original article

Sound pressure level tools design used in occupational health by means of Labview software

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ABSTRACT

Aims: This study was carried to control and monitor the sound using LabVIEW software.
Methods: The research was done using LabVIEW software, microphones, and data-acquisition card hardware. Environmental information collected as sound pressure level via microphones and then processed by the data-acquisition card hardware. The information is showed by software as a graph or plot in the next step.
Results: This software includes front panel, back panel, and connector panel and with these panels, we can determine information such as various frequency weighting and time weighting. Also, can be specified the sound pressure level, sound amplitude, power spectrum, power spectral density, and other sound characteristics.
Conclusion: LabVIEW programming capabilities in the field of sound can be referred to the measurement of sound, frequency analysis, and sound control that actually the software acts like a sound level meter and sound analyzer. According to the mentioned features, we can use this software to analyze and process sound and vibration as a monitoring system.

Key words: Frequency weighting, labview software, power spectrum, sound amplitude

INTRODUCTION

Today, advances in technology and increasing manufacturing industries led to the creation of sources of noise pollution in the work environment and it will also increase the exposure to noise. Harmful physical factors such as exposure to sound and vibration are the cause of hearing loss, cardiovascular disease, and damage to the joints.[1,2] Therefore, these factors must always be monitored and controlled to avoid excessive exposure of workers from these agents. The sound pressure level is measured by sound level meter to determine the noise exposures. Nevertheless, better control of hazardous agents requires more robust and efficient monitoring in order to avoid the excessive rise and go beyond from limits defined by these factors. In order to perform this type of monitoring should be defined the hardware and software system to is sampled from moment of exposure to noise.[3-5]

The labview software from USA National instrument Company (laboratory virtual instrument engineering workbench) is a graphical programming language, which is used widely in industry, education, training, research

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laboratory and has become as a standard model for collecting and processing data and is a tool for controlling and simulating virtual instruments. This program is powerful and flexible software for analyses of measurement systems.[6,7]

Labview software performance is quite distinct from the sequential and nature chains in the common and conventional textual programming languages and provides a graphical interface for the user. This software is suitable for numerous applications in science and engineering and helps to solve the existing problems in programming at the short time.[7]

Labview has created a fundamental and modern change in the ways of programming languages. Programmers create powerful applications without writing any code however with just available graphical tools in the program. In order to use the software, the objects must be removed from the "control and function pallet," and put in the "front panel" window and then connect them together using the correct wiring. Labview is a versatile programming language that it has the network programming, database, input and output files, etc. In the labview, a user interface was made that is called "front panel." This interface includes control tools (such as keys) or display tools (such as degrees, graph, and displays).[6]

In fact, the sound and vibration measuring requires a software program that considers the environmental information and hardware parts such as microphone and sound analyzer card that avoids increased risk with real-time control of sound. According to mentioned applications of labview software and purchase costs of sound level meter and also lack of information before and after of exposure, the aim of study is to set up monitoring system via labview software that to perform real-time sound monitoring.

METHODS

The research is an experimental study that was done using labview software and hardware components such as microphone and data-acquisition card hardware[8] from USA National Instrument Company for sampling the frequencies.

In order to validation and feasibility of using the software, the sound was generated under laboratory conditions, and then sound levels were measured by the sound level meter and software at the same time. For this purpose, we used devices that include sound level meter (model 2231) and sound analyzer (model 1625) from Brüel and Kjær company, ½ inch microphone, 3 W power speaker, and computer and labview software. Also, Frequency analyzer selected from China BSWA Company with data-acquisition card hardware from USA National Instrument Company for sampling the frequencies. First, the sound is produced by software and speaker.

Then, sound level meter and microphone were placed at a certain position and distance from the speaker, and the sound was measured in A and C frequency weighting, fast mode, frequency range of 20 to 20,000 Hz and one-third octave band at the same time. The sound intensity values were compared with each other. According to the normal distribution of noise levels measured by the software and sound level meter, comparisons were performed by Pearson's correlation coefficient and *t*-test statistical test. Finally, the results were analyzed by SPSS 20 software from IBM company.

The labview software has a variety of toolkits such as sound and vibration. To work, this program should be used from embedded blocks. For example, to simulate a sample of low-frequency sound, the input block is selected and placed on a microphone block in the screen. In order to display the sampled sound, should be selected the output block.[9]

Simulation of sound monitoring is performing in three parts:

The first part is the preparation and collection of sound data from the environment or machines. The sound data are sampling by microphone as the sound pressure level in units of dB. Sound sampling is in the range of 16 to 20,000 Hz for frequency range of human hearing. For sampling the sound, is defined the time and rate of sampling with software, for example: 8000 samples were collected in every second and were displayed 8000 samples per second. In general, we can use the lower rate of sampling for uniform sound, because high-speed sampling requires high capacity of hardware such as the microphone and vibration analysis card. In the section, microphone receives information of sound wave and transmits to the sound analysis card.

The second part is related to sound analysis that processes the sound information and refer to other sections. Sound analysis card is the core of the sound signal processing that transmits the sampled sound characteristics in terms sound pressure to the graphic part. In addition, the features of section can be used to active control of sound.

The third part displays the output of sound analysis card in state of noise or graph. At this stage, processed data from the microphone are displayed in term of logarithm and based on known unit (dB) in the frequency range of human hearing.

RESULTS

Labview is suitable software for measurement and control of systems in the workplace and helps to engineers that they can create the wide of application programs in short time.[6,7]

The below figures show the feasibility and efficiency of the Labview software. According to Figure 1, measured sound pressure with sound level meter and software in A frequency weighting has a direct relationship with a correlation coefficient of 0.89 ($P < 0.001$). In addition, there is direct relationship between measured sound pressure with sound level meter and software in C-frequency weighting with a correlation coefficient of 0.91 ($P < 0.001$) [Figure 2]. Also, the *t*-test analysis showed that there is no significant difference between measured sound pressure with sound level meter and software in A-frequency weighting ($P = 0.17$). The result was observed in the C-weighting also ($P = 0.1$) [Tables 1 and 2].

Each of the subgroups of this program is called a "virtual instruments" that each of them is used in various environments such as industrial, medical, laboratory, etc.

The virtual instrument consists of two components:
- Front panel
- Back panel or block diagram.

Front panel

This page is a user interface that is composed of monitors and control devices. Control tools allow us to enter the inputs and information related to the purpose of work. Display tools are also used to indicate the outputs and outcomes of work [Figure 3].

Back panel

Back panel or block diagram is included from graphical sources code and functions. Objects are placed in the page depending to purpose in the form of blocks. The blocks are connected by straight lines and constitute the basic structure of the method. Functions are located inside the function panel that perform the control operations and supply input to the display tools [Figure 4].

To start of work, after opening the program, a new file is created. In this case, two windows of front and back panel are appeared. Then, depending on the purpose, the needed objects are selected from "show control panel" option in the front panel. Therefore, all objects are displayed on the back panel in the form of block that must be connected together via correct wiring. Thus, the data are converted to machine codes. After processing the data by sound analysis card, functions in the back panel sent the results to the display tools in the front panel.

Sound waves are longitudinal mechanical waves that generally propagate into the air and make sense of hearing when receive by human ear. The range of sound frequencies that can be heard by human is between 20 Hz and 20 kHz.[10] Labview programming capabilities in the sound field can be used to the measurements, analysis, and control of noise. In fact, this software can be operated as a sound level meter or noise analyzer. Finally, the information on the front panel is specified that includes: Number of microphone connection channel to data-acquisition card, microphone sensitivity with unit of millivolt per Pascal, and hearing range (20–2000 Hz). In addition, based on the aim of the task, the various frequency weighting includes: A, B, C, D, and linear can be selected.[10,11] In this software based on the

Table 1: Relationship of the measured mean of sound pressure level by the sound level meter and software in A-weighting

Statistical feature measurement method	Mean ± SD	*P*
Sound level meter	60.55 ± 12.65	0.17
Software	64.53 ± 9.81	
Total	125.08 ± 40.4	

SD: Standard deviation

Table 2: Relationship of the measured mean of sound pressure level by the sound level meter and software in C-weighting

Statistical feature measurement method	Mean ± SD	*P*
Sound level meter	69.04 ± 10.07	0.09
Software	64.43 ± 9.77	
Total	133.47 ± 19.84	

SD: Standard deviation

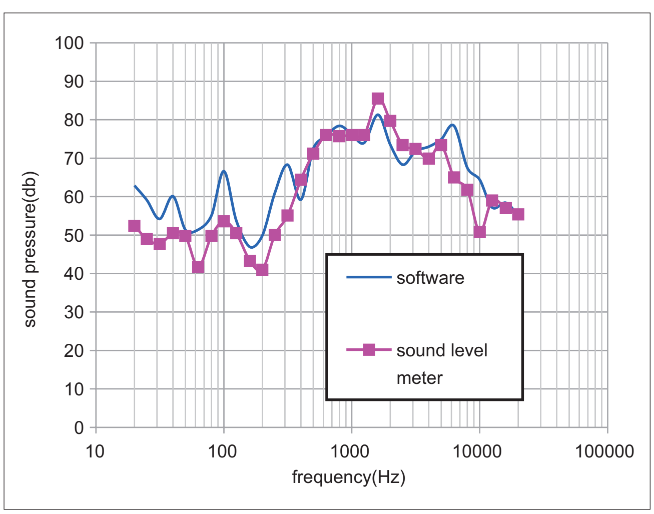

Figure 1: Comparison between measured sound pressure level by the software and sound level meter in A-weighting

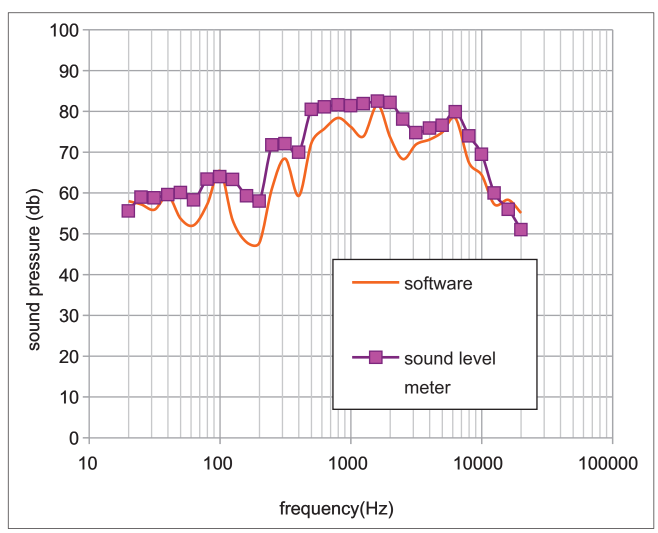

Figure 2: Comparison between measured sound pressure level by the software and sound level meter in C-weighting

type of sound, time weighting can be determined in one of three modes: Slow, fast, and impulse. In the fast mode, the software responds are quickly to rapidly changing sound levels, whereas in the slow mode the level variations appear to be reduced. In addition, the impulse mode is using for measurement of impulse or impact sound and program detects the sound amplitude variations at microsecond. As shown in Figure 5, the time weighting of the program can be determined in part of "exponential averaging setting" and "mode" options.[10,11]

The frequency range or spectrum of most interest in noise control engineering varies from about 20 to 20,000 Hz. Due to the wide range of variation, the acoustical engineers developed a scale of octave bands and one-third octave band.[10] Labview program will be able to show the sound pressure levels at various octave bands [Figure 6].

The amplitude is defined as the maximum displacement of sound wave during one period of oscillation.[11] Another software capability is determining the changes of sound pressure amplitude to unit time that is shown in Figure 7.

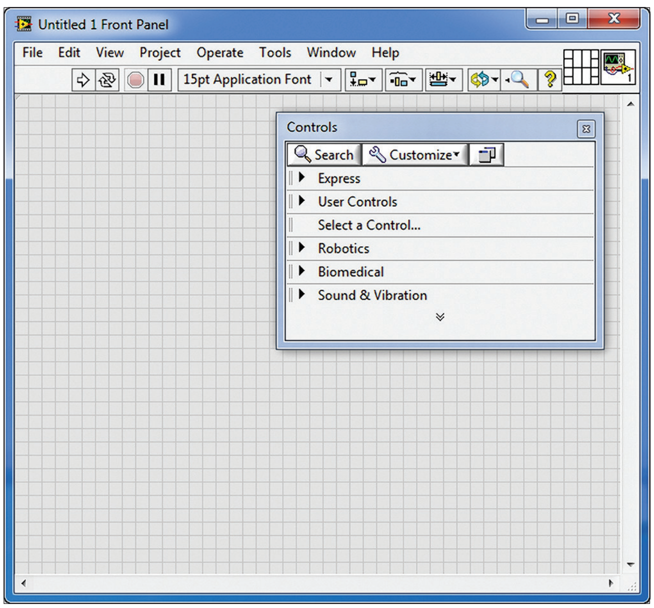

Figure 3: Front panel

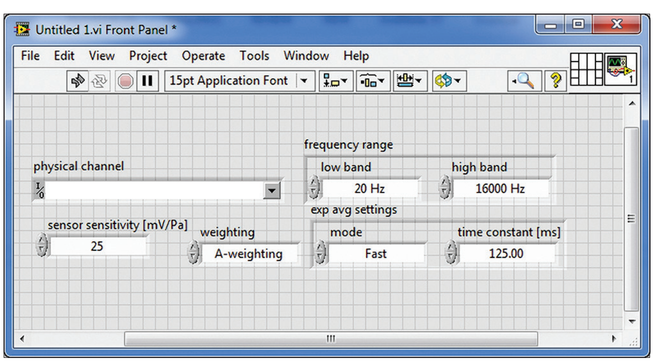

Figure 5: Entering the information in front panel

In the survey of the workplace, sound pressure levels are used mostly for environmental assessment and evaluation of employee exposure. In fact, this software can measure the sound pressure levels at different frequencies. The results are displayed in the form of analog and digital [Figure 8].

Spectral analysis is one of the most important issues in signal processing that is used in various fields such as industry, radars, sound processing, etc. The sound level as the power spectrum depends on the measurement bandwidth that is controlled by the number of samples and sampling rate. This information is specified in the "power spectrum" menu and in the options of "number of sample" and "scan rate," respectively. Power spectrum can show sound power level based on the mean-square sound pressure at each frequency, but this option does not provide the information about of phase. Therefore, it is used from Fast Fourier transform (FFT) that in addition to displaying data in the frequency domain provides information related to the phase. The "power spectral density" option also shows the energy

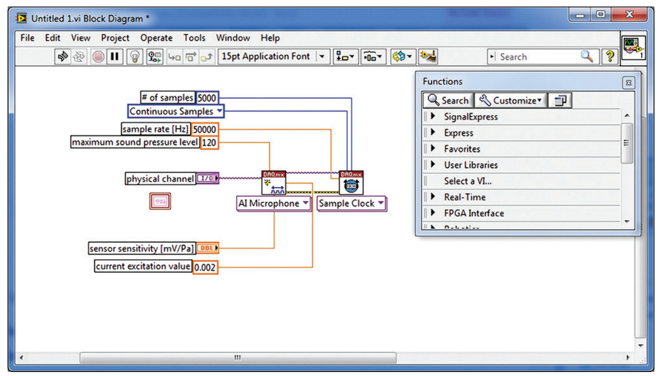

Figure 4: Back panel or block diagram

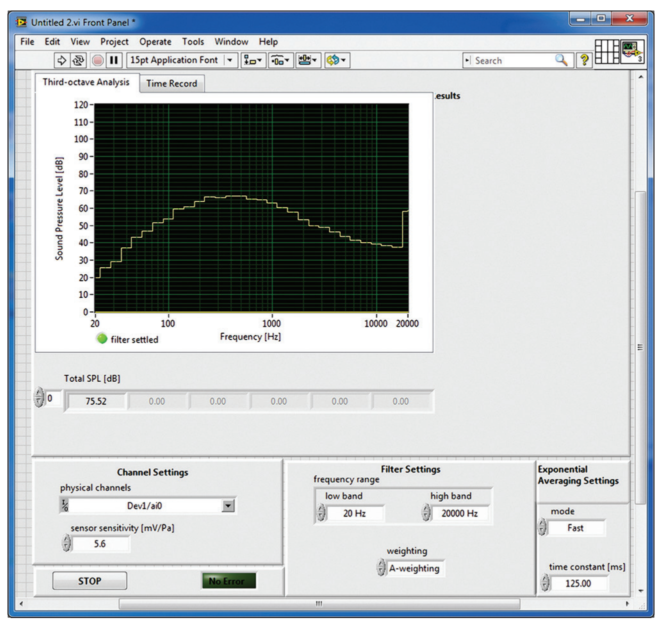

Figure 6: Measurement of sound pressure levels in one-third octave band

changes as a function of frequency. This measurement is typically used to examine the noise floor of a signal or the power in a specific frequency range. In other words, it shows which frequency variations (energy) are strong and which frequency variations are weak. After entering the information of sensor sensitivity, frequency weighting, sampling rates, and number of samples, three menus (power spectrum, FFT, power spectral density) can be used according to Figure 9.

Options in this section include:

- "Average mode block" that is contains three subgroups as follows:
    - Root mean square (RMS) averaging: This option reduces signal fluctuations but not the noise floor. The noise floor is not reduced because RMS averaging averages the energy, or power, of the signal
    - Vector Averaging: It eliminates noise from synchronous signals and computes the average of complex FFT spectrum quantities directly. The real part is averaged separately from the imaginary part that can reduce the noise floor for random signals
    - Peak Hold: It performs averaging at each frequency line separately, retaining peak levels from one FFT record to the next
- "Weighing mod block" is contains two options include linear and exponential that if in previous case is selected the options RMS or vector, can be used from both subgroups
    - Linear averaging applies equal weighting to all the data and when the number of averages is completed; the analyzer stops averaging and presents the averaged results
    - Exponential averaging applies more weight to the most recent data and is a continuous process.
- "Number of average" that specifies the number of averages used by the selected weighting mode.

When weighting mode is set to linear, "auto-restart control" is used to configure averaging to automatically restart When the average equal to desired number.

An example of measuring the FFT and power spectral density is shown in Figures 10 and 11 respectively.

DISCUSSION

Labview is powerful and efficient software that can be used for processing and analysis and is applicable for various purposes. Labview programming capabilities in the field of sound can be referred to the measurement of sound, frequency analysis, and sound control that actually the software acts like a sound level meter and sound analyzer.[7]

In this program, according to the aim, the sound pressure levels can be selected based on various frequency weighting.

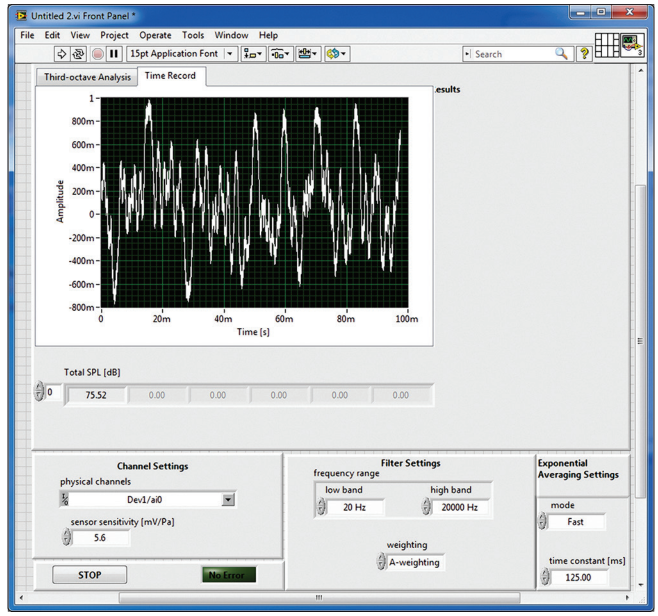

Figure 7: Measurement of sound pressure amplitude in unit time

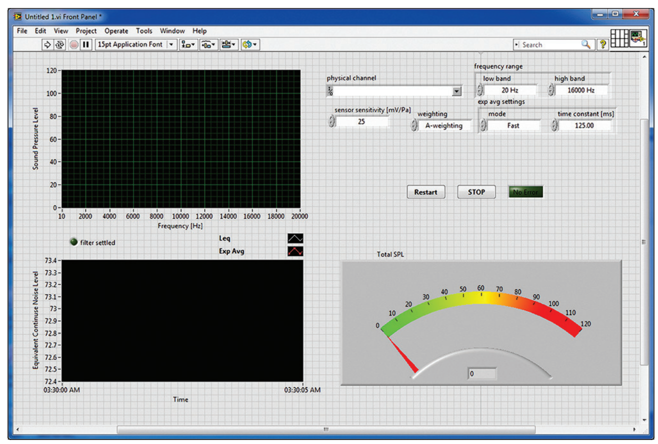

Figure 8: Measurement of sound pressure levels at different frequencies

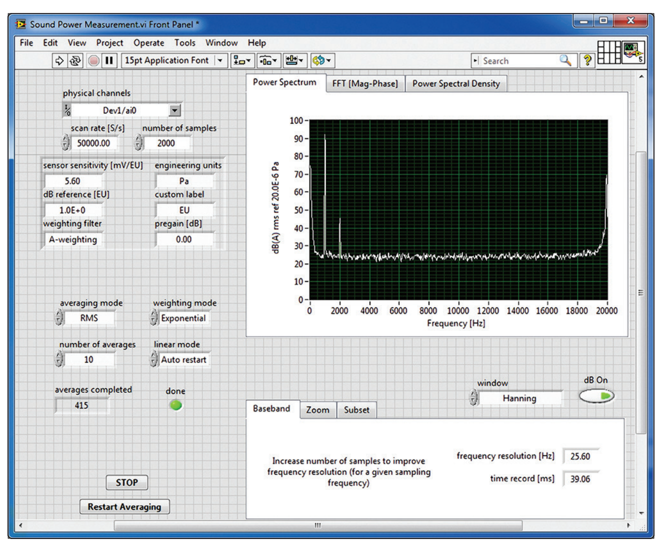

Figure 9: Analysis of sound power spectrum

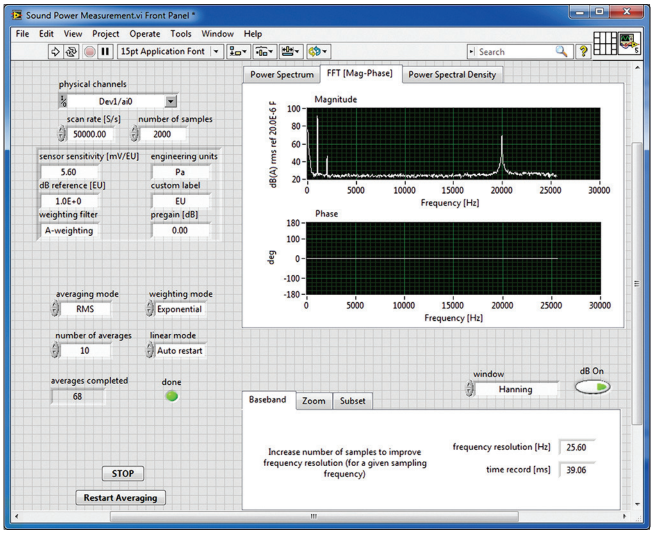

Figure 10: The result of the fast Fourier transform measurement

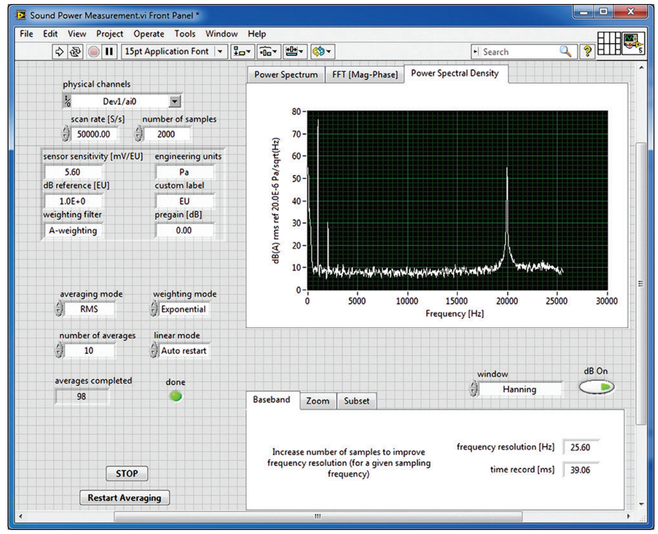

Figure 11: The result of the power spectral density measurement

The time weighting of software is also determined. After specifying the required information such as: time weighting, frequency weighting and time and rate sampling, the sound pressure levels can be measured at various octave bands range, sound amplitude, power spectrum density and other sound characteristics. In fact, this software is a suitable choice for monitoring and control of noise pollution in the environment and industry and can be used easily by the computer at the desired locations. In addition, significant direct correlation was observed between the results of measurement of sound pressure levels by software and the sound level meter.

It should be noted that some cases are suggested the slight differences of this comparison that are include:

- Sound level meter measures the sound level in single frequency, but the software performs measurements in a frequency range in a moment and reduces the likelihood of errors
- The frequency response of the microphone is different. In fact, the threshold sound pressure levels at different frequencies or the range of the frequency spectrum are different for microphones even two similar microphone of a company.

Robert and Grazyna (2013) used from labview for Measurement and analysis of noise signals and reported that is an application program for teamwork in the noise measurement. In fact this software is more accurate than the sound level meter.[12] A study by Trojanowski and Wiciak describes the active control of plates via piezoelectric elements and used from labview for analysis of results. This study shows another feature of the software.[13] Another study by Schon e*t al*. is used from labview for the analysis of suckling grunts of domestic pigs. The results showed that the labview is an advanced tool for analyzing and processing of sound and graphical language allows that engineers use this program without having much experience. Also, this study reported that labview can be used in same cases as analysis of animals bioacoustics studies, evaluation of human speech and other environmental sounds.[14] Nobuhiko used from labview to reduce fan noise by active control method. In fact, the phase difference and increase of sound can be done using the options provided on the front panel of software.[15]

On of the important and distinctive feature of software is the export of results to *.exe file. It means that results can be run on any computer, even if there is no software to install.[6,7]

Previous surveys show that using of labview software in the field of occupational health in order to monitoring noise and simulation of sound level meter was performed for the first time in Iran by this study. It is hoped that through study and achieve goals can be used to analysis and processing of sound and vibration as monitoring in the workplace and industry, and finally perform the necessary measures to prevent and control of noise and vibration risk factor.

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