ASSISTED DESIGN OF THE EXPERIMENTAL RESEARCH AT DIMENSIONAL PROCESSING BY ELECTRICAL EROSION WITH MAGNETIC ACTIVATION USING VIRTUAL DEVICES

Borza Sorin [1], Țîțu Mihail Aurel [2], Banu Ilie [3]
[1] "Lucian Blaga" University of Sibiu, titu.mihail@gmail.com
[2] "Lucian Blaga" University of Sibiu, sorin.borza@gmail.com
[3] "Lucian Blaga" University of Sibiu, iliebanu@yahoo.com

ABSTRACT: The assisted programming of the experiments for the dimensional processing by electrical erosion with magnetic activation for the general validation of certain theories, casts aside mistakes, compromises and puts thoughts, conception, planning and management into order. Processing the experimental data by statistic methods requires knowing and making proper use of the necessary knowledge. The analysis of the complex technological processes, the classical dimensional processing by electrical erosion procedure, as well as with magnetic activation, being one of them, can be done through various methods. The random balance method is an experimental statistic pre-modelling method that was used for determining the order of influence of the process parameters. For this, the chosen performance criteria were taken into consideration. The influence order according to the performance criteria has been exemplified in this paper using virtual devices.
KEY WORDS: method, virtual device, influence factor, diagram, panel.

1. INTRODUCTION

By applying science as productive force, people's work moves more and more towards the rationalization and decision making activity, the operation work being gradually taken by machines and automatic equipments.

For the rationalization and decision making activity in leading a process, science offers the necessary means as models – physical and mathematical – capable to react to any change of the working conditions.

Because research on physical models represents certain important disadvantages, such as a long period of time for the research with a high consumption of intellectual work, as well as the impossibility of enclosing the economic factors, the current trend in leading technological processes is using mathematical models on a large scale.

These models reproduce the researched process with the help of some functional relations and allow the finding of the optimal operation conditions in a much shorter period of time and with much lower material expenses than in the case of using physical models [174, 238].

The virtual device was done using the LABVIEW software.

LabVIEW (LV) is a visual type of application environment, using objects called virtual instruments (Virtual instrument – VI). For this reason, LV is also called virtual instrumentation environment.

The LV programmes are called virtual instruments (VIs) because they use graphical structures which imitate real instruments. The main characteristics of an LV programme are:

Virtual instruments organized in a hierarchical and modular format. They can be used as such in the LV programmes or as sub-instruments (sub VI) contained by a VI. The icons and connectors work under LV as graphical parameters used in passing the values between VIs or between VIs and subVIs [1].

2. THE DIMENSIONAL PROCESSING BY ELECTRICAL EROSION WITH MAGNETIC ACTIVATION PROCESS INTERPRETED AS A CYBERNETIC SYSTEM

The assisted programming of the experimentations at the dimensional processing by electrical erosion with magnetic activation for the general validation of some theories, casts aside mistakes, compromises and puts thoughts, conception, planning and leading into order

The modelling process of the dimensional processing by electrical erosion with magnetic activation process will have to comply with 2 (two) principles:

- the experiment on the chosen model should be as simple as possible;
- Knowing the calculation modality of the original parameters based on the studies done on the model.

In the study, analysis and leading process of the electrical erosion processing with magnetic activation process certain optimal conditions of the researched object are looked for using mathematical modelling.

This mathematical modelling will have 2 (two) components:

- a theoretical component, which in fact represents a physical-mathematical modelling of material sampling at the processing by electrical erosion with magnetic activation. The physical-mathematical modelling refers to the design, foundation, control and suggestion of the author of a physical-mathematical model of the material sampling process at the electrical erosion processing with exterior magnetic activation;
- an experimental component which has the purpose of also indirectly controlling the suggested and theoretically proven theory by the suggested theoretical physical-mathematical modelling.

In another order, referring to the experimental modelling suggested and presented in the present chapter of this doctoral dissertation the modelling is based on a mathematical algorithm made out of equations which correctly describe the inter-dependencies between the variables of the analyzed process.

The algorithm used has the following stages:

- Formulating the model:
- Establishing the scope;
- Elimiting the process;
- Establishing variables;
- Establishing the type of model.
- Establishing the objective function.
- Establishing the equations of the mathematical model.
- Controlling the suggested model with errors analysis and computer simulation.

The literature dedicated for studying technological objects, [174], [238], underlines the fact that for studying kinematics and the mechanisms of the electrical erosion processing a programming of the experiments is required in order to establish a mathematical model well informed.

Thus, the stages that were tackled in order to prepare the experiments were:

- The processing of the antecedent information and the elimination of the insignificant parameters factors;
- Obtaining the mathematical model of the object subject to research under the form of a mathematical function;
- Finding an optimal field.

The models of the preliminary research taken into consideration are: the rank correlation method, the dispersion analysis, the random balance analysis, methods that basically require the creation of some experiments for selecting parameters and significant factors of the process.

The basic research methods are based on classical experimental programmes and the active experiment programmes.

Statistic modelling was mainly done in 2(two) stages, namely:

- pre-modelling;
- the actual modelling;
- pre-modelling had a well established purpose which in the end was reached in 4(four) stages:
- establishing the state variables and the process parameters;
- determining some limits and variation intervals of the process parameters;
- establishing an experimental error, as well as the means of reducing it;
- naming the interactions and the degree of connection between the state variables and the process parameters.

The actual statistic modelling was done by active experiment.

In order to obtain a programming of the lab experiments at the dimensional processing by electrical erosion with magnetic activation the active experiment method was used, namely a complete central factorial experimentations programmes composed 2n where n=4 was done.

3. CREATE VIRTUAL INSTRUMENTS USING LABVIEW SOFTWARE

NI LabVIEW, a software based on the G programming language, is ideal for creating flexible and scalable design, measurement, control, and test applications rapidly and at minimal cost. Because of this, scientists can use it to interface with real-world signals, analyze and visualize data, and develop and prototype new algorithms. They and the students can make interface with external scientific computing libraries and text-based programming languages and scripts. But G is not the typical text-based programming language when combined with LabVIEW. LabVIEW G is a graphical programming language based on the dataflow model of execution.

The basic concept of dataflow programming is that each node is enabled (executes) as soon as data is available at all of the node's inputs. This intrinsic architecture of LabVIEW and its G programming language is important for scientific computing applications because it allows nonprogrammers and domain experts to develop sophisticated, math-intensive applications that take advantage of parallel programming and parallel hardware. LabVIEW G is an ideal development language for targeting multiprocessor, hyperthreaded, and multicore systems, all of which are common in the scientific computing environment. The LabVIEW G language is different from commercial C or Java programming languages, because it uses pictorial form to create lines of code. It is not a text-based language as C or Java. This pictorial form called a block diagram, eliminates a lot of the syntactical details. With this method, you can concentrate on the flow of data within your application. Because their appearance and operation imitate virtual instruments, LabVIEW programs are called virtual instruments (VIs) However, behind the scenes they are analogous to main programs, functions, and subroutines from popular programming languages like C or Visual Basic. A VI program has two main parts:

The front panel is the interactive user interface of a VI, so named because it simulates the front panel of a physical instrument. The front panel can contain many controls (which are user inputs) and indicators (which are program outputs) like: knobs, push buttons, graphs, and many other;

The block diagram is the VI's source code, constructed in LabVIEW's graphical programming language, G. The block diagram is the actual executable program. The components of a block diagram are: built-in functions, constants, and program execution control structures. You draw wires to connect the appropriate objects together to indicate the flow of data between them. Front panel objects have corresponding terminals on the block diagram so that data can pass from the user to the program and back to the user [2].

A VI that is used within another VI is called a subVI and is analogous to a subroutine. The subVI use in the block diagram, it must have an icon and a connector. Virtual instruments are hierarchical and modular. You can use them as top-level programs or subprograms. With this architecture, LabVIEW promotes the concept of modular programming. First, you divide an application into a series of simple subtasks. Next, you build a VI to accomplish each subtask and then combine those VIs on a top-level block diagram to complete the larger task [3].

4. VIRTUAL EQUIPMENTS FOR EXPERIMENTAL RESEARCH AT THE DIMENSIONAL PROCESSING BY ELECTRICAL EROSION ACTIVATED WITH AN ENSEMBLE OF EXTERIOR MAGNETIC FIELDS

In programming the lab experiments at the processing by electrical erosion in magnetic field one at a time, all stages of the experimental research presented in the previous paragraphs of this chapter have been followed through.

However, in short, one can say that the state variables and the process parameters which rose interest have been defined and a pre-modelling of the electrical erosion with magnetic field processing process was done by establishing an order, as precise as possible, of the parameters taken into consideration which have an important influence on the mentioned processing process using the random balance method, as well as the dispersion analysis.

Generally, the empirical methods used, especially the classic experiment, were distinguished through a laboriously manner of treating the problem and a low efficiency.

The experimentations programme that took place was done based on an active experiment and thus, the regression equation and the realization conditions of the optimal value were obtained, without making too many experiments.

The general objective function was the known one:

$$y = f(x_1, x_2, x_3, \dots, x_n); \quad (1)$$

where the influence factors' levels were determined x1, x2, x3, …, xn for which the function has maximal values.

Due to the complexity of the phenomenon, due to a relatively high number of parameters initially taken into consideration (10 parameters) the objective function could not be determined exactly. That is why generally, as in the present case, the real model (the objective function) is replaced with a statistic model, resulted by the Taylor series, developing around a point that was considered to be convenient, which is basically the centre of the experiment.

The initially used function was under the form of:

$$y = \beta_0 + \sum_{i=1}^{k} \beta_i \cdot x_i + \sum_{\substack{i=1 \\ j=1 \\ i \neq j}}^{k} \beta_{ij} \cdot x_i \cdot x_j + \sum_{i=1}^{k} \beta_{ii} \cdot x_i^2 + ... \quad (2)$$

where β0, βI, βij are real coefficients of the equation and the variables (x) are the factors' values.

The values of the coefficients (β0) which otherwise are real values, are replaced with their calculated values.

The xi, xj factors do not participate at the construction of the model with concrete values but with codified values. For each variable (in the end 4) certain basic levels x0n were determined which are in fact starting points (coordinates) within the experiment. Next the variation intervals Δxn are determined from where a maximum and a minimum limit results.

The codified value of the factors is α:

$$\alpha = \frac{x_n - x_{on}}{\Delta x_n} \quad (3)$$

The superior level, meaning the superior limit is marked (+1), and the minimum with (-1). Coming back to the multitude of parameters that can be taken into consideration, it was however established that in the electrical erosion with magnetic activation processing process "at the beginning" 8(opt) parameters that can significantly influence the process are sufficient.

These parameters taken into consideration are in a random order:

- The intensity of the electrical current: I [A];
- The impulse time ti [μs];
- The pause time: tp [μs];
- The material of the object to be processed;
- The material of the transfer object;
- The intensity of the magnetic field: H [A/m], (or the induction of the magnetic field: B [T]);
- The polarity of the processing
- The direction (sense) of the magnetic field lines.

At the same time within the research the state variables (the objective functions) have been determined, namely:

- Productivity of the processing: QP [mm3/min];
- Volume wear: QE [mm3/min];
- Relative wear : γ [%];
- Specific energy consumption: We [J/mm3];
- Quality of the processed surface: Ra [μm].

The random balance method, as experimental statistic pre-modelling method was used for determining an order of influence as precise as possible of the process parameters taking into calculation according to the chosen performance criteria.

Thus, this influence order on the process of the previously enumerated parameters was determined.

The method actually allows the inference of different combinations of the independent variables on the performance criteria based on a single series of experimentations and in the end ordering the parameters based on the amplitude of the produced effect.

The stages undergone by the calculation programme afferent to the method were:

Calculation of the average of the performance criteria for each level of the variable and the average of their average;

Calculation of the dispersion field of the average values and of the correction for each level of the variable (parameter) with the maximum dispersion;

Eliminating the effect of the variable (parameter) with the biggest influence on the chosen performance criteria and re-making the calculation with the corrected values of the performance criteria for the other variables.

In the case of the 8(eight) parameters, namely of the 5(five) state variables the calculation volume is relatively high.

In order to be able to introduce the data the programme needed, a few preliminary experiments were necessary.

A table was created which was similar to table 1.

Table 1. Process variables and their levels

Ord. No	Independent variables (parameters)	Levels	No. of levels
1	I [A]	12,5 / 37,5	2
2	ti [μs]	24 / 95	2
3	Tp [μs]	12 / 48	2
4	O.T. Material	Copper bar = OT1 / Black-lead = OT2 Steel = OT3 / Copper bar = OT4	4
5	O.P. Material	C120 = OP1 / OLC45 = OP2 OL60 = OP3 / Black-lead = OP4 Carbide= OP5 / Other materials= OP6	6
6	Intensity of the magnetic field [A/m]	H1 = 54219 / H2 = 71022 H3 = 108809 / H4 = 233600 H5 = 350000	5

7	Processing polarity	Direct connection= POL1 Reversed connection= POL2	2
8	Direction of the field lines	Direction 1 = DIR1 Direction 2 = DIR2	2

Based on the experimental statistic analysis the objective functions were also determined for each factorial experiment.

The general equation of the objective function finally took the shape:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{14}x_1x_4 + b_{23}x_2x_3 + b_{24}x_2x_4 + b_{34}x_3x_4 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^2 + b_{44}x_4^2 \quad (4)$$

for which the coefficients appear in table 2:

Table 2. Coefficients of the objective function

y1=Qp [mm3/min]	x1 = tp [µs]	b0=constant	b34= C * D	b12=A * B
y2=Qe [m3/min]	x2 = ti [µs];	b = A	b13= A*C;	b11=A * A
y3 = γ [%]	x3 = I [A];	b22 = B * B;	b2= B;	b14=A *D
y4 = Ra [µm];	x4 = H [A·spiral]	b = C	b23= B * C	b33=C * C
		b4= D	b24= B * D	b44=D * D

The general equations of the objective functions are presented in table 3.

Table 3. The equation of objective functions

Qp [mm3/min]	Qp = -62,6217 + 1,40521*tp + 0,843566*ti + 10,9220*I + (7,1250*10-4)*H + (-4,47897*10-4) *tp*tI + (4,95226*10-3) *tp*I + (-2,18267*10-6)*tp *H + 0,0238253*ti*I + (-6,59257*10-6)*ti*H + (1,2231*10-5)*I*H+ (-0,0230731) *tp2 + (-6,71295*10-3) *ti2 + (-0,834951) *I2 + (-1,89569*10-8) *H2
Qe [mm3/min]	Qe = -1,26902 + (8,41509*10-3)*tp + (5,11352 * 10-3) * ti + 0,28867 * I + (7,61549*10-6) * H + (2,55878*10-4)*tp*ti + (-4,54601*10-3) *tp*I + (-1,28201*10-7)*tp *H + (-7,01329*10-3)*ti*I + (-6,6519*10-7)*ti*H + (1,92036*10-5)*I*H+(1,90578*10-4)*tp2 + (2,30287*10-4)*ti2 + 0,0306776*I2 + (-2,07814*10-9) *H2
γ [%]	γ = 17,1382 + (-0,48513)*tp + (-0,493938)*ti + 2,31266*I + (8,95959*10-5)*H + (4,12754*10-3)*tp*ti + (-0,0754861) *tp*I + (6,575552 10-6) *tp *H + (-0,0649648)*ti*I + (2,31074*10-6)*ti*H + (-3,04687*10-5)*I*H+0,011734*tp2 + (4,93132*10-3)*ti2 + 0,389499*I2 + (-3,01084*10-9) *H2
Ra [µm]	Ra = 6,72173 + (-0,0443228)*tp + (-7,30174*10-4)*ti + (-0,809742)*I + (2,38057*10-5)*H + (1,27152*10-4) *tp*ti+ (-1,90972*10-3) *tp*I + (-3,20095*10-6)*tp*H +(-6,07394*10-3)*ti*I + (7,42738*10-7)*ti*H + (-2,44141*10-6)*I*H +(1,32791*10-3)*tp2 + (2,42992*10-4)*ti2 + (0,104496) *I2 + (2,7042*10-9) *H2

Using the objective function and the general equations of the objective functions, Qp, Qe, γ and Ra were calculated using the virtual device. The virtual device allows the marking of the graphs corresponding to the calculated sizes.

The diagram of the virtual device for calculating the Processing productivity: QP [mm3/min], is presented in figure 1.

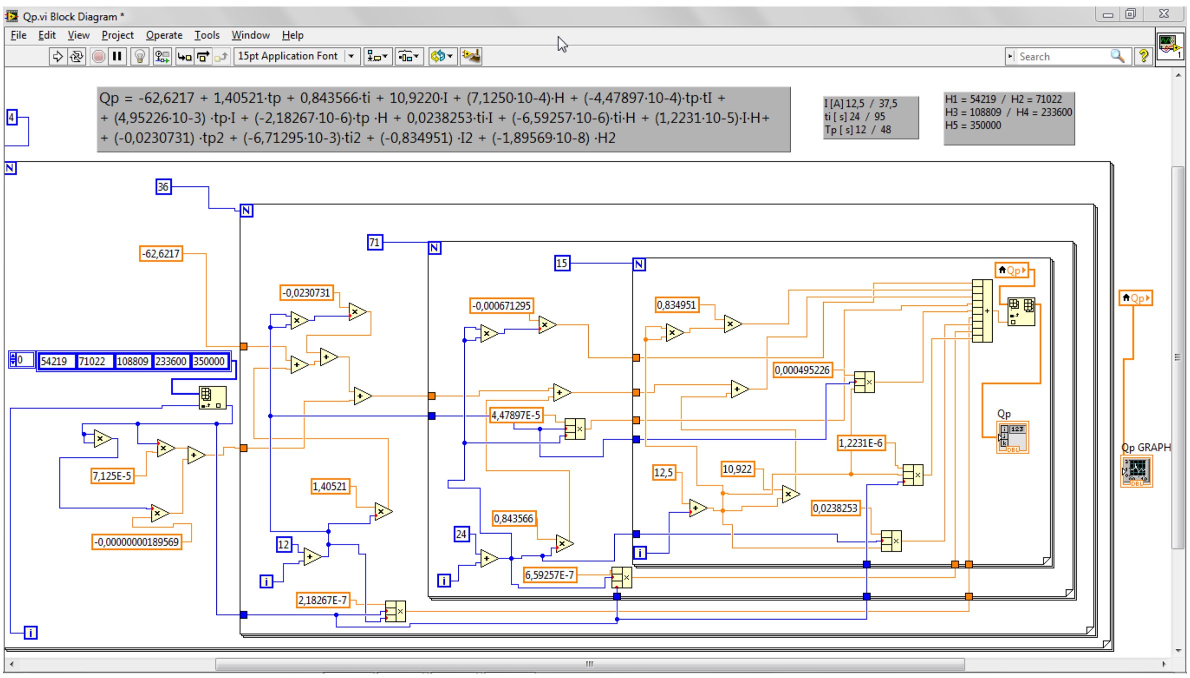

Figure 1. Diagram of the virtual device for calculating the Processing Productivity

The programme takes about 10 minutes. The panel of the device and the graphical representation of the obtained data are presented in figure 2. The graph contains approximately 270000 points.

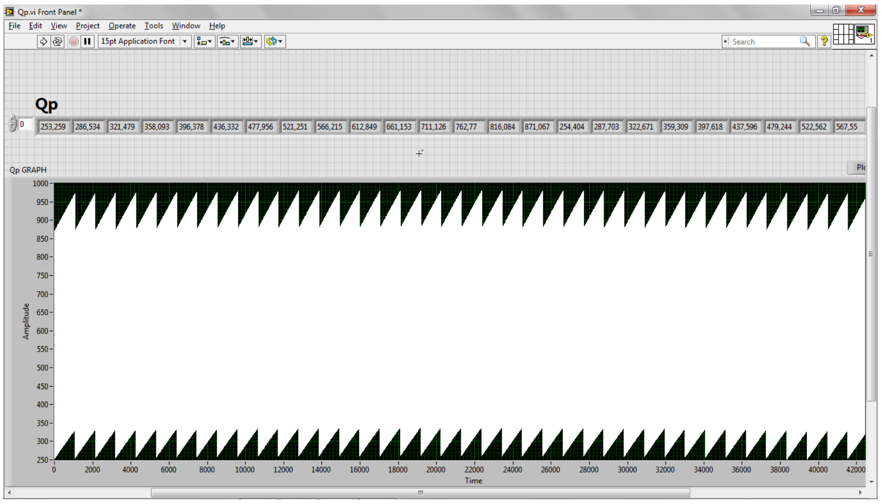

Figure 2. Virtual device panel for calculating Processing Productivity

A detail from the graphic for 1000 points is presented in figure 3. The chart Virtual device which calculates Volume wear: QE [mm3/min], in 273600 points is presented in figure 4.

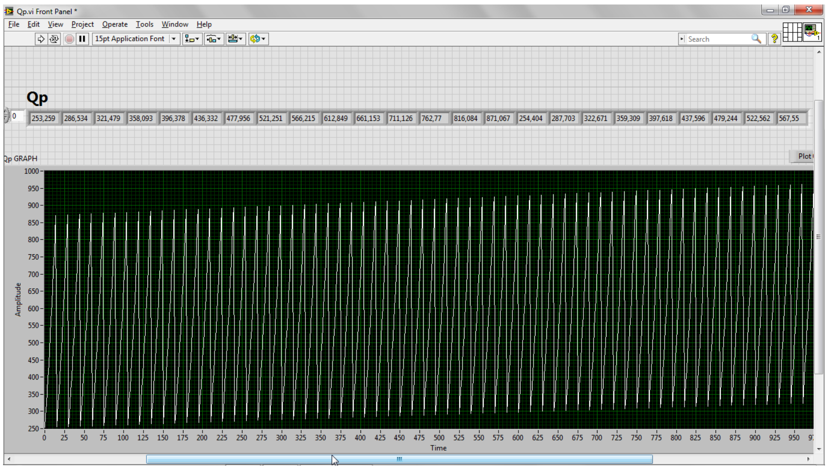

Figure 3. Graphical detail for calculating Processing productivity

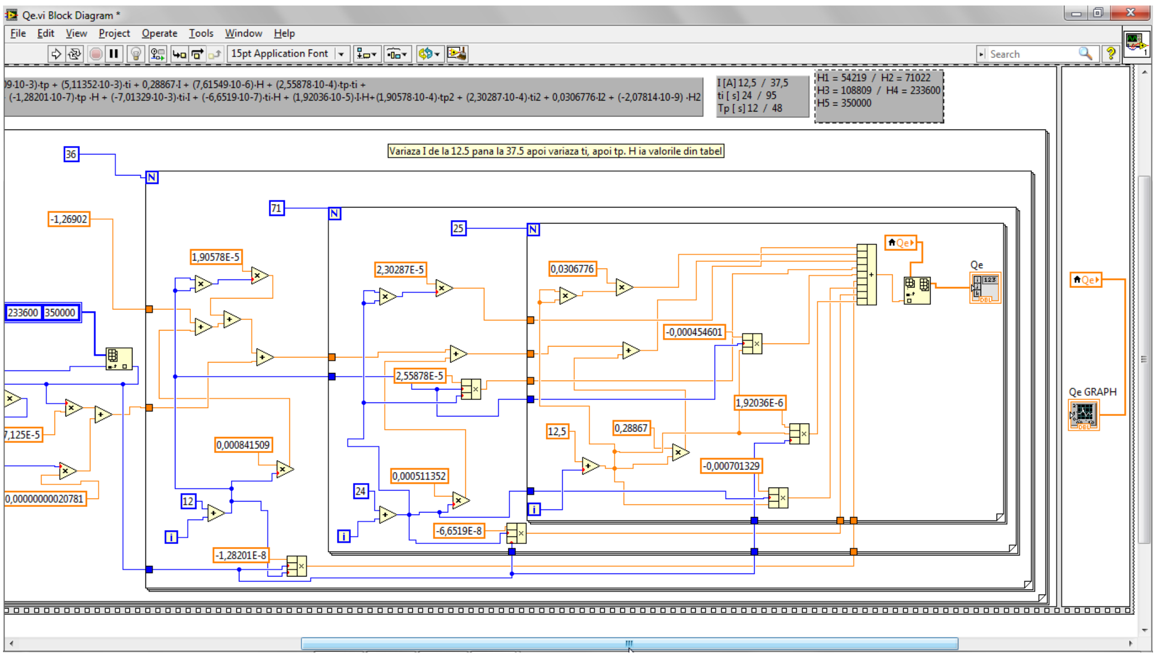

Figure 4. Virtual device diagram which calculates Volume Wear

The graph for all points is presented in figure 5. Detail from this graph for 5000 points is presented in figure 6.

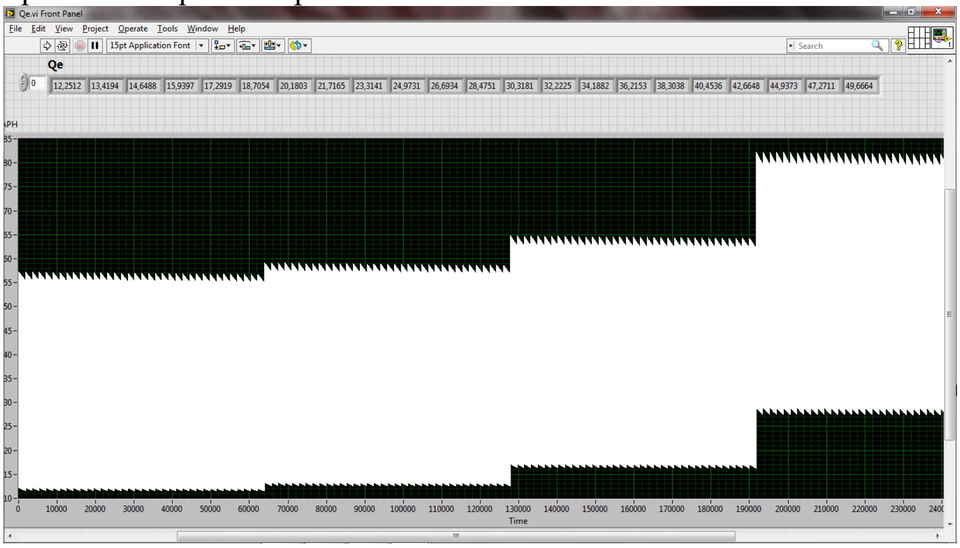

Figure 5. Virtual device panel which calculates Volume Wear

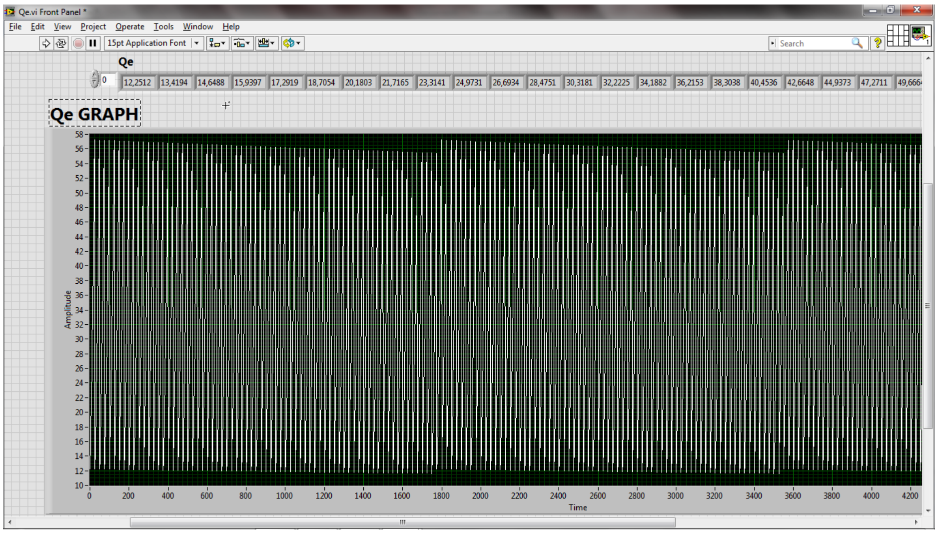

Figure 6. Graphic detail Volume Wear

5. CONCLUSIONS

Using virtual devices proves to be beneficial in different fields. Using sensors and acquisition boards allows obtaining data directly, visualising them in different shapes, as well as storage them in databases. In this paper we have illustrated the manner in which the virtual device can be used in the process of experimental research at the dimensional processing by electrical erosion, with an ensemble of exterior magnetic fields. In the future we will illustrate the manner in which the sensors and the data acquisition board are used for the automation of the experimental process and increasing the productivity of the experimental research.

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