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MEASURING CHAIN FOR CHECKING THE VIBRATION OF MECHANICAL PARTS

Urgency of the research. *Interest in this topic is aroused, because mechanical vibration may damage the machinery or parts of machine. Therefore, it is appropriate to design systems that detect problems. Also these systems can help in the timely replacement of the worn part.*

Target setting. *The main goal is to design a system that can detect in a timely manner a problem that could destroy the device. It is therefore necessary to design systems that can record this.*

Actual scientific researches and issues analysis. *In recent years, there has been an increase in demand for equipment that can detect a timely problem. Many such devices already exist and are still being upgraded. This industry is called vibrodiagnostics.*

Uninvestigated parts of general matters defining. *This paper is focused on the analysis of mechanical systems and the creation of a measuring chain.*

The research objective. *The aim of this research is to analyse the mechanical systems and the assembly of the measuring chain. The functionality of the device can be verified on this measuring chain. Whether or not it is suitable for operation. In the future these systems will be upgraded with software that better records the vibrations.*

The statement of basic materials. *The analysis consists of basic information about mechanical systems and sensors. The definition of this problem is described below. Based on this knowledge of mechanical systems, a measurement chain was designed.*

Conclusions. *Our vision is to implement knowledge of mechanical systems not only on a simple fan stator. Problems of vibrodiagnostics are still progressing and increasingly in technical practice. We would continue to do more testing on more complex devices.*

Keywords: *mechanical vibration; mechanical systems; damage; vibrodiagnostics.*
Fig.: 5. Table: 1. References: 9.

Problem definition. The operation of each machine produces effects that cause the machine to oscillate. Increasing the performance of the device leads to an increase in the level of dynamic effects, which results in unfavorable consequences, namely a reduction in the service life, reliability and, above all, wear of the machine parts of the device. However, the oscillation cannot be completely eliminated and therefore a certain permissible value is prescribed for each device. Compliance with this standard ensures long-term and trouble-free operation of the device. Each machinery should include its continuous vibration diagnostics coupled with monitoring of the operation to enable its immediate control of the operating parameters.

The accuracy of production, technological assembly, used material of its parts, loading, etc. also have a significant influence on the oscillation of the device itself. Analytical, numerical and experimental methods of mechanics, which are part of the analysis of machines and equipment, are used to solve the vibration problem. In many cases, they are the only possible procedure for determining real dynamic parameters. There are already enough publications in this area. The importance of solving this issue is versatile, because the solution of this issue can prevent unnecessary waste of economic resources and, in extreme cases, loss of life [1].

Problems of mechanical systems and their oscillations, therefore the Fig.1 shows the distribution of oscillating processes. The distribution is given by STN ISO 2014 and in this standard vibration is understood to be a change in the time value of the defining quantity of the vibration that expresses the movement or position of the mechanical system when the defining quantity is alternately greater or less than a certain average or reference value. The aim of the research is to get acquainted with the possibilities of vibrodiagnostics. To accomplish the goal there were such tasks. To describe the Fourier transformation and assemble the measurement chain [2].

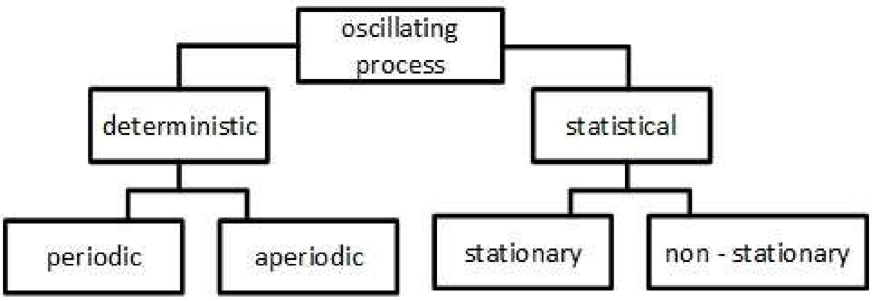

Fig. 1. Oscillating processes

Sensors for measuring mechanical vibration. A measuring device is a set of instruments that works by obtaining at its output information *y (t)* about the time course of the quantity *x (t)* that acts on the input of this device. In order to obtain complete information about the measured quantity, it is necessary to know the transmission properties of the measuring device used (e.g. sensitivity, working range, linearity, etc.) [3].

At Fig. 2 is a block diagram of a measuring device for measuring mechanical vibration. Transmitter *I* transmits mechanical vibration from the measured object to the sensor. An example of such a transfer member is e.g. clamp for fastening the sensor to the measured object, glued connection of the sensor to the object, etc. The sensor contains a detecting element that determines the physical nature of the sensor output signal [4].

Sensors:
- absolute and relative,
- touch and non-touch,
- mechanical,
- hydraulic,
- pneumatic,
- optical,
- electrical,
- active or passive.

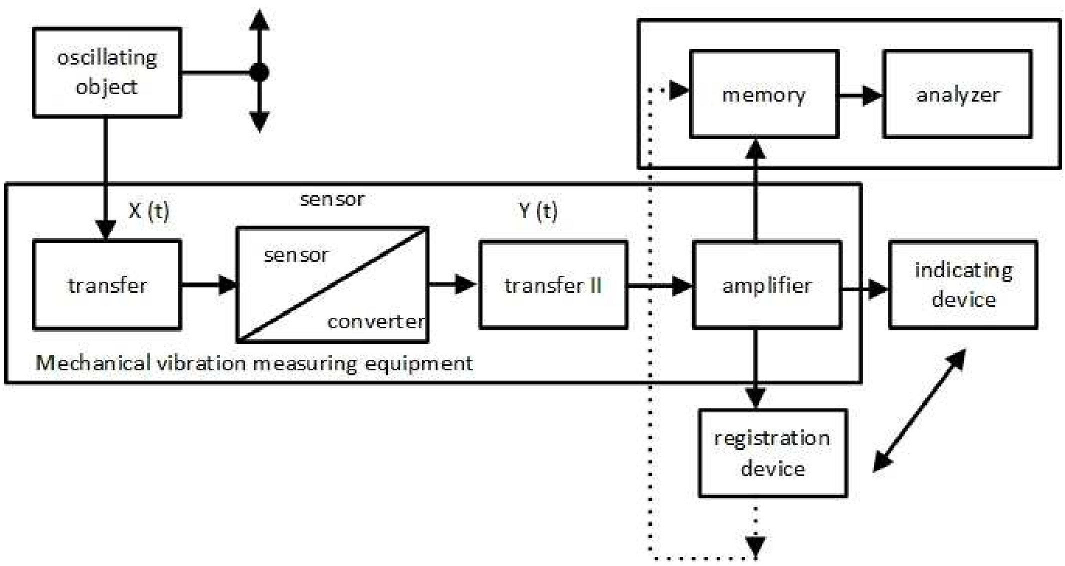

Fig. 2. Measurement block diagram

A transducer is a device that extracts energy from one system and supplies energy in the same or in another form to another system so that the required input energy characteristics are present in the output energy. The converter transforms the quantity obtained by the sensor into another analog physical quantity. The main types of electromechanical converters are:
- piezoelectric, piezoresistive,
- electrostatic transducer,
- magnetostrictive transducer,
- inductive – electronic transducer,
- moving coil transducer.

Frequency analysis of vibration. There are methods for analysing the time wave itself and are very effective for some disorders. But this is not the most common way to analyse vibrations. The most commonly used so-called. Frequency analysis. The basic consideration of how to analyse vibrations in more detail is shown at Fig. 3. Each time wave consists of contributions from individual vibrating parts, mostly with different frequencies. Frequency analysis is a tool that is able to show these individual contributions directly. Vibration diagnostics detects a machine error based on the frequency components that occur in the vibration spectrum. Frequency analysis is performed by Fourier transform (Fourier series decomposition) [5].

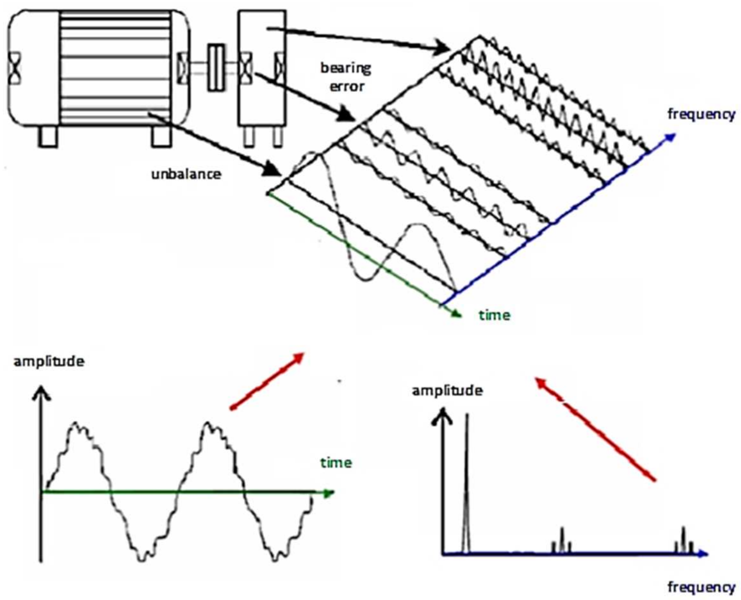

Fig. 3. Principle of frequency analysis

The function *x (t)*, which is periodic at time T, can be expressed as an infinite sequence in the form:

$$x(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty}[a_n \, cos(n\omega t) + b_n \, sin(n\omega t)] \; ; \; \omega = \frac{2\pi}{T}. \quad (1)$$

This relation means that the original function *x (t)* can be composed of infinitely many sinusoidal waveforms that have different amplitudes and their frequencies are multiples of the fundamental frequency ω. The coefficients a_n and b_n are Fourier or spectral coefficients of the function *x (t)* and are calculated from:

$$a_n = \frac{2}{T}\int_0^T x(t) \, cos(n\omega t) \, dt \quad (2)$$

$$b_n = \frac{2}{T}\int_0^T x(t) \, sin(n\omega t) \, dt \quad (3)$$

When working with measured vibration signals, we consider the function to be periodic in the measured interval *T*. Current signal analysers do not work with a continuous time wave, but the measured signal passes at the input to the A / D analyser (analog / digital), which records the time wave as a sequence of *N* discrete values with regular time intervals in the *T* interval is called discretization. The discretized function *x (t)*, which is defined on the set *N* of individual time moments t_k, (k = 1 ... *N*), can be written as a finite Fourier series:

$$x_k(= x(t_k)) = \frac{a_0}{2} + \sum_{n=1}^{\frac{N}{2}} \left[a_n cos\left(\frac{2\pi n t_k}{T}\right) + b_n sin\left(\frac{2\pi n t_k}{T}\right)\right] \; ; \; k = 1 \dots N \quad (4)$$

Fourier coefficients are often displayed in the form of amplitude c_n and phase φ_n:

$$c_n(= (t_k)) = \sqrt{a_n^2 + b_n^2} \quad (5)$$

$$\varphi_n = arctg\left(-\frac{b_n}{a_n}\right) \quad (6)$$

$$x_k(= x(t_k)) = \frac{a_0}{2} + \sum_{n=1}^{N/2} \left[c_n \cos\left(\frac{2\pi n t_k}{T} + \varphi_n\right)\right] \quad (7)$$

This form of Fourier transform is called a Discrete Fourier Transform (DFT). The resulting Fourier series, or a set of sinusoidal waveforms from which the original time wave can be composed, is called the frequency spectrum. Thus, by Fourier transform, we transmit information about vibrations from the time domain where the individual events are mixed to the frequency domain in which each event is represented by a separate sinusoidal waveform corresponding to the frequency (frequency or spectral line) [7].

The basic relationship between sample length T, the number of discrete values N, the sample rate f_s and the range and resolution of the frequency spectrum applies. The range of the spectrum is $0\text{-}f_{max}$, where f_{max} is the Nyquist frequency and the line resolution in the spectrum is Δf:

$$\Delta f = \frac{1}{T} = \frac{f_s}{N} \tag{8}$$

$$f_{\max} = \frac{f_S}{2} = \frac{1}{2} \cdot \frac{N}{T} \tag{9}$$

In current analysers is used algorithm called Fast Fourier Transform (FFT), where N is the integer power of number 2. In fact, the upper frequency limitation of the spectrum $f_{\max}$ is somewhat reduced from the theoretical value (e.g. for $N = 2^{11}$, 1024 frequency lines are not used, but only 800).

The basic principles of vibration diagnostics consist in consistent and correct measurement of mechanical vibration of machines and structures in industrial or laboratory environments. Vibrodiagnostics can be briefly compared to ECG examinations of the human body in health care, even if another physical factor is measured and analysed and, of course, the method of measurement and analysis is applied. However, the objectives of the two different fields are common. In the case of ECG, to determine the health status of a person - in particular the heart as the engine of the human body and in the case of vibrodiagnostics determine the technical condition of the machines, including the various drives, without decommissioning and disassembly [8].

Realization of the proposed measuring chain. The object of measurement was a fan, which represented the analysed rotary machine. For measurement, uniaxial acceleration sensors *Brüel&Kjær* 4507B were used, which were applied to the fixed part of the fan at a position above its rotor. Tab. 1 is shown parameters of used sensors for measuring [9].

Table

Accelerometer parameters

sensitivity	9,927 mV / ms^{-2}
frequency range	0,3 Hz – 6 kHz
measuring range	± 700 ms^{-2} peak (± 71 g peak)

The sensors were applied to measure acceleration in three directions: radial - horizontal direction, radial - vertical direction, axial direction, Fig. 4.

Fig. 4. Sensors on stator of motor

The sensors were connected to the USB 4431 A / D converter, which was connected to a computer via a USB interface. This type of converter has 4 analog inputs and 1 output. After the wiring of the sensors, the power supply, the converter and the computer, the measurement was made. The proposed chain works and the measurements were performed. The measurements will be processed. At Fig. 5 is shown proposed measuring chain.

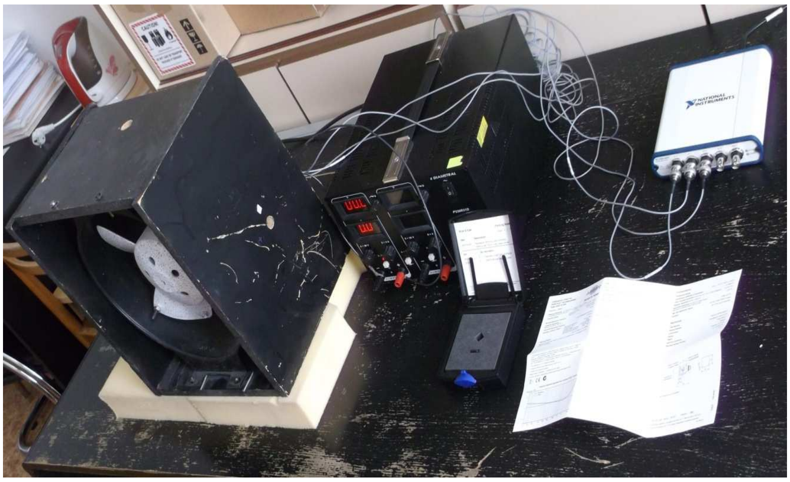

Fig. 5. Measuring chain

Conclusions. Based on the described analysis, we became acquainted with the measurement by means of vibrodiagnostics. In the future, we would like to make multiple measurements, using other sensors, on machinery and thus verify the measurement chain in practice. This chain should continuously monitor the oscillations on the devices. For more accurate measurement it is necessary to create data collection. This method could be used to detect machine failure in a timely manner.

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References

1. Marcinko, P., Huňady, R.: *Návrh meracieho reťazca pre kontrolu kmitania mechanických častí strojného zariadenia* (proposal of the measurement chain to check the vibration of mechanical parts of machinery). Bachelor thesis. Technical university of Košice, Košice 2014, 43 pp., (in Slovak).

2. Trebuňa, F., Šimčák, F., Huňady, R.: *Kmitanie a modálna analýza mechanických sústav.* Technická univerzita v Košiciach, Košice 2012, ISBN 978-80-553-1206-4.

3. *Měření vibrací ve vibrodiagnostice*. Retrieved from http://www.odbornecasopisy.cz/res/pdf/40375.pdf.

4. *Meření vibrací pro diagnostiku opotřebení strojú.* Retrieved from https://automatizace.hw.cz/mereni-a-regulace/mereni-vibraci-pro-diagnostiku-opotrebeni-stroju.html.

5. *Základné princípy vibrodiagnostiky a jej prínosy pre prax*. Retrieved from https://www.atpjournal.sk/buxus/docs/atp%20journal%205%202011%20str%2018-19.pdf.

6. Bilošová, A., Biloš, J.: *Aplikovaný mechanik jako součást týmu konstruktéru: část Vibrační diagnostika*. VŠB TU Ostrava, 2012.

7. Demetrian, M.: *Fourierove rady a Fourierov integral*. Univerzita Komenského Bratislava, 2012. ISBN 978-80-223-3171-5.

8. *STN ISO 10816-1 Mechnické kmitanie. Hodnotenie kmitania strojov meraním na nerotujúcich častiach*. SÚTN, Bratislava, 1999.

9. *Piezoelectric CCLD accelerometer.* Retrieved from https://www.bksv.com/en/products/transducers/vibration/Vibration-transducers/accelerometers/4507.

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ВИМІРЮВАЛЬНИЙ КАНАЛ ДЛЯ ОЦІНКИ ВІБРАЦІЇ ДЕТАЛЕЙ МЕХАНІКИ

Актуальність теми дослідження. *Інтерес до цієї теми підвищений, оскільки механічні вібрації можуть пошкодити машини або деталі машини. Тому доцільно розробити системи, що виявляють ці проблеми. Також ці системи можуть допомогти в своєчасній заміні зношеної деталі.*

Постановка проблеми. *Основна мета - розробити систему, яка зможе вчасно виявити проблему, яка могла б зруйнувати пристрій. Тому необхідно розробити системи, які можуть це реєструвати.*

Аналіз останніх досліджень і публікацій. *В останні роки спостерігається зростання попиту на обладнання, яке може вчасно виявити ці проблеми. Багато таких пристроїв вже існують і все ще оновлюються. Ця галузь називається вібродіагностикою.*

Виділення недосліджених частин загальної проблеми. *Ця стаття присвячена аналізу механічних систем та створенню вимірювального каналу.*

Постановка завдання. *Метою цього дослідження є аналіз механічних систем та складання вимірювального каналу. Функціональність пристрою можна перевірити на цьому вимірювальному каналі. Придатний він для експлуатації чи ні. В майбутньому ці системи будуть модернізовані програмним забезпеченням, яке краще реєструють вібрації.*

Виклад основного матеріалу. *Аналіз складається з основної інформації про механічні системи та датчики. Визначення цієї проблеми описано нижче. На основі цих знань механічних систем був розроблений вимірювальний канал.*

Висновки відповідно до статті. *Наше бачення - впроваджувати знання механічних систем не лише на звичайному вентиляторі. Проблеми вібродіагностики все ще прогресують і все частіше в технічній практиці. Ми будемо продовжувати тестування на більш складних пристроях.*

Ключові слова: *механічні вібрації; механічні системи; пошкодження; вібродіагностика.*

Рис.: 5. Табл.: 1. Бібл.: 9.

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