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MULTIFUNCTIONAL ANALYSIS OF LONG REALIZATIONS OF VIBRATION SIGNALS

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Modern computer or embedded systems make it possible to obtain long (tens of seconds, minutes, hours, days) realizations of vibration signals, which continuously reflect the vibration state of the investigated mechanism in different modes of operation. Received large amounts of data are subject to rapid automated processing, to provide the user with the required information and the formulation of conclusions about changes in the technical state of the controlled object. The decomposition into periodic and noise-like components, wavelet analysis, Hilbert-Huang transform, as methods of primary transformation of initial vibration signals and representing it as a composition of components. The next step is to determine the values of the parameters of the obtained components of the expansions and plotting time trends of the calculated parameters. Next, assess the changes in the parameters of the components and their time trends and make decisions on the technical condition of the monitored technical object.
Keywords: vibration, control, digital signal processing, monitoring

1. Introduction

To obtain information about the vibration state of the monitored equipment and its analysis, it is currently advisable to use measuring and computing complexes and systems, distributed collection and centralized processing systems, to continuously monitor the state of the object, record rare and short-term anomalous situations, store large amounts of received data, implement a variety of processing and diagnostic algorithms. Building such systems for the purpose of monitoring the overall level of vibration, its individual spectral components, vibration characteristics of starts and runs, have been worked out to some extent [1-7].

One of the most advanced are multichannel stationary measuring complexes or systems for continuous vibration control. It is allowed to receive information of various types: (RMS of the general level, spectral components of vibration, phase vectors, histograms of distributions, etc.) in continuous operation and save the received data, and also carry out the functions of warning and protection. This mode of operation makes it possible to comprehensively monitor the state of the object and identify even rarely occurring anomalous situations, which makes it possible to detect the initiation of defects at the earliest stages. But such systems are relatively expensive. However, the expediency of their application is undeniable at economically important and complex technical facilities [6-8].

2. Analysis of vibration signals in an emergency situation

When operate complex mechanisms and rotary-type units using standard systems and measure and compute complexes the tasks of current vibration control, monitoring and protection are being solved [1,3,8]. Let us consider the situation of a change in the vibration state of an expander-generator unit (EGA) when change its operating modes. EGA consists of a generator (4 points of control, vertical and horizontal directions of vibration of bearing supports), a gearbox that reduces the shaft speed from 9600 min^{-1} (160 Hz) to 3000 min^{-1} (50 Hz) (3 points of control), a turbo expander - a turbine operating on the basis of the use of the energy of the differential pressure of natural gas, when it is throttled before burning (3 points of control). Turbine shaft speed is 9600 min^{-1} (160 Hz) .

During the operation of the EGA in certain modes of its operation standard vibration control system [7] the facts of an abrupt change in the root mean square value (RMS) of the vibration velocity on the turboexpander were recorded (figure 1). The data acquisition period of each vibration sensor is 2 seconds.

Figure 1: Change in RMS vibration velocity when changing the operating mode of the DGA. The jump in the RMS vibration velocity of the vertical direction of the turbine

To find out the reasons for this situation, analysis the continuous vibration signal that excited on the turbine housing during the occurrence of abnormal situations[9]. The received signal is processed in different ways: averaging in the time domain [10], wavelet analysis [11,12], decomposition into periodic and noise-like components [13, 14], band spectral analysis [15] and Hilbert-Huang transform [16].

Figures 2-3 show the vibration signal for vertical direction of the turbine in units of vibration acceleration and the amplitude spectrum of this signal during normal operation of the EGA. Figure 4 shows the same vibration signal and amplitude spectrum, but after averaging the vibration signal in the time domain synchronously with respect to the frequency component of 160 Hz, the turbine shaft speed.

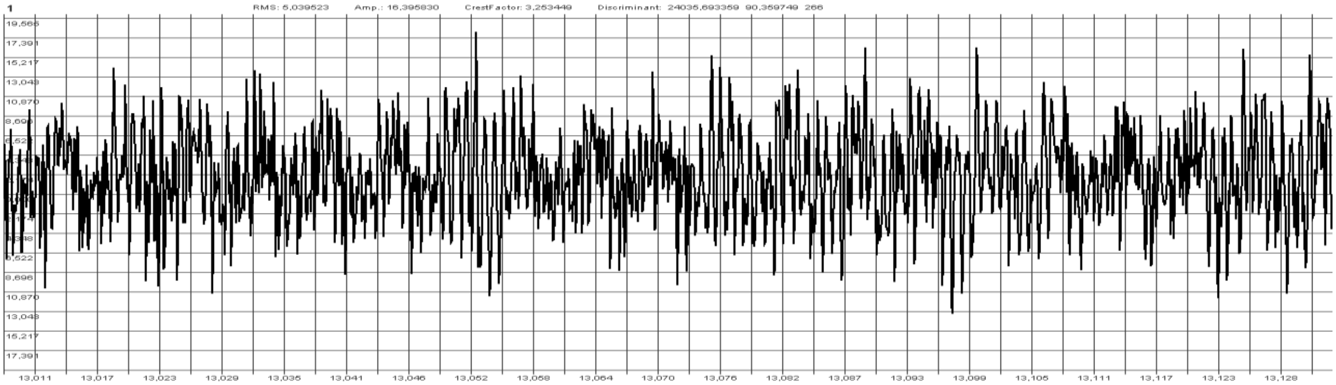

Figure 2: Temporary implementation of a vibration signal in normal turbine condition.

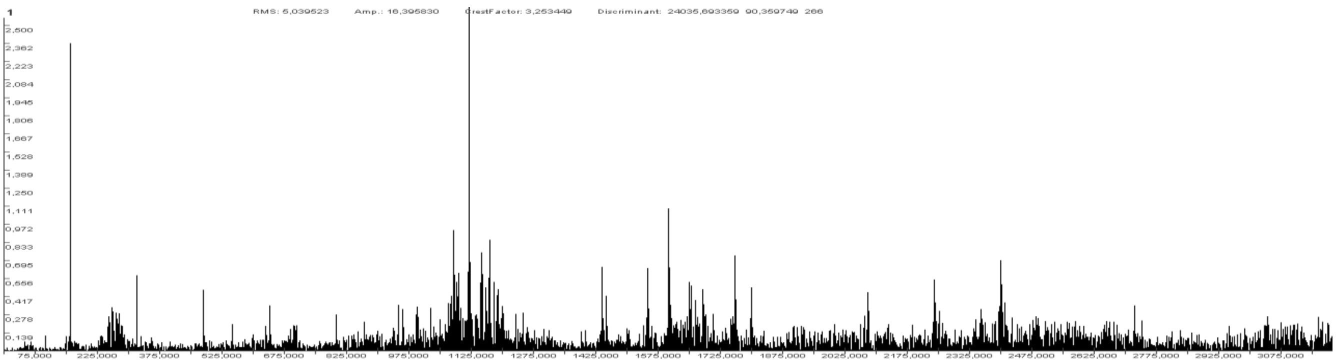

Figure 3: Amplitude spectrum of the vibration signal in the normal state of the turbine.

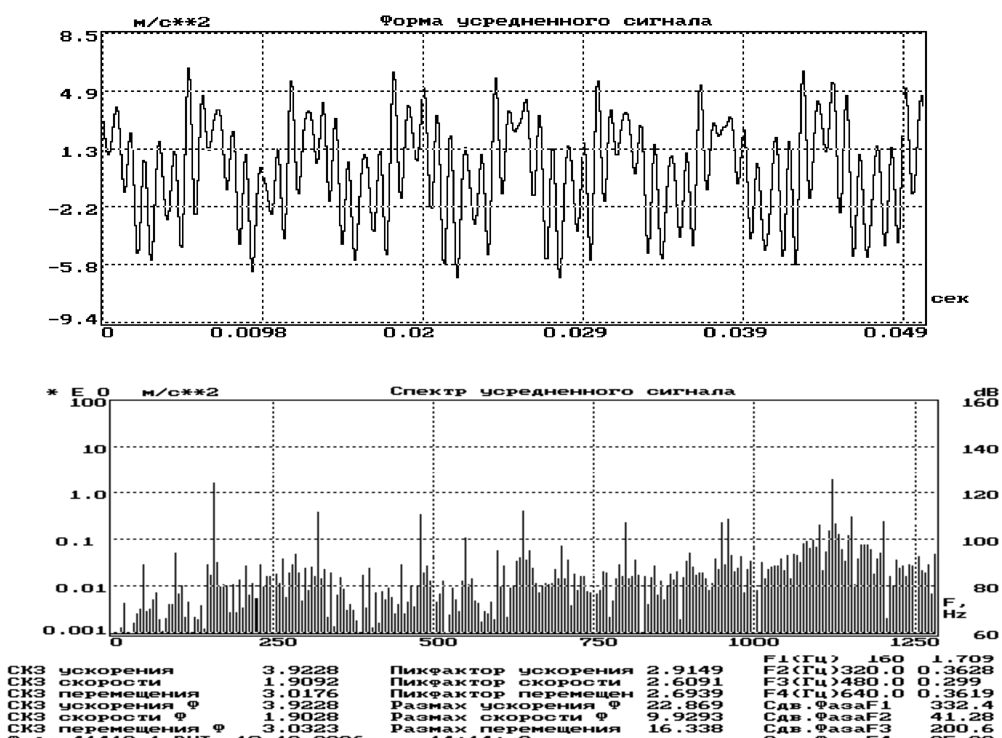

Figure 4: Vibration signal, averaged in the time domain synchronously with the frequency component of 160 Hz, turbine shaft speed, during normal operation

Good visibility, after averaging in the time domain, the periodic structure of this signal appears and random noise and interference are suppressed. The vibration signal for the vertical direction of the turbine after an emergency is shown in the figures 5-6.

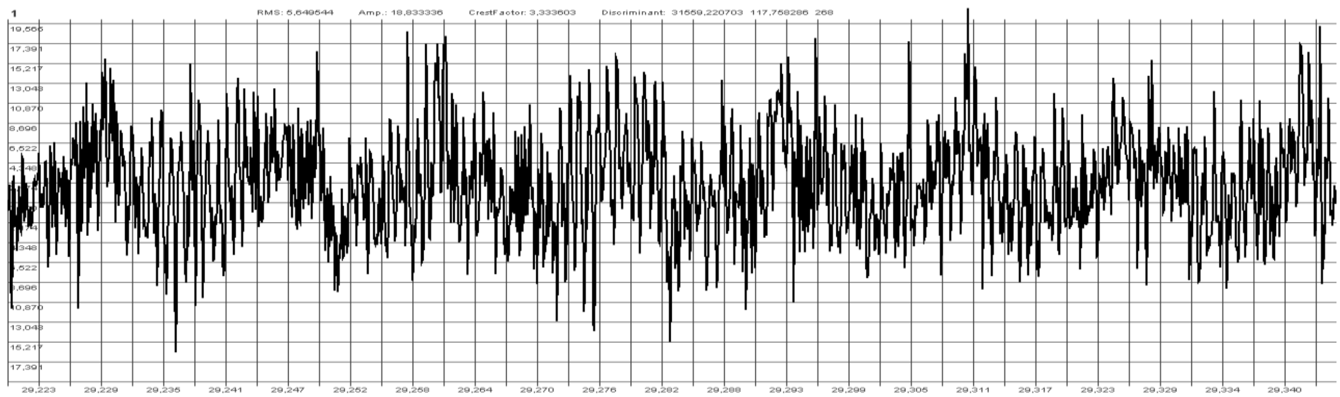

Figure 5: Temporary realization of a vibration signal in an emergency condition of the turbine.

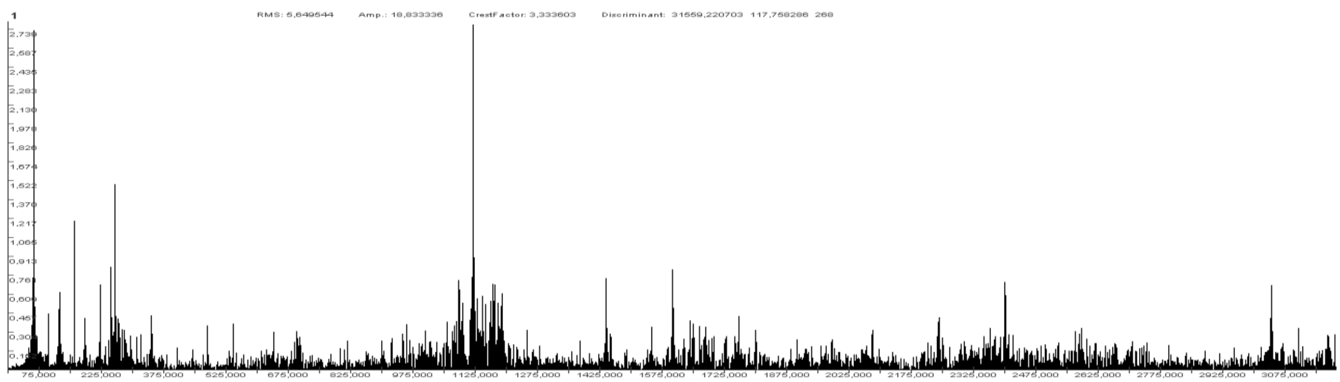

Figure 6: Amplitude spectrum of the vibration signal in an emergency condition of the turbine.

A distinctive feature of this vibration signal is the appearance of predominant amplitude, whose frequency component is equal to 62 Hz, which is not a multiple of the turbine shaft speed.

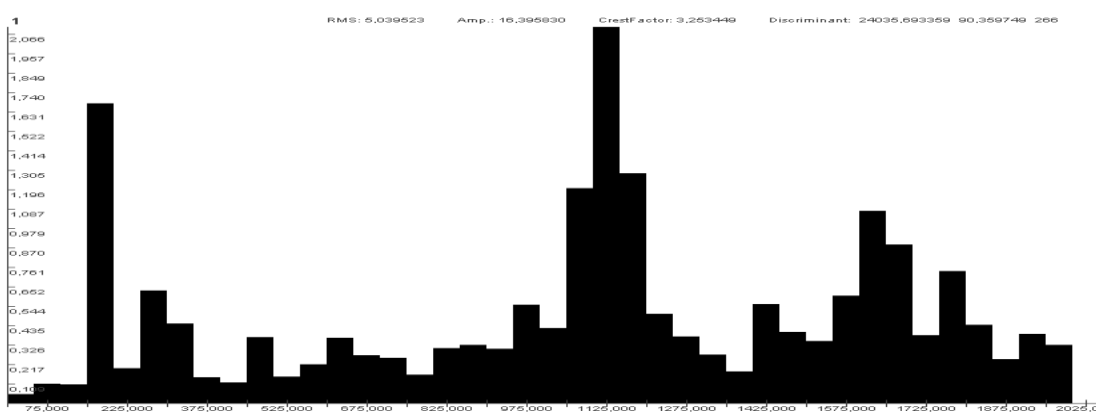

Figure 7: Band spectrum at normal turbine state

Changing the frequency composition of the vibration signal for an emergency condition well observed in the band spectrum, where the frequency bands are in 50 Hz steps (figures 7-8).

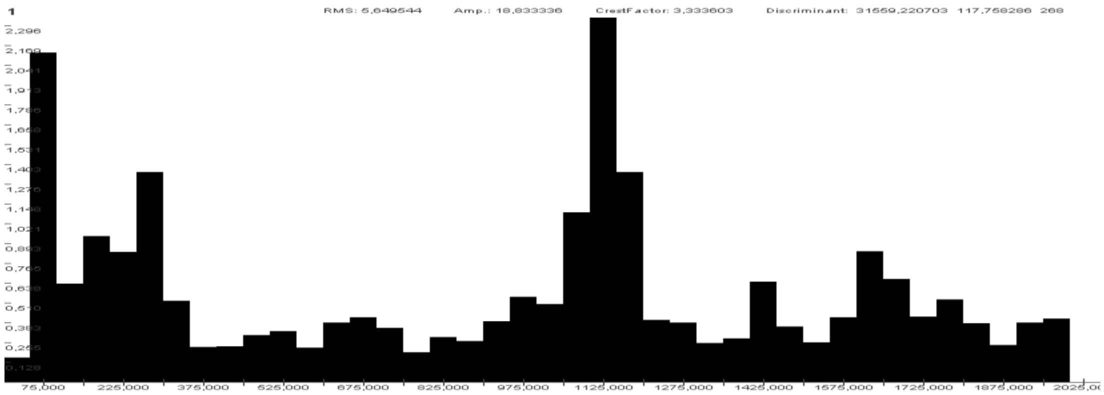

Figure 8: Band spectrum of vibration signal during turbine emergency state.

To determine the interdependencies of the frequency components of the vibration signal, it is averaged in the time domain with respect to the frequency component 160 Hz (figure 9) and a frequency component of 62 Hz (figure 10). This study shows that the frequency components that are multiples of 160 Hz and frequency components that are multiples of 62 Hz are absolutely not interconnected, since there is their mutual suppression with synchronous averaging in the time domain. Blurring of frequency components, multiples of 62 Hz, occurs due to that time interval is not a multiple of the frequency component period 62 Hz.

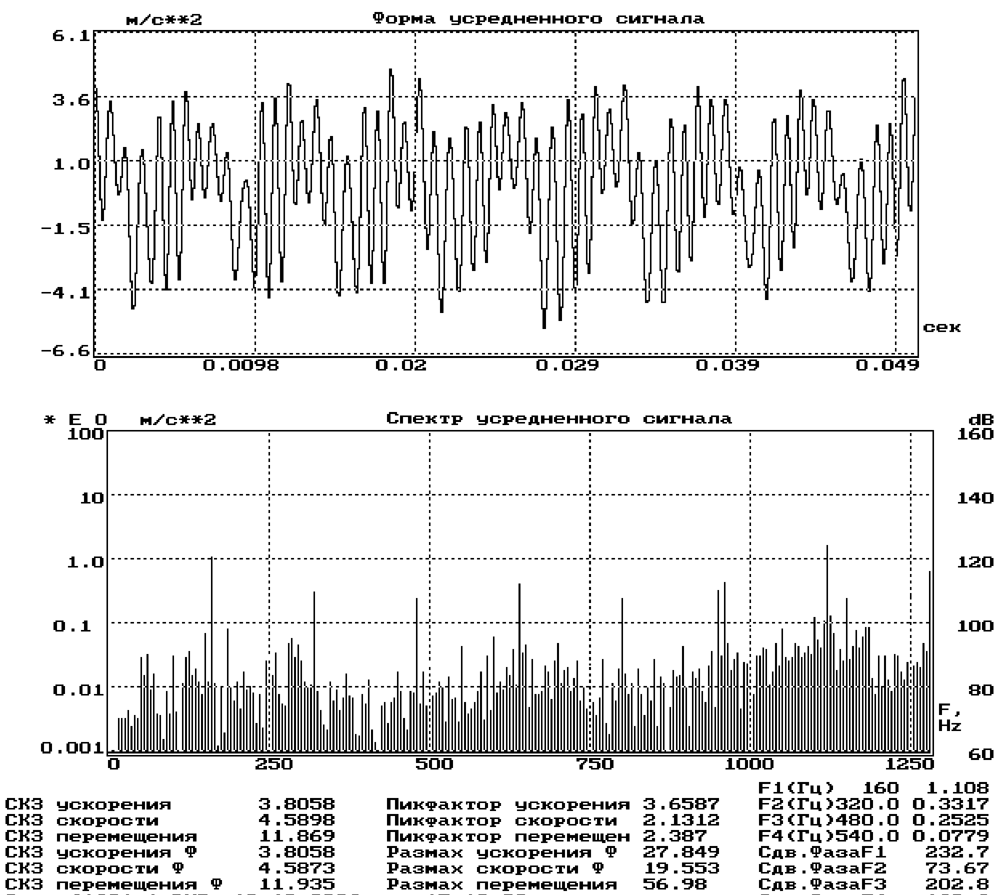

Figure 9: Vibration signal, averaged in the time domain synchronously with the frequency component of 160 Hz, turbine shaft speed, in emergency operation

Figure 10: Vibration signal, averaged in the time domain synchronously with the frequency component of 62 Hz, basic disturbance frequency in emergency operation

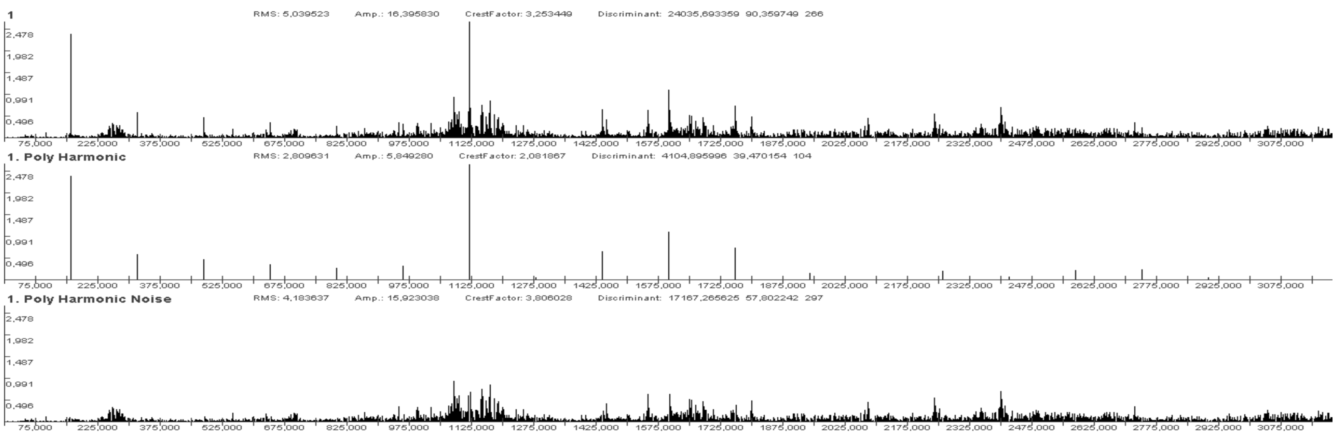

Figure 11: Decomposition of the vibration signal into periodic (frequency 160 Hz) and noise-like components in the normal state of the turbine.

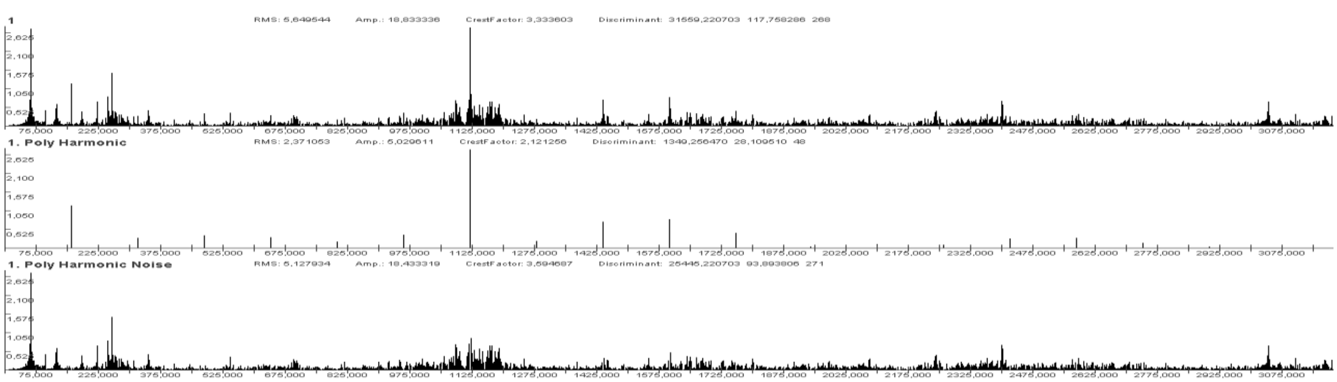

Figure 12: Decomposition of the vibration signal into periodic (frequency 160 Hz) and noise-like components in an emergency condition of the turbine.

The structure of vibration signals can be studied in more detail by decomposing them into periodic and noise-like components (figures 11-14). Decomposition of vibration signal, obtained during normal operation of the turbine (figure 11), clearly distinguishes the periodic component, with a period of 160 Hz and noise-like. Decomposition of vibration signal, obtained during emergency operation of the turbine (figure 12), splits the signal into a periodic component, with a frequency period of 160 Hz, and the remainder is noise-like component plus additional component. Figure 13 shows the decomposition of the hazard signal on a periodic component, with a frequency period of 62 Hz, and the remainder is a noise-like component plus a periodic component with a period of 160 Hz.

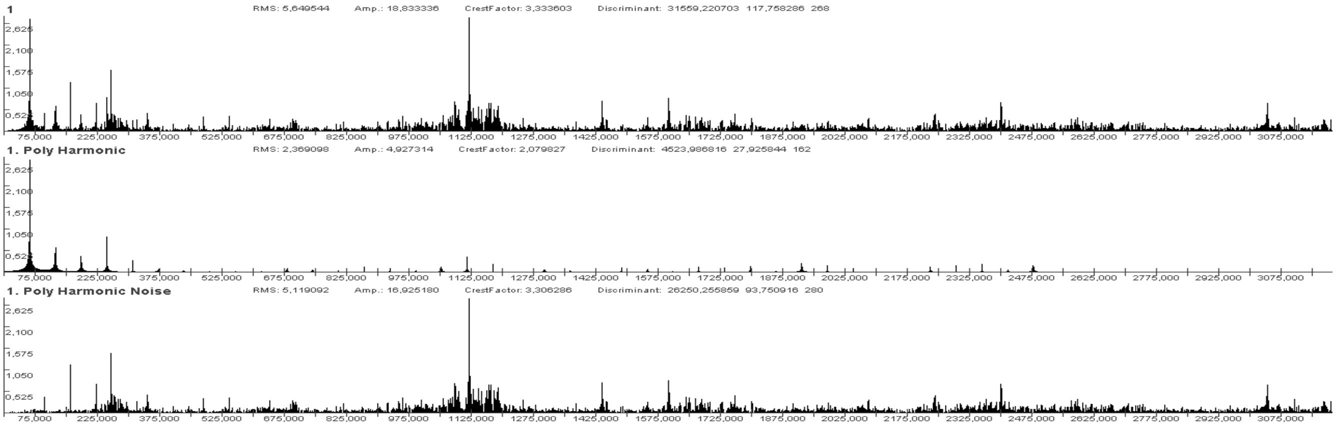

Figure13: Decomposition of the vibration signal into periodic (frequency 62 Hz) and noise-like components in an emergency condition of the turbine.

3. Conclusions

Disturbing vibration impact and vibration impact, caused by the rotation of the turboexpander shaft, are not correlated with each other. To prevent situations accompanied by an increase of the vibration of the turboexpander, the mode of operation of the EGA is recommended. The considered methods of analyzing vibration signals show that the values of various informatively significant parameters can be determined in real time, which will then be used in decision support systems according to technical condition assessment complex mechanisms and units with rotary motion [17].

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