECM on the workpiece (+) as cathode (−) to connect the electrode reduction process by the positive electrode (+) and connect to the flooded electrolyte or electrolyte current is injected to be conducted. Oxidation–reduction occurs between both poles in the high voltage and low voltage, which acts on the anode (+) side, while trace amounts of oxygen causes the workpiece to begin the dissolution process. For cathode (−) side, large amounts of hydrogen gas occur but that does not result in equilibrium.[3,4] Fig. 2 shows a schematic of the experimental setup for the sur-face analysis. A tungsten electrode, which has superior conductivity, is used for the tool electrode. The tool diameter is 1.2 mm. Among the conditions of the experiment, the electrode feed rate, machining time, and electrode gap distance between the workpiece and tool electrode are fixed.[5-7]

Experiments were carried out with three different applied voltages, machining depth in aged PECM electrolyte in order to see the effect of the applied voltage. The current density could be controlled by varying the voltage applied to the electrodes. After the PECM, STS 316L plate was rinsed in ultra-pure water, and all the samples were carefully detached.

Table 1 describes the experimental conditions of the lab-oratory PECM.

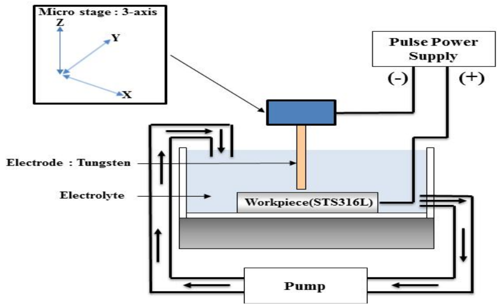


Fig.2 The experimental setup

PECM time(min)	27
Machining depth	1, 2, 3min(10μm)
Voltage(V) / Current(A)	4, 6, 8 / 3
Electrode feed rate	200
Electrode(cathode)	Tungsten ∅ 1.2
Workpiece(anode)	STS 316L
Electrode gap(μm)	100μm
Electrolyte	Sulfuric acid 0.5mol

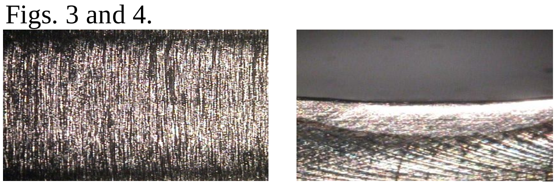
Table 1 Experimental conditions

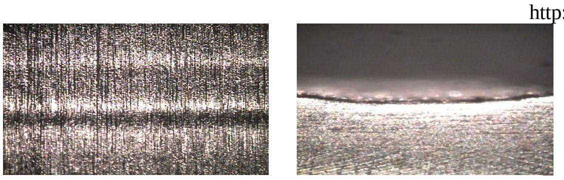
Data rate	25 – 30 data/s
Dim	500 mm × 610 mm × 400 mm
Max. readings	5000
Max. XY scan length	100 mm × 50 mm
Min. step size	0.001 mm
Throat depth	70 – 120 mm
Z adjustment	50 mm
Light	White light microscopes

Table 2 The specification of non-contact 3D

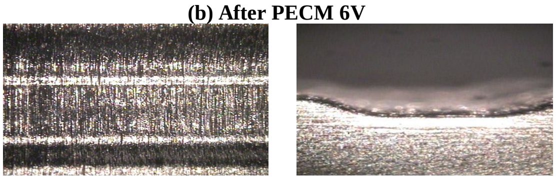
IV. RESULTS AND DISCUSSION

Optical microscopy and non-contact 3D profile experiments were performed on the samples to reveal the sur-face features of Invar alloy after PECM. The optical microscopy and non-contact 3D profile studies were performed for the surface analyses. The kind of electrolyte applied voltage, and machining depth in PECM were examined in the surface analysis. Selective optical microscopic to pographic images before and after PECM of the STS 316L are presented in Figs. 3 and 4.


(a) After PECM 4V



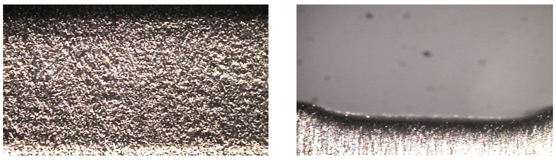
(b) After PECM 6V



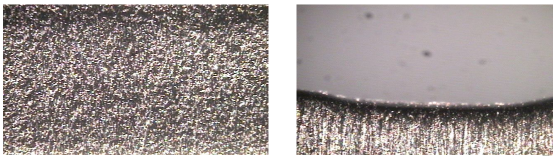
(c) After PECM 8V

Fig. 3 Optical microscope of machined surface [applied voltage]

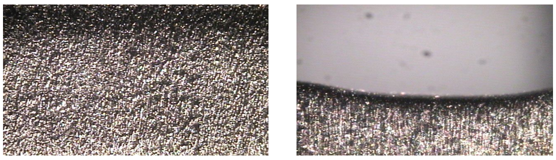
Fig. 4 shows the surface conditions according to the areas of each voltage. The scratches in the specimens before the processing disappear as the processing progresses, and blurred boundary structures appear in the range of4 – 6 V. A boundary can be clearly identified at 8 V.



(a) After 1min 10㎛



(b) After 2min 10㎛

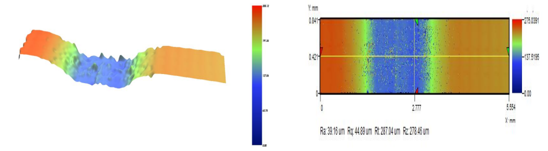


(c) After 3min 10㎛

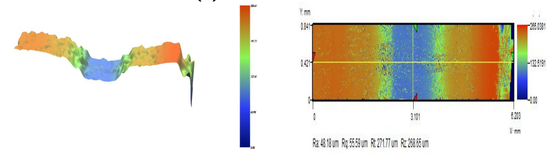
Fig. 4 Optical microscope of machined surface [machining depth]

Fig. 3 and 4 shows the surface structure pictures after PECM. Even though the structures were not examined after PECM 4V (Fig. 3a),it was dentified that the transformed layer was removed, and shape was obtained after PECM (Fig. 3c).

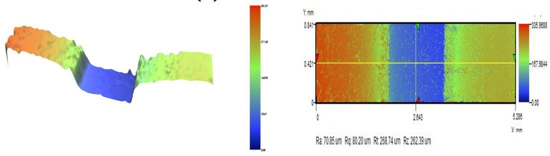
The other way, structures were examined after PECM 4V (Fig. 4a),it was dentified that the shape was not obtained after PECM (Fig. 4c). Fig. 3 and 4 shows an excessive concentration of voltage according to the applied voltage and machining depth. Shape were generated by the concentration of voltage according to the surface materials, which occurred during the processing.



(a) After PECM 4V

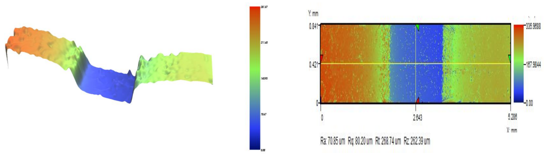


(b) After PECM 6V

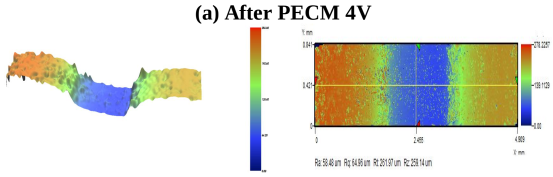


(c) After PECM 8V

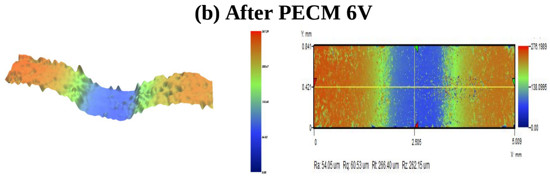
Fig. 5 Non-contact 3D surface measurement [applied voltage]



(a) After PECM 4V



(b) After PECM 6V

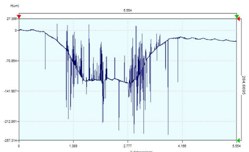


(c) After PECM 8V

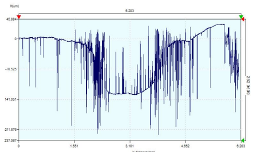
Fig. 6 Non-contact 3D surface measurement [machining depth]

From the 3D and 2D views of the morphology in Figs. 5 and 6,we found that the surface condition has an immediate connection with the applied voltage and machining depth. Experiments were also conducted with optical microscope and non-contact 3D with the same conditions, and the results show that the surface conditions clearly differ according to the applied voltage, machining depth of the electrode.

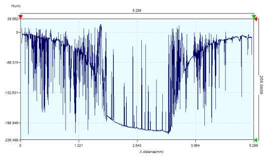
It could be identified that the voltage was increased with the flat shape and the materials which form during the processing affect the workpiece surface, because the materials remained between the electrode and the workpiece. Good shape conditions of the materials could be identified, because excessive voltage was not concentrated in the case of the applied voltage(Fig. 5c), machining depth(Fig. 6c) and the materials did not have much of an effect on the workpiece shape.



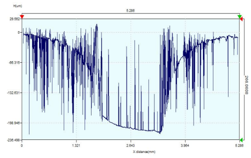
(a) After PECM 4V (Depth : 106μm)



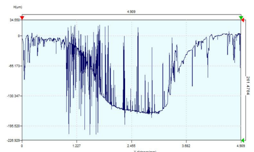
(b) After PECM 6V (Depth : 131.7μm)



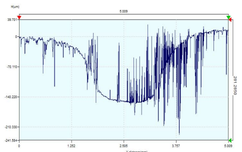
(c) After PECM 8V (Depth : 205.5μm)



(d) After PECM 1min 10μm (Depth : 205.5μm)



(e) After PECM 2min 10 μm (Depth : 169.6μm)



(f) After PECM 3min 10 μm (Depth : 156.5μm)

Fig. 7 Surface shape profile[(a)-(c) applied voltage, (e)-(h) machining depth].

The surface conditions were measured using a Nano View non-contact surface profiler, as shown in Figs. 7. Table 2 shows the specifications of the non-contact 3D analysis. The workpiece surface, which is deformed by chemical reaction with the electrolyte, is deteriorated due to the increase in voltage. During the processing, one of the critical removal mechanisms(the PECM mechanism) occurs between the workpiece and the electrode. This electrolyte chemical reaction on the surface of the workpiece generates impurities through its active motion. However, excessive chemical reaction can lead to excessive surface shape treatment of the workpiece.

CONCLUSIONS

This study demonstrated that PECM is a suitable process for machining shape machining. Optical microscope and non-contact 3D measurement analyses characteristic that the morphology of the surface with increased voltage was regularly changed out. Then, the machining shape and surface qualities such as the surface condition and electropolishing effect were observed. The important factors influencing the PECM quality of the shape machining are the applied voltage, conductive material, the machining depth of the positive pole, and the electrolytic process parameters. An applied voltage with an adjustable current pulse is necessary to dissolve the metal of the shape machining evenly. During the application of PECM to shape machining, the electrochemical machining characteristics of the surface of the workpiece were revealed and analyzed(for applied voltage, machining depth).

This study indicates that the applied voltage, machining depth have surface effects on obtaining suitable PECM conditions, and that there is aclose interrelation between the electric field on the surface shape and the polishing rate. The optimum surface quality, effectiveness, and cost can be found by proper control of the electrolytic process parameters.

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