

Noise and Vibration Measurement System



Anzhelika Stakhova

Contents

1	Introduction	244
2	Methods and Tools for Measuring Noise and Sound Level	244
3	Results and Discussion	247
4	Conclusion	248
	References	248

Nomenclature

- A Amplifier
- ADC Analog-to-digital converter
- BT Bluetooth module connected to the sensor to transmit a signal to the main board
- BTM Bluetooth module for receiving a signal on the main board from measuring channels
- LCD Module for displaying the result
- M Microphones
- MCU Microcontroller
- V Accelerometers

A. Stakhova (✉)
National Aviation University, Kyiv, Ukraine
e-mail: sap@nau.edu.ua

1 Introduction

At the present stage of aviation development, the main direction of ensuring the working condition of aviation equipment is to increase the efficiency of its control. For this purpose, work on studying of a technical condition of special equipment and the analysis of its changes is carried out.

Most machine failures are expressed in increased vibration, so vibration analysis is a powerful tool for diagnosing equipment. Each fault or damage has its own type of vibration (Barkov et al., 2000). Exceeding the acceptable level of vibration during the operation of different kinds of equipment leads to a decrease in the reliability and durability of particular elements in these devices. The advent of modern vibration-measuring equipment provides the ability to make exact measurements, registration, and subsequent analysis of dynamic processes, that is, vibration signals.

It is impossible to ensure the working condition of machinery without the introduction of modern diagnostic methods and the development of new methods and systems, the use of which will significantly increase the effectiveness of control. Therefore, in the course of the work, a review and analysis of modern means of measuring vibration and noise according to the vibroacoustic parameters of the working area was carried out. The actual task of designing and research of the system of monitoring of vibroacoustic parameters of the working zone in which the influence of vibration and noise parameters is present is set.

2 Methods and Tools for Measuring Noise and Sound Level

Today, the number of devices and ancillary equipment for measuring vibroacoustic parameters is in the hundreds of types. They differ in accuracy, cost, and availability of different functionality. As a rule, firms specializing in the production of combined sanitary control devices of vibration and noise can call them both vibrometers and sound-level meters. Thus, in this chapter, the proposed system, which has high accuracy at low cost, as well as the ease of installation for measuring vibroacoustic parameters of the working area have been discussed.

For the sanitary standardization of noise and vibration, a large range of measuring instruments of varying complexity is produced. Let us review the existing means and methods of noise measurement. When developing methods of noise control and comparison of noise characteristics created by mechanisms and machines with acceptable sanitary norms, it is necessary to know its spectral composition as well as the level of its intensity.

There are two methods for measuring noise levels:

- Subjective
- Objective

When measuring by the subjective method, devices – phonometers (<https://infocom-m.ru/uk/inzhenernye-sistemy/air-and-structural-noise.html>) are used. In these devices, the pure tone of a certain frequency is compared with the measured sound or noise. Phonometers have a very limited application due to the complexity of measurements and the dependence of their results on the characteristics of hearing.

When measuring by the objective method, noise meters are used, which have become widespread for measuring noise parameters (<https://infocom-m.ru/uk/inzhenernye-sistemy/air-and-structural-noise.html>). Noise meters perceive noise with a broadband microphone. The microphone converts sound vibrations into electrical ones. Electric in turn are amplified, and then fed to the rectifier of the switch, that is, the meter. Frequency analyzers, recorders, and other devices can be connected to the output of the amplifier.

Due to the limited frequency characteristics of the sensitivity, the noise meters of the objective measurement method allow to determine only the approximate values of the noise volume levels.

Measurements of noise levels in industry are performed by noise meters of different kinds, of which the most common are the noise meter Sh-63 with an octave bandpass filter PF-1 and the noise meter Sh-3 M with 1/3-octave analyzer Liote.

The noise meter has three scales (A, B, and C), which take into account the frequency composition of the measured noise (<https://infocom-m.ru/uk/inzhenernye-sistemy/air-and-structural-noise.html>). The noise characteristic on the scale A corresponds to the volume curve 40 phon, that is, to some extent the subjective perception of the volume level and allows you to make an approximate assessment of the “trouble” or “harmfulness” of the noise. Therefore, the noise level measured on a scale A in decibels (dBA) is of great importance for the hygienic practice of industrial noise assessment (Cheremisinoff, 1996).

The noise characteristic on the B scale corresponds to a curve equal to a volume of 70 phon. To obtain the noise spectrum, the measurement must be performed on a scale of C. The linear frequency response will show a purely physical value (sound pressure level) in the range of 60–5000 Hz.

Special devices (noise analyzers) study the spectral composition of noise. Octave analyzers should often be used to measure sound pressure levels in octave bands.

The band in which the upper limit frequency is equal a twice the lower frequency (45–90, 90–180, etc.) is called the octave band. It is characterized by the average frequency (geometric mean of the upper f_1 and lower f_2 limit frequencies $f = \sqrt{f_1 \cdot f_2}$).

GM1352 digital noise meter, manufactured by Benetech (<https://gtest.com.ua/benetech-gm1352.html>). This noise meter can measure noise levels in the range of 30 to 130 dB; it has a highly sensitive capacitive microphone and can record sound oscillations in the frequency range from 31.5 Hz to 8 kHz. A distinctive feature of the noise meter Benetech GM1352 is small size, ease of use, and functionality.

Let us review the existing tools and methods for measuring sound level. A sound-level meter is a tool that determines the sound level by measuring the pressure of the noise level (De Silva, 2005). Sound enters the sound-level meter through the microphone input. Then the sound is evaluated in the device and the results are

displayed in decibels. The PCE sound-level meter meets the highest industry standards. In addition, it is light and easy to use.

PCE-428 is a class 2 sound-level meter with protocols that meets the requirements of IEC 60651 (https://pragmatic.com.ua/pce_428). This portable high-precision sound-level meter has a large backlit LCD display that displays the sound pressure level (SPL) numerically and graphically in real time. Thanks to the octave bandpass filter, even the smallest difference in frequency is detected.

The basis of any vibration-measuring instrument is a measuring transducer (vibration transducer), which converts it into an electrical signal. More often, such a transducer is called a vibration sensor.

Vibration monitoring differs from vibration control also in that when observing changes in a vibration signal, it is not necessary to carry out only quantitative measurements of parameters with a minimum total error. It is possible to carry out measurements of vibration characteristics and with a constant system error, provided that the coefficient of conversion of the vibration parameter into the controlled electrical parameter is constant over time. Therefore, when monitoring vibration measurements, it is possible to control the development in time of vibration components having frequencies up to 90–95% of the resonant frequency of the accelerometer.

If the upper limited frequency of the piezoaccelerometer is determined by its own resonance or the resonance of the sensor, taking into account the rigidity of attachment to the object, and its value is usually in the range of 1–100 kHz, then the lower limited frequency of the measured vibration depends on the electrically conductive properties of the piezoceramic element. It can be determined not only by the leakage resistance of the piezoelectric element, but also by leaks in the charge transfer circuit to the input of the matching amplifier in the measuring device. The typical lower limited frequency of a piezoaccelerometer is 0.5 Hz, but piezoaccelerometers with significantly lower limited frequencies can be manufactured to solve special problems. Typical accelerometers are most often combined with matching amplifiers in one package. There are also standards for such accelerometers, including those with power supply of the matching amplifier through the signal circuit.

Dynamic range and linearity are also important characteristics of a vibration sensor, as a such used electronic devices. A typical measurement range for the absolute vibration displacement of machines and equipment is from one to a thousand microns, that is, 60 dB. But if a vibration acceleration transducer is used, it is necessary to take into account the fact that the signal from the transducer (at the same value of vibration displacement) at the lower frequency of the measured range f_{\min} is $n = (f_{\max}/f_{\min})^2$ times less than the signal at the upper frequency f_{\max} , and this value must be added to the dynamic range of the meter. When measuring vibration displacement in the range of 2–1000 Hz, this addition to the dynamic range of the device is a very large value – 108 dB, and it is necessary to take measures to eliminate this contradiction.

3 Results and Discussion

The main goal of the project is to develop a system for monitoring vibroacoustic parameters of the working area.

The main functions of the system are constant measurement of noise and vibration parameters of the working area, analysis of measured parameters, signalling of exceeding the allowed range of measuring parameters of the working area, and display of measured data in decibels.

Based on the review and analysis of technical solutions, the main functions of the system were proposed a block diagram of the system, which is shown in Fig. 1.

The diagram shows the following:

- M1–M4: microphones (noise sensors)
- V1–V4: accelerometers (vibration sensors)
- A: amplifier
- MCU: microcontroller
- BTM: Bluetooth module for receiving a signal on the main board from measuring channels
- BT: Bluetooth module connected to the sensor to transmit a signal to the main board
- LCD: module for displaying the result

Figure 1 shows that the system has eight measuring channels: Four for vibration measurement and four for noise measurement. Each measuring channel consists of the sensor itself (M1–M4, microphone for noise measurement; V1–V4, accelerometer for vibration). The data obtained from the sensors are amplified by the operational amplifier A, such amplifiers are 8, for each of the measuring channels. After amplification, the analog signal is converted into discrete code using a single-channel ADC. The digital signal after the ADC is transmitted to the main board with a microcontroller. The board receives data from all eight measuring channels. Collecting the values obtained from the sensors, the main board uses software processing to analyze the data and transmits them to the LCD display, which in turn displays them.

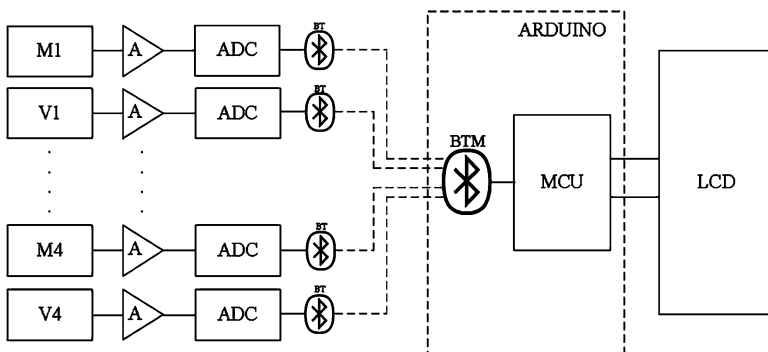


Fig. 1 Block diagram of the MVP system

A microphone is used as a sensor for each noise measurement channel. The analog signal from the microphone is amplified by an amplifier and converted into digital code by an ADC. Then the digital signal is transmitted to the main board with a microcontroller.

Similarly, an accelerometer is used for each parameter measurement channel. On each measuring channel, both for vibration parameters and for noise parameters, the analog signal received from the sensor is amplified, sampled, and transmitted to the microcontroller.

The measuring channels of the designed system transmit the measured data via a wireless connection, which simplifies their use and placement in any place in the work area and allows you to cover a larger area of the measured area. Analogs are portable devices that measure certain small planes of the working area.

As for the principles of operation, despite the large number of devices, the principle of their operation remains unchanged. The principle of measuring noise parameters is based on the received acoustic waves with the subsequent conversion of their energy by means of the most various technologies in electric potential which is directly proportional to size of a signal. As for the principle of measuring vibration parameters, vibration sensors are used, which perceive mechanical vibrations, which are also converted into the corresponding electric potential by means of various technologies.

4 Conclusion

The system of monitoring of vibroacoustic parameters of the working zone was proposed in the work, which performs the following functions: measurement of vibroacoustic parameters (vibration and noise parameters) of the working zone, analysis of measured values of vibroacoustic parameters, alarm of the user about exceeding of the allowed range of parameters of vibration and noise of a working zone, saving the measured data for a specified period of time, and display of measured data.

References

- Barkov, A. V., Barkova, N. A., & Azovtsev, A. Y. (2000). *Monitoring and diagnostics of rotary machines by vibration*. SPbSMTU.
- Cheremisinoff, N. P. (1996). *Noise control in industry: A practical guide*. Elsevier.
- De Silva, C. W. (Ed.). (2005). *Vibration and shock handbook*. CRC Press.
- <https://gtest.com.ua/benetech-gm1352.html>. Accessed on 13 Apr 2021.
- <https://infocom-m.ru/uk/inzhenernye-sistemy/air-and-structural-noise.html>. Accessed on 13 Apr 2021.
- https://pragmatic.com.ua/pce_428. Accessed on 13 Apr 2021.