EXPERIMENTAL STUDIES ON THE VIBRATION OF THE SOLID BODY WITH VISCOUS-ELASTIC BEARINGS USING VIRTUAL INSTRUMENTATION METHOD

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Abstract: The virtual instrumentation takes into consideration a new construction principle for the measuring tools and systems, with a brand new architecture. These systems and tools are assembled into a "virtual space" computer programming environment which provides such basic elements of construction. The article presents the virtual instrument developed by the author on the basis of LabView® ver. 8.5 from National Instruments.

1. INTRODUCTION

A virtual instrument (**VI**) can be defined as a complex software and hardware interface that is implemented in PCs, so the user can interact with traditional analysis tools [1], [2].

The virtual instrument can perform the following functions:

-the function of data collection, executed by acquisition card DAQ connected directly to the processor bus; memory registers are accessible directly on the PC's motherboard to address the cells I/O on computer memory;

-the function of data control and analysis, which is completely taken up by the existing hardware and software in the PC;

-the function to display of the results; the existence of a graphical unit interface (GUI) driver permits a much easier handle and control of any application of virtual instrument.

The virtual instrument panel is displayed on the computer monitor, which can look just like traditional instrument panel. Virtual instrument panel has a background program which simulates the controls of the real instruments, allowing the working routines of acquisition, data analysis, graphic presentation and storage of data or results files. Virtual instrument construction is done in accordance with the user's „specifications". In order to do that, the programme uses standard hardware architectures, proper drivers, specific software packages and special libraries. The virtual instrument uses digital tools like traditional software modules from a large package, difference being that while traditional instruments include the software in its ROM memory, the virtual instrumet uses the computer HDD to do it.

2. THE VIRTUAL INSTRUMENT CONSTRUCTION AND OPERATION

In order to analyze the dynamic parameters of vibration, there were designed and built two virtual tools:

-one for acquiring and saving acceleration values taken during experiments;

-second to analyze the acceleration parameters.

The acquisition of vibration analog signals is made by acceleration transducers (accelerometers). The analog signals are transmitted to DAQ, which may be inside (internal) or outside (external) of the PC. The DAQ performs a signal conditioning and conversion in the digital format. Digital values are transmitted directly or through a cable

into a USB port on the PC which is running the signals' acquisition program. The acquisition program has some features which provides the opportunity for memorizing information about the measurement conditions.
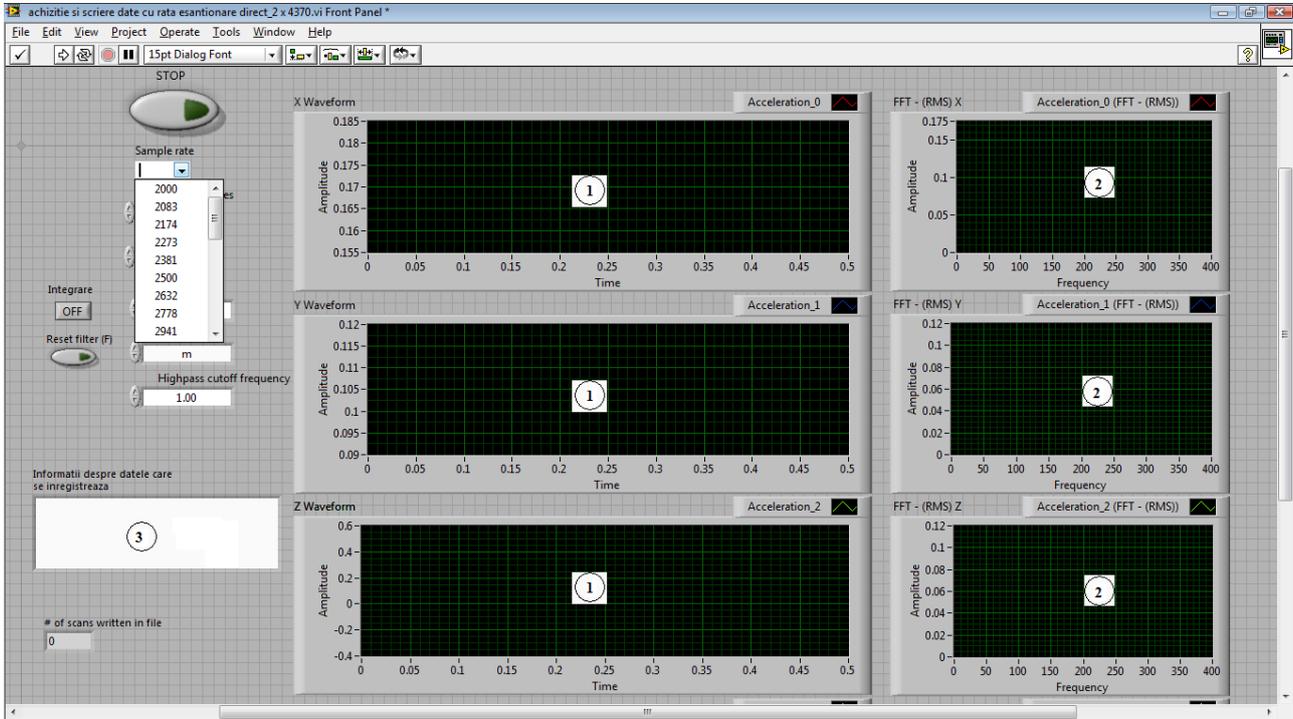
Fig. 1 Front panel of VI for acceleration data aquisition on four channels
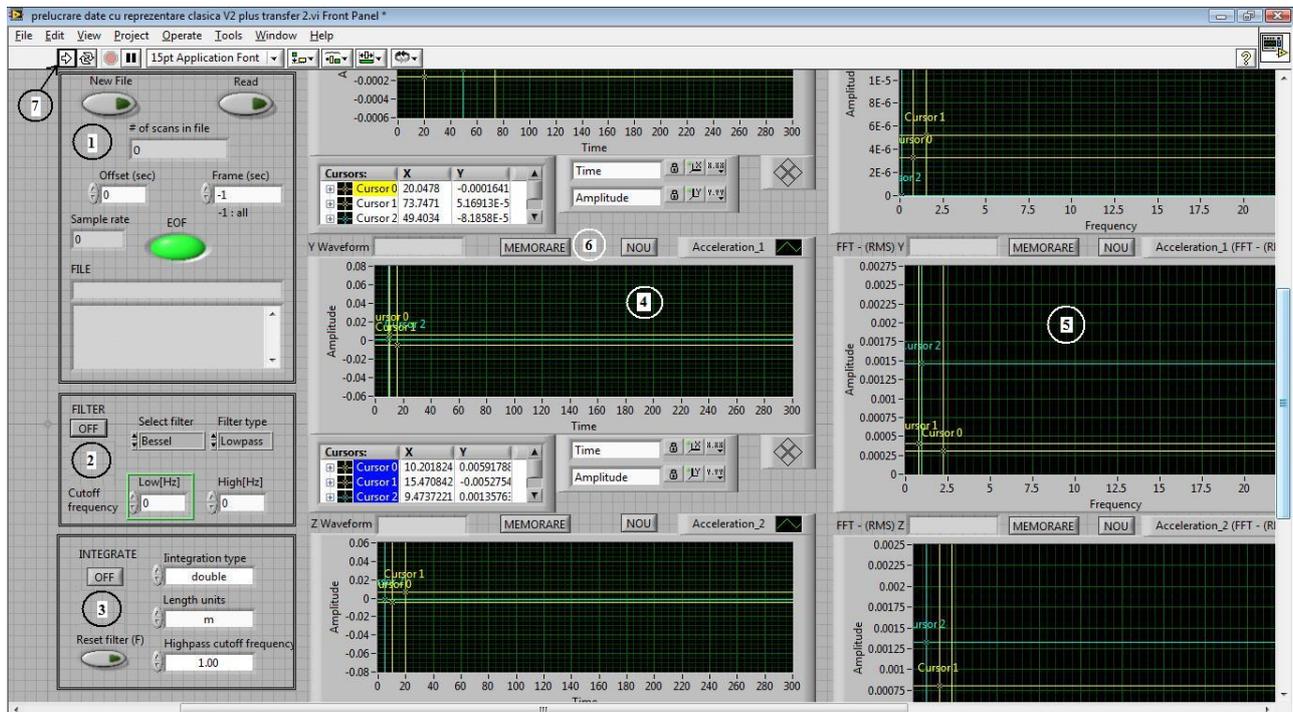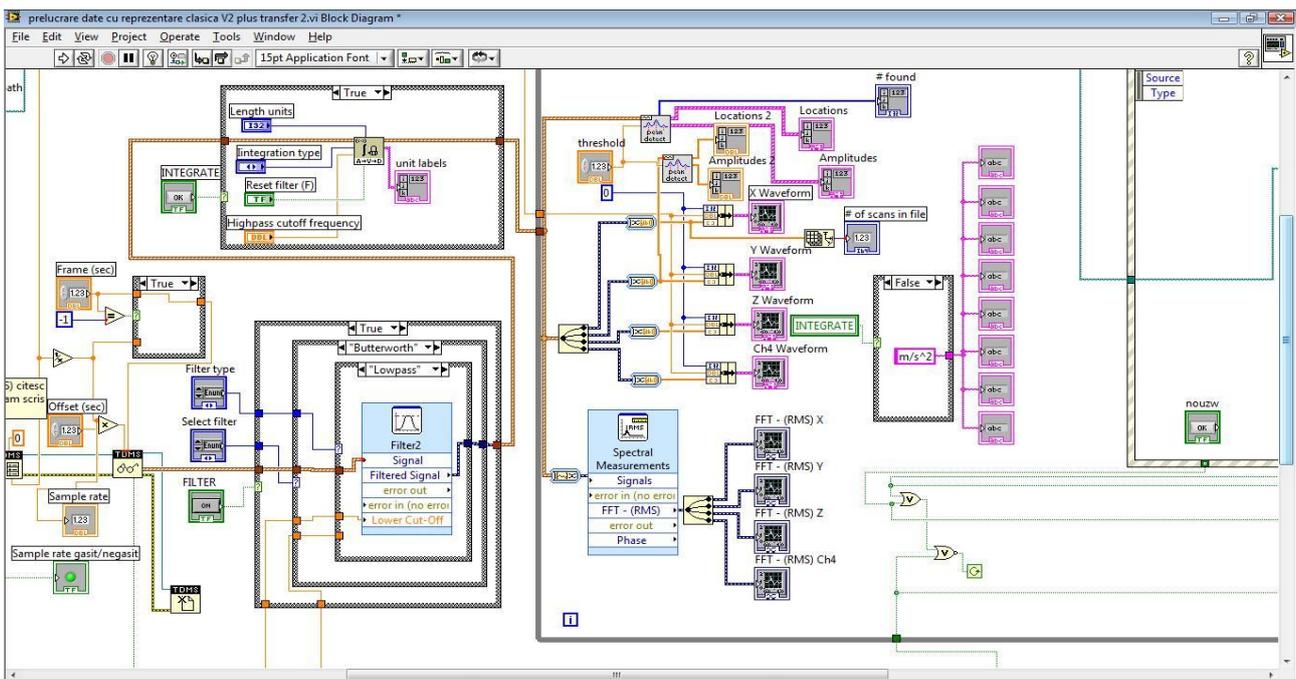

Figure 2 The front panel of VI (partial view of the analysis module)

Figure 1 shows the front panel of the virtual instrument designed to acquire the experimental data from the accelerometers. The values of the vibration accelerations are shown as evolving over time (time representation) in the graphs numbered with 1; the graphs numbered with 2 show the results of FFT analysis of the acceleration signals from graphs 1. In the front panel of the virtual instrument, the buttons from area 3 permit the introduction of additional information.

Figure 2 shows the virtual instrument for signal processing. Area 1 can read all data, or only a portion of the signal, by specifying an offset, in seconds. Area 2 contains buttons that allow filtering the input signal indicating the type of filter and filtration method. Area 3 is the control area of the instrument which contains buttons that perform the numeric integration of the input signal of acceleration; in this way, the virtual instrument can offer the velocity and the displacement parameters of the vibration (time representation, frequency distribution). In the 4th area of the virtual instrument there are values for the signal (the „on-line" values of the accelerations). Area 5 shows the corresponding signal spectrogram (frequncy distibution) of the signal displayed in area 4. The panel of the virtual instrument contains such pairs of graphs for the all channels DAQ. The button numbered with 6 allows to store, in another file, the values corresponding to the cursor number 2 in the chart, for other data processing. The front panel cannot fully be displayed on the screen, because there are a lot of data to be displayed in the virtual instrument front panel; the window of the instrument front panel has vertical and horizontal scroll bars that allow displaying the desired area.

Figure 3 shows a block diagram for the virtual instrument analysis (partially view). We can see blocks that allow the filtering and the integration of the signal and the function to display the processing results. Block diagram is a WHILE-DO BLOCK with a stopping condition (by pressing the Stop button). In the scketch from fig. 3 there are all other functional blocks. Colored lines represent different data moved between functional blocks. Starting the program is running from the power button 7 in fig. 2. The "push" on this button opens a dialog where the user selects the file containing the signal to analyze.

*Fig. 3 The VI block diagram analysis (partial view)*

Figure 4 shows a part of the front panel after reading a data file. It is possible to modify the extremes of the x-axis for any graphic. The resulting image is automatically extended to the whole area of the graphic. In this way actually runs a zoom image.
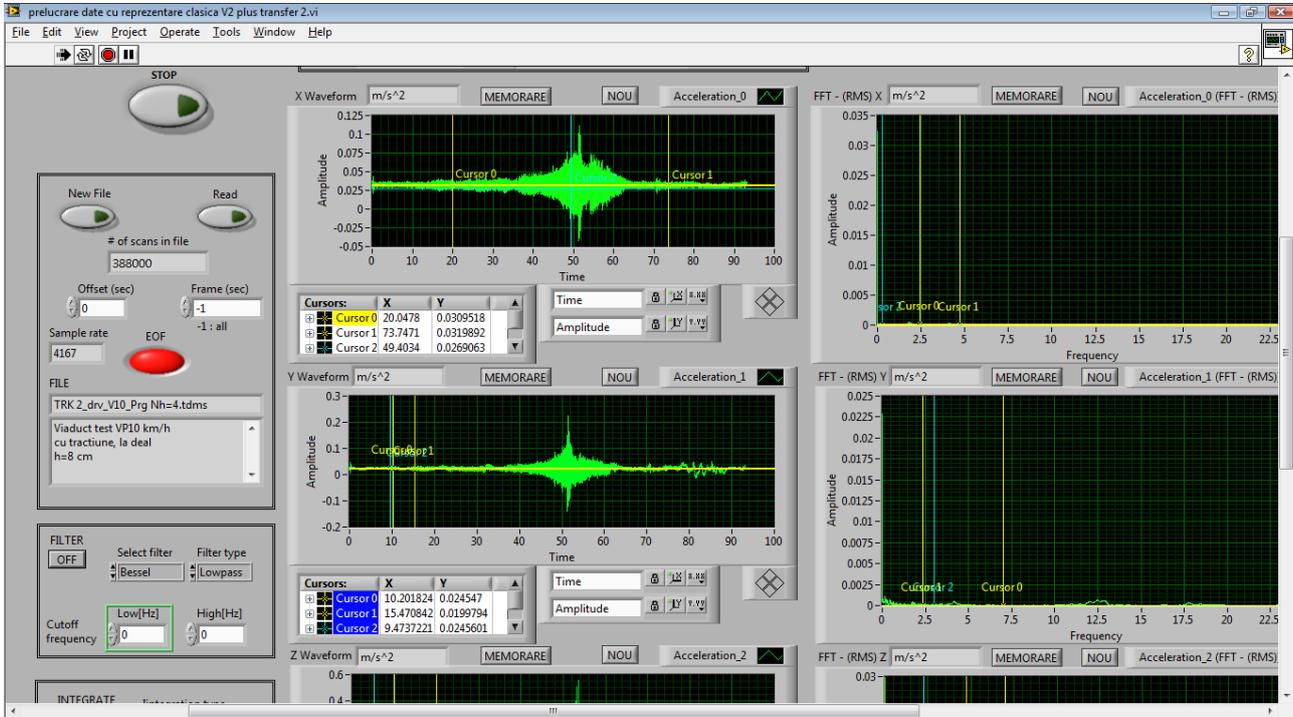

Fig. 4 The VI front panel display for an experimental data analysis

Figure 5a) shows a time representation of a signal between 0 and 100 seconds. Modifing the time limits, 40 seconds in left and 65 seconds on the right, figure 5b shows the appropriate time representation of the signal between these two moments of time.

Cursors can be moved to any point in the graphs; in this case, in the area under the time representation of the signal graph is shown the corresponding values of the two axes. Virtual instrument was designed to be able to save the coordinates of any point of view graphics in another Excel compatible file. By using the zoom function of the virtual instrument, we can view a desired area. By moving the cursor to the desired point to read its details.
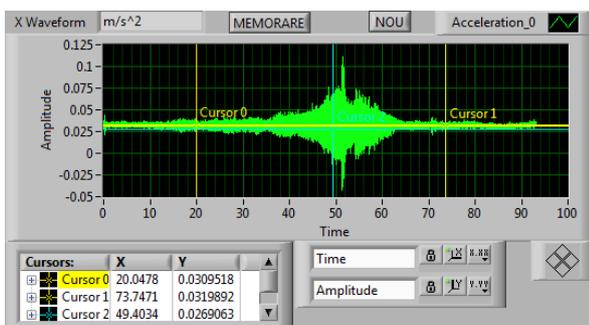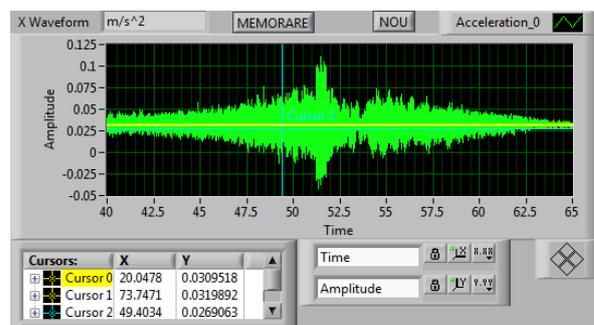

a)   b)

Fig. 5 Zoom in a graphic time representation display: a)time 0÷100 sec.; b)time 40÷65 sec.

3.14

3. FFT ANALYSIS OF THE SOLID BODY WITH VISCOUS ELASTIC BEARINGS. CASE STUDY – MODAL ANALYSIS OF THE REINFORCED CONCRETE BRIDGE

The virtual instrument developed on the basis of LabView® ver. 8.5 was used to perform the dynamic tests in site on the viaduct situated on km 29+602,75 - km 29+801,25 on A3 Romanian highway; the dynamic actions were generated by a running four axle 41 tons truck over standardized height h=4 cm obstacles fixed on the viaduct surface with chemical anchors; running speeds were 10km/h, 20km/h, 30km/h and 50 km/h. The experimental data were acquainted on three channels (accelerations on the axis x, y and z) by a four channel DAQ from National Instrument (NI 9233) through the USB port of a PC workstation.
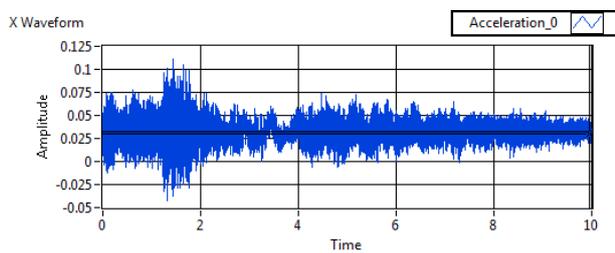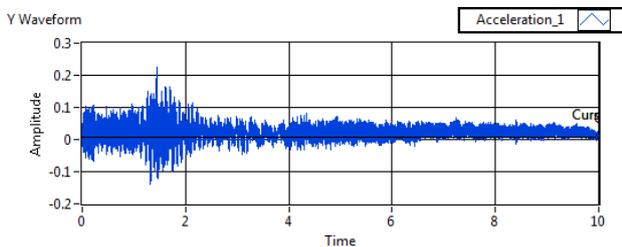

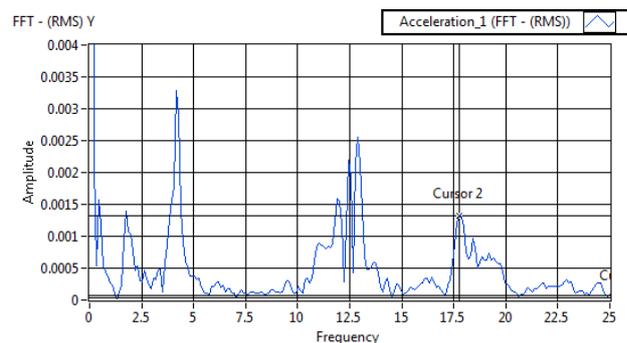**Fig. 7 Longitudinal acceleration X - time representation ($v_0 = 10km/h$ with traction)**
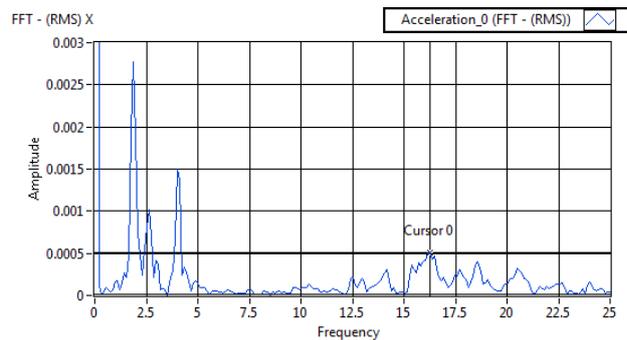
Fig. 8 Longitudinal acceleration X - frequency representation ($v_0 = 10km/h$ with traction)

Figure 7 shows the time representation of the longitudinal acceleration [m/s^2] of the viaduct in the point where the transducer was mounted for a period of 10 seconds of signal analysis. In the time representation, we can see the acceleration signal when the tyres of the truck is passing over the obstacle. In the frequency representation of the same signal from figure 8, we can see the frequency response of the bridge; the significant natural frequencies resulting after FFT analysis are about $f = 1.85Hz$ and $f = 2.62Hz$.
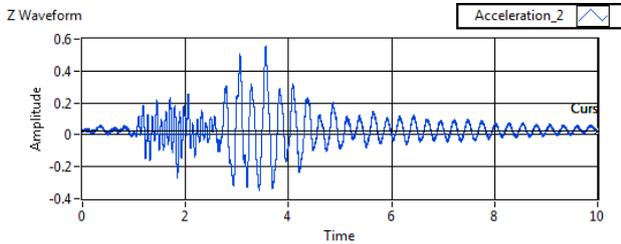

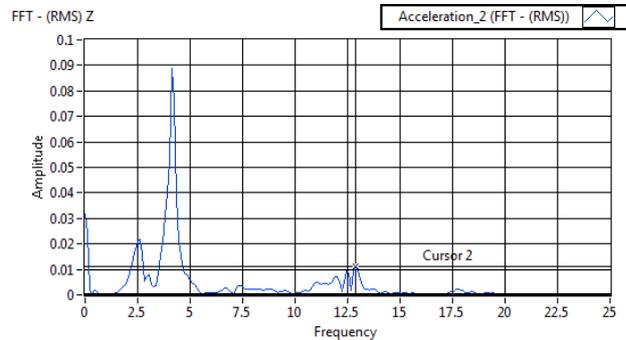**Fig. 9 Lateral acceleration Y - time representation ($v_0 = 10km/h$ with traction)**

Fig. 10 Lateral acceleration Y - frequency representation ($v_0 = 10km/h$ with traction)

Figure 9 shows the time representation of the lateral acceleration [m/s^2] of the bridge for the same period of 10 seconds, as in case of longitudinal acceleration. Figure 10 shows the frequency representation of the lateral acceleration signal after FFT analysis. As for the longitudinal acceleration representation from figures 7 and 8, we can see in the two graphs of the lateral acceleration representations (time and frequency), the damping of

the vibration period and the natural frequencies (significant values being $f = 0.44Hz$, $f = 1.75Hz$ and $f = 4.15Hz$).

Fig. 11 Vertical acceleration Z - time representation ($v_0 = 10km/h$ with traction)

Fig. 12 Vertical acceleration Z - frequency representation ($v_0 = 10km/h$ with traction)

Figure 11 shows the time representation of the vertical acceleration signal along the shock moment and the damping period. In the graph from figure 12, we can see the frequency distribution of the vertical acceleration for a 10 seconds time of FFT analysis. The significant frequencies are $f = 2.62Hz$ and $f = 4.15Hz$

Table 1. Frequencies of the unforced damped vibration of the bridge (v=10km/s)

Direction	Longitudinal **X**	Lateral **Y**	Vertical **Y**
		0.43632873	
		1.74531492	
	1.85439710		
	2.61797238		2.61797238
	4.03604075		
		4.14512294	4.14512294
		11.88995789	
			11.99904008
		12.43536881	12.43536881
		12.87169754	12.87169754
	16.14416301		
	16.25324519		
		17.78039575	

(Direction column cell spanning all rows: **Frequency [Hz]**)

The figures from table 1 show a detailed analysis of the eigenfrequencies of the damped vibration of the concrete bridge.

4. CONCLUSION

In comparison with the real measurement apparatus and/or systems, the different virtual instrumentation software (LabView® from NI U.S. is not the only software dedicated to virtual instrumentation [4], [5], [6]) have the following advantages:
-they can "build" complex measuring instruments, which are not possible for physical instruments;

-they are "open systems": the achievement of virtual instruments may be realized by the sub-programs provided by the programming environment, but also by the human programmers sequences (written in C++, MATHLAB, a.s.o.);
-processing results can be saved in different file types, allowing export of such data to other applications;
-graphic module of the instrument allows the viewer to enable zooms to display the contents of small details.

The greatest advantage of this type of measurement tools is that on the same PC can coexist more virtual instruments using the same monitor, independently or in relation to each other.

For the LabView® software from National Instruments U.S., we can say that in 2010 the producer just have developed the fourth generation of equipment (the version 8.6), which has the following advantages [3]:
-the executable code programming environment is optimized for performing computations in parallel processor cores and the user is able to program the kernel routing calculations;
-the substantially reducing the number of devices required for data acquisition and processing;
-the improving the reliability of the virtual measuring system;
-the existence of rapid decision capabilities and error correction;
-the improvement of the possibilities of analysis, displaying and storage of results;
-the possibility of direct connection with performing numerical analysis programs;
-the reducing of the expenses with experimental research.

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[4] http://www.mathworks.com/academia/
[5] http://www.ptc.com/products/mathcad/
[6] http://www.datatranslation.com/products/dataacquisition/software/measurement_application.asp