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Detection of Electric Discharge Machining State By Using Ultrasonic Technique

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Abstract

The electric discharge die-sinking is widely used in order to make a mold and so on. In the electric discharge die-sinking, an electric discharge occurs between an electrode and a workpiece. When a lot of debris exists at the discharge gap, the electric discharge becomes abnormal. Therefore, in this study, a detection method of the electric discharge die-sinking state by using an ultrasonic technique has been examined in order to prevent the abnormal discharge.

In this study, the following results have been obtained. (1) The discharge gap can be measured by using the pulse echo technique during the electric discharge die-sinking. When the abnormal electrical discharge occurs, the gap becomes large. (2) The abnormal discharge can be detected by the variation of the received elastic waves which are generated at a discharged point and transmitted through the workpiece. (3) The depth of the hole machined by die-sinking can be measured by using the pulse echo technique during machining. (4) The abnormal discharge can be prevented by vibrating the electrode by an ultrasonic vibration.

Keywords: Electric Discharge Die-Sinking, Ultrasonic, Discharge Gap, Ultrasonic Vibration

1. Introduction

The electric discharge die-sinking is widely used. In the electric discharge die-sinking, an electric discharge occurs between an electrode and a workpiece. Then, a part of workpiece surface is melted and removed by the electrical discharge energy. Anything can be machined in case of a conductor. Especially, a material which can be hardly machined by cutting can be machined. Moreover, in order to make a metal mold of an injection molding of a thermoplastic, the electric discharge die-sinking is widely used. In general, the electrode is made of carbon or copper. The electrode is machined to the shape of the mold cavity in advance.

However, when debris remains between the electrode and the workpiece surface, the electric discharge occurs not between the electrode and the workpiece surface but between the debris and the electrode[1]. Then, the workpiece can not be machined. That is an abnormal discharge state.

On the other hand, it is very important to measure a discharge gap to clarify the discharge behavior[2]. The electrode erodes during the electric discharge die-sinking. So, it is difficult to measure the discharge gap from a position of a machine head to which the electrode is attached[3]. It is also difficult to measure a depth of a machined hole from the position of the machine head.

Therefore, in this study, a detection method of the abnormal discharge state by using an ultrasonic technique has been examined. Measurement methods of the discharge gap and the depth of the machined hole during the electric discharge die-sinking by using the ultrasonic technique also have been examined. Moreover, a method of controlling the abnormal discharge state by using an ultrasonic vibration has been studied.

2. Detection of the electro discharge state

Fig. 1 shows the schematic view of the experimental apparatus. The discharge gap, L, is a gap between an end surface of the electrode and the workpiece surface. The pulse echo technique is used to measure the discharge gap and to detect the abnormal discharge state. In this study, the workpiece is machined by the die-sinking. The machined depth, D, can be also measured by using the pulse echo technique. The electrode approaches the workpiece surface from its upper side. Then, the electric discharge is generated between the electrode and the workpiece surface. The electrode is made by copper and its diameter is 10mm. The workpiece is made of steel and it is put in working fluid. The electric discharge is generated between the electrode and the workpiece surface in the working fluid. Oil is used as the working fluid. An ultrasonic transducer is attached at the bottom surface of the workpiece. Its diameter is about 6.4mm and its frequency is 5MHz. The ultrasonic wave is generated at the ultrasonic transducer and it transmits through the workpiece. A part of the transmitted ultrasonic wave reflects at the workpiece surface and it can be observed as a reflected wave, S_1 and S_2, as shown in Fig.1. The other ultrasonic wave transmits through the working fluid and it reflects at the end surface of the electrode. It can be observed as a reflected wave, F_1, as shown in Fig.1. A distance between the electrode and the workpiece, L, the thickness of the workpiece, H, and the machined depth, D, can be obtained from the following equation.

$L=C\Delta t/2$, $H=C_m\Delta t_m/2$, $D=H_0-H$

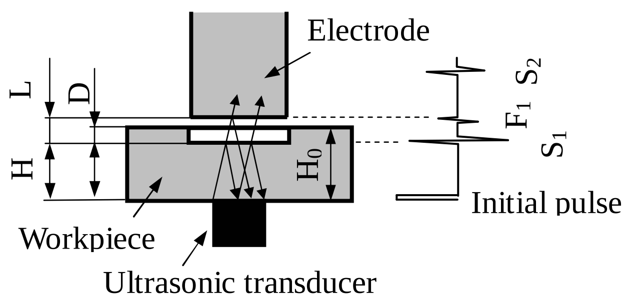


Fig.1 Experimental apparatus

Here, C is a sound velocity of the working fluid, C_m is the sound velocity of the workpiece, Δt is a time interval between the reflected echo S_1 and F_1, Δt_m is a time interval between the reflected echo S_1 and S_2. H_0 is an initial thickness of the workpiece.

Fig.2 shows the measured discharge gap, L. X axis is machining time, t, and Y axis is the distance between the electrode and the workpiece, L. Fig.2 (a) shows a normal discharge state. In the case of the normal discharge state, the discharge point moves and the electric discharge is generated one after another. The surface of the workpiece is removed one after another by the generated electric discharge. As shown in Fig.2 (a), when the electrode approaches the surface of the workpiece, the electric discharge is generated at once. Elastic waves are caused at electric discharge points. Then, the reflected ultrasonic wave cannot be detected because the elastic waves become a noise. Moreover, it is indicated that the discharge gap, δ, become narrow. It is about 50 μm.

However, when a lot of debris exists at the discharge gap, the electric discharge becomes abnormal. Fig.2 (b) shows an abnormal discharge state. In the case of the abnormal discharge state, the electric discharge is centered at a point where debris concentrates. Moreover, when the amount of the debris increases and the electrode connects to the workpiece by the debris, the discharge is not generated. As shown in Fig.2 (b), the electric discharge is hardly generated and the discharge gap, δ, becomes larger than that of the normal discharge state.

Fig.3 shows the relationship between the displayed depth of hole, D_d, and the measured depth of hole, D. The displayed depth of hole, D_d, is obtained from the position of the machine head. X axis is the displayed depth, D_d. Y axis is the measured one, D. It is indicated that displayed depth of hole, D_d, is almost equal to the measured one, D, in a rough machining condition. However, in a finish machining condition, the displayed depth of hole, D_d, is smaller than the measured one, D, because an erosion of the electrode is very large.

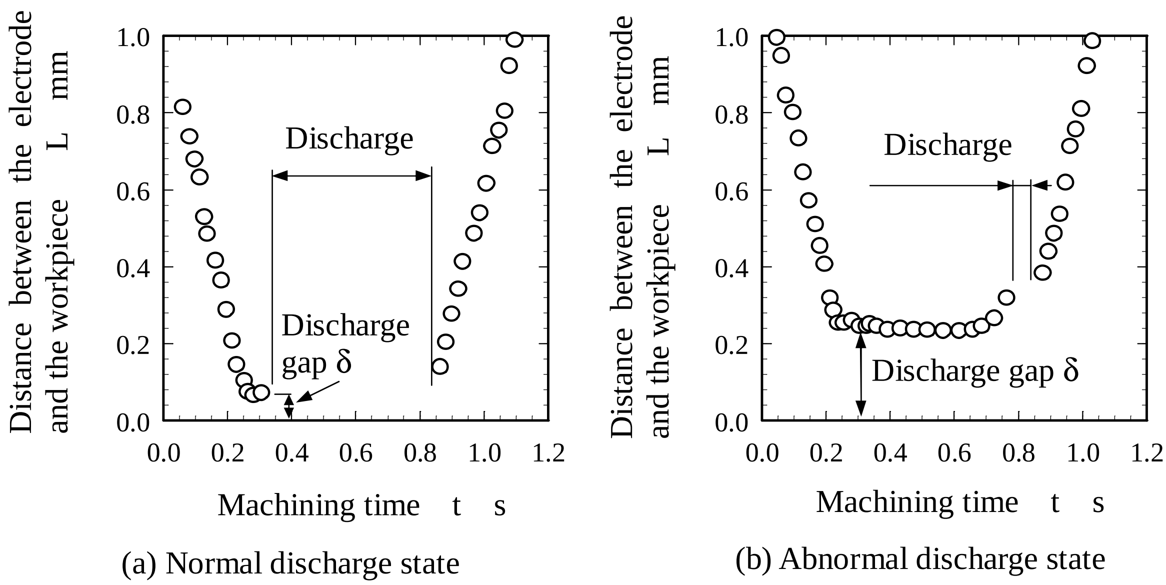


Fig.2 Discharge gap

The ultrasonic transducer must be attached to the bottom of the workpiece in order to detect the abnormal discharge state by using the pulse echo technique. However, there are many cases where the ultrasonic transducer can not be attached at the bottom of the workpiece. Then, a method to detect the abnormal discharge state by receiving the elastic waves generated at the discharge point has been examined. The schematic view of the method is shown in Fig.4. In this study, the upper surface of the workpiece is machined by the die-sinking. The ultrasonic transducer is attached at the side surface of the workpiece. The elastic waves generated at the upper surface of the workpiece are received by the ultrasonic transducer.

In Fig.4, the received elastic waves are shown. Fig.4 (a) shows that of the normal discharge state. Fig.4 (b) shows that of the abnormal discharge state. In the case of the normal discharge state, the elastic waves are continuously received as if the noise. Because, the

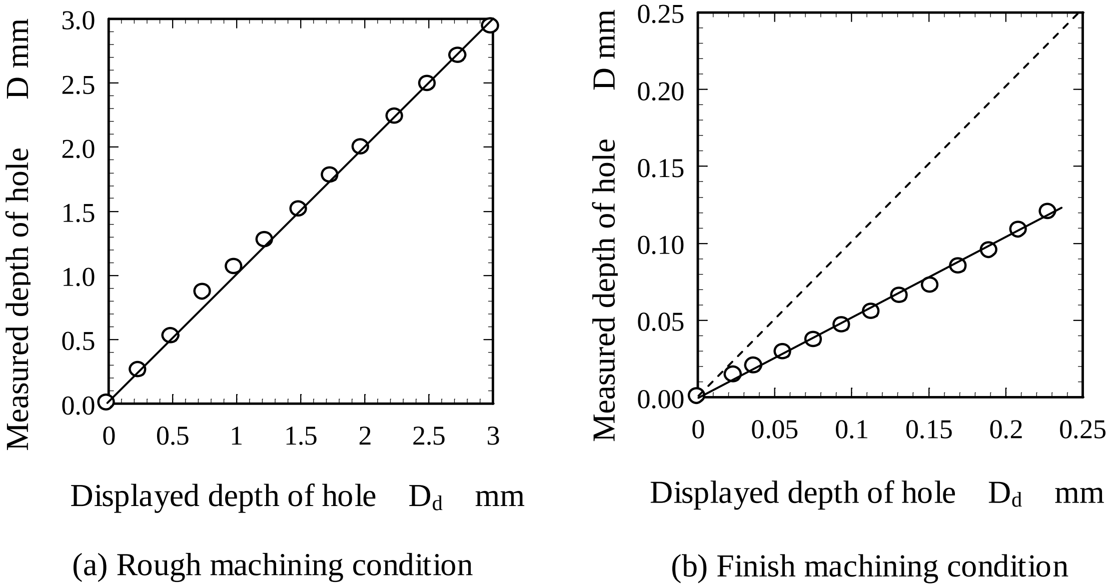


Fig.3 Relationship between the displayed depth of hole and measured one

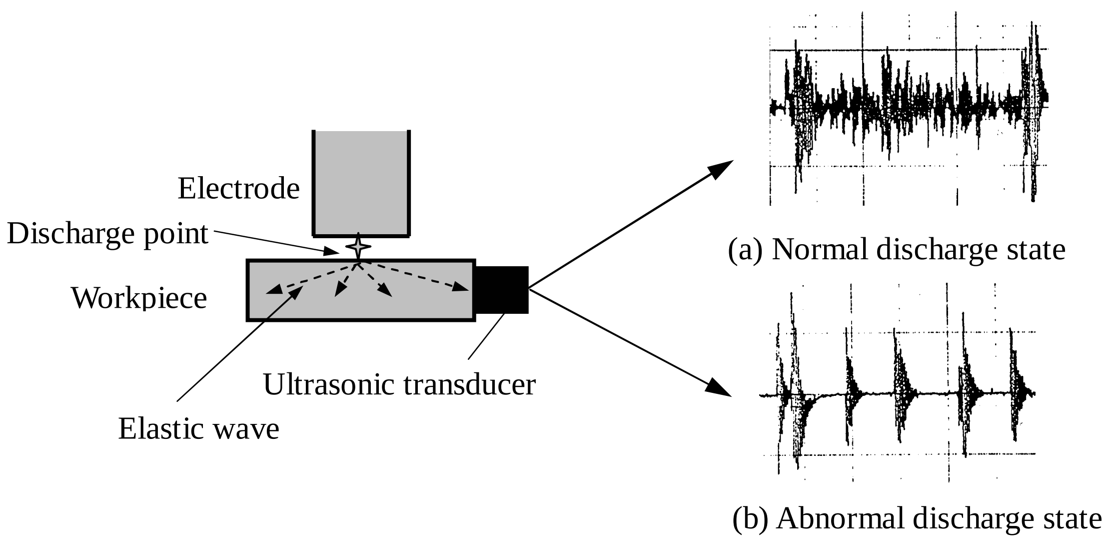


Fig.4 Received elastic waves

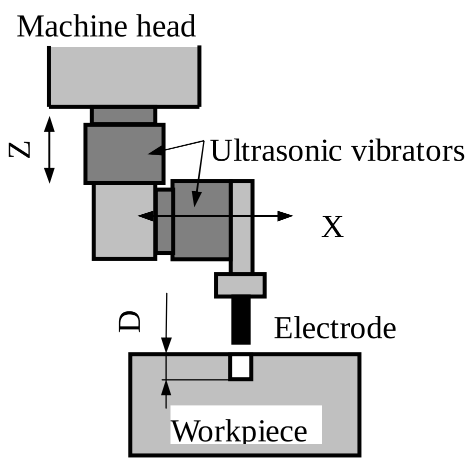
discharge point moves and the electric discharge is generated one after another. However, in the case of the abnormal discharge state, the elastic waves can be intermittently observed because the electric discharge is concentrated at a point. The discharge point can not move and the electric discharge can not be generated one after another.

3. Control the abnormal discharge by the ultrasonic vibration of the electrode

When a lot of debris stays at the discharge gap, the electric discharge is concentrated and it becomes the abnormal electric discharge state. Then, the workpiece can not be machined. In order to control the abnormal discharge state, the debris is prevented from remaining at the discharge gap. In general, the working fluid is blown into the discharge gap[4]. However, when the depth of the machined hole becomes deep, the blowing fluid can not reach to the discharge gap. So, it is difficult to prevent the remaining of the debris by blowing the working fluid.

Therefore, in this study, a method to prevent the remaining of the debris at the discharge gap has been examined. In this method, the electrode is vibrated by using ultrasonic vibrators. Fig.7 shows the outline of the experimental apparatus. The electrode is vibrated by using two ultrasonic vibrators. The diameter of the electrode is 10mm and it is made of copper. The electrode is vibrated in X and Z directions by the sinusoidal wave. The phase of each vibration can be changed. The acceleration in X and Z directions at the head of the electrode has been measured by using an acceleration sensor. The frequency of the ultrasonic vibration is set to the frequency of which the acceleration becomes the maximum. It is 32.0 kHz. The workpiece is made of steel. In this study, the depth, D, until the abnormal discharge occurred has been measured.

The results are shown in Fig.5. X axis is the machining time, t. Y axis is the depth, D.



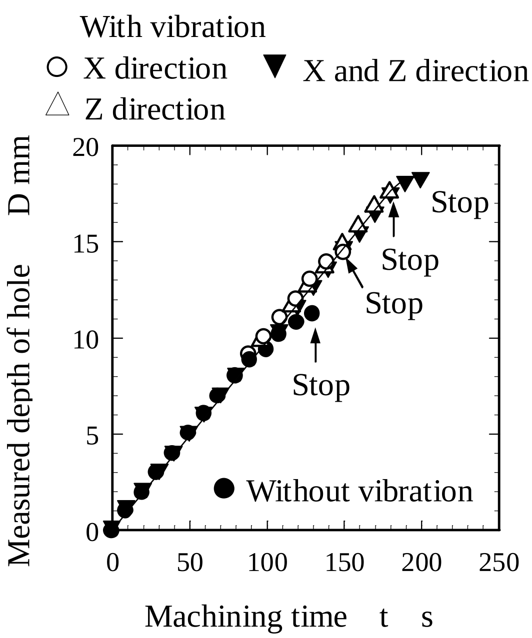


Fig.5 Electric discharge with the ultrasonic vibration

When the electrode is vibrated only in X direction, the depth is almost equal to that when the electrode is not vibrated. However, when the electrode is vibrated in Z direction or both in X and Y direction, the depth is about 1.6 times deeper than that when the electrode is not vibrated.

5. Conclusions

The following conclusions are obtained.

(1) The discharge gap can be measured by using the pulse echo technique during electric discharge machining. When the abnormal discharge is occurred, the discharge gap becomes large.

(2) Elastic waves which are generated at a discharge point and transmitted through the work piece can be received by the ultrasonic transducer. Then, the abnormal discharge state can be detected by the variation of the received elastic waves.

(3) The depth of the hole machined by die-sinking can be measured by using the pulse echo technique during machining.

(4) The abnormal discharge state can be controlled by ultrasonic vibration of the electrode in Z direction or both in X direction and in Y direction.

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