INVESTIGATIONS ON ULTRASONIC VIBRATION ASSISTED EDM IN TIN POWDER MIXED DIELECTRIC

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Abstract - This research was studied about ultrasonic machining (USM) and Electrical Discharge Machining (EDM) in TiN powder mixed dielectric fluid. The experiments were carried for improving surface characteristics and related to the surface modification. The experiment was carried out on a tool steel (SKD11) using a copper tool electrode. In this research, to obtain the even modified layer, the effects of EDMed conditions and ultrasonic frequencies were investigated. The EDMed surfaces were observed by SEM. Under the suitable discharge conditions in TiN powder mixed kerosene, the stable thick TiN layer adhered on the workpiece surface. The microcrack length per unit area treated in TiN mixed kerosene was greater than that treated in normal kerosene. Microhardness and wear resistance tests were conducted to evaluate the modifications on the machined surface caused by the combined process. Titanium carbon nitride (TiCN) was found on the modified layer by XRD analysis. The effect of the diffusion of carbon during cooling on the characteristics of the recast layer was discussed.

Index Terms - EDM, USM, Combined process, Material removal rate, Surface modification

I. INTRODUCTION

Tool steel Type JIS SKD11 is widely used in applications requiring hardness and good elevated temperature strength. Because of its properties, the SKD11 is good to fabricate mold and die using electrical discharge machining (EDM). EDM is based on the erosion of materials by electrical sparking. Solid, liquid or gas particles can be removed [1,2]. The EDM process generates a recast layer cover the surface after the process. The recast layer is called a white layer due to its colour after etching. This comprises a spattered surface layer and a layer that is removed during the spark process.

The next layer is a new layer that is formed by melting but it is not removed from the material and is referred to as a recast layer. This also results in metal is deposited on the workpiece surface as a coating layer. The study of the surface modification using EDM began about a decade ago [3,4]. Furutani et al. [5] used titanium powder in kerosene dielectric and obtained titanium carbide layer on a steel with a copper rotating disk electrode and they kept the powder concentration high in the machining area on carbon steel. This occurs because titanium and carbon from the degradation of the dielectric combine during the spark process with the material surface while it is cooling [2,6]. Yan et al. [7] obtained TiN on the titanium's workpiece using EDM in urea solution. EDMed surfaces have defects such as microcracks and pores that form because of the temperature gradient that is created near the surface, which induces a substantial modification of the thermally affected layer during the machining process. This work aimed to study surface modification of the recast layer onto a surface by electrical discharged machining.

The proposed technique associated with surface modification not only modifies the machined surface but also promotes the machining efficiency. Some researchers have investigated the effects of EDM combined with ultrasonic machining (USM). Kremer et al. [9] dealt with EDM assisted with ultrasonic vibration of electrode and introduced the beneficial effect of ultrasonic vibration. Yan and Chen [10] proposed a new method for improving the EDM performance of Ti–6Al–4V alloy using ultrasonic vibration in dielectric. Zhixin et al. [11] developed a new technique of ultrasonic vibration pulse EDM for drilling precision holes on ceramic materials. Lin et al. [12] conducted a experimental study using a combined process of EDM with USM to investigate the machining characteristics of Ti–6Al–4V alloy, the experimental results confirmed that this combined process increased the overall machining efficiency. The combined process promoted the circulation of the dielectric, so the debris was easily expelled from the machining region.

The present study investigated EDM combined USM for surface modifications that improved the properties of the modified surface.

II. EXPERIMENTAL PROCEDURE

EDM and USM were combined to conduct a series of experiments, in which the surface modifications of SKD11 (in JIS specification) were studied. Fig. 1 shows a schematic diagram of experimental apparatus.

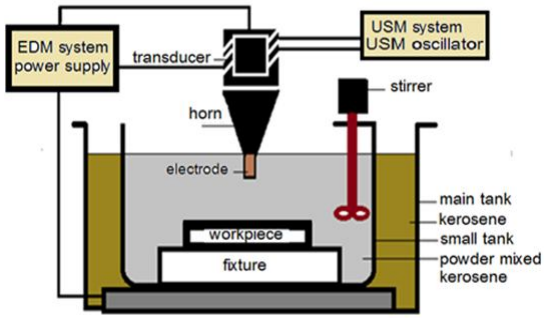


Fig.1 Experimental setup for EDM/USV

In this combined process, a transducer of USM was attached to a conventional EDM machine. The USM transducer was joined to a electrode to transfer the USM power to the EDMed zone at a resonant frequency of 40–120 kHz. Table 1 shows the chemical composition of SKD11. Carbon 1.5 % is important to affect to heat treatment. Machining conditions were set as shown in Table 2. The tool electrode is a copper cylinder of 3 mm in diameter. As machining fluids, kerosene and titanium nitride powder mixed fluid were used at a concentration rate of 15 g/l. The particle size of TiN powder is not over 2 μm in diameter. Fig. 2 shows generation mechanism of modified layer. In EDM phenomena, polarity of electrode plays important role for machining, the positive (+) electrode polarity is chosen for the machining [4,8]. On the contrary, the negative polarity (-) often uses for the modified technology. Carbon from the powder and/or resolved carbon from the kerosene combine with the material of the electrode during the discharge phenomenon, and so a new compound material is formed on the EDMed surface. In our setup, the polarity of the electrode is set to negative in order to make wear of electrode.

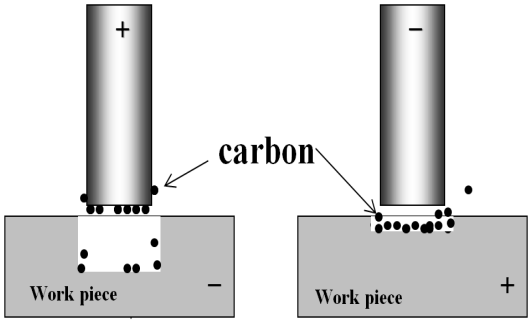


Fig. 2 Generation mechanism of modified layer.

III. RESULTS AND DISCUSSIONS

Fig. 3 shows SEM micrographs of EDMed surface using discharge current 6 and 21 Amperes with on time 50 and 500 μs in TiN powder mixed kerosene. The EDMed surfaces are composed of unstable fusing structure, debris, shallow craters, voids and cracks. Cracks can be reduced with covering of the TiN powder [13].

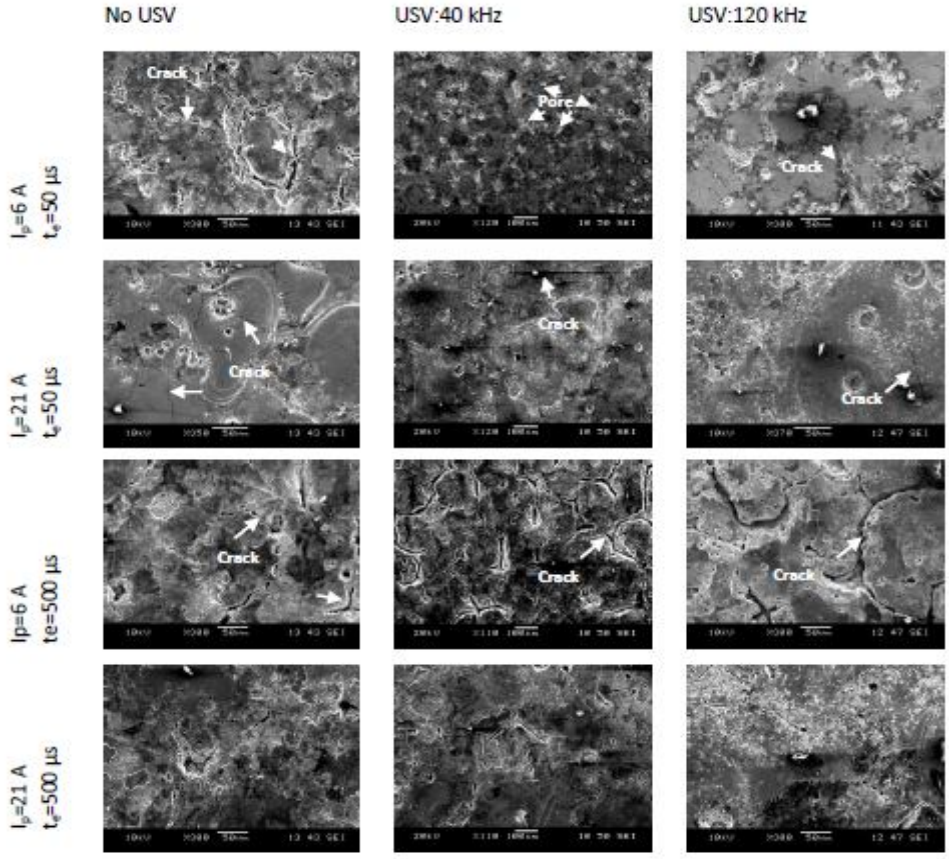


Fig. 3 SEM micrographs of the machined surface obtained using the conventional EDM and combined process with 40 and 120 kHz

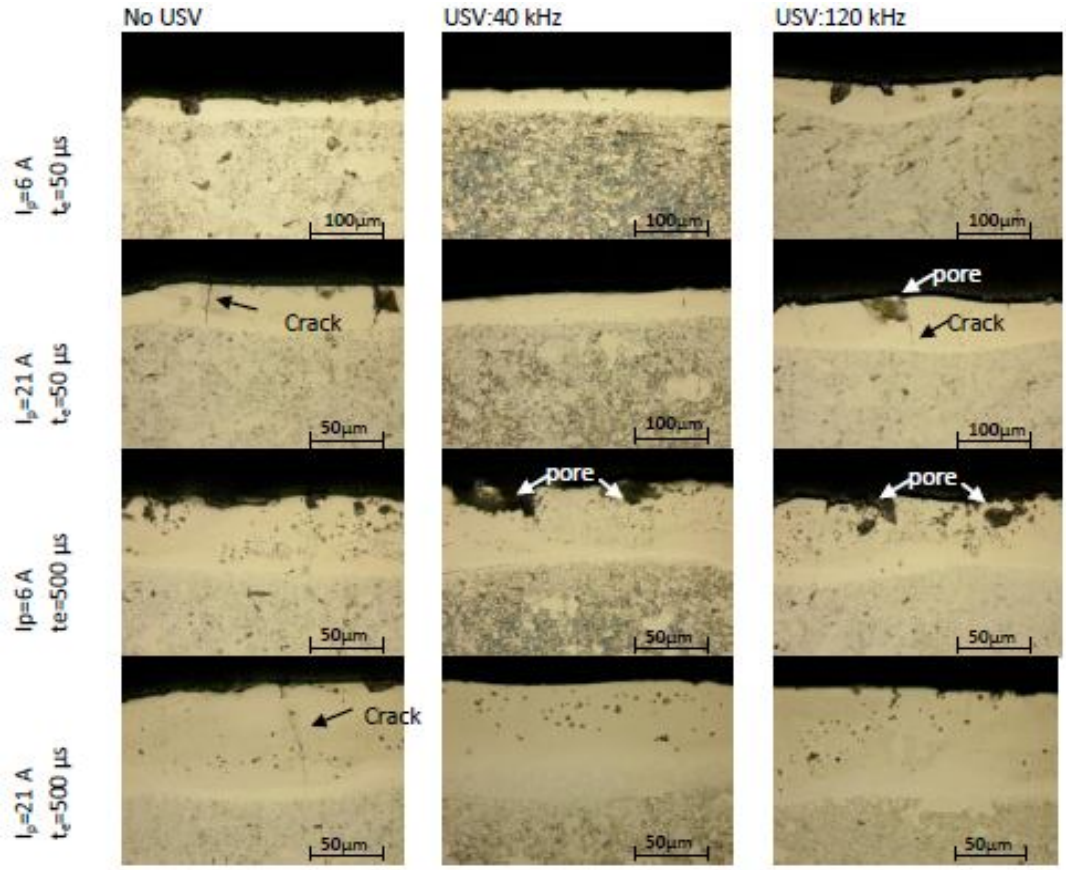


Fig.4 Cross sectional SEM micrographs of the machined surface obtained using the conventional EDM and combined process with 40 and 120 kHz

Fe	C	Si	Mn	Mo	Cr	Ni	V	Co
bal.	1.5	0.3	0.3	1.0	12	0.3	0.8	2.1

Table 1. Chemical Compositions of SKD11 (wt.%)

	Levels
Current, I (A)	6 and 21
Discharge duration, t_e (µs)	50 and 500
Duty factor (%)	50
Ultrasonic amplitude (µm)	30

Table 2. Experimental Conditions

The figures are compared with conventional EDM and EDM combined with various frequencies of USV. For on time (t_e) = 50 µs, they are found that USV combined EDM can reduce cracks on the surface for both discharge currents (6A and 21 A). The figure shows that cracks and pores of the combined surface was not much different comparing with that of conventional EDM. However, it seems more cracks using 40 kHz of USV combined with EDM than that of 120 kHz of USV and conventional EDM. However, cracks were violent when using frequency of 120kHz for discharge current =6 A and on time = 500 µs. For discharge current = 21 A and on time = 500 µs, frequency of 120kHz can reduce few crack compared with no USV and frequency of 40kHz. The frequency of 40kHz for discharge current = 21 A and on time = 500 µs shows that cracks and pores of the combined process was not much different comparing with that of conventional EDM.

Fig. 4 displays cross sectional SEM micrographs of the machined surface obtained using the conventional EDM and combined process with 40 and 120 kHz in TiN powder mixed dielectric fluid. As shown in the figure, the thickness increases with increasing of on time. The white parts on the top surface seen on the micrographs are the coated layers. The layer contains cracks and pores. This is due to the large amount of heat generated by the discharges, which causes melting of the material, followed by rapid cooling. The undulation is very small and the thickness is approximately uniform when using shorter on time at 50 µs. The USV combined EDM can reduce cracks that are shown in discharge current= 21A with on time= 50 µs and on time= 500 µs. For discharge current= 6 A with on time= 50 µs, size of pores can be reduced using 40kHz of USV, but it is not different using 120 kHz of USV. For discharge current= 21A with on time= 500 µs, it seems that it is not much different for modified layer. Moreover, size of pores for USV combined seems bigger than that of conventional EDM.

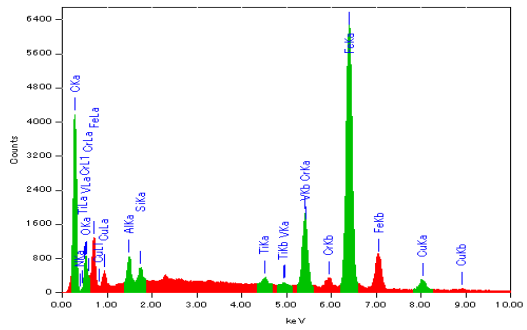


Fig.5 Elemental composition of EDS.

In order to observe TiN on the recast layer, EDS analysis is discussed. Fig.5 shows the elemental composition of EDS. As can be seen from the figure: Ti, C and Fe elements images of machined surface analysed by EDS. It is also confirmed from the component images that components Ti and C exist in this layer, while component N is rarely detected on the layer. Fig. 5 shows the elemental concentration of Ti and C measured from a line scan of EDS on a cross-section of the machined surface. The figure demonstrates that the Ti and C contents in the combined process exceeded those obtained using conventional EDM. The result may be attributed to the integration of USM mechanisms with the combined process. The USM mechanisms facilitate the penetration of Ti and C elements into the machined surface, so a modified layer forms on the machined surface

Afterwards, the composition of the layer was analysed using XRD (X-Ray Diffraction) as shown in figure 6. According to this figure, besides the components of the base material such as Fe, the component TiCN also exists on the EDMed surface. Carbon from kerosene reacts to the TiN become to TiCN on the layer. Fe_7C_3 also can be found on the layer. TiN cannot be found due to there is much carbon in the working medium fluid.

Fig. 7 presents the microhardness distribution obtained by the combined process and conventional EDM on the cross-section of the modified surface. Hardness of layer was examined using load at 10gf. Hardness of base material is 500 HV. The figure shows that thickness of modified layer is about 30 µm. Both EDM and EDM combined USV are same trends. From the figure, it can be seen that, the hardness of the recast layer is much higher than that of base material using on time = 50 µs , but hardness of the layer is not improved using on time = 500 µs. It may be explained that 500 µs of on time make more thickness of layer, however it was composed of many pores. On the other hand, the hardness of modified layer that is more than 1100 Hv which indicates that this method hardness of TiCN and Fe_7C_3.

Fig.8 shows surface roughness(Ra) values for two discharge duration (50 µs and 500 µs) and two discharge current (6 A and 21 A) of EDM with and without ultrasonic vibration assistance using TiN powder mixed in kerosene. When using conventional EDM with TiN powder mixed in kerosene, The values of surface roughness were continuously increasing when discharge current and discharge duration were increased that the most values is 6.89 µm for discharge current at 21 A and discharge duration at 50 µs. The results show the best values was about 6.02 µm for discharge current at 6 A and discharge duration at 50 µs.

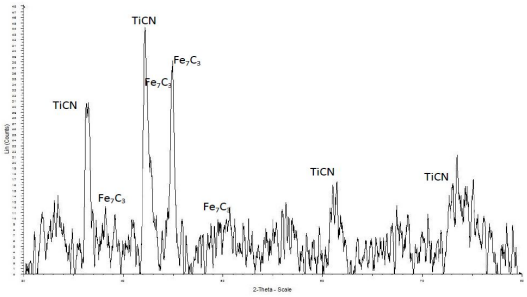


Fig.6 XRD analysis result of EDM with TiN powder electrode.

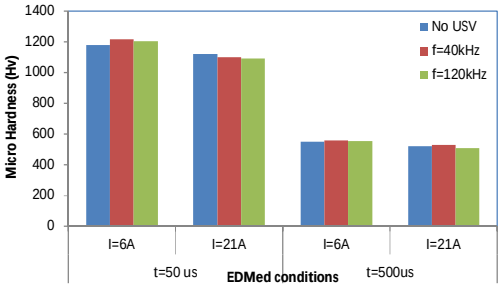


Fig.7 The values of Nano-hardness test

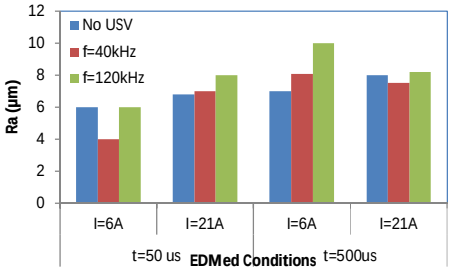


Fig. 8 Surface roughness of modified layer using TiN powder mixed in kerosene for four machining condition

CONCLUSION

In this study, a surface modification technique using EDM with TiN mixed fluid is proposed. Results were summarized as follows:

1. The resolidified layer containing TiCN can be generated on EDMed surface.
2. For discharge current= 21A with on time = 50 µs, USV combined EDM can reduce cracks on the surface.
3. For discharge current= 6 A with on time= 50 µs, the uniform modified layer can be obtained and size of pores can be reduced using 40kHz of USV.

4. Although the increasing of modified layer using on time= 500 µs, the hardness is not improved.
5. Frequency of USV seems not affect to surface roughness for each EDMed condition.

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