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Deep Small Hole Drilling with EDM

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KEY WORDS: small hole drilling, inductive learning, decision tree

ABSTRACT

This paper discusses a technological application of deep small hole drilling with EDM where the ratio between depth and width is about 10. Many different authors suggested new approaches when producing small and deep holes (d≤1mm) which is a rather complicated technological task. Additional special generators, extra vibration of the electrode, additional relative motion and many other solutions have been proposed. In this research we studied the influence of high pressure of the dielectric in the gap to improve flushing conditions and to perform better technological results. Process evolution is studied by identification of pulse series by means of high frequency digital oscilloscope connected to the computer. We developed a special chamber-device in which dielectric pressure is augmented locally. In this way the drilling of small holes is enabled on a classical ED sinking machine. Process behaviour is studied by means of voltage pulse parameters and the technological characteristic of machined hole. Voltage and current pulses play predominant role in the optimisation of EDM process. The results will be applied as a data base for the automatic control of the gap distance and flow of the dielectric that are the most common actions of the operator. The experiments are evaluated by the expert using inductive machine learning approach in order to develop a Technological Knowledge Data Base (TKDB), as well as decision support system for adaptive control of the process.

1. INTRODUCTION

Small hole drilling is rather difficult process in most technological applications [1,2,3,4]. The producing of deep small holes (d<1mm,h/d>10) is often associated with unfavourable metal and other particles, tool cooling and especially the stiffness of tool at conventional machining processes [5]. Some of the nonconventional machining processes like laser beam machining (LBM) or electron beam machining (EBM) enable producing deep and small holes. The problem of insufficient accuracy and costs still consist. Electro discharge machining process (EDM) is convenient for machining electro conductive materials. It is made up to produce irregular shapes in the workpiece from the beginning of EDM technology. Present technological inconveniences in small hole drilling with EDM are:

- working accuracy
- electrode material
- to clamp and to position the electrode
- to attain acceptable dielectric pressure in deep small holes
- the selection of dielectric
- the working condition assortment

2. SMALL HOLE DRILLING WITH EDM

The radical technological problem in producing deep small holes with EDM is to attain efficient working conditions in the working gap by means of flushing out the produced particles [2,3]. In this purpose we developed special chamber-device (Figure 1.) to enable EDM process locally without drowning the workpiece into the dielectric and to achieve higher dielectric pressure in the gap.

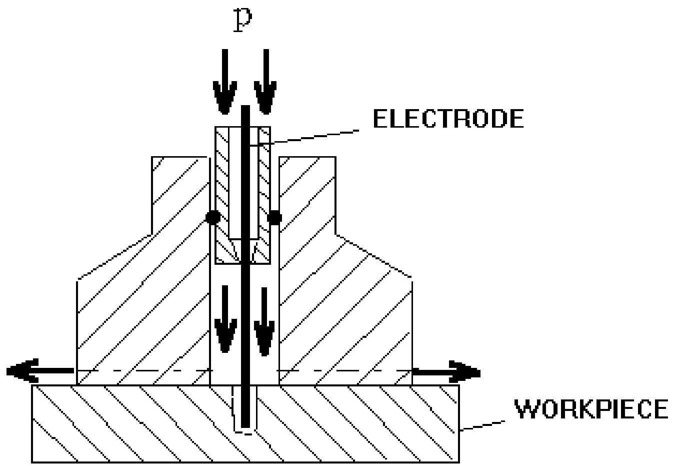

Figure 1: Dielectric flow in chamber-device

The technological database for existing EDM sinking machine is based on standard experiments (diameter of the electrode d=20mm). The optimal working conditions for small hole drilling (d>1mm) differ from standard conditions essentially. We have chosen 5 different working conditions to define proper working parameters with tested Ingersoll 80P sinking machine (tab.1.).

regime	sign.	tp/µs/	ti/µs/	ui/V/	τ/-/	ie/A/
1	M1.4.4.10	50	48	180	0.96	4.5
2	M1.4.4.7	50	34	180	0.68	4.5
3	M1.6.4.7	50	34	180	0.68	6.5
4	M1.8.4.6	50	30	180	0.60	13
5	L1.9.4.10	510	450	180	0.88	19

Tab.1.:Working conditions

Electrodes for tests were made from electrolytic copper. We used the electrodes with diameter d=20mm for standard experiments and with diameter d=0.65mm in the case of deep small hole drilling tests. Workpieces were made from tool steel OCR12 hardened and annealed to 60-62 HRc. High speed digital oscilloscope attended the pulse series (Figure 2). Each serie inferred 320 pulses in progression and was transferred to the computer.

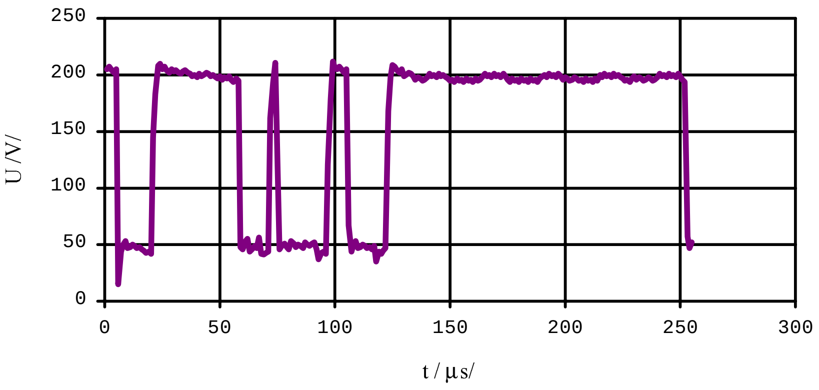

Figure 2: The sample of pulse serie in progression

The chosen machining parameters enabled the comparison between standard process and small hole drilling with EDM (Figure 3.). The derived conclusions are:

- the material removal rate V_w is higher when using standard electrode (d=20mm) in all working regimes. The difference is still increasing with higher maximum discharge current $\hat{i}_e$=4.5A (1.regime) to $\hat{i}_e$=19A(5.regime);

- the electrode wear V_e is lower when testing small hole drilling with EDM at 2.,3. and 4. regime. This results probably derived from the fact that 2., 3. and 4. regime are rather fine regimes.

- the relative electrode wear V_w/V_e increase especially at 5. regime. The 5. regime's working conditions are too rough (t_i=450µs and $\hat{i}_e$=19A). The cumulated heat increases melting of the small electrode (d=0.65mm). The appropriate small hole drilling working conditions seems to be at shorter pulses (t_i=50µs).

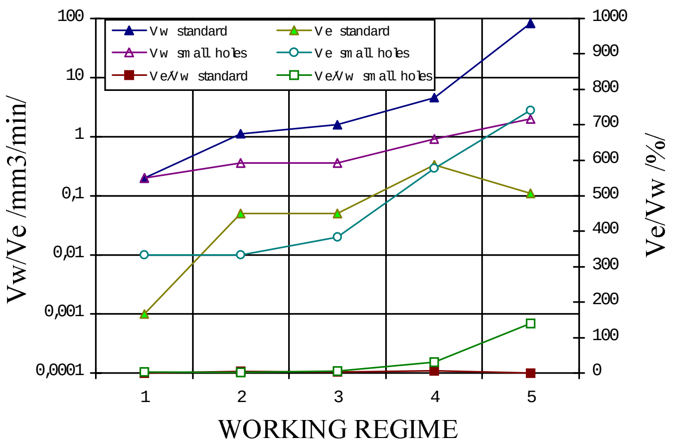

Figure 3.: The removal rate, wear and relative wear versus working conditions

The removal rate is not eligible for machining valuation. The process of small hole drilling is valuated better with V_p [mm/min] which is the measure of permeate speed (Figure 4.). We achieved the best machining parameters with 4.regime. These results were applied in the next step of the research the recognition with inductive machine learning.

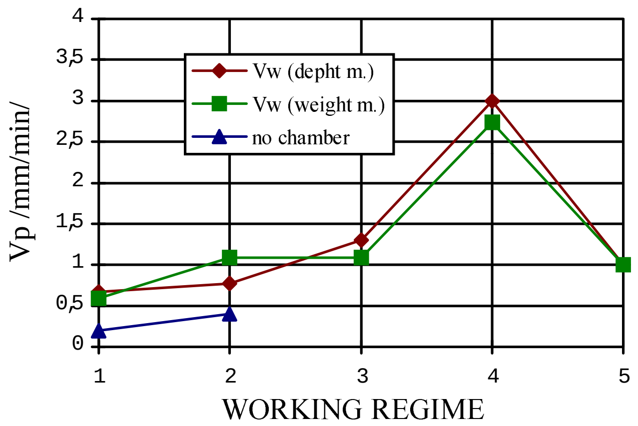

Figure 4.: The permeate speed V_p versus working regime

3. SMALL HOLE DRILLING RECOGNITION WITH IML

The database of pulse series in progression was the starting point for inductive machine learning (IML) [6,7,8,9]. The goal of this research is to gain as many as possible information about deep small hole drilling process. On the base of the IML approach we wanted to recognise the standard process or small hole drilling process. So we have defined the samples of each process. Each sample consisted of 8 pulses in progression. Each of the tested working conditions (regimes 1 to 5) was listed with at least 40 samples. The appointed portions of characteristical pulses in each sample were conducted with statistical analysis and existing knowledge. The characteristical EDM pulses are: open voltage pulses A, effective discharge B, arcs C and short circuits D. The evaluated results enable to define the discrepancy between standard EDM process and deep small hole drilling process with EDM (Figure 5.).

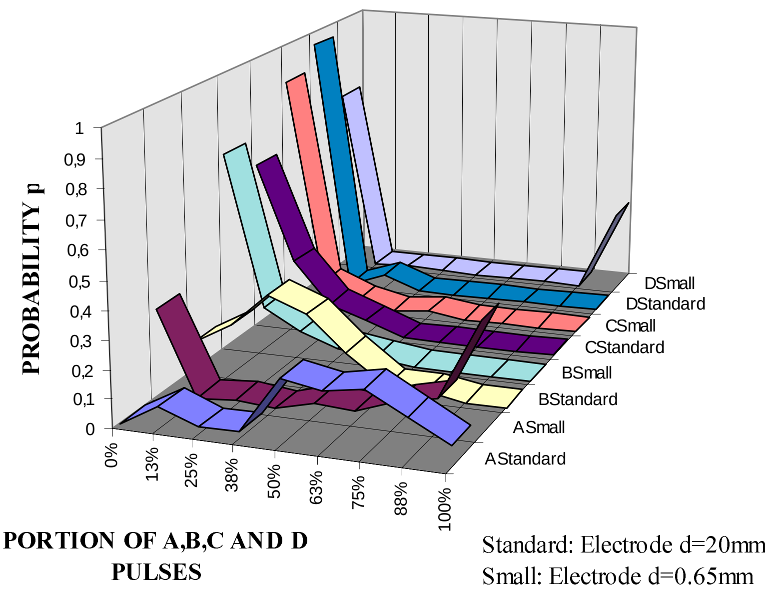

Figure 5: The probability of characteristical pulse portions in comparison with standard EDM process and deep small hole drilling process.

At this point the research was compassed on the study of voltage pulses in progression only. The IML approach demands experts knowledge about the process. We tested the possibility of the process recognition on the base of voltage pulse parameters with inductive learning approach. The induction of the decision tree with IML depends on ponderation of tested examples into classes. The examples consisted on probabilities of pulse area attributes were comparted in three classes: INEFFECTIVE, LESS EFFECTIVE and EFFECTIVE process. We evaluated the most effective working conditions (regime 4) in the case of small hole drilling with IML approach. The decision of the probability of defined pulse area as a process attribute derived from the pulse analysis. For example: pulse with area of 17 mV·s is typical open voltage, pulse with area of 8 mV·s is effective discharge with long t_d (60% of t_e), pulse with area of 1 mV·s is arc and pulse with area of 0 mV·s is short circuit. The samples of probability trends enable the process ponderation (Figure 6.).

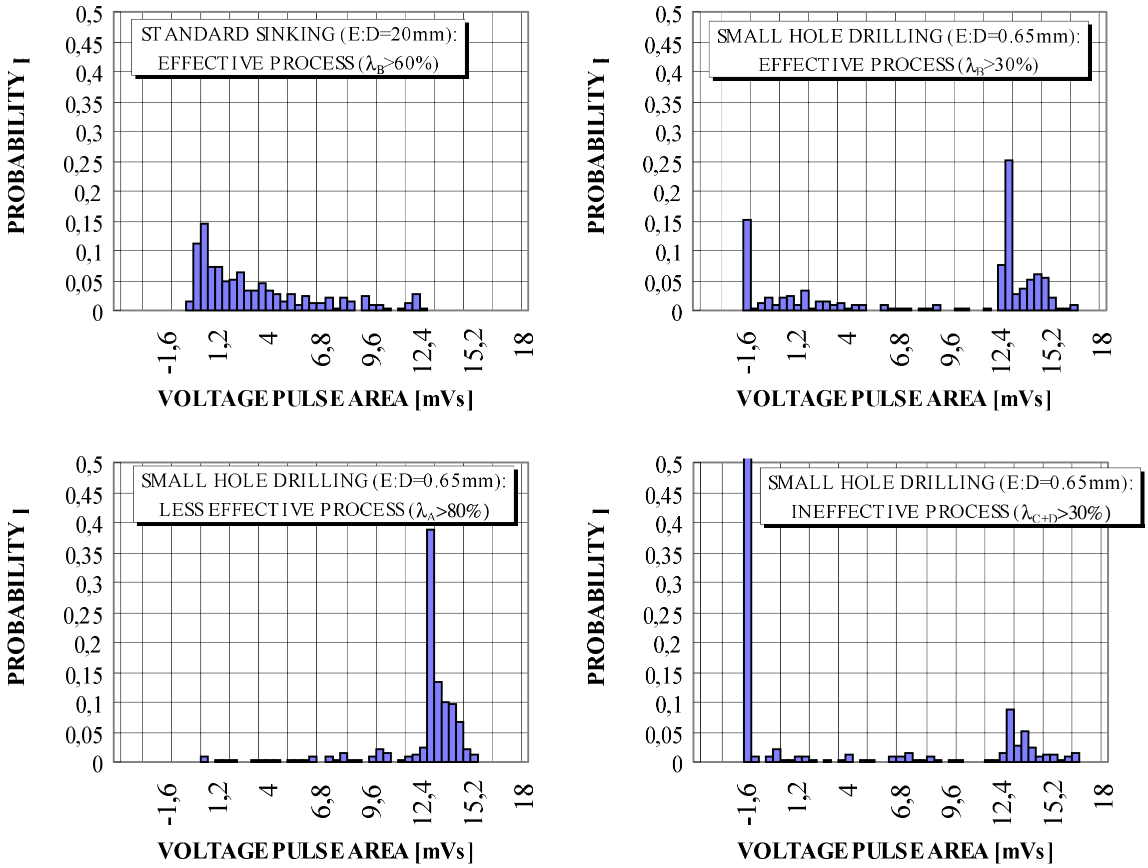

Figure 6.: Probability trends versus voltage pulse area

The decision tree derived from probability trends is in this case is very informative. The accuracy of this process quality-efficiency classification is 78% (Figure 7.). There is still a problem of evaluating this rules on other working regime parameters.

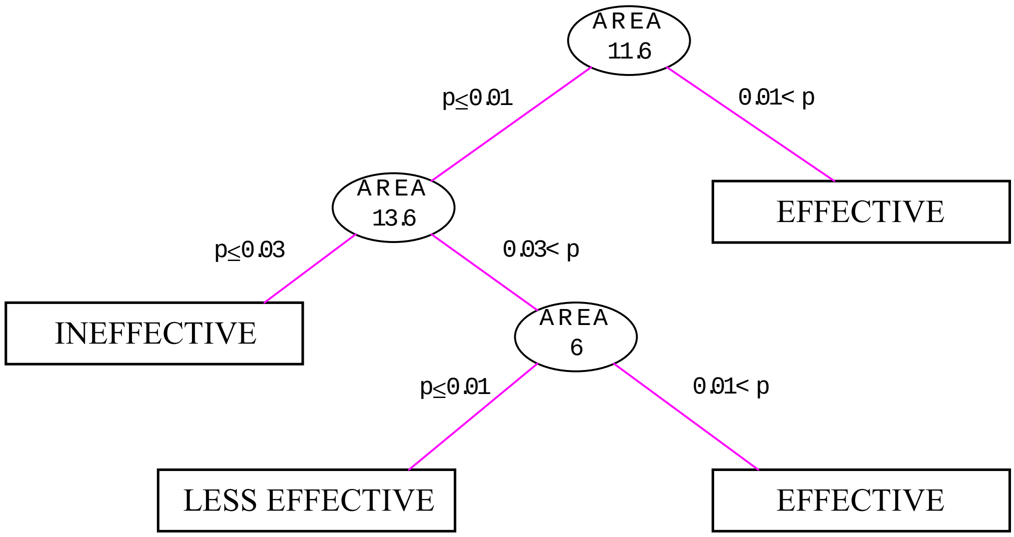

Figure 7. Decision tree made to enable process efficiency recognition

The IML approach also enables the recognition of process category (in our case small hole drilling and standard sinking process). The class NULL evidence that we used small database (about 30 cases) and that more experiments should be done (Figure 8.).

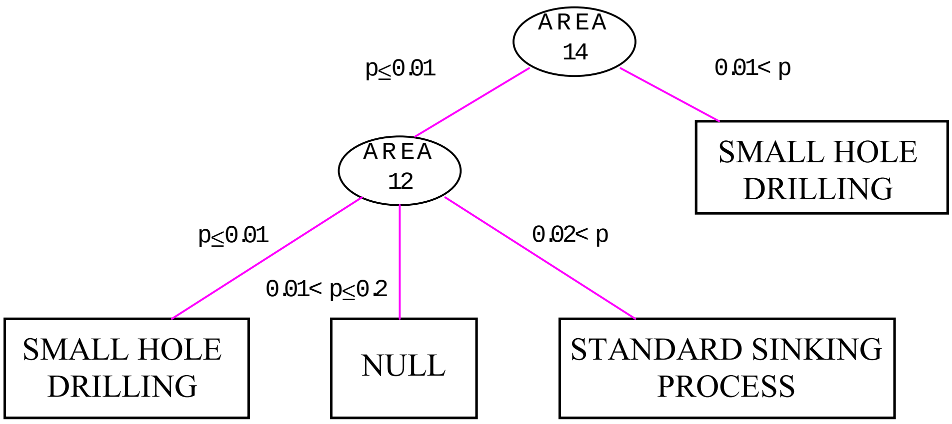

Figure 8.: Decision tree made to enable process category recognition

4. CONCLUSIONS

The results of deep small hole drilling tests were conducted to complement the technological database on classical EDM sinking machine. The IML approach enables process efficiency classification and process category recognition at sufficient accuracy. The conclusions are based on the following findings:

- the classical EDM device is appropriate for deep small hole drilling with certain limits like high accuracy of machined hole;

- the special chamber-device was developed to enable EDM process on workpieces which are not under the dielectric level and to improve flushing conditions in the working gap;

- the small hole drilling process demands different working parameters in comparison with standard EDM process. The portion of arcs and short circuits is increased. That means disabled flushing especially when producing deep small holes (h/d>10);

- at certain conditions it is possible to work out a hole with diameter d=0.65mm and depth h=6.5mm in the time t<3.5min. This results enable comparison with other competitive machining processes directly;

- the IML approaches empower the process recognition in certain case. The accomplished experiments developed a Technological knowledge data base (TKDB) and the decision system for process control.

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