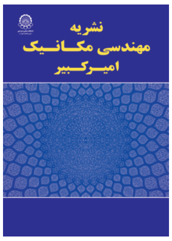

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Investigation of Ultrasonic Assisted Electro Discharge Machining with TiO_2, Al_2O_3 and ZnO Nano-Powder

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ABSTRACT: Electrical Discharge Machining (EDM) is one of the most important nontraditional manufacturing processes in machining of precise and complex parts made of hard materials. Improvement of its machining operation, due to the application of this method in advanced industries is important. One of the effective methods to improve the efficiency of electrical discharge machining is the addition of powder to the dielectric fluid and usage of ultrasonic Vibrations of electrode.
In this paper three Nano-powders, TiO_2, Al_2O_3 and ZnO and ultrasonic vibrations were investigated, and the effects of input parameters including powder type and concentration, pulse-on time and the current on the material removal rate, surface roughness, and tool wear rate were investigated.
Based on the results, this method has no significant effect on the tool wear rate but Average material removal rate can be increased up to 30%, So that the mean surface roughness and tool wear rates remain constant. Addition of the ZnO Nono-powder to the dielectric fluid caused the most material removal rate and surface roughness. Addition of the Al_2O_3 Nono-powder to the dielectric fluid caused the least surface roughness. In addition, the most material removal rate was obtained at powder concentration equal to 3 g/lit.

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1- Introduction

Erden and Biglin in 1980 studied the effect of powder suspension and they found that added powder improved the condition for a dielectric break and the material removal rate became better [1]. In addition to different powder usages, the effect of powder concentration, size, density, electrical resistance and thermal conductivity of different powders were investigated. Results show that smaller size powders with more uniform distribution and the suspension lead to a better machining condition with higher material removal rate and better surface quality [2-4]. Moreover, many studies concentrated on applying ultrasonic waves in Electrical Discharge Machining (EDM) and the findings confirm higher material removal rate, higher surface health and a little increase in surface roughness [5-7]. Study on a combination of ultrasonic waves with particle powder suspension at the first time was performed by Prihandana et al. in 2009 [8]. Later in 2011, they studied the process of EDM combined with ultrasonic waves using graphite nano-powders. It was observed that applying nano-powder particles by imposing ultrasonic pulses led to a decrease in machining time with the amount of 35%, increase in accuracy and decrease in surface micro cracks [9].

The aim of this paper is to study the effect of adding TiO_2, ZnO, Al_2O_3 nano-powders to dielectric fluid on EDM process assisted with ultrasonic waves. In this paper, in addition to considering the effect of nano-powder's type, concentration, pulse on-time and electrical current on material removal rate, surface roughness and tool wear rate in machining of an H13 sample were taken into account. Furthermore, in order to design optimal experiments Response Surface Method (RSM) in the design of experiments was chosen since the interaction of different parameters was known.

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2- Methodology

To conceive the relation between input and output variables and their interactions, a response surface methodology with box Behnken design is used and the design of the experiment and statistical analysis were performed using Minitab software. Since frequency and amplitude of pulse were constant four variables of powder type, concentration, electrical current and pulse on-time were selected as input variables of the experiments.

Samples of hot work steel H13 with a diameter of 20 mm and a copper electrode with a diameter of 25 mm are used. The ultrasonic head was designed in the way that complete transferring of waves to the front surface of the tool becomes possible. The experiment condition and machining parameters are listed in Table 1.

3- Results and Discussion

Fig.1 shows the mean value of Material removal rate (MRR) for three added nano-powders. It can be seen that compared to a conventional EDM, by applying ultrasonic waves and using nano-particles in the dielectric, MRR for all cases increases. This increase is about 30% for zinc nano-powder. It can be attributed to its lowest electrical resistance, in comparison with other nano-powders, which causes a lower total resistance of the machining gap and hence machine controller makes a bigger machining gap.

Fig.2 compares surface roughness for conventional EDM and that assisted with ultrasonic waves and nano-powders in

Table 1. Experiments conditions and machining parameters

Machining parameters	Experiment condition
Workpiece (-)	AISI H13
Workpiece diameter, mm	25
Electrode (+)	Copper
Electrode diameter, mm	20
Machining time, min	10
Generator type	ISO pulse
Applying ultrasonic waves	from tool
Ultrasonic Waves Frequency, Hz	20000
Dielectric	Kerosene
Dielectric volume, lit	2.5
Type of nano-powder	TiO2,Al2O3,ZnO
Nano-powder size, nm	20
Nano-powder concentration, g / lit	1.5,3,4.5
Open circuit voltage, V	80
Current, A	5.8,9.6,13.4
Pulse on-time, µs	30, 40, 50

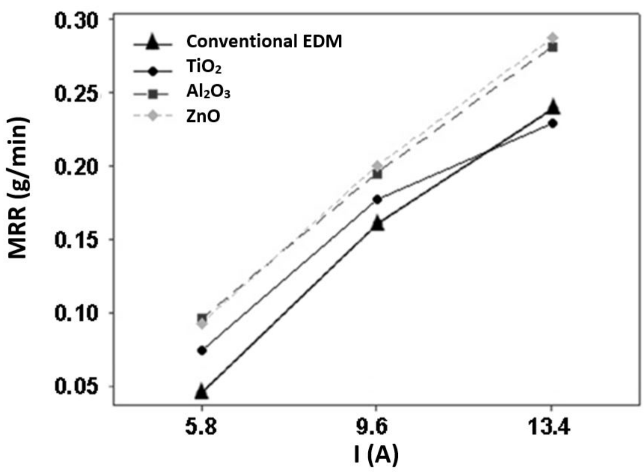

Fig. 1. The mean value of MRR in conventional EDM and ultrasonic assisted EDM and nano-powder

the dielectric. As can be seen, applying ultrasonic waves and Al_2O_3 nano-powder slightly reduces the surface roughness, while for other nano-powders surface roughness increases.

The lowest surface roughness occurs when Al_2O_3 nano-powder is used. When Al_2O_3 nano-powder is used due to its lower density, ultrasonic waves make a better suspension of nano-particles that increases the number and uniformity of sparks. In other words, the number of sparks increases but the energy of each spark reduces and therefore cavities with the lower depth are produced. It also can be observed that in the beginning with the increase in nano-powder concentration surface roughness increases, but more increase in nano-powder concentration results in a reduction of surface roughness. The former is attributed to the reduction in specific resistance of machining gap, increase in machining gap and therefore a higher discharge energy releases.

ZnO nano-powder makes the lowest tool wear rate. It can be attributed to its high thermal conductivity which reduces the

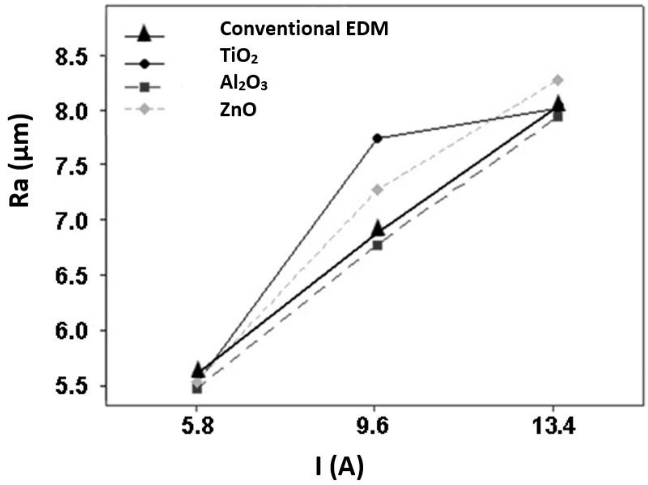

Fig. 2. The mean value of surface roughness in conventional EDM and with ultrasonic assisted EDM

variation of gap temperature during machining and therefore tool wear rate, which is directly related to the temperature, decreases.

Fig.3 shows the mean value of tool wear rate for conventional EDM and that for EDM assisted with ultrasonic waves and nano-particles in the dielectric. As can be seen, applying ultrasonic waves and using nano-powders are not influential on tool wear rate. In high currents, the longitudinal vibration of ultrasonic improves renewal of dielectric, better cleaning and heat transfer in machining gap and consequently decreases tool wear rate.

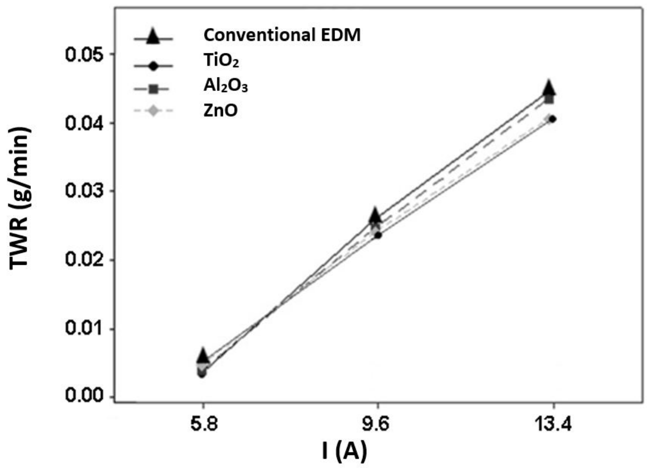

Fig. 3. The mean value of tool wear rate in conventional EDM and ultrasonic assisted EDM and nano-powder

4- Conclusions

Main conclusions of the paper are noted below.

- For ZnO nano-powder with the highest electrical and thermal conductivities, MMR and surface roughness are higher and tool wear rate is less.
- Ultrasonic longitudinal vibration leads to a better heat transfer and high thermal conductivity of ZnO nano-powder and results in its least tool wear rate.
- For Al_2O_3 nano-powder with the least thermal and electrical conductivity, less surface roughness is produced.
- The effect of ultrasonic on nano-powders includes

the inhibition of nano-particles' concentration, better suspension in dielectric and consequently a better condition is provided for machining.

- Using both ultrasonic waves and nano-powders MMR can increase by around 30 %.
- Nano-powder concentration was not very influential for the tool wear rate and MMR while it was effective on the surface roughness.

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