with a poor-quality covering.

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CONTRIBUTIONS CONCERNING VIRTUAL INSTRUMENTATION IN SPECTRAL ANALYSIS

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Spectral analysis is the most widely used technique in the extraction of information from measured signal patterns.

This paper presents virtual instruments for spectra estimation included in a more complex program that makes signal processing in time, amplitude and frequency domains.

The results of these studies can serve the projection of industrial equipment for the tool wear monitoring and for the creation of a database for automatic estimation of tool wear by vibration processing.

1. ***Introduction.*** Vibration monitoring is used both as a maintenance and as a production quality control tool for machinery systems.

While often similar in concept, these differ considerably in some aspects. Vibration monitoring as a maintenance tool, often called *condition monitoring,* enables the establishment of a maintenance program based on a early warning.

This can be of great value in cases involving critical machinery, where an unexpected shutdown can have disastrous economical or environmental consequences. In general, these cases involve the monitoring of a single or a few systems where continuing operation is imperative.

Applications involving quality control often deal with the opposite situation: a large amount of sometimes low-cost components have to be tested during production. The identification of faulty components not only reduces manufacturing cost, but often pinpoints production problems, which are then usually remedied.

The sensing feature of vibration monitoring make it a viable quality control tool, especially where other practical tools may be almost unavailable.

An unviable state of system may be recognized, even when there is no faulty component at hand. The recognition of an early failure prediction necessitates the identification of the state of the system, based on the variables monitored. The knowledge needed for such an absolute identification is often not available and continuous or regular measurements are collected during operations [1].

Frequency domain analysis is the most widely used method and many monitoring methods classify almost exclusively on the base of patterns in the frequency domain. This fact is also reflected by the increased availability of spectrum analyzers dedicated to vibration signals.

For example, to rotating machinery, where many frequencies are proportional to that of the main rotation, continuous harmonic signals are recognizable by such a presentation.

The paper presents a method for spectra evaluation. The spectrum of a test signal is first determined; then it is compared with the spectrum of a reference signal.

The difference between the spectra is displayed. The analyzed spectrum is also compared with the warning level and the alarm level that were previously determined by the operator.

2. ***2.The main contents and outcomes of activity.*** Most frequency domain methods are based on the direct application of Fourier transform to deterministic power and energy signals [2]. This enables a one-to-one mapping between the time, *x(t)*, and the frequency domains, *X(f)* and are given by the equations:

$$X(f) = \int_{-\infty}^{\infty} x(t)\exp(-j2\pi ft)t,$$

$$x(t) = \int_{-\infty}^{\infty} X(f)\exp(j2\pi ft)df.$$

For continuous signals it is possible to use the power spectral density function (p.s.d.), $S_{xx}(f)$. This function of frequency gives the distribution of the power of the signal with frequency:

$$\overline{x^2(t)} = \int_{-\infty}^{\infty} S_{xx}(f)df.$$

The p.s.d. and auto-correlation function, $R_{xx}(\tau)$ are related for stationary signals:

$$S_{xx}(f) = \int_{-\infty}^{\infty} R_{xx}(\tau)\exp(-j2\pi f\tau)d\tau.$$

The paper presents a virtual instrument for frequency domain analysis based on the estimation of the spectra for two signals: reference and test signals [3], [4].

First, we build virtual instruments for data acquisition and analysis.

A virtual instrument consists of an interactive user interface, a dataflow diagram that serves as the source code and icon connections that allow the virtual instrument to be called from higher level virtual instruments.

More specifically, the virtual acquisition instrument has a structure as follows:

- The interactive user interface is called the front panel, because it simulates the panel of a physical instrument. The front panel contains knobs, push buttons, controls and indicators.
- The virtual instrument receives instructions from a block diagram, constructed in graphical programming language, *G*. The block diagram is a pictorial solution to the programming problem. The block diagram is also the source code for the virtual instrument.
- The virtual instrument are a hierarchical and modular structure. It can be used as top-level programs or as subprograms within other programs or subprograms. The icon and connector of the virtual instrument work like a graphical parameter list so that other virtual instruments can pass data to a subvirtual instrument.

With these features, the virtual instrument promotes and adheres to the concept of modular programming. The application is divided into a series of tasks until a complicated application becomes a series of simple subtasks.

The block diagram of the virtual acquisition instrument is constructed by wiring together objects that send and receive data and perform specific functions and control the flow of execution.

Data are read and saved as global variables.

We build a virtual instrument to accomplish each subtask and then combine those virtual instruments on other block diagram to accomplish the larger task. Finally, the virtual instrument contains a collection of subvirtual instruments that represent application functions.

Because each subvirtual instrument is constructed by itself, apart from the rest of the application, debugging is much easier.

The appliance of the general scheme for monitoring uses a virtual instrument for acquisition and saving to files the signals received from the sensor.

A main program, modulated, containing four levels, makes the processing of the files' data:

- Time domain analysis;
- Frequency domain analysis;
- Amplitude domain analysis;
- Dynamic analyser.

In figure 1 is presented the block diagram of the virtual instrument for data analysis.

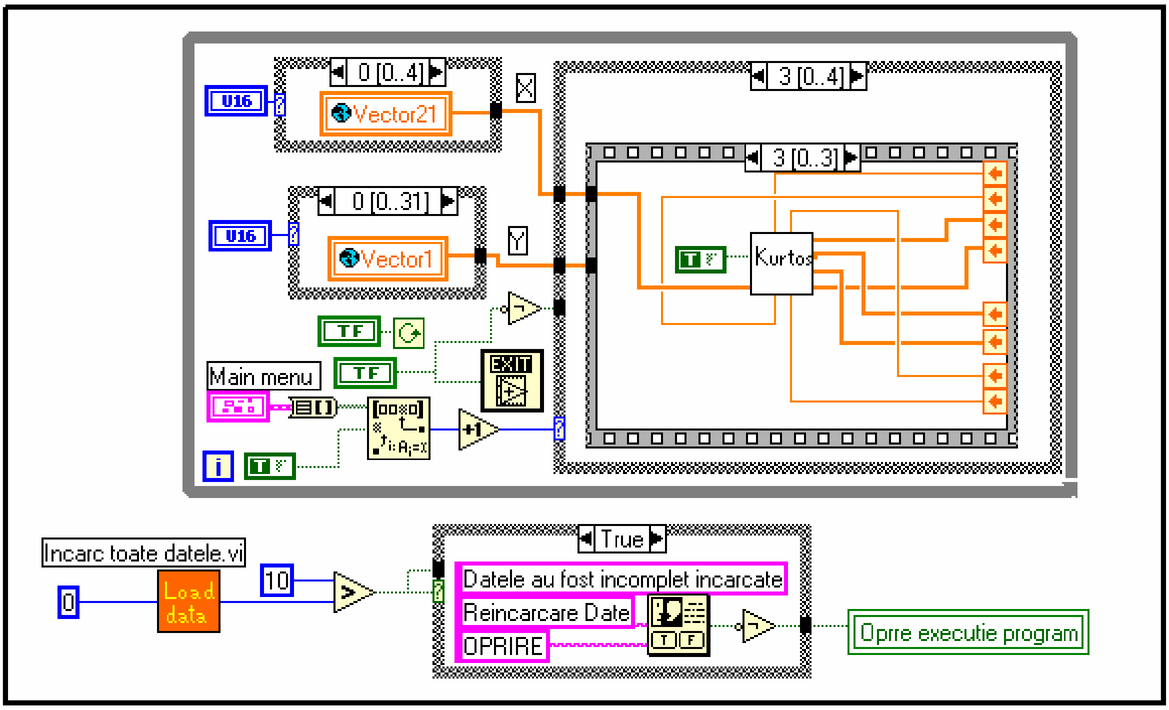


Fig. 1. Block diagram of the virtual acquisition instrument for data analysis

On main program run all the files saved using the virtual acquisition instrument. After data loading the analysis domain is chosen.

The operator can choose the reference vectors and the test vectors using selection buttons. In each domain, the signal is process with dedicated virtual instruments.

For example, the frequency domain analysis is based on the estimation of the spectra and follow these steps: obtaining the reference pattern, defining the limitative profiles, making spectra comparison and drawing the trend graph.

We build a virtual instrument for frequency domain analysis based on the estimation of the spectra for two signals: reference and test signals [3], [4].

Theoretically, it can be considered that the complex signal produced in the machining operation time can be described by a function that depends on multiple variables: cutting conditions, dimensions, form, and homogeneity of the workpiece, tool geometry, ans. Practically, solving this function is very difficult from the mathematical reasons and requests a very large experimental data. This function is replaced by functions that partially characterize the process.

For tool wear monitoring five independent variables were considered:

- Revolution, n [rev/min]
- Feeds, s [mm/rev]
- Depth, t [mm]
- Hardness, HB
- Wear along the clearance face, VB [mm].

For each variable, five values are set up a medium, a minimum, a maximum and two intermediate values. The chosen values of independent variables are:

- n = 260; 425; 660; 850; 1040 [rev/min]
- s = 0.025; 0.05; 0.1; 0.12; 0.25 [mm/rev]
- t = 1; 1.25; 1.6; 2; 2.5 [mm]
- HB = 165; 180; 200; 210; 230
- VB = 0; 0.15; 0.3; 0.5; 0.7 [mm]

To reduce the number of experiments, an experimental project, with factorial programming, second order, with central rotation, was used. The central programs need a central point in the middle of the program and equidistant repartition of the other values.

This experimental program reduces the number of experiments from 3125 to 32 and has good results because it doesn’t lose experiment significance.

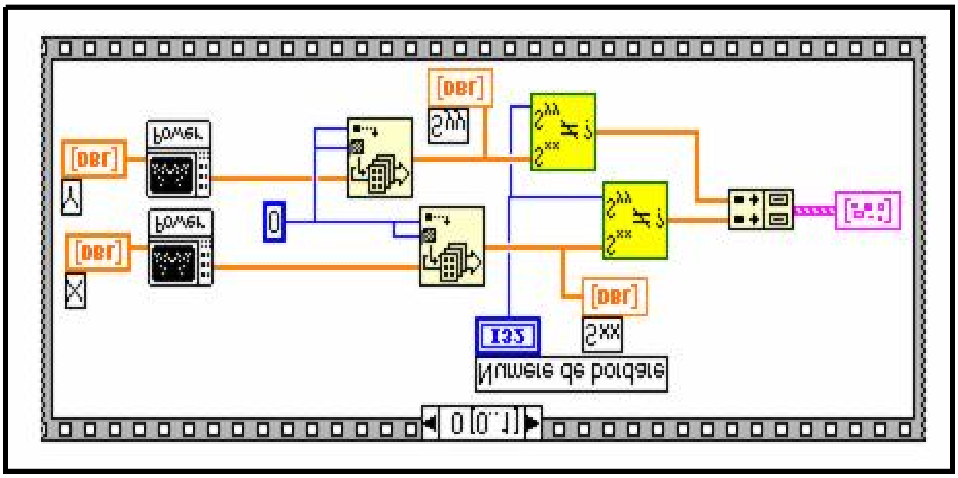
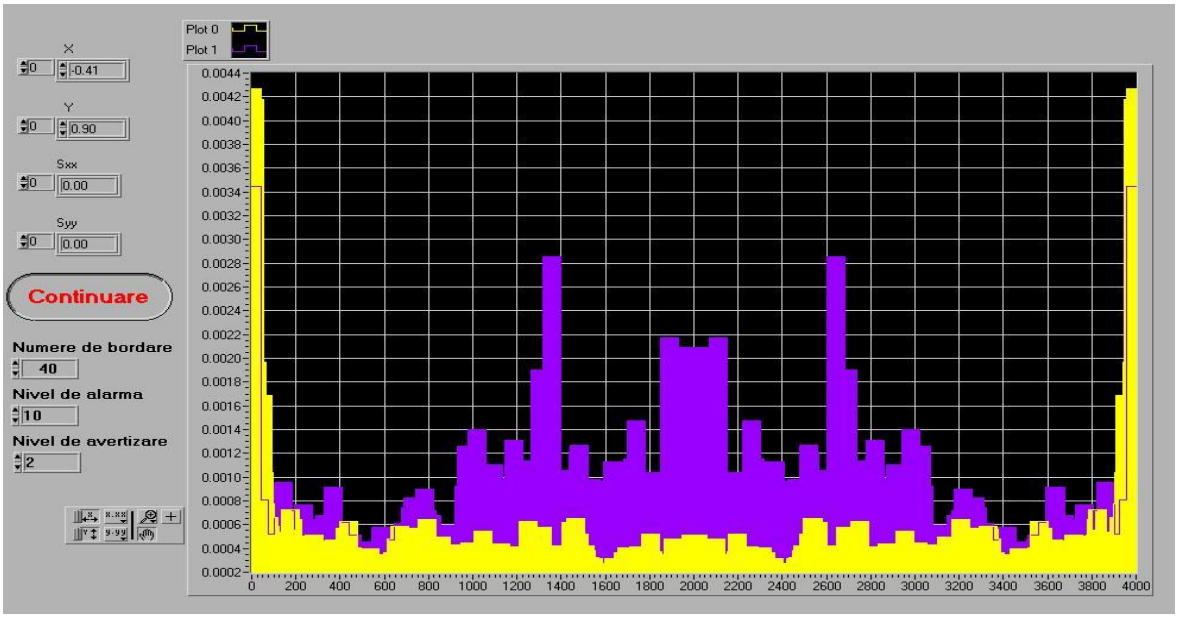


Fig. 2. Block diagram of the virtual instrument


X 0 -0.41

Y 0 0.90

Sxx 0 0.00

Syy 0 0.00

Numere de bordare 40

Nivel de alarma 10

Nivel de avertizare 2

Fig. 3. Front panel of the virtual instrument

A virtual instrument was designed for processing the signal captured by the sensor, make a comparison between the reference signal and the analyzed signal, obtain information on tool-wear and identify the trend in it’s evolution (figure 2,3).

The front panel of the virtual instrument for spectra estimation is presented in figure 3. Using contrasting colors, the differences between the two graphs are made visible.

3. Conclusions. We have presented virtual instruments for frequency domain analysis. It has been made the comparison between the reference signal and the test signal.

The results of these studies can serve the projection of industrial equipment for the tool wear monitoring and for the creation of a database for automatic estimation of tool wear by vibration processing.

The modular flexible structure allows the usage in other programs and it makes it useful in digital signal processing.

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