Surface texture modelling to predict EDM surface roughness

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Abstract

Based on previous research on EDM surface texture and the unit removal event- the crater, a model to simulate surface texture generated by the EDM was developed. The model is realised as a computer program, which deals with statistics of the real crater geometry obtained from a set of experiment and empirical criteria gained from existing theoretical knowledge about the electrical discharge in the gap.
The comparison of real and simulated surface roughness showed good agreement, confirming the validity of the simulation.

Key words: simulation, crater modelling, control.

Surface related EDM process characteristics

EDM is a machining process where material removal is caused by repetitive minute electric discharges within the electrode-workpiece-dielectricum interface. Each discharge, due to high energy concentration, removes from the workpiece surface a small quantity of material in form of molten metal drops and vapours, meanwhile the discharge location on the workpiece surface is in part stochastic and in part dependent on surface micro relief. The result of such a unit-event is the characteristic crater. The mechanism of the crater formation is still now not completely clarified. The recent research discovered micro migration of plasma channel within the discharge area and it's relations to the resulting crater geometry (Kuneida 1992). Based on stated assumptions, our crater model has been developed.
We've started to build up a system for on line surface texture simulation by means of unit event approach. The surface texture is simulated by a computer program which with consecutive formation of a single crater generates a fictitious workpiece surface. Criteria of this 'crater loading' are in part imitations of experimentally obtained real occurrences and in part based on empirical models using theoretical knowledge.

Basis of surface texture simulation

In previous research two unit event parameters of main influence on the surface texture were figured out (Junkar 1993):
- Crater geometry and dimensions
- Crater's vertical location respective to the surface micro-relief's altitude

Crater geometry mainly depends on electric pulse power and it's duration. Crater's vertical location was discussed in our previous research (Junkar 1993) and is supposed to depend on non homogeneously distributed debris in the gap resulting in non homogeneous dielectric discharge resistance over the working space-gap (Schemata 1990).

Data Acquisition

All experiments were conducted on an ED sinking machine, at three different regimes. The device was an Ingersoll 80P with 2200 generator and two specific experiment configurations were used in order to determinate the two unit event parameters.
To numerically define the crater's vertical location, a special experiment was carried out: On the ground flat surface a set of deepenings was obtained as shown on figure 1. On this deepenings different depths were regulated in order to cover the range of possible discharge locations regarding distance from the electrode. Afterwards a few seconds of machining was carried out and on each deepening on the workpiece surface a certain number of craters were obtained. The dependence of the crater number on respective deepening's depth was obvious and expressed as a histogram describing relation of the electric discharge probability on electrode to workpiece distance. Obtained histogram was directly used in the simulation algorithm as a reference of subsequent choice of the crater locations.
The second experiment we carried out was to obtain discrete craters. It enabled us to observe and measure the single crater geometry. Experiment which permitted us to reach such a result was carried out with a wire electrode of 2mm diameter rotating on 150 mm circle at rotational speed of 1m/s.

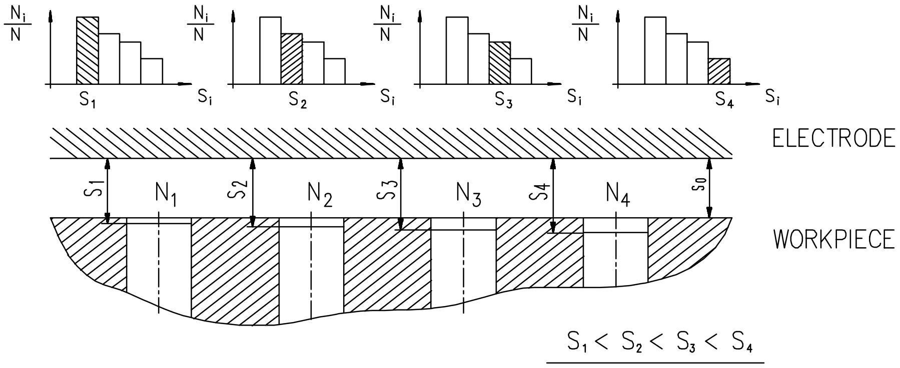

Figure 1. The crater's vertical location determination

Electric pulse duration and interval at such rotational speed and electrode dimensions produced distinct craters on a circular trace. In view of relating the electric pulse to crater geometry the voltage and current signals were recorded as well. In this way 30 distinguish craters on flat polished surface were collected and measured by the profilometer. On each crater 10 to 15 parallel tracings resulting in 10 to 15 digitised and recorded profiles were made. Since the crater shapes were of distinctive stochastic shape, we decided to elaborate them in an attributive way. For this purpose we defined nine attributes characterising main crater geometry features.

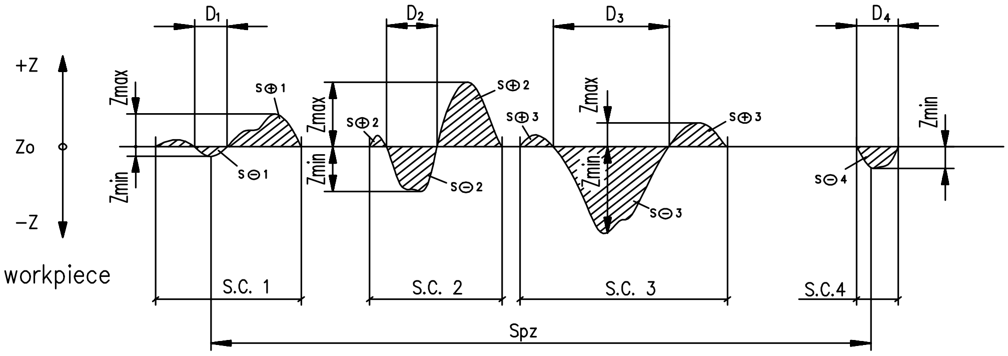

Figure 2. The crater's descriptive features

Crater geometry attributes:

ΔHmax	maximal crater height difference
Vmax	maximal crater volume
Zmax	maximum peak of the satellite crater
D	diameter of the satellite crater
S+	satellite crater area above the reference Z=0
S-	satellite crater area bellow the reference Z=0
Zmin	maximum valley depth of the satellite crater
Sp	crater spacing in horizontal direction
S.C.	satellite crater spacing

For some of stated attributes a three-dimensional compilation of the crater shape from the obtained profiles was done, using the computer profile evaluation program. Since the population of measured craters was very broad in shape and dimensions, we decided to represent the entire crater population by three representative craters. For this purpose, all craters were classified in three classes regarding their geometry attributes. The classification was made by a clustering computer program in order to obtain greater geometrical similarity of craters within the same class (Jambu M. 1983). Further on, out from each class a representative crater was chosen. It was measured by the profilometer and digitised at 12μm steps in both horizontal directions. The obtained data were arranged in the form of two dimensional matrix. The so obtained three characterising crater classes were stored in the simulation data-base as representation of the whole real crater's population. In addition also a measure for occurrence probability of each representative crater was obtained by computing their relative frequency.

Surface simulation algorithm:

In our case the simulation operates by means of in time consecutive crater loading as the real process does. The surface geometry is presented numerically. The starting point of the simulated surface generation is ideal flat surface sample. To create a crater on this surface, some information about the real craters are needed, so the data base consultation process can be performed.

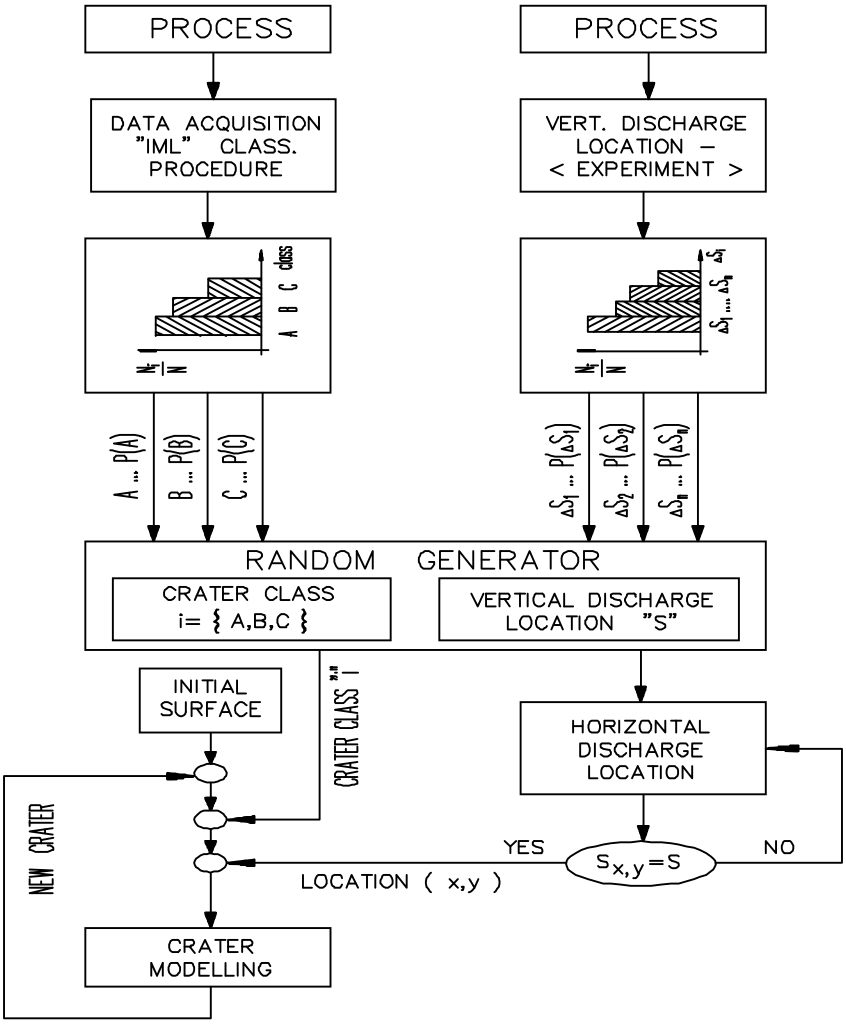

Figure 3.The simulation algorithm

Simulation's Data Base:

Data base comprises data of the two unit event parameters. Crater geometry is in form of the three two-dimensional matrixes, including their respective occurrence probability. The second attribute, crater's vertical location, is represented as the discharge probability within six layers along the micro relief's height. The probability within each layer is approximated as being constant.

Having on disposition all the data about the real process needed, a stochastic behaviour of a simulation should be reproduced. Therefore two random generators are involved in the process of the data base consultation.

Random Generators:

In order to perform consecutive random generation of crater class and vertical crater location, the simulation algorithm uses two random generators. One for crater class and the other for vertical crater location determination. A special request for both generators is to reach the same probability distributions as are obtained by measuring. This is achieved by a random function with constant probability distribution changed by a conditional loop containing probability acceptation thresholds. The latter ones are stored in the data base in form of probability histograms.

To choose the right horizontal crater location on the simulated surface, respecting already defined vertical one, unconditional random searching over the simulated surface is performed until the right point is found.

In this manner the process stochastic features, regarding crater geometry and location, are reproduced. At this point, the location for crater generation 'initial surface' is available. The right crater class and location are chosen by respective random generators as well. So the crater generation can be performed.

Crater Modelling:

Since the real crater generation is a process occurring in a three element interface, tool-electrode-dielectricum, with remarkable workpiece influences, the assumption of fixed crater geometry regardless of the existing surface texture, is not the appropriate one. Therefore some empirical procedures were realised in order to take into account also the existing surface texture in the area of crater formation. The migration phenomena of plasma channel during crater formation was detected and discussed in literature (Kuneida 1992). This fact should favourites the plasma channel development where the micro-relief's peak is present. This assumption should lead into more effective material removal on micro-relief peaks than in valleys. On the other hand solidification of the particles not removed by the dielectricum stream will more probably take place at the micro cavities - valleys, which will be thus filled up. In our model, the intensity of material removal and molten metal deposition at the specific micro point is first of all dictated by the reference crater geometry stored in the data base. This is afterwards adapted to the existing surface relief, using amplitude probability function of the surface profile and therefore the corresponding bearing ratio tp(z).

Figure 4. The crater's descriptive features

The generation of a new crater is in fact the superposition of the reference crater geometry Zc(i,j) upon the existing surface Ze(i,j), (Fig. 4), (Eq. 1), performed by considering the adaptation factor K.

$$Zn_{(i,j)} = \begin{cases} Ze_{(i,j)} + (Zc_{(i,j)} \cdot K \cdot (1+\delta))\ldots\ldots\ldots & Ze_{(i,j)} > Z_{(x,y)} \\ Ze_{(i,j)} + (Zc_{(i,j)} \cdot K \cdot (1-\delta))\ldots\ldots\ldots & Ze_{(i,j)} < Z_{(x,y)} \end{cases} \qquad \text{Equation 1.}$$

Factor K, by it's definition (eq. 2), empirically simulates phenomena of real crater generation.

$$K = \begin{cases} 1\ldots\ldots\ldots\ldots & (Ze_{(i,j)} > Z_{(x,y)}) \wedge (Zc_{(i,j)} < 0) \\ \dfrac{tpi^{p}_{(Zc_{(i,j)})}}{tpi^{p}_{(Zc_{(0)})}}\ldots\ldots & (Ze_{(i,j)} > Z_{(x,y)}) \wedge (Zc_{(i,j)} > 0) \\ 1\ldots\ldots\ldots\ldots & (Ze_{(i,j)} < Z_{(x,y)}) \wedge (Zc_{(i,j)} > 0) \\ \dfrac{tpi^{v}_{(Zc_{(i,j)})}}{tpi^{v}_{(Zc_{(0)})}}\ldots\ldots & (Ze_{(i,j)} < Z_{(x,y)}) \wedge (Zc_{(i,j)} < 0) \end{cases} \qquad \text{Equation 2.}$$

Important starting-point of the crater model is also the criteria to keep the reference crater's volume, during it's geometry adaptations, invariant. This derives from energy criteria of crater formation (Snoeys 1971). In the simulation the constant crater volume is achieved by the iteration, where δ is used as a iteration variable.

Results of Simulation

In order to confirm theoretical principles and empirical criteria used in the surface simulation, 36 simulated surface profiles were compared to 36 profiles obtained by profilometer measuring on real surface. For qualitative comparison average roughness Ra was calculated on real and simulated profiles for three regimes. Results are shown on fig. 5. The accordance of simulated and real roughness is up to 5 %.

figure 5. Average roughness Ra of the real and the simulated EDM surface at different regimes

Conclusions

The results obtained by the simulation prove that with limited amount of information, regarding the unit event, the surface roughness prediction is possible. Since the EDM process is widely used in the manufacturing of tools a surface roughness monitoring system would be of a great support to operator's process optimisation. Focusing on this objective, we succeeded in roughness prediction by using data regarding the two unit-event parameters, acquired with off line experiments. However, our unit event parameters don't exclude the possibility of on-line and real-time identification, even more, a procedure to predict crater geometry out from electric pulse has already been constructed by using the AI approach. Further on we will tend to build an operating surface roughness monitoring system suitable to different working conditions and electrode-workpiece configurations.

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