EXPERIMENTAL RESEARCH REGARDING OPTIMISATION PARAMETERS FOR ULTRASONIC CLEANING

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În acest articol sunt prezentate câteva modalități de optimizare a parametrilor procesului de curățire ultrasonoră. Prin folosirea de noi senzori precişi de temperatură se poate măsura în timp real temperatura mediului de curățire ceea ce duce la o creştere a gradului de curățire.

In this article some optimisation methods regarding the parameters of cleaning with ultrasounds procces are presented. Using new precise temperature sensors, we could measure the real time temperature inside the cleaning enviroment which could improve the cleaning degree.

Keywords: ultrasound, cavitation, cleaning

1. Introduction

Precision or critical cleaning is at this time a great demande and it is expected to grow up in the future. The rapid advancement of various current technologies and the constant trend in component miniaturization has created the need for higher cleaning levels. Monolayer level contamination can drastically alter surface properties such as wet ability, adhesion and optical or electrical characteristics. The few microns particles are tracing contaminants such as nonvolatile residues in the range of micrograms/cm^2 and pictogram/cm^2, ionic in the same range or traces of corrosion have become a part of the daily concerns of the major industry's manufacturing engineers (some industries involved:

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semiconductors, automotives, disk drives, optics, ophthalmic glass, medical, aero spatial industry, pharmaceutical and tool coatings)

The various ultrasonic parameters or degrees of cleaning, available to the engineering process define the ultimate limits for the cleaning process.

Recently the computer systems allow real-time measurments for the ultrasonic cleaning process system's parameters.

With the help of a virtual instrumentation program, we can realize eficient virtual mesurement instruments implying low costs and minimum measuring errors.These instruments are especialy made for rapid measuremets and real-time optimisation of the parameters. In the real-time aquisitions, the time dedicated to the measurement is decreasing. Also the measuring chains are excluding measurement errors.

2. Experimental contributions regarding real-time aquisition for cleaning parameters

LabView simulation program creates a virtual instrument wich allows mesurement and monitoring of the next specific parameters for ultrasonic cleaning: temperature (two chanels), vibrations of ultra-acustics sytems and level of noise during the implosion. Virtual instrument contains four instruments one for each parameter such as *sub-VI.*

The mesurements were done in the following conditions:

- the time is inside of 0...99s interval;
- the power of piezoceramic transducer can be modified depending on application diferent tension levels and on active piezoceramic elements: 35W and 60W;
- there have been used three ultrasonic cleaning liquids: neutral PH detergent, isopropyl alcohol and acetone.

The experimental stand SEM-CU contains: 8 chanels LabView aquisition board conected with a PC, ultrasonic cleaning equipments, vibration meter which preamplifies acelerommeter signal.

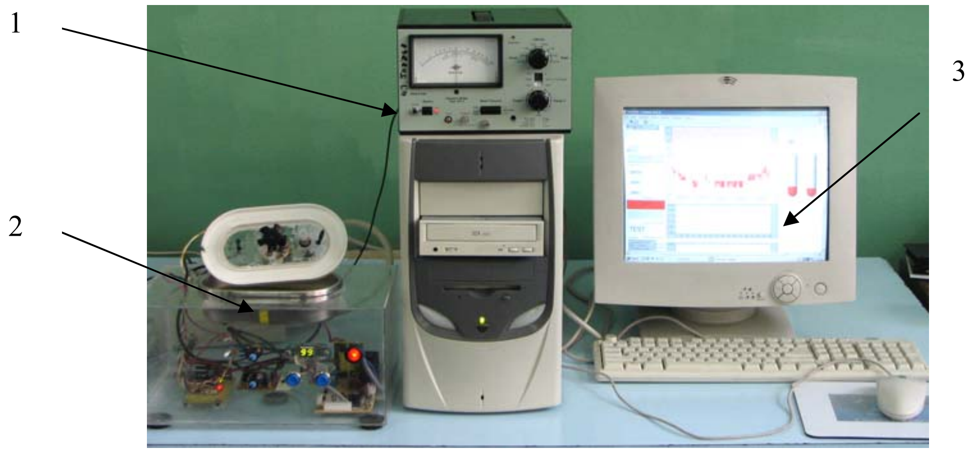

Fig.1. Experimental stand SEM-CU: 1 – vibration meter; 2 – ultrasonic cleaning equipments; 3 – LabView aquisition board

The aquisition results are recorded in data files. They are proccesed and used for graphical comparisions afterwards.

National Instruments M-Series are high-accuracy multifunctional data acquisition devices (DAQ) optimized for 18-bit analog input accuracy. This resolution is equivalent to 5.5 digits for DC measurements. The NI-M Series high-accuracy devices are the world's most accurate multifunctional data acquisition devices.

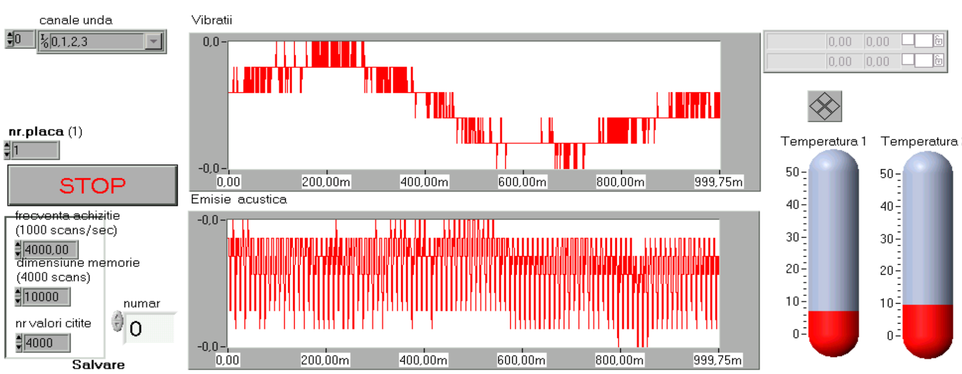

Fig.2. Frontal Panel - temperature, caracteristic of vibration and noise level

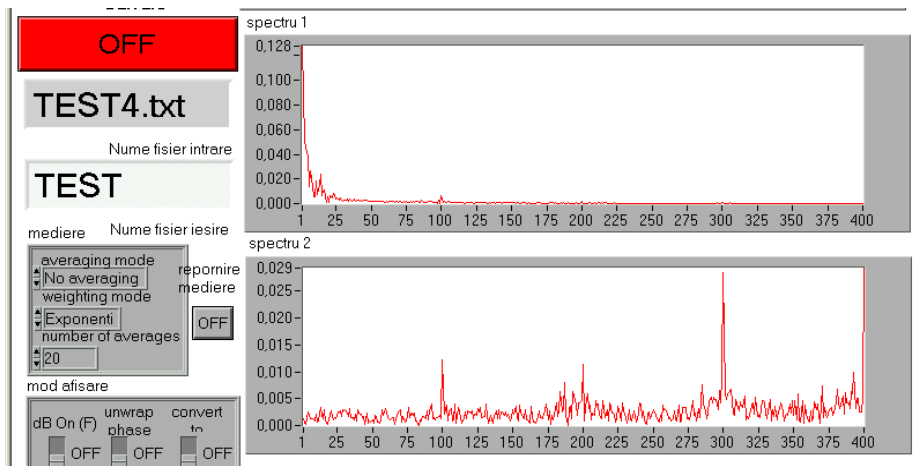

Fig.3. Frontal Panel - vibrations spectrum and noise level

The frontal Panel of this virtual instrument has:

- two virtual thermometers (of maximum 50^{o}C) used for measuring the temperature in diferent points of the ultrasonic bath
- an apparatus for measuring ultraacoustic system vibration characteristics
- a virtual instrument for measuring noise level during the implosion of the cavitation buble.

Each *sub VI* is connected to the logical VI diagram through logical gates coresponding to the behind diagram panel, named Frontal Panel.

A Sub VI, can work like a VI and can do separate aquisitioning and monitoring for each of the involved parameters. Using LabView simulation program measurement times have been reduced and also measuring erors have been removed and the measuring chain have been reduced.

An adaptor with 18 I./O slots, into which four sensors are introduced, was used between the computer and the aquisition board. The adaptor is converting each sensor's signal into analogical signal captured. The signal is captured and transformed by the aquistion board. Even if the aquisition board has 8 data inputs, only four will be used, one for each sensor.

The necesity of different electric characteristics adaptation implies the use of an adapter board beetwen the sensors and the aquisition board. This adapter board protects the aquisition board from missconections.

The adapter converts different power levels generated by the aquisition board through virtual instruments to a data file.

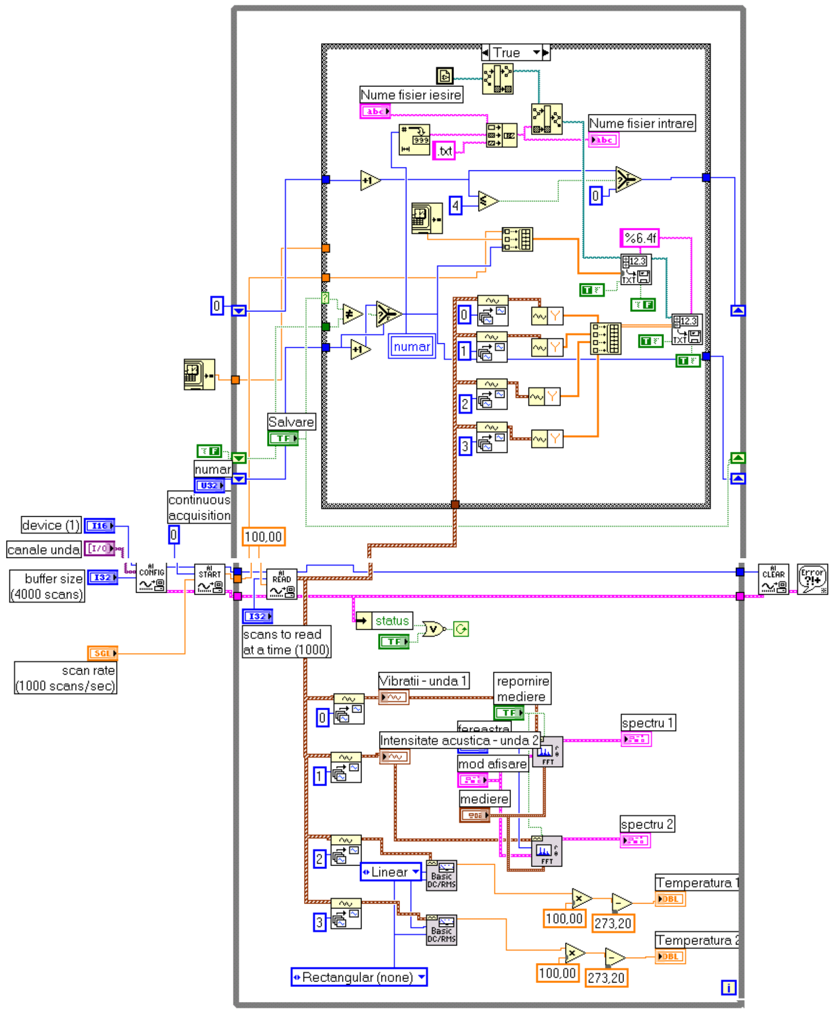

Fig.4. Block diagram of *VI*

The scope of this instalation is to determine some cleaning regim parameters. These parameters have a direct influence on the pieces from electronic and electrotechnical industry regarding ultrasoning cleaning. To reach a very good level of cleaning we have to do a permanent monitorization of the cleaning parameters.

A very good level of temperature aquisition can be obtained using sensors inside the instalation.

Using different kind of cleaning solutions implies different variations of the cleaning regim paramaters.

The change of power levels influences also the ultrasonic cleaning because the cleaning level depends on the piezoceramic transducer power.

2.1 Experimental contributions regarding the aquisition of the temperature during the cleaning process

For temperature aquisition we used two LM335Z sensors placed in two different points inside of the cleaning bath. One of them was placed near the piezoceramic transducer and the other one was pasted to one of the cleaning bath walls. Temperature measurements were done for two values of the transducer power (35W and 60W) using three different cleaning liquids (detergent, acetone and alcool isopropilic).

LM335Z temperature sensors are higly precise. They were created to simplify the measuring chain and to have exact measure of the temperature in different places inside the bath, during the cleaning process. Using a flexible connection system inserted inside of the thermoretractant tubes (where the measured signal has a low degree attenuation) the temperature would be determined with a good precision and also some detailed studies regarding the cleaning level depending on temperature can be realized.

The cleaning environment must be chosen so as to take off chemically the existing dirt layer and to contribute to the cavitational process growth.

The cleaning liquid effects and its influence on the cavitation are two very important factors for an increased level of cleaning.

The experimental data are operated with mathematical calculus programs TC2D. In order to operate this data acquisition we imported data as string values in TC2D.

The program TC2D is specialized in mathematical calculus and it can process strings presented as in the tables. This program is a very useful instrument in experimental analysis, because it has inside many default functions. These functions have attached the calculus of the statistics indicators. To choose the proper form of the function, the program uses the concomitant visualization of the data strings graphic representation, suggesting right functions, as well as reliable dependence. It’s also possible to choose the precision of the estimation. Using Table Curve 2D program some possible equations have been determined, which are estimating the time-temperature dependency.

The virtual thermometers are acquisitioning and recording the system power levels in a text file. These data are processed in concordance with the sensors calibration schema and also with the calibration constant, followed by the transformation of the real-time measured power in temperature.

For detergent with neuter PH, data acquisition is made at every second along four cleaning loops. In the following graphics the results of data acquisition representing variation of the temperature depending on time can be seen.

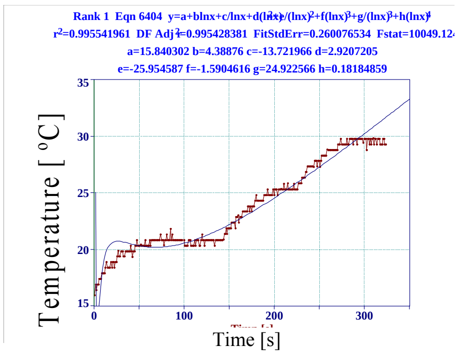

Fig.5.Curve approximating the temperature variation on the sensor 1, for detergent with neutral PH at 35W, with a polynomial function

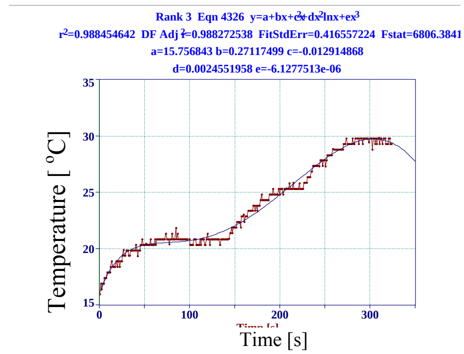

Fig.6. Curve approximating the temperature variation on the sensor 1, for detergent with neutral PH at 60W with another polynomial function

The first sensor variation curve depending on temperature(at 35W) can be approximated with an polynomial function (1). Its graphic representation is presented in fig.5.

$$y = a + b\ln x + c/\ln x + d(\ln x)^2 + e/(\ln x)^2 + f(\ln x)^3 + g/(\ln x)^3 + h(\ln x)^4 \quad (1)$$

The level of reliability is: $r^2 = 0{,}9955411961$

The same temperature variations could be approximated using the next polynomial equation:

$$y = a + bx + cx^2 + dx^2 \ln x + ex^3 \quad (2)$$

the level of reliability is being: $r^2 = 0{,}9884546416$

The function (2) is presented in fig. 6.

For the approximation of the cleaning liquid temperature variation the polynomial function (presented in fig.5) was selected because its reliability level is 99%, the calculated and posted overlap standard error is 0, 82 (this value is inside of the exclusion level); the value of the correlation coefficient, r^2 must be between 0 and 1). It has very convenient values (around 0, 9955), near the higher accepted level. The estimation is efficient because it has the least value of dissipation among all unmoving estimations made on the data string values.

For the first sensor, the temperature variantion curve (at 60W) can be approximated by an equation similar to a polynomial function (3); its graphic representation is presented in fig.7,

$$y = a + b\ln x + c(\ln x)^2 + d(\ln x)^3 + e/(\ln x)^4 + f(\ln x)^5 + g(\ln x)^6 \qquad (3)$$

the reliability level being: $r^2 = 0{,}983475749$

The same function of temperature variation could be approximated by the next polynomial equation:

$$y = (a + cx)/(1 + bx + dx^2) \qquad (4)$$

the reliability level being: $r^2 = 0{,}974116997$.

The graphic representation of functions (4) is presented in fig. 8.

To approximate the cleaning liquids variation of temperature we selected, between the two suggested functions, the polynomial one (presented in fig.7) because the reliability suggested level is 98% while the calculated overlapping standard error is around 0, 83, under the exclusion level

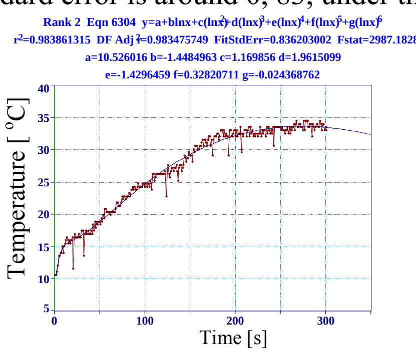

Fig.7. Curve approximating the temperature variation on the sensor 1, for detergent with neutral PH at 60W with a polynomial function

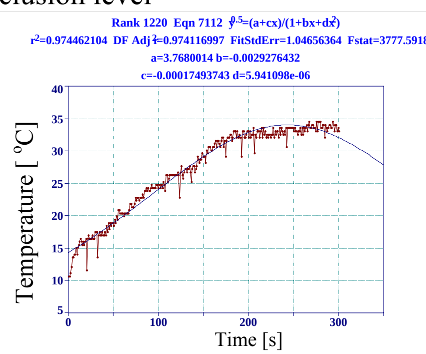

Fig.8. Curve approximating the temperature variation on the sensor 1, for detergent with neutral PH at 60W with a rational function

The value of correlation coefficient, r^2 (its values must be between 0 and 1), have been very convenient values around 0, 9834, near the higher accepted level. The estimation is efficient because it has the least value of dissipation among all unmoving estimations made on the data string values.

To higher power level of the transducer a quicker heating of the cleaning liquids can be observed. During the temperature growth, the cavitational process intensifies and therefore the cleaning degree increases.

Looking at acquisitioned values and in its afferent chart it could be noticed a different growth of the temperature depending on time and also a very important temperature growth when the transducer power is growing up (fig.9).

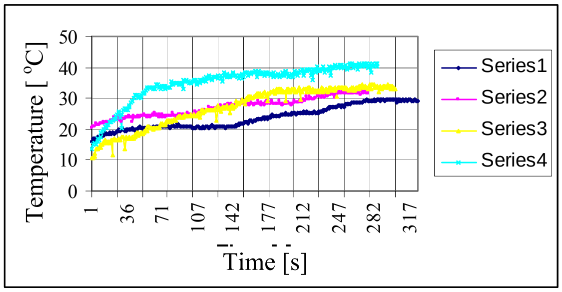

Fig.9. Curve approximating the temperature in time variation on two sensor at 35W and 60W : series1 – senzor 1 at 35W; series 2 - senzor 2 l at35W; series3 - senzor 1 at 60W; series 4 - senzor 2 at 60W

Superposing the curves of temperature variation over the two pick-up transducers it can be noticed that the temperature increases to a higher value of the transducer power. This leads to an upper cleaning degree. The temperature is also growing on the location near the piezo-ceramic elements sensor.

The aqueous solutions are more frequently used because they do a better cleaning without polluting the environment.

The ultrasound effect inside water-based solutions depends on temperature until 70^{o} C after which it is stabilized and is decreasing after cleaning liquid boiling point is exceeded.

2.2. Experimental contributions regarding the aquisition of the vibrations during ultraacoustic cleaning process.

The mechanical vibrations are defined as an alternative motion of a material point, of an assembly or of a system of assemblies, around a reference position.

An assembly vibration, identified with a material point placed in the mass center and also having the assembly mass, is mathematically represented by χ which represents the motion elongation, the distance between the point and a fixed reference position. It is introduced by the next formula:

$$x = x(t) \quad (5)$$

The motion parameters are not the only ones used to characterize the vibrations. Sometimes, speed or acceleration are used much as in theory like in practical vibration measuring Vibration measurement apparatus has integrated circuits able to measure any of the three above mentioned parameters.

Inside the cleaning bath, vibrations are increasing or decreasing depending on the rhythm of appearance or disappearance of the cavitational implosions following the appearance of acoustic cavitation phenomenon and the appearance of high-speed micro-jets produced by the cavitational implosions

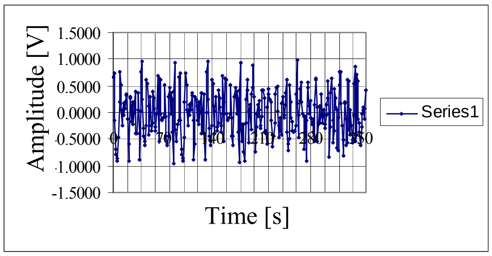

Fig.10. Graphic reprezentation of the ultraacoustic system vibration, at 35W power

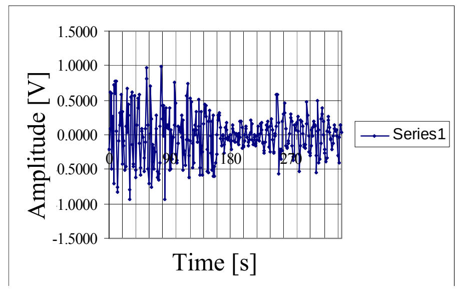

Fig.11. Graphic reprezentation of the ultraacoustic system vibration, at 60W power

For real-time acquisition a virtual instrument was created which allows the acoustic system vibrations acquisitioning and monitoring. This virtual instrument is taking over classical vibration-meter functions. The graphic representation of acoustic system variations (during a period of time) using a power of 35W is presented in fig.10 while that using a power of 60W is presented in fig.11.

If this two vibration specters are overlapped (using that two power levels) it could be noticed a growth of signal's amplitude at 35W combined with a lower impulse frequency and also at 60W it can be noticed that for lower signal amplitude the frequency of the impulses is higher. (fig. 12)

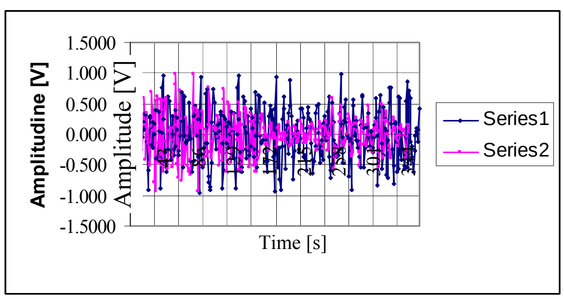

Fig.12. Graphic reprezentation of the ultraacoustic system vibration: series 1 – power 35W; series 2- power 60W.

Cleaning liquid modification has no influence on changing acoustic system vibrations. Only cleaning liquids with higher viscosity can influence ultrasonic vibrations.

2.3 Original contributions regarding cavitation noise level aquisition

After cavitational implosions, the noise level inside the cleaning bath increases With the hydrophone help, realized with a microphone with pre-amplified signal especially made for high-frequency sound measurements, the noise produced by cavitations can be stored and analyzed..

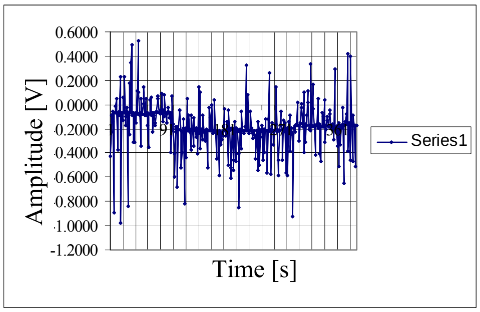

Fig.13. Graphic reprezentation of the noise acustic cavitation, at 35W power

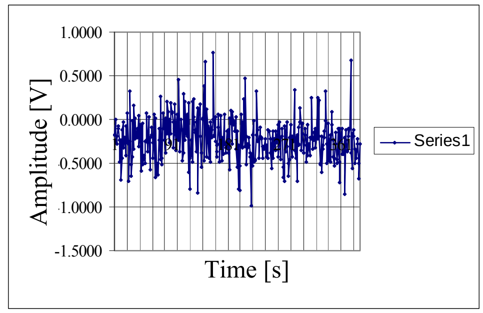

Fig.14. Graphic reprezentation of the noise acustic cavitation, at 60W power

If this two vibration spectra are overlapped (using that two power levels) it can be noticed a growth of the signal's amplitude at a higher transducer's power (fig. 15)

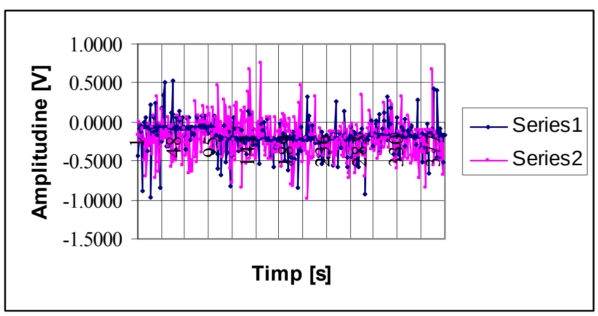

Fig.15. Graphic reprezentation of the noise acustic cavitation: series 1- power 35W; series 2 – power 60W

3. Conclusions

Folowing the above described experimental research the next conclusions can be drawn:

a) the temperature is growing up depending on time and also it is growing up during the modification of the piezoceramic transducer power which brings to the intensification of the acoustic cavitation and to the growth of the cleaning degree;

b) the temperature grows in a diferent mode in the ultrasonic cleaning bath (more around piezoceramic elements and less around the cleaning bath walls).
c) the amplitude of the noise level grows when transducer power is modified and when the vibration frecvency characteristics are rising with the growth of the piezoceramic transducer's power.
d) the virtual instruments asociated with clasical measuring apparatus reduces and optimazes the measurement time giving also higher measurements precision.
e) the use of precision sensors for mesurement of the cleaning system temperature favours an easier and quicker temperature aquisition. This precision sensors decreases the measurement errors.

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