SURFACE GENERATION IN ELECTROEROSION DISSOLUTION AND ELECTRODISCHARHE MACHINING

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ABSTRACT

Electroerosion dissolution machining EEDM is a combination of pulsed electroerosion action EEM aided by electrochemical dissolution ECD. This paper applies the dynamic data system DDS to model and analyse surfaces produced by EEDM process. A first order stochastic differential equation is developed and physically interpretted from EEDM surface profile measurements. Using this model, the characteristic crater geometry, depth, diameter to depth ratio as well as the crater volume are determined under different machining speeds and pulse durations. The smoothing effect, by the new combined process, is demonstrated when comparing by EDM surfaces.

INTRODUCTION

The complexity and random nature of EEDM and its inherent metal removal mechanisms had defied attempts to formulate a quantitative theory of its metal removal process. Numerous investigations and theories postulated from these do not clarify the crater geometry and its relation to the discharge parameters.

Single discharges in elcolrolytes have been attemped by Chrichton [1]. However such a model does not consider the random nature of the new process leading to the superimposition of a roughly spherical craters which are conditioned by a further random dissolution process.

The description of electroerosion dissolution machined surfaces under actual working conditions are developed through the measurements of the surface roughness profiles [2] and scanning electron microscopy (SEM) technique [3]. The conventional techniques used to measure the volume of a crater are steromicroscopy, interferometry and a profilometer. These are either inadequate or extremely teduis. Moreover, the conventional roughness measurements by stylus instruments provide a very limited indication of the effective surface characteristics [4].

Obtaining the crater volume from a multiple discharge experiment is very difficult and complicated. In the present work, a mathematical model descriping the surfaces machined by EEDM has been developed directly from the machined surface profiles by means of a general methodology called dynamic data systems. Such a model has proved to be capable of providing comperhensive description for the electrodischarge machined surfaces. Topographical indices such RMS, effective correlation length and the effective spectral frequency have been evaluated, [5,6]. This paper elusidates the physical interpretation of the first order model by identifying its parameters with a characteristic crater geometry under different conditions.

Under such bases, comparative study between EEM surfaces and EEDM are also presented.

First order model and a characteristic crater.

The complex and stochastic nature of EEDM surfaces is the result of the discrete random attack of pulses of discharges which are assisted by a random electrochemical dissolution phase. Such machining actions have a random varying intensity and spatial distribution. The surface, therefore can be considered as representing the randomness inherent in the erosion-dissolution phenomena. Hence the DDS analysis of surface profiles will eventually lead not only to a comperhensive topographical characterization but also to a better understanding of the process behaviour [6,7].

A continuous first order model of DDS, denoted by A(1) has been obtained from the recorded surface profiles. The model in the form of a stochastic diffrented equation is given by.

$$\frac{dx(t)}{dt} + \alpha_o\, x(t) = Z(t)$$

$$E[Z(t)\, Z(t-u)] = \sigma_Z^2\, \delta(u)$$

where

$x(t)$: The measured profile

$Z(t)$: white noise

α_o : Autoregressive parameter

$Z(t)$ has a covariance function in the form of an impulse of strength σ_Z^2

The discrete model parameters ϕ_1 and σ_a^2 are calculated from the digitized profile measurements. Then the parameters of the continuous model are evaluated.

If $x_1, x_2, \ldots x_N$ are N profile measurements at a sampling interval Δ, then the parameters of the discrete model ϕ_1 is given by

$$\phi_i = \sum_{t=t}^{N} (x_t - \bar{x})(x_{t-1} - \bar{x}) / \sum_{t=2}^{N} (x_t - \bar{x})^2$$

and σ_a^2 which is the variance of uniformly sampled A(1) discrete model.

$X_t - \phi_1 X_{t-1} = a_t$ is given by

$$\sigma_a^2 = \frac{1}{N-1} \sum_{t=2}^{N} [(X_t - \bar{x}) - \phi_1(X_{t-1} - \bar{X})]^2$$

$$\textit{where}\quad \bar{x} = \frac{1}{N} \sum_{t=1}^{N} X_t$$

Then

$$\alpha_o = -\frac{\ln(\phi_1)}{\Delta} \quad \textit{and}$$

$$\sigma_Z^2 = \sigma_a^2 \frac{2\alpha_o}{1-\phi_1}$$

Surface characteristic indices:

Figure (1) shows a section of a typical crater formed in EDM. According to Pandit and Rajurkar [5,6].

Diameter to depth ratio of the characteristic crater = $9/\alpha_o$,

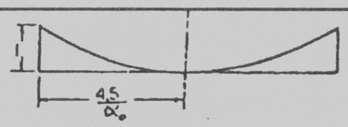
Characteristic crater volume = $0.512\, (\sigma_z^2)^3\, (9/\alpha_o)^2$

Crater depth = σ_Z^2

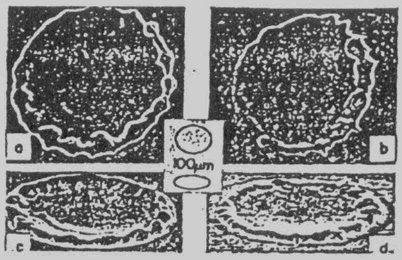
and

Surface roughness RMS = $\sigma_z^2/2\alpha_o$

Tests were conducted using copper electrode and mi steel workpieces. The machining medium was 20% w/ $NaNO_3$ [2]. Surfaces profiles are then digitized at sampling interval of 1 μm . The above mentioned surfa indices are then calculated. Surface profiles produced b EEDM are shown in Figure (2) while craters formed b this particular process is shown in Figure (3). Craters i Figure (3) are identical to those assumed by Pandit et a [5,6] and experimented in reference [8] during EDM, se Figure (1).



A. Section of a crater. /5/



B. Scanning electron micrographs of Ta electro-erosion craters produced by 180 mJ single discharges in kerose (a,c) Anode (b,d) cathode. /8/

Figure 1. Craters formed in EDM.

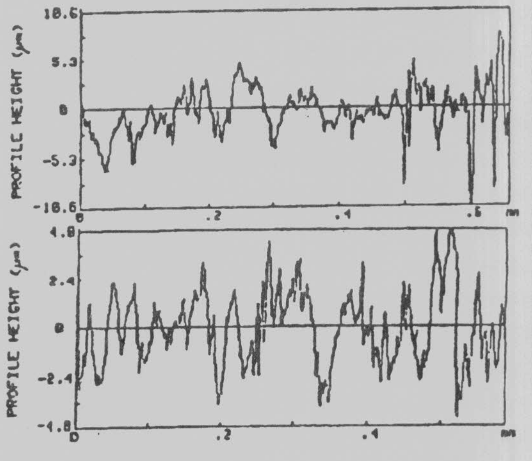


Figure 2. EEDM surface profiles.

RESULTS AND DISCUSSIONS

The crater volume, shown in Figure (4) increases with pulse duration which is expected due to the increase in crater depth σ_z^2. Such an increase causes the diameter to depth ratio $9/\alpha_o$ to decrease at long pulse duration. Under such conditions the change in crater diameter is small.

The increase in crater diameter to depth ratio $9/\alpha_o$ indicates the spreading of craters with increase in pulse duration. This trend is well in agrement with conclusions of a greater concentration of the discharge channel with low energy discharges and a widening phenomenon of this channel with discharges of longer pulse duration. It should be mentioned however that, the presence of the ECD phase which becomes more intense at longer pulse dura2tions causes surface smoothing to the formed craters thus reducing the crater diameter and hence causing a reduction in the diameter to depth ratio. This argument can be supported by obtained trend in surface RMS. In EDM activation of kerosire with surfactants reported by Meshcheryakar [9] reduced the rate at which the discharge channel is widened adjacent to the electrode, facilitating energy concertration on the workpiece surface thus reducing the radius and depth of individual craters and affecting the roughness of the resultant surface.

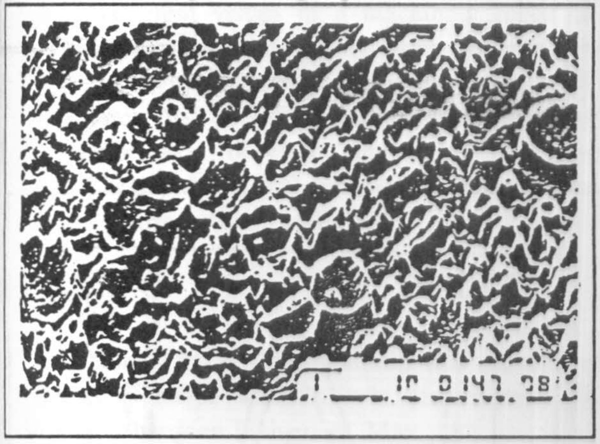


Figure 3. Scanning electron micrographs for surface craters firmed in EEDM.

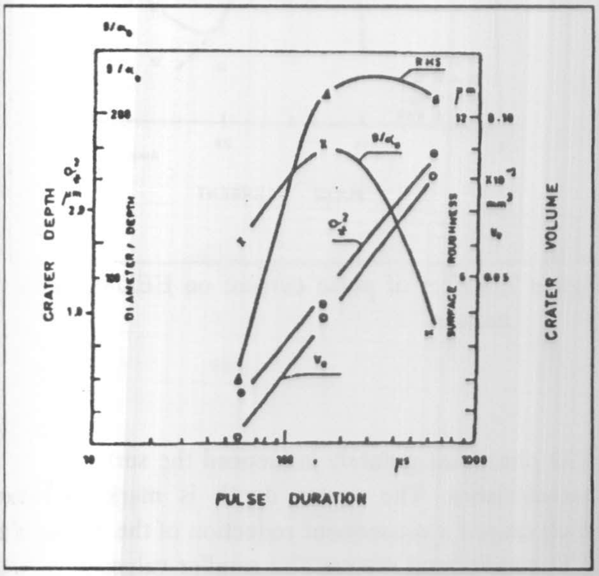


Figure 4. Effect of pulse duration on EEDM surface characteristics.

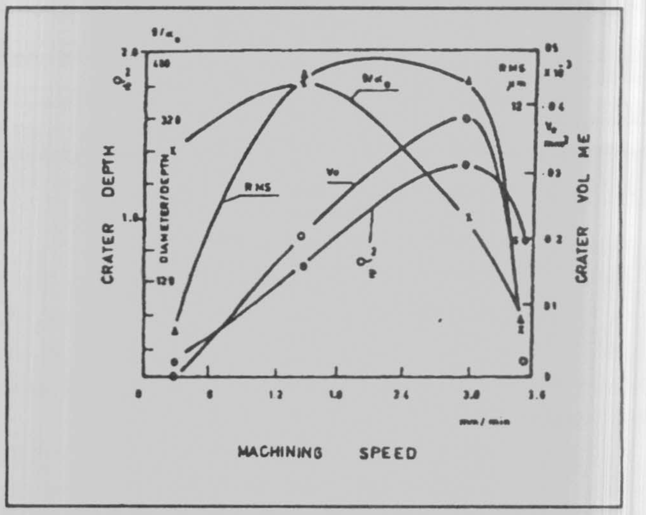


Figure 5. Effect of machining speed on EEDM surface characteristics.

The increase of surface roughness , with higher pulse energy, has been recorded in EDM by Jeswani [10].

Figure (5) shows the effect of machining speed and hence the machining time on the produced surface indices. Accordingly, at the smallest speed tried, machining was entrirly caused by a pulsed ECD action. Therefore crater depth and volume are small. As the speed increases, EEM phase dominates in the metal removal mechanism which in turn increases the crater depth and volume.

A further decrease of crater depth and volume is observed at the highest speed. The reason behind higher σ_Z^2, Ve and RMS may be related to the decreased ECD action by stray current along the side gap which keeps the original surface , machined by EED, unsmoothed, see Figure (6).

The decrease in crater volume at the greatest machining speed again is affected by the decrease in crater depth σ_Z^2 and diameter to depth ratio. More intense ECD phase

Table 1. Comparison between EEDM and EDM

Pulse duration	EEDM					EDM				
μ sec.	D μm	σ_z^2 μm	Ve mm^3 x10^{-3}	g/α_o μm	RMS	D μm	σ_z^2 μm	Ve mm^3 x10^{-3}	9/α_o μm	RMS
60	46	0.38	.0004	123.15	2.6	284.33	71.8	3.002	3.98	15.9
160	245	1.30	.039	191.33	13.6	395.26	76.6	6.127	5.16	21.96
540	242	2.8	.0.85	85.64	13.5	593.56	83.6	15.08	7.1	32.98

could be the reason behind such a trend.

Figure (7) shows the increase in crater diameter, depth and hence crater volume with greater pulse current. As mentioned earlier, more energy becomes available in the plasma channel thus causing higher metal removal rates and rougher surfaces.

Further increase in pulse energy causes electrolyte boiling and evaporization which in turn encourages the widening phenomenon and produces lower depth and volume of craters.

Table (1) shows the crater indices and surface RMS produced by EDM [5], and EEDM.

It is evident from these results that, the presence of the

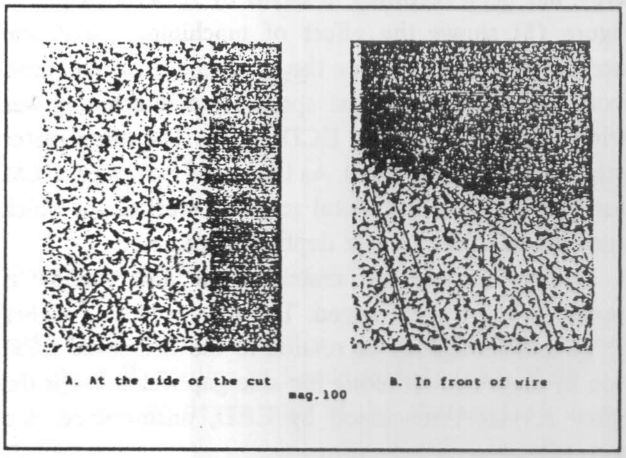


Figure 6. Frontal and smoothed EEDM surfaces.

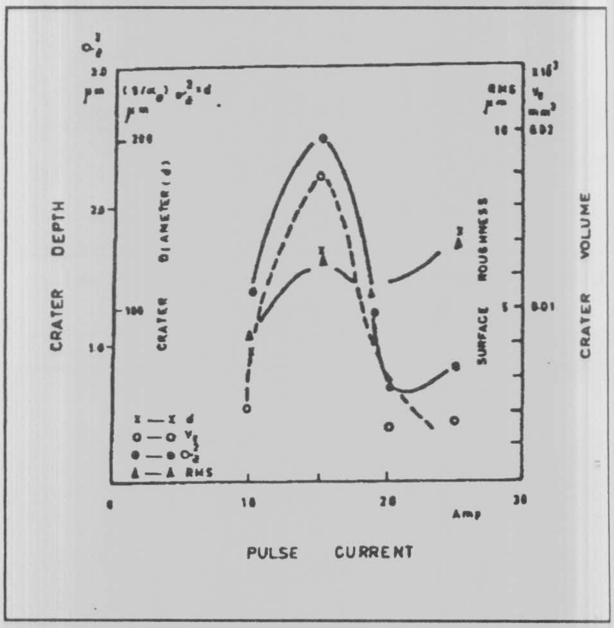


Figure 7. Effect of pulse current on EEDM surface indices.

ECD phase has greately influenced the surface characteristics. The crater depth is markedly reduced which caused a consequent reduction of the volume of the ECD conditioned craters.The smaller values of crater depth σ_z^2 is the reason behind the increase in diameter to depth ratio despite the low values of crater diameters which are again related to the dissolution action.

CONCLUSIONS

Electroerosion dissolution machined surface profiles are modelled by the dynamic data systems (DDS) in the form of a first order autoregressive stochastic differential equation.

The following observations are made from the experimental results with 60-540 μs pulse duration (on - time), machining speeds 0.3-3.5 mm/min and 10-25 Amper pulse current.

1. The depth, volume and hence the RMS of the ECD conditioned craters increase with pulse duration while it has maximum values of a machining speed of 3 mm/min and 15 Ampers of pulse current.
2. The diameter to depth ratio has a maximum level at 1.5 mm/min, 160 μs and 20 Amper.
3. The combination of ECD and EEM has greatly reduced crater depth, volume and hence produced a smoother surface than the EDM.

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