ASSESSMENT OF MECHANISM VIBRATION CONDITION BASED ON THE INTENSITY OF VIBRATION IN THE WAVELET ALLOCATED FREQUENCY BANDS

Brancevich Peter

Belarusian state university of informatics and radioelectronics, P. Brovka 6, Minsk, Belarus, 220013

Li Yibin

Computer Science and Engineering Department of Shandong University, Shunhua road NO.1500, Jinan, P.R.China, 250100
e-mail: liyibing@sdu.edu.cn

Increasing rivalry in the consumer markets requires producers and service providers to increase efficiency of their activities. In some cases, this leads to the fact that the intensity of machines and equipment operation increases, so do their work load conditions, and this in turn leads to their rapid depreciation and probability of failures and accidents increases. In such circumstances, the most important task is to develop effective means of monitoring the parameters of an operating equipment technical condition. For rotary type mechanisms (turbines, generators, motors, gearboxes, pumps, compressors, fans, etc.), the parameters of vibration reflect the functional state of objects well and do not require too much effort on their measurement. The simplest, but used in most cases intensity of vibration control uses its root mean square (RMS) in the frequency band of 10-1000 Hz in terms of vibration velocity. Various vibration parameters obtained from the application of mathematical processing methods (digital filtering, spectrum, cepstrum, envelope etc.) of the original vibration signals are applied to solving complex problems of vibration diagnostics. Condition assessment by RMS vibration velocity is fairly common and is used in solving problems of equipment protection from serious accidents and implementation of vibration diagnostics systems is costly and demands highly qualified personnel. It is proposed to establish a system of technical condition evaluation which would be some middle ground between the two and would have a relatively simple implementation. As the parameters characterizing the state of the technical object, it is proposed to use the intensity of the vibration frequency bands allocated by wavelet function, and divide all the frequency band observed into several sub-band in such a system. The report provides an example to illustrate this approach.

1. Introduction

Increasing competition in the consumer markets requires manufacturers of products and service providers to improve production efficiency and productivity, reduce operating costs. Thus, in some cases, this leads to the fact that increases the intensity of operation of machines and equipment, increasing load to operate them, and this in turn leads to their rapid wear and increase the likelihood of failures and accidents.

In such circumstances, the most important task is to develop effective means of controlling the parameters of technical condition of equipment, devices, machines and plants. To achieve this goal, it is advisable to choose the proper parameters, which represent well the functional state of the objects and do not require too much effort on their measurement. In this regard, the mechanisms for the rotational motion (turbines, generators, motors, gearboxes, pumps, compressors, fans, etc.), which are considered the most wear out, so are the parameters of vibration [1-4].

At its simplest, but is used in most cases, control the intensity of vibration used its mean square value (RMS) in the frequency band of 10-1000 Hz in terms of vibration. [5]

In some cases, controlled by a variety of parameters of vibration resulting from the application of mathematical methods for processing (digital filtering, spectrum, cepstrum, envelope, etc.). Raw vibration signals, and solving complicated problems of vibration diagnostics [6].

Assessment of technical conditions for the RMS vibration is quite common and is used to solve problems to protect it from serious accidents and implementation of vibration diagnostic systems is costly and highly qualified personnel. Therefore, there is the problem of creating a system of evaluation of technical condition, which would be some middle ground between the two and would have a relatively simple implementation. To solve it, we propose a variant based on the use of wavelet processing of vibration signals

2. The discrete wavelet transform

In solving the problems of assessing the technical condition of real objects on the vibration source vibrates parameters $x(t)$ can be pre-processed using wavelet transform [7-8]:

(1) $$C(a,b)=\int_R x(t)\cdot a^{-\frac{1}{2}}\cdot\psi\left(\frac{t-b}{a}\right)dt,$$

where $\psi(t)$ - wavelet function or simply wavelet;

a - Scale factor, which determines the width of the wavelet, and is analogous to frequency in the Fourier analysis;

b − A time shift

If you spend time sampling (argument) under the assumption that the change in the interval argument of the main functions of the wavelet -4 to +4 will correspond to change discrete argument from 0 to N, then it should be substituted instead

(2) $$t=\frac{8(n-b)-4aN}{aN}.$$

When $a=1$, $b = m$ in the form of discrete wavelet transform may be expressed as:

(3) $$C(N,m)=\sum_{n=0}^{N}x(n+m)\cdot\psi\left(\frac{8(n-m)-4N}{N}\right),\ m=0\div L-1,$$

Where L, the number of discrete samples analyzed in the time series of the test signal.

Wavelet transformation is a variant of a digital bandpass filter. In this connection there is the need to identify discrete dots wavelet number to be matched bandpass filter with a center frequency (frequency at which the digital band pass filter has a maximum transmission rate).

Experimentally obtained an expression for determining the width for some types of wavelets [9]:

$$N_{wave} = round\left(k_{wave} \cdot \frac{f_S}{f_W}\right), \tag{4}$$

where f_S - the sampling frequency of the analog signal;

f_W −The frequency at which the digital bandpass filter is implemented wavelet has a maximum transmission rate;

$round$ −Rounding operation.

k_{wave} - Normalizing factor for wavelet type symmetric wave it is equal to 1.275; for wavelet like "Mexican hat" - 1,816; for Gaussian wavelet third-order-ka - 2.22; for Gaussian wavelet 4th order - 2.55; for Morlet wavelet - 8.0.

To ensure unity gain at the central frequency of the wavelet digital filter function should be normalized wavelet amplitude. Normalized wavelets substituted in expression (3) to calculate the wavelet coefficients test signal.

3. Experimental studies

Consider the application of wavelet parameters in determining the vibration signals to a vibration signal processing example obtained by controlling turbine bearing assembly (Fig. 1).

In accordance with the standards [5] vibration control system of such units should determine the RMS vibration in the frequency range 10 - 1000 Hz. As vibration transducers are most commonly used piezoelectric sensors generates signals proportional to vibration acceleration. Because to go to the units of vibration required to perform the operation of integration, which is very sensitive to drift constant component and low-frequency vibrations. It is desirable to solve the problems of vibration diagnostics, and this requires to determine the intensity of the vibration frequency components of multiple speeds.

Using Gaussian wavelet first and fourth order response to the central frequency equal to 25, 50, 100, 400, 800 Hz for processing the original signal. Figures 1.2 shows examples of the vibration signal processing such wavelets.

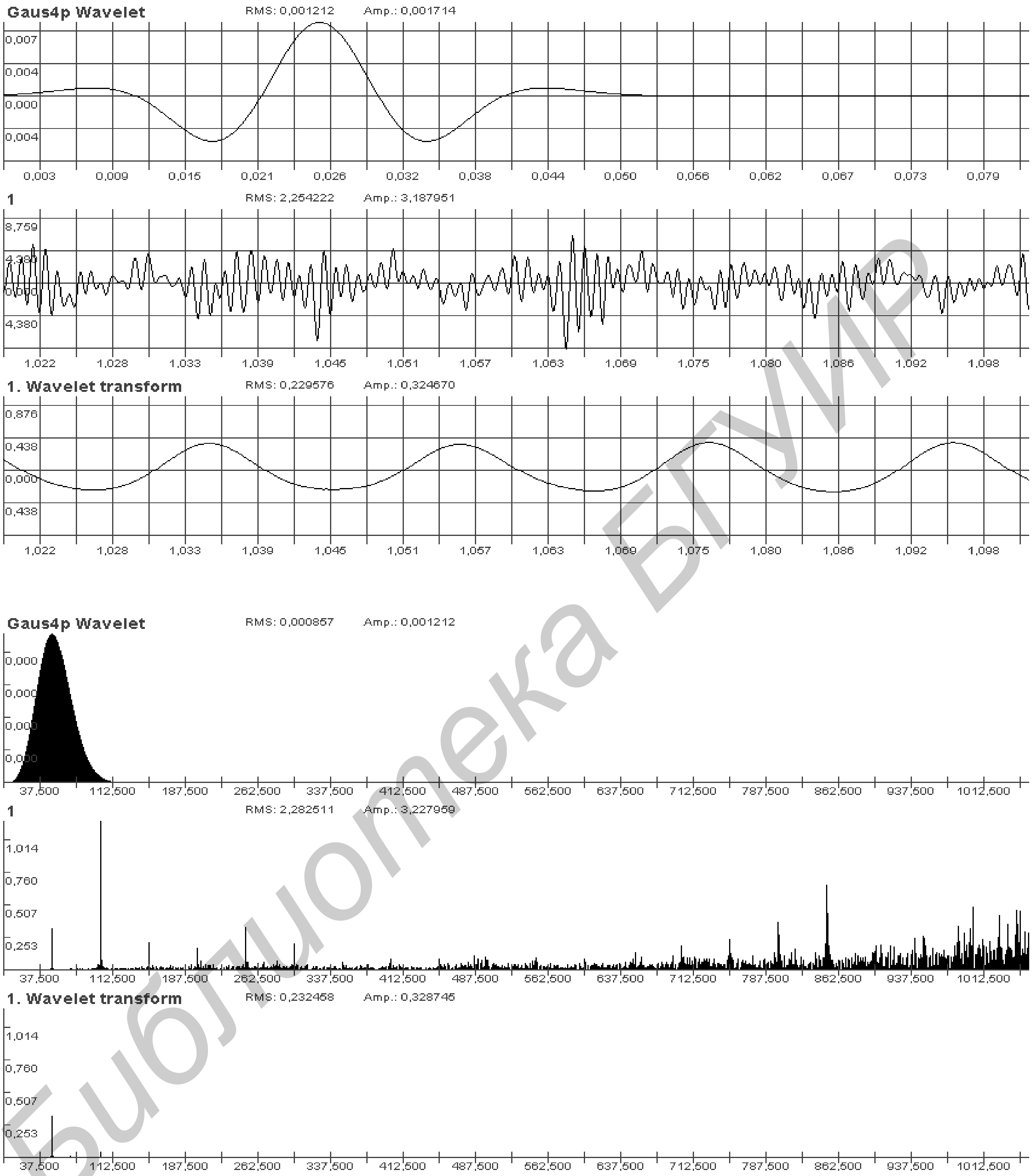

Figure 1. Gauss wavelet fourth order with a center frequency of 50 Hz, the original and the transformed wavelet vibrate in terms of acceleration and Amplitude spectra of these signals

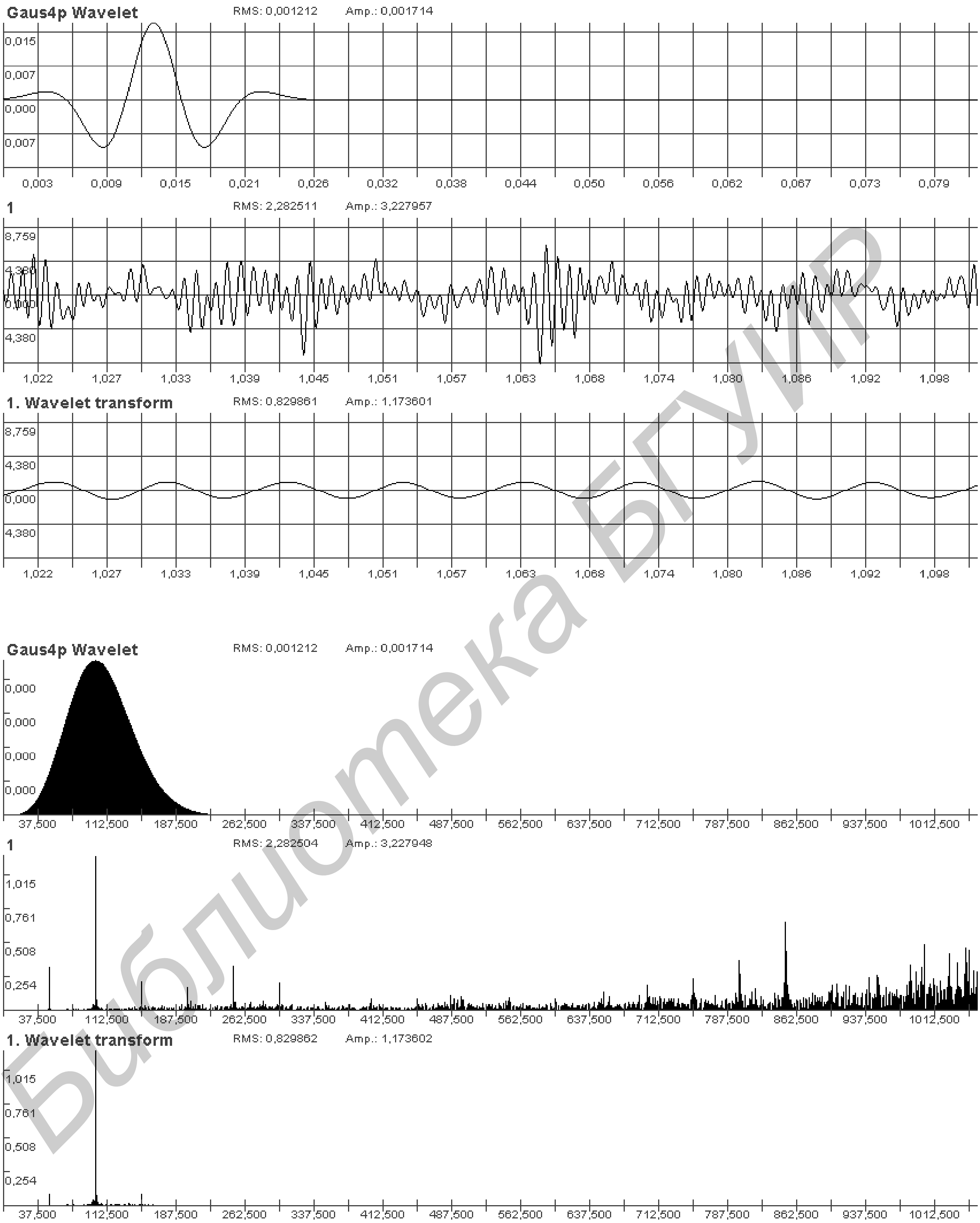

Figure 2. Form, Gauss wavelet fourth order with the central 100 Hz, the original and the transformed wavelet vibrator
in terms of acceleration and amplitude spectra of these signals

Table 1-2 shows the results for the calculation of RMS vibration acceleration and vibration velocity after processing the original vibration signal Gaussian wavelets first and fourth order with the central frequency response 25, 50, 100, 400, 800 Hz, and the total value of the RMS calculated by the formula

(5) $$w_{\Sigma} = \sqrt{w_{25}^2 + w_{50}^2 + w_{100}^2 + w_{400}^2 + w_{800}^2},$$

where w_s - RMS vibration acceleration or velocity calculated for the signal after wavelet center frequency response equal.

Table 1 - vibration when processing Gaussian wavelets first order

Center frequency response wavelet Hz	25	50	100	400	800	Total value
RMS vibration acceleration	0,103	0,434	0,861	0,775	2,21	2,53
Power of vibration acceleration	0,0106	0,1884	0,7412	0,601	4,88	6,42
RMS of Vibration	0,334	0,94	1,43	0,616	0,455	1,9
Power of vibration	0,112	0,884	2,04	0,38	0,21	3,62

Table 2 - Parameters vibrate when processing Gaussian wavelets fourth-order

Center frequency response wavelet Hz	25	50	100	400	800	Суммарное значение
RMS vibration acceleration	0,012	0,232	0,83	0,366	1,56	1,81
Power of vibration acceleration	0,00014	0,0538	0,689	0,134	2,43	3,31
RMS of Vibration	0,059	0,734	1,32	0,166	0,269	1,54
Power of vibration	0,0035	0,538	1,74	0,028	0,073	2,38

The results indicate that the wavelet transform is a variant of nonrecursive digital filter with linear phase and frequency response of the bell type, with more gradual attenuation in the higher frequencies. Therefore, you can choose, depending on the rotor speed and the type of mechanism, a set of wavelet functions, which will allocate a vibrating alarm for users of the frequency band. It provides good attenuation outside the bandwidth of wavelet function. So for the first order Gaussian wavelet attenuation greater than 20 dB is achieved at frequencies less than 0.06 f_s , and more than 40 dB at greater frequency of 3.55 f_s . For a Gaussian wavelet fourth-order attenuation greater than 40 dB is achieved at frequencies less than 0.19 f_s , and the frequency of greater than 2.2 f_s . Here - the center frequency response wavelet.

For the test signal in the frequency band of 10-1000 Hz, which is standardized to evaluate the intensity of the vibration of many mechanisms with a rotational movement RMS vibration acceleration -1.62, and the vibration velocity - 1.55. If we compare these values with the total value of the same parameters calculated for the signal after processing wavelets, we can see that the results after the wavelet transform have slightly higher values, since there are overlapping frequency response of individual wavelets. Although differences of vibration and not so great, especially for the Gaussian wavelet fourth order, which has a steeper response. It is also understood that the vibration signals having different frequency content, the differences in these calculations will also differ.

Analysis of the results shows that after wavelet transform takes good suppression of low-frequency drift and noise, which may introduce significant errors in the calculation of RMS vibration.

4. Conclusion

Choosing the width of the wavelet function can be recovered signal in a certain frequency band-term, and then calculate the vibration parameters for this frequency band. It should be borne in mind that the frequency band after wavelet transformation may cover several circulating components of the vibration or informative significant spectral components present in the original signal, with different coefficients of suppression.

You can pick up a set of wavelet functions to their width, which will overlap some, sufficiently wide frequency range, and calculate estimates of some parameters (eg RMS) for the entire frequency range based on the values of these parameters obtained after processing of vibration signals extracted from the individual wavelets set.

When used in processing systems vibro-signals sets of wavelet functions should be noted that the frequency bands allocated to the individual wavelets can overlap, and significantly.

Wavelet function quite effective in minimizing the impact of slow drifts constant component.

In addition to standardized assessment system technical condition of rotary type, based on the control of RMS vibration in the frequency band of 10-1000 Hz, can be developed a system for assessing the technical state-controlled mechanism as a whole, or the degree of development of individual defects based on the change in the intensity of the vibration frequency bands allocated wavelet function. The criterion for the transition from one state to another can take the change in intensity of vibration in wavelet band by 4 dB (as stipulated standards [5]), or both, theoretically grounded and experimentally confirmed, value. Such an extension of the functionality of vibration control systems, monitoring and protection aimed at improving the efficiency of their work and a more rapid adaptation to application on objects that do not have the rate of vibration.

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