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EXPERIMENTAL SYSTEM FOR MONITORING OF OPERATIONAL VIBRATIONS

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Abstract: *Reliability of the production systems depends on the standard of maintenance. Number, duration and cost of such a service can be optimized using diagnostic systems that perform evaluation of the manufacturing system condition. For many applications, portability and flexibility of the diagnostic system is crucial. In this paper, experimental system designed to monitor, evaluate and indicate operational vibrations is presented. The system was developed at Technical University of Košice, Department of the manufacturing processes operation. The system is based on modular hardware and software platforms with using of the virtual instrumentation.*

Key words: *vibrations, monitoring system, virtual instrument, data acquisition.*

1. INTRODUCTION

Manufacturing system usually produces unintentional vibrations during its operation which have negative influence for the machines working life and quality of a product [1]. In this respect, identification and avoiding of particularly the system resonance frequencies plays an important role in effort to ensure optimal operational condition of the system. In addition, quantitative determination of the vibrations that are present in a system provides a tool that enables to evaluate condition of the key parts of the machines [2], need of the maintenance treatment and to evaluate effect of modifications made on a system.

There are several commercial systems available for monitoring and evaluation of vibrodiagnostic signals. Most of them can be divided into two groups: portable pocket-size instruments processing usually signal from single sensor and comprehensive modular systems that are usually mounted on the monitored machines permanently [3]. Main problems connected with usage of the diagnostic devices that are used in the practice can be formulated as following: there is one group of the devices that provide limited set of functions with practically no possibility of upgrade or extension; the others are often not suitable to be displaced or able to monitor travelling objects. Both of them typically provide limited possibilities to select visualization of measured parameters.

The main goal of this paper is to present the experimental vibrodiagnostic system designed and completed at Technical University of Košice, Department of the manufacturing processes operation. The system is designed with stress laid on portability and flexibility to allow its modifications with respect to a particular monitoring task. Number of physical components of the system is minimized by using virtual instrumentation. Functionality of the system was tested at various monitoring tasks, e.g. vibrations generated by the abrasive water-jet cutting system [4]. In this paper, vibrations produced by the laboratory vibrodiagnostic model are presented and discussed.

2. VIBRODIAGNOSTIC MONITORING SYSTEM STRUCTURE

The system for monitoring vibrations was designed and developed at the Faculty of Manufacturing Technologies of Technical University of Košice with seat in Prešov, Department of Manufacturing Processes Operation.

System for monitoring and evaluation of vibrations typically consists of units that are in practice more or less visible or separable and can be divided into groups as follows (see schematic representation on Fig. 1):

- sensors;
- data acquisition and signal processing hardware;
- PC with software;
- indicators and data storage.

2.1. Sensors

Selection of a proper measurement method and sensor is the most important part of the measurement sequence. In the case of non-destructive measuring, the operation of the object of measurement should not be affected by the process of monitoring. As for vibrodiagnostics, that results in the usage of miniature contact-type sensors (e.g. accelerometers) and as many as possible of non-contact methods of measurement (laser Doppler vibrometry, inductive sensors, tachometers etc.).

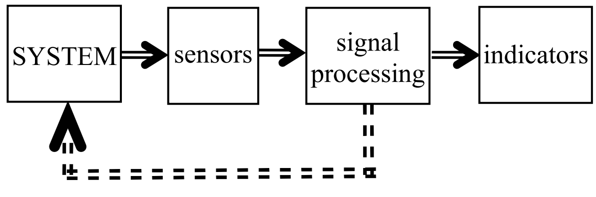

Fig. 1. Schematic representation of the monitoring system. System represents manufacturing system; signal processing is performed partially in NI CompactDAQ hardware, partially by software. Indicators are realized mainly using virtual instrumentation. Dashed line represents possibility of the feed back control.

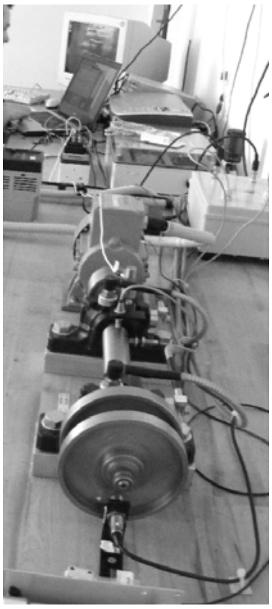

Fig. 2. Experimental monitoring system applied to measure operational parameters of the laboratory vibrodiagnostic model.

For the purpose of acceleration monitoring uniaxial miniature piezoelectric accelerometer Bruel & Kjaer 4507 was chosen. The sensor has electrically grounded casing and enables its simple replacing along with the accurate measurement repetition by placing at the same measured point in special backplate. The accelerometer measures in the range up to 70 g, can be placed in the backplate in any orientation (axis *x*, *y* or *z*).

Mounting of the accelerometer or its backplate is of critical importance as improper mounting can enhance unintended components in the signal as noise or spurious signal components coming from other objects. Fixation of sensor and its cable (if present, as RF communication is taking part in the communication between sensors and data acquisition devices too) can be performed in various modes, considering specificity of the application.

For the most temporary applications and about room-temperature surfaces typical for cold technologies as abrasive water-jet cutting [5], the honey-bee can be used as the sticking solution particularly for its good resistance against the self-resonance. However, in the case of warm surfaces, e.g. monitoring of the die-casting vibrations [6], the heat-resistant glue must be chosen or mechanical fastening (e.g. bolt) should be used. Sensors can be typically operated in the temperature up to 250 °C. In many applications magnetic mounting can be used, but magnet has much lower resonant frequency and enlarges total weight of the sensor.

For measuring of vibrations with extremely high amplitude, Omega accelerometer type 103 with range up to 500 g is used.

Figure 2 illustrates application of the developed system in the laboratory conditions, measuring operational parameters of the experimental vibrodiagnostic model [7].

2.2. DAQ and signal processing

The vibrations are measured using monitoring system based on modular chassis National Instruments CompactDAQ [8]. Key functional module in the system is NI-9233, designed for communication with IEPE-standard (know also as ICP) sensors of vibration and acoustic signals. Chassis has 8 slots for input or output of digital or analogue signals that gives possibility of simultaneous signal processing from 32 accelerometers or for processing of other types of signals – thermocouples, optical gates, generation of voltage, relay switching etc.

In the case of monitoring of moving objects, module can be supplied through USB port of notebook using data bus and processing chassis NI-9162 and thus whole system is independent of permanent power supply.

2.3. Software part

The system is using data processing functions of the object-oriented programming environment LabVIEW Full Development System, version 8.5. This software provides possibility to create monitoring task by creating the virtual instrument that is kind of a software application.

Visible user interface is called front panel and includes control parts and indicators. Function of the virtual instrument is defined by the program instructions defined in the block diagram which is in normal regime hidden schematic representation of the objects on the front panel and functions, values and operations with their bindings and dependencies. Data flow is controlled by objects connecting and grouping.

To enhance processing and presenting possibilities of the system, the core LabVIEW was extended by software module for the vibration processing Sound and Vibration Toolkit. This module consists of tools and functions that enable transformation of measured time-based vibration acceleration signal after corresponding processing (FFT, integration, statistical operations, weighting filtration, noise filtering) into results in the form of frequency based values and graphs, 1/n octave analysis, velocity, displacement, waterfall graphs etc.

2.4. Front panel of the monitoring system

To minimize number of parts of the system and to simplify its upgrading or modification, virtual instrumentation was used to create its indicators, control parts and outputs. This approach provides possibility to define displayed information with simple setup of e.g. scales or alarm levels, created in the LabVIEW environment.

The experimental vibrodiagnostic virtual instrument created by authors is presented on the Figs. 3 and 4. The instrument is usually processing signal from one sensor while using of more accelerometers is also supported and synchronization through CompactDAQ hardware provides possibility of their signal comparison.

Front panel of the created instrument is subdivided into sections grouping preferably similar operation controls and indicators. To mention some of them, specification of integration (none, single or double) and engineering unit defines the monitored parameter that is indicated – acceleration, velocity or displacement (section 8). Units on the scales and indicators are automatically updated regarding selected value. Definition of the frequency range for calculating the band power value can be found in the section 13; display of average and instantaneous values of the rms value is in the section 14. Frequency-based power spectrum of the vibration signal after FFT is indicated on the graph (section 1) and time-based behaviour of the signal in the section 2. Behaviour of the RMS value with time is indicated on the graph in the section 3 that indicates also alarm levels defined under the graph; signal lights in the section 5 indicate actual level of the monitored system operational state.

The virtual instrument includes substitutes of two external devices. One of them is acoustic generator with adjustable sound frequency and volume, type of signal and other parameters (see Fig. 4 – sections 4, 6, 12 and 15). Definition of the output sound signal provide possibility for its usage preferably as frequency defined vibration source; selection of the frequency and presence of the sound, quality of the signal governed by the sample rate; volume; time-based graph of the sound wave, device (typically sound card of the computer) and waveform type can be set. The generator can be used either for generation of constant or sweeping sound pressure excitation, forming vibration source that can be used e.g. for identification of resonance frequencies of smaller objects, secondly functioning as acoustic alarm indicating operational state of the monitored system or exceeding of the monitored operation parameter limit.

The second virtual device is coloured signal-lights indicator of the operational states. Number, colour and operation of lights is defined by simple modification of the program or the object properties with typical configuration such as green light – normal operation, yellow –

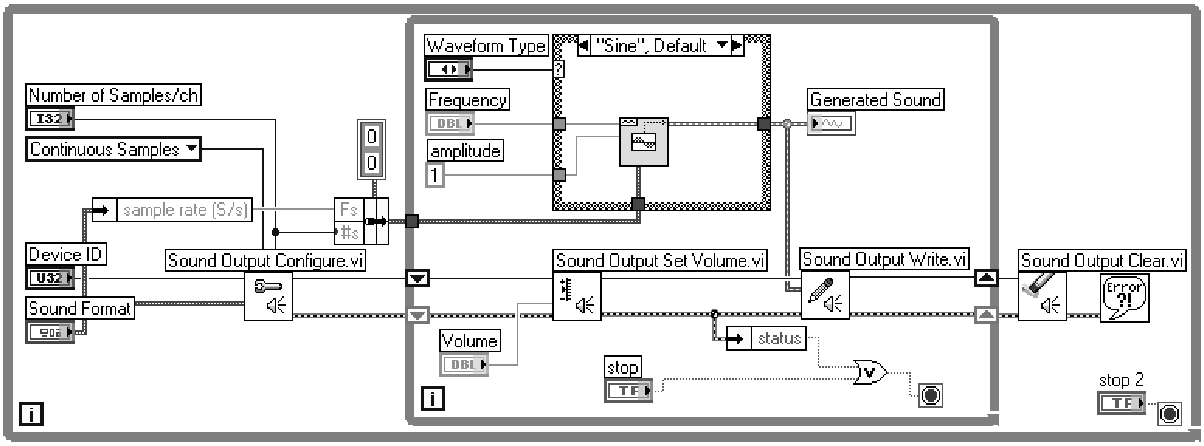

Fig. 3. Part of the virtual instrument block diagram containing source code of the application controlling sound device.

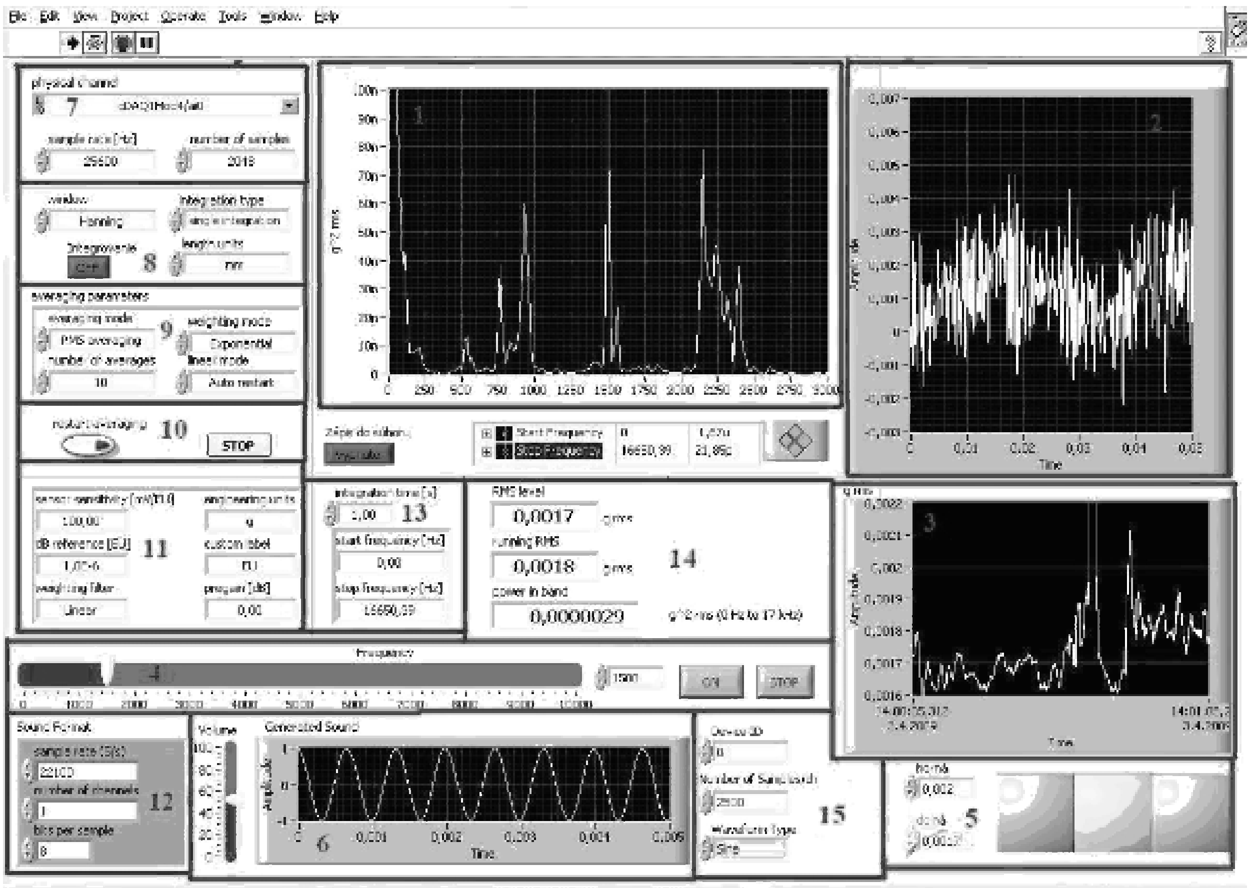

Fig. 4. Front panel of the application with graphic, numeric and colour indicators; control buttons and constants.

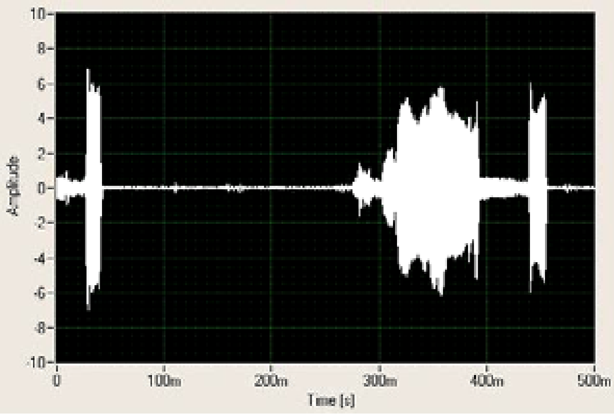

Fig. 5. Periodic failure signal measured on the laboratory vibrodiagnostic model with damaged part within the gear-box.

attention, red – monitored parameter is out of limits of the regular operation meaning that an intervention should be made.

Figure 4 represents typical non-periodical vibration signal whilst periodic failure measured on the vibrodiagnostic model with rotating parts, monitored on the gearbox with damaged part is illustrated on the Fig. 5.

3. CONCLUSIONS

In this paper, design and application of the experimental system for monitoring of operational vibrations is presented. The system was developed and tested by authors at the Faculty of Manufacturing Technologies of Technical University of Košice with seat in Prešov, Department of the Manufacturing Processes Operation.

Substantial part of the system is created using virtual instrumentation that partially supplies function of typically stand-alone external devices as e.g. light or sound alarm indicators of operational states and source of defined excitation. Moreover, the system possesses its own source of well-defined vibration excitation using sound card of a computer.

Such approach to the instrumentation provides very flexible approach to the monitoring set-up and reconfiguration or upgrading of the system. Virtualization simplifies handling with user interface providing possibility to indicate monitored data on user demand. Appreciable is acquisition of possibility to adjust appearance, colours, size and spacing of objects in the front panel to the individual function and aesthetic preferences. Amongst the merits, system can be operated without need of the power supply just using the laptop battery.

Application of the system to monitor periodic and non-periodic vibrations and processing possibilities of the system are also shown.

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