The Study of Vibrations of an Elastic System Using the LabView Graphic Programming Medium

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***Abstract*—The usability of this paper is to study from an experimental point of view the vibrations of an elastic system consisting of an elastic lamella using a data acquisition system as hard support and the LabView graphic programming medium as soft support.**

***Index Terms*—Acceleration transducer, elastic lamella, system of data acquisition and data processing, the LabView graphic programming medium.**

I. Introduction

The first part of this paper presents some theoretical notions regarding the vibrations as physical phenomena.

In the second part of the paper we have experimentally determined the acceleration, speed and the vibrations displacement of the studied elastic lamella.

II. The Vibration Notion

The vibrations are dynamic phenomena which appear in elastic media after a local excitation and which convey within the medium under the form of oscillations [1].

The vibration is a mechanic oscillation around a reference point and defines the movement of a mechanic system. The medium should be large enough in order to talk about a local excitation and to be conveyed through oscillations [2].

The vibration is characterized by amplitude, speed, acceleration and frequency spectrum. The vibration is often destructive, on the other side it is the disturbing side of a useful thing but it can also be deliberately generated in order to achieve some requirements [2].

The measures which characterize the movement (vibration) of the system that is the displacement, speed and acceleration are defined according to the relations (1), (2) and (3):

$$d = D\sin\omega t \quad (1)$$

$$v = dd/dt = D\omega\cos\omega t \quad (2)$$

$$a = d^2d/dt^2 = D\omega^2\sin\omega t \quad (3)$$

Actually, these measures are more complex, the variation law is not sinusoidal. That is why, there is a record of the vibration, it is decomposed in components which are already sinusoidal, we achieve a spectral analysis and on its grounds the nature of the vibration is determined [1].

The knowledge of measures characteristic to vibrations has a great importance in science [2].

The amplitude of vibrations informs about the games between the parts, the acceleration of the vibration informs about the intensity of loading forces which act due to vibration and the speed informs about the acoustic sound produced by the medium which vibrates but also by the energy of vibration [2].

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III. The Triaxial Acceleration Transducer

The piezoelectric accelerometer converts the acceleration into an electric measure which is proportional with the force applied on the internal ceramic element (piezoelectric), the mechanic variable (acceleration) being obtained by a measurement of the force [3].

The assembly is composed of a central shaft, a ceramic piezoelectric element, a seismic body and a pre-load arrow. During operation, the unit sends a perpendicular movement towards the basis.

When the accelerometer is attached to a vibrant structure, the seismic mass practices a force on the ceramic piezoelectric element. This applied force determines the piezoelectric material to produce an electric measure. The force is equal to the mass multiplied by acceleration (*Newton's second law:* $F = m * a$), the result obtained is proportional to the acceleration as long as the mass *m* is constant [3].

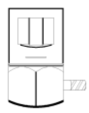

Fig. 1. Internal view of an accelerometer with a single axis.

The construction of the sensitive ceramic element presented in Fig. 1 offers many advantages, among which the insensitivity of the accelerometer to temperature variations, transversal movements along the axis and effects based on efforts. For the beginning, we have used a quartz element which had many standard uses. The ceramic accelerometer uses similar rings or it has a ring design which provides the same advantages [3].

IV. The Component Modules of the Used System of Data Acquisition and Data Processing

A. The Acquisition board SCXI 1600

SCXI 1600 is an advanced *USB* data acquisition module on 16 bits which achieves the direct connection between a *USB* compatible computer and a SCXI system. SCXI 1600 receives analogical signals from other SCXI modules and amplifies, digitizes and sends the data through the medium of the *USB* port; likewise it can control the digital input and output of the SCXI module.

SCXI 1600 is connected to other SCXI modules in order to get 352 analogical signals from thermocouples, measuring instruments, tension and current sources. The SCXI 1600 module is based on the *DAQ* series *E* appliance and uses the time controller *DAQ*-STC for the time functions. The system *DAQ-STC* is used in order to make possible the applications as time sampling and the linear modification of the sampling rate, the system includes three groups of timers which controls the analogical input [4].

B. The System Chassis and the SCXI 1000 Power Unit

The SCXI 1000 chassis contains modules from the SCXI series that it controls and supplies, being conceived for 4 modules [5].

The SCXI 1000 chassis is traversed by a standard alternating current and it contains a low noises medium for the conditioning signals and supply and control circuits from SCXI series.

In order to use the chassis a specialized soft is necessary such as: LabView, *LabWindows/CVI or Measurement Studio* or *NI-DAQ.*

Before the configuration of the chassis, we decide the way the work will be done, parallel or complex [5].

C. The SCXI 1530 Module Specialized for Accelerations

The SCXI-1530 module is a circuit piezoelectric integrated with 4 channels, the conditioning way which has programmable current and the possibility to set the filter for each channel [6].

SCXI-1530 has simultaneous sampling and restraint circuits. Each channel has the possibility of setting a factor of signal amplification from 1, 10 or 100 and to set the 4 programming poles of the filter to 2.5, 5, 10 or 20kHz, each channel has a current source programmable at 4mA, 24V.

SCXI-1530 provides 4 *BNC* connectors (connectors of coaxial signal) at interface with accelerometers. This module accepts both ways of multiplexed and parallel outputs [6].

V. Experimental Results

In order to measure the vibration we use a triaxial ceramic accelerometer 8762A5T.

The accelerometer is fixed on an elastic lamella at one end and the other end of the lamella is embedded, the lamella being subject to a force *F*, manually applied.

As for the majority of the accelerometers, the sensitivity is given by the rate of electric output to apply accelerations, at the output we obtain a low impedance, which is proportional with the applied acceleration. Due to the low impedance, there is no need of special connections and the transmission at distance is possible to be achieved with minimum of noise [7].

In order to sense the vibrations, the accelerometer fixed on the elastic lamella converts the acceleration in an electric measure which is proportional with the force applied on the internal ceramic element (piezoelectric), the mechanic variable (acceleration) being obtained by a measurement of force.

The assembly is composed of a central shaft, a ceramic piezoelectric element, a seismic mass and a pre-load arrow.

During operation, the unit sends a perpendicular movement towards the basis. When the accelerometer is attached to a vibrant structure, the seismic mass practices a force on the ceramic piezoelectric element. This applied force determines the piezoelectric material to produce an electric measure. The force equals the mass multiplied with acceleration (Newton's *second law:* $F = m * a$), the result obtained is proportional to the acceleration as long as the mass *m* is constant [3].

The components of the system of acquisition and processing of the presented vibrations of the elastic lamella are given by the modules SCXI 1530 and SCXI 1600, the conditioning circuit of the signal (vibration) which is the board of the used accelerometer, that is the acquisition board, both of them being supplied by the SCXI 1000 power unit.

In the processing of the acquired data through the medium of the acquisition board of the SCXI 1600 module the LabView development medium is used through which the used module is controlled with the help of the NI-DAQmx [8]. The use of DAQ Assistant can simplify the development of the application. National Instruments recommends the creation of the tasks through the medium of DAQ Assistant at the use of sensors [9].

In Fig. 2 we have presented the block diagram of the virtual instrument achieved for the proper acquisition of data. The acquired data are written in a text file from which later they are read in order to be processed. The future processing refer to a simple and a double integration obtaining speed and displacement which can be displayed at the level of the front panel in Fig. 4 on two graphic indicators to which the graphic representation of acceleration is added and the display of its amplitude and frequency, obtained through the medium of the *Tone Measurement* block.

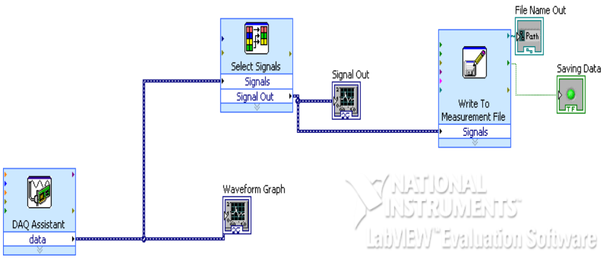

Fig. 2. The block diagram of the virtual instrument achieved for data acquisition.

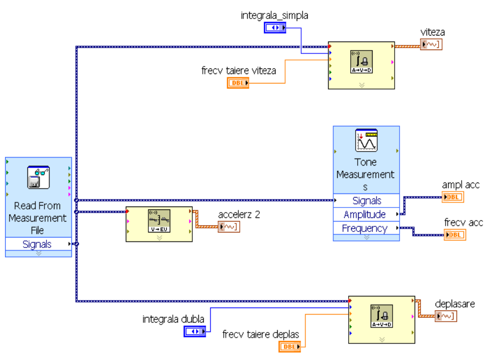

Fig. 3. The block diagram of the virtual instrument achieved for data reading.

With the help of the acquired data, which are later read (the *EOF*? indicator of *boolean* type is materialized in a LED which can have one of the values TRUE or *FALSE*, its role is to inform the user that all the acquired data were read, the moment when the value TRUE and the LED turn on) the duration of the signal can be calculated through the medium of the virtual instrument *Waveform Duration* of the block diagram as in Fig. 5 which has embedded the following calculation formula[8]:

$$durata = (nr.esantioane - 1)xdx \quad (4)$$

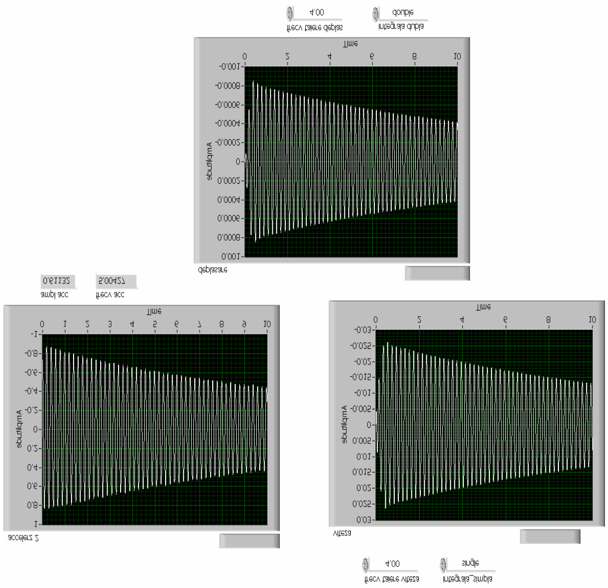

Fig. 4. The front panel of the virtual instrument achieved for data reading.

The type of the data connected to the input of the block determines the polymorphic model which is to be used. The output *Waveform Aut* represents the input for the virtual instrument *Number of Waveform Sample*, through the medium of which the number of samples will be returned, visualized on the front panel by the numeric indicator *number of sample* [9]. The second output *Duration* indicates at the level of the front panel the duration of the signal. The graphic representation of the signal is done on the indicator *Signals* of the front panel in Fig. 6.

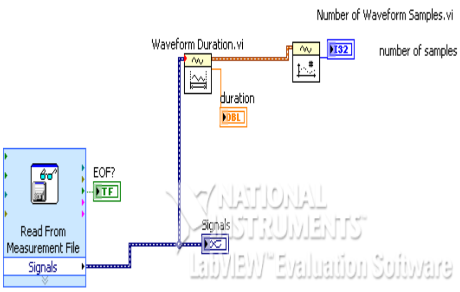

Fig. 5. The block diagram of the virtual instrument used for the display of the read signal, of the value of the signal duration and the number of samples of the signal.

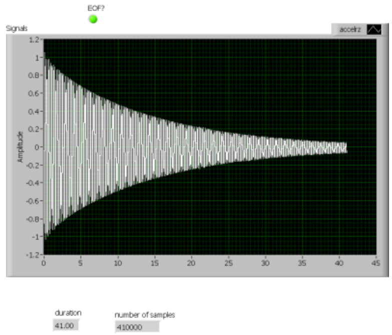

Fig. 6. The front panel of the virtual instrument used for the of display of the read signal, of the value of the signal duration and the number of samples of the signal.

The programming medium LabView offers as well as the possibility to obtain the curve of amplitudes and the theoretical curves starting from the acquired data which are subject to processing, for this the data should be re-read from the file in which they were saved through the medium of the block *Read From Measurements File*, the *boolean* indicator *EOF?* marks the end of the data reading. Thus, the read data are used as input signal in the block *Trigger and Gate*, by which a segment of the signal is extracted, after introducing a condition referring to the start or stop step or it can be a static condition in the presented model, the start condition is 408000 samples [8]. At the output *Triggered Signals* we obtain a signal between *Start Trigger* and *Stop Trigger*, in the case when the analyzed data do not fulfill the imposed condition, the signal obtained at this output will be empty, its visualization can be done on the graphic *Waveform Graph*, in the front panel in Fig. 8 [8]. Thus, from the signal obtained the number of total samples can be determined by *Number of Waveform Samples*, the duration of the acquisition through the medium of the block *Waveform Duration*, and the period using the block *Pulse Measurement*, which also has at the output an indicator with the name *Measurement info*, which returns at the front panel level the time for the selected pulse and the absolute level of reference used in order to define the measurement cycle [8].

The block Timing and *Transition Measurements* being used in the process of timing and transition of measurements such as the frequency, period, pulse and *duty cycle* (represents the balance between the duration of the first semi period and the period, expressed in percents [9]:

$$\frac{a}{a+b}100 \quad (5)$$

where “a” is the semiperiod, a+b represents the period).

In the given example the frequency is displayed which multiplied with the acquisition duration leads to the number of periods equal to 2.

The signal obtained after the trigger is converted in a numeric signal through the medium of the block *Convert from Dynamic Data*, thus, transmitted to the block *Get Waveform Components*, in order to return the analogical signal on components as *dt* (sampling data, acquisition, measured in seconds), *t0* (the initial moment in time) and *y* (the values of the signal, samples at a given moment). At the front panel level through the medium of the indicator *dt* the value of the sampling period is displayed, at which the period is divided and the number of samples on a period is obtained [8].

In order to obtain the location, amplitude and the derivative of order two of the signal top is transmitted to the obtained numeric signal at the input of the block Waveform Peak Detection, at which there are added the controls threshold (threshold by which the too small values are ignored, the minimal limit is -∞, and the maximal is +∞), width (band width 54, minimal limit 0, maxim 2147483647) and peaks/valleys (minimal limit 0, maximal 65535) [9].

At the output of the block the asked results are obtained: location (which multiplied with duration equals the time moments), the amplitude and the number of tops found in vectorial form which contains the location, amplitude and derivative of order two *(#found)*.

Adapting the general form of the results of amplitude and moments at an exponential curve is achieved through the medium of a block *Exponential Fit*, according to [9]:

$$f = ae^{bx} \tag{6}$$

where x represents the moments t, a the amplitudes and b the amortization factor, according to the chosen method by a control called *method* (it stays at the pre-defined form of the development medium and namely, *Least Square*, the method of the smallest squares) after the application of the adapting exponential algorithm, the exponential curve will be described by the equation [9]:

$$y[i] = a_0 e^{a1x[i]} \tag{7}$$

We obtain at the output the results adapted to the exponential form.

The curve of the amplitudes by the medium of the block *Build XY Graph*, according to amplitudes and moments, the graphic representation being materialized on the front panel by a graphic indicator with the name amplitude curve. The same block is also used to obtain the theoretical curve 1, with the assignation that it is connected to the input of adapted amplitudes which likewise the moments are converted in numeric signals.

For a more precise association of the obtained data with those read at the input we use the block *Curve Fit*, in order to determine the interpolation of the theoretical curve, through which we calculate the coefficients representative for the input data, having as basis the chosen model, namely, the non-linear one, which is represented by a non-linear function as [9]:

$$y = f(x,a) \tag{8}$$

where a represents the set of coefficients, at the block input the amplitudes and the moments are connected, and at one of the outputs we obtain the desired coefficients, displayed on the front panel by a vectorial coefficient and at the other output with the name best fit returns the most precise data which are later transmitted to the block Build XY Graph, at whose input the moments are attached, and the display on the front panel of the theoretical curve 2 follows [9].

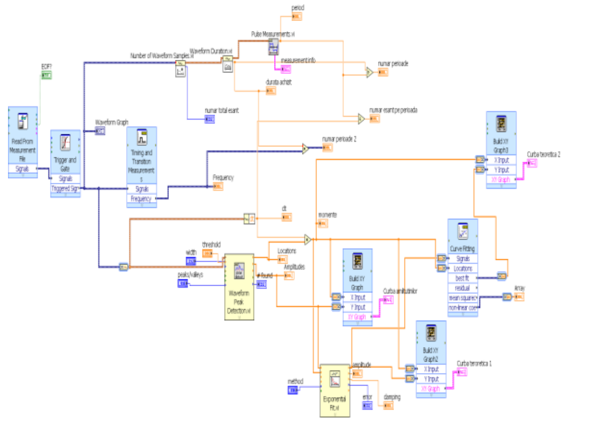

Fig. 7. The block diagram of the virtual instrument used for the processing of acceleration.

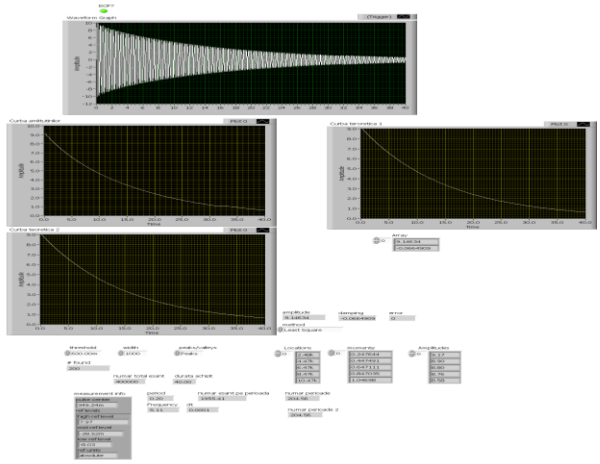

Fig. 8. The front panel of the virtual instrument used for the processing of acceleration.

To such a processing as the one presented above is subject the speed as well, in order to obtain it we use an integrating block at whose input a control is attached through which the type of the integral is established, in the case of speed, this is obtained by a simple integration of the acceleration.

For the processing of the displacement, a similar virtual instrument is used, the difference consists in the fact that we obtain it by a double integration of the acceleration.

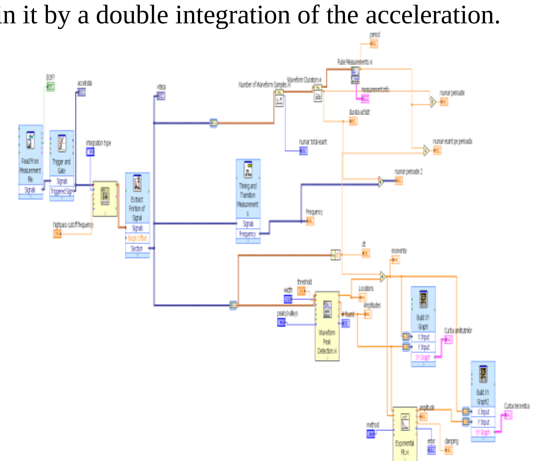

Fig. 9. The block diagram of the virtual instrument used for the determination and processing of speed.

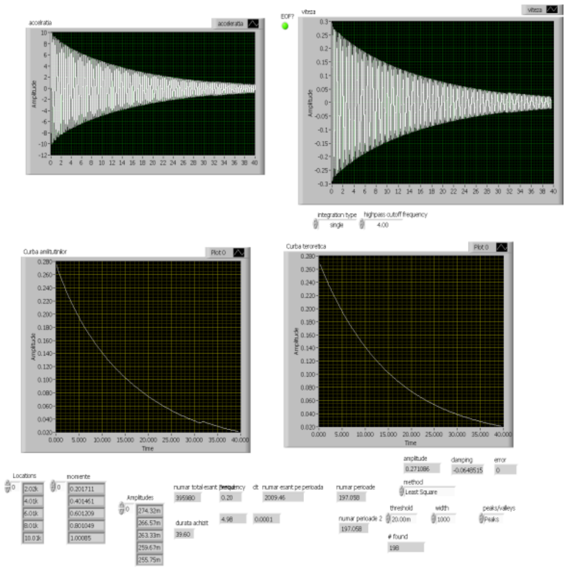

Fig. 10. The front panel of the virtual instrument used for the determination and processing of speed.

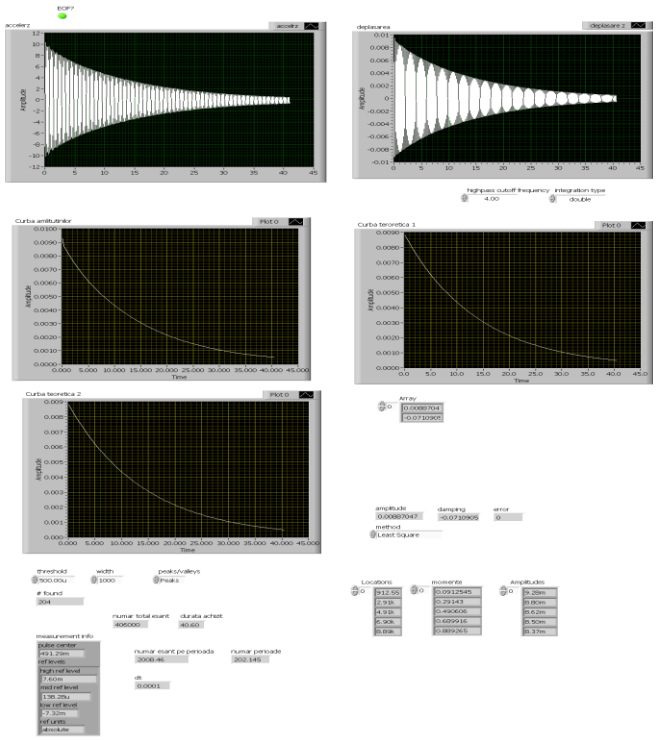

Fig. 11. The front panel of the virtual instrument used for the determination and processing of displacement.

VI. Conclusion

The schemes are not complex which an advantage to use in various applications is.

The schemes are flexible and they can be applied in a large field of vibrations measurement with a minimum level of knowledge.

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