DEVELOPMENT OF FREQUENCY-BASED TECHNIQUE OF INTERNAL COMBUSTION ENGINE DIAGNOSTICS

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Automobile engine diagnostics is one of the most important procedures during vehicle inspection because early detection of problems and troubleshooting increases vehicle uptime and decreases risks of unexpected failure. Nowadays, specialists are interested in the diagnostics techniques that do not require engine disassembly because these techniques are much cheaper, faster and do not present any potential hazard for the operating conditions of the engine.

One of the promising solutions for in-place engine diagnostics is related to frequency-based techniques, the essence of which is analyzing the frequency of vibro-acoustic oscillations occurring during engine operation. One of the possible ways to use frequency is comparing frequency characteristics of the diagnosed engine with the reference characteristics [1]. This approach is really easy to implement but its accuracy is not always sufficient for diagnostics. Further development of frequency-based technique is related to correlation analysis of signals [2]. This approach has some advantages, for example, a technique based on this idea does not need any engine reference characteristics because it is possible to indicate an engine fault only by analyzing the correlation function of the tested engine signal.

Using correlation analysis in any field of technology allows to obtain acceptable results even in the conditions of high interference when the signal to noise ratio is really low. Advanced diagnostics techniques are using modern software and hardware analysis tools, which are becoming more sensitive. In his paper, Avramchuk proposes [3] some measures to improve sensitivity. The main idea is to limit the noise impact by filtering acoustic sensor signals that contain a significant proportion of noise. That is why the mathematical apparatus of time-frequency correlation functions was developed. It allows to provide signal information not only traditionally in time domain, but in the frequency domain as well.

In this case, engine vibrations are read by a piezoelectric vibration measuring converter DN-3-M1 and recorded to the computer as a .wav file with a sampling frequency of 44100 Hz. It is possible to chart a time-frequency autocorrelation function of the signal by using specialized software [4]. This software is quite convenient because it allows to analyze this function at certain frequencies, which is very important because the operating frequency range of the vibration sensor does not exceed 4800 Hz [5].

The time-frequency function of the signal previously recorded by the vibration sensor is given below as an example. Figure 1 shows the time-frequency autocorrelation function of the vibration signal and Figure 2 shows its 3D representation.

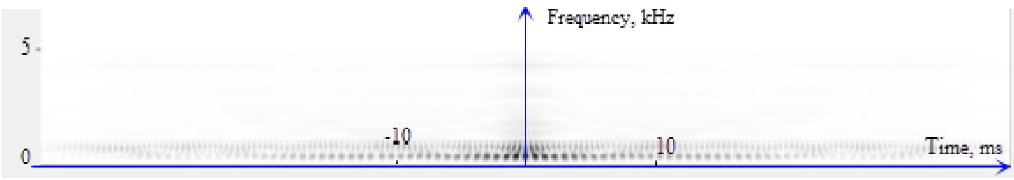

Figure 1. Time-frequency autocorrelation function of the vibration signal

As we can see from these figures, the most valuable information is the signal at low audio frequencies. The chart of the time-frequency autocorrelation function of the vibration signal has a series of local extrema that occur with a certain periodicity at different frequencies. The most clearly visible extrema occur at the audio frequencies of 300 Hz and 650 Hz, they have different periodicity which indicates a different nature of their occurrence. At the sound frequency of 300 Hz, the function reaches the extremum every 0.75 ms, which corresponds to the frequency of 1330 Hz. At the sound frequency of 650 Hz, the function reaches the extremum approximately every 0.45 ms, which corresponds to the frequency of 2220 Hz. These frequencies are directly related to engine operation and correspond to specific mechanical frequencies, for example the operational frequency of a particular mechanical element (bearing, piston in cylinder, etc.).

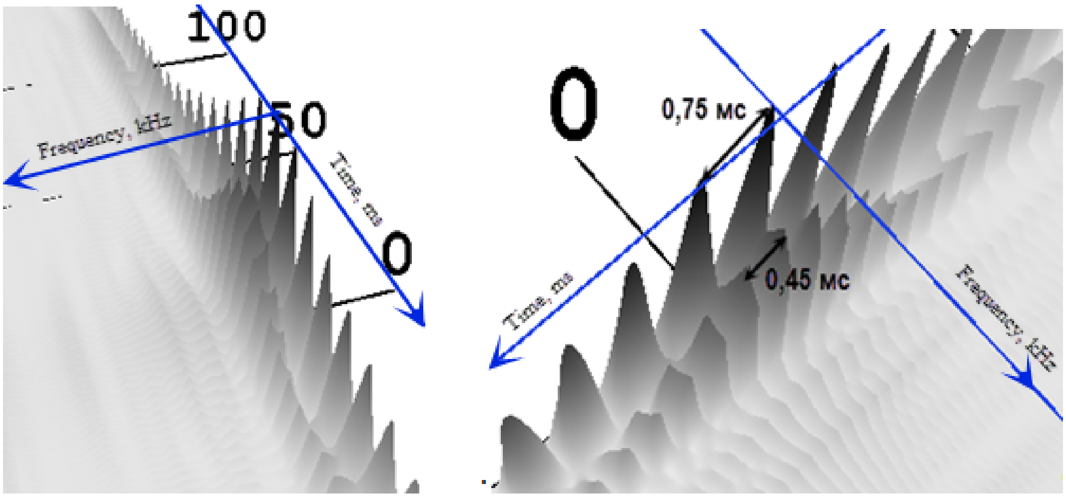

Figure 2. 3D representation of the time-frequency autocorrelation function of the vibration signal

The software settings and the considered time interval of the test signal under study also play a significant role. Different time intervals and software settings lead to different results, which makes it possible to identify new previously unidentified frequencies corresponding to other mechanical frequencies.

The article presents a part of the results of analyzing the time-frequency autocorrelation function of a car engine. Certain frequencies were recorded that have important information about signals in audio frequencies that correspond to different mechanical units. Further work is based on establishing the compliance between recorded frequencies and mechanical units.

References

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