THEORETICAL VERIFICATION OF ENVELOPE ANALYSIS OF ROLLING ELEMENT BEARINGS WITH USING MATLAB

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ABSTRACT

This text examines envelope analysis, which is the most used Method for diagnostics of rolling element bearings. The study is realized in Matlab, where is monitored every step of this method. Results are compared with results from Envelope Analysis module 7773 of Multianalysator PULSE (Bruel & Kjaer). Whole study is the first step in investigation of posibility of using Electro-Magnetic Acoustic Transducer (EMAT) for diagnostic of rolling element bearing. EMAT then should guarantee better sensitivity of this method.

1. INTRODUCTION

Nondestructive testing (NDT) is very important problematics in condition monitoring of dynamic machines. In our case we are talking about rotating machines. Rolling element bearing is one of most often used parts in this area and their failures can often conduce to expensive losses. Early recognition of these failures is very important and envelope analysis is one of methods used for it. Traditional envelope analysis is using accelerometers, which are sensors of vibrations working in area around to 20kHz. This area can be called area of machanical vibrations. EMAT transducer operates in areas of essentialy higher frequencies, accordance with its design from hundreds kHz and higner, thus we talk about ultrasound area. Envelope analysis consists of these steps: Fourier transformation, band pass filtering of choosen frequency area, amplitude demodulation and if needed frequency averaging. Module 7773 enables this method in real time with many various properties. In this experiment it was used for comparing of final results with results from Matlab and for data acquisition for Matlab too.

2. ANALYSIS

Rolling element bearing (in experiment cylinder type) with failure is producing typical vibration signal. It is a series of impulses (close to Dirac) with frequency dependent on size of bearing. Every part of bearing (inner ring, outer ring rolling elelments or cage) can produces this signal [5]. In our case was the outer ring harmed (groove perpendiculer on direction of rolling). Frequency of impulses was determined

85Hz. First step in envelope analysis for rolling element bearings diagnostics is dettermination of area in frequency domain used for band-pass filtering. The frequency spectrum of measured vibration signal or frequency spectrum of response on impulse excitation (modal analysis) is needed for it. In figure 1 is time signal of acceleration of vibration and in figure 2 is frequency spectrum of this signal.

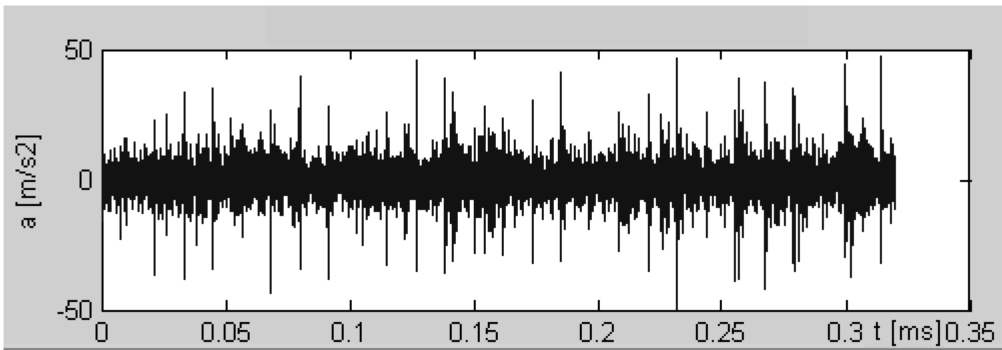

Figure 1: Acceleration vibration signal

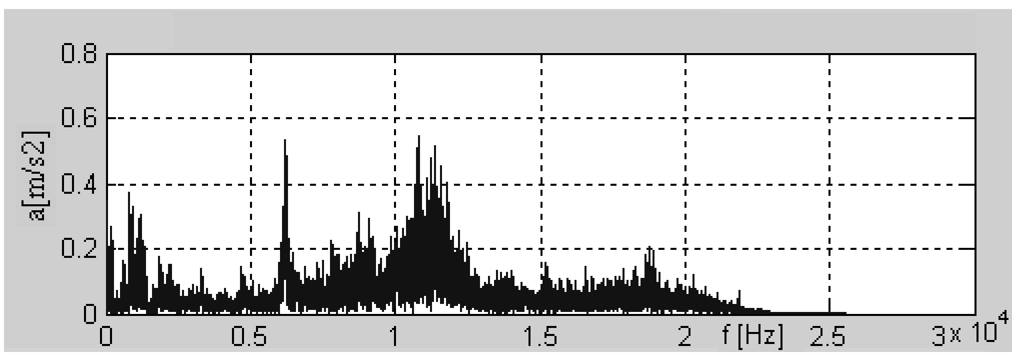

Figure 2: Frequency spectrum of acceleration vibration signal

Every part of machine has its own resonance frequency. We can talk about systém with more degrees of freedom. For determination of central frequency of bandpass filter is ordinary choosing meachanical resonance area of bearing housing. It can be verified with realization of modal analysis, which results are shown in figure 3.

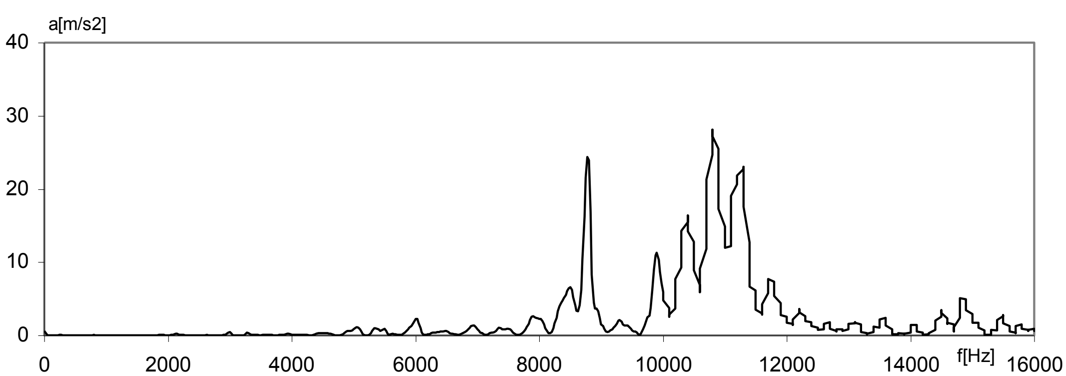

Figure 3: Response on impulse interaction

In mechanical resonence area (accordance with figure 2 and 3 area around 12kHz) the bearing failure signal is amplified and the signal-noise ratio dramatically increases. For the filtration was used Butterworth band-pass filter of 20^{th} order. Filtered signal is displayed in figure 4.

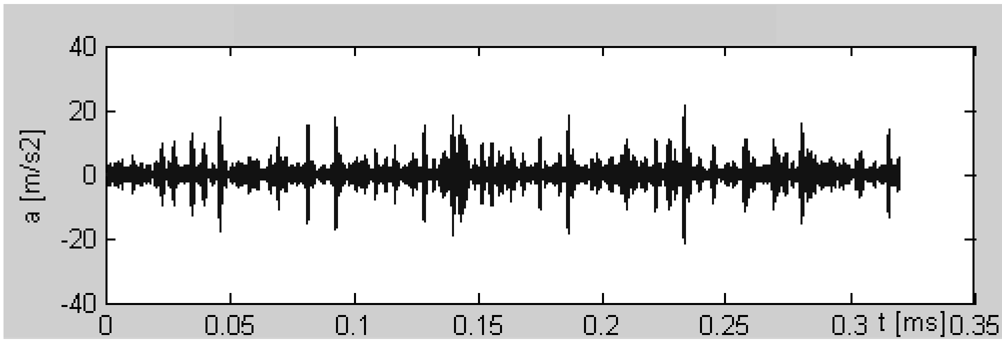

Figure 4: Vibration signal after band-pass filtration

Other step is amplitude demodulation. In Matlab environment was used Hilbert transformation. It is defined with formulation (1)

$$h(t) = H\{x(t)\} = \frac{1}{\pi}\int_{-\infty}^{\infty}\frac{x(\tau)}{t-\tau}d\tau = (\pi t)^{-1} * x(t) = F^{-1}\{-j \cdot sign\,\omega \cdot F\{x(t)\}\} \quad . \qquad (1)$$

In Matlab computation was used function *hilbert(...)*, and then along formulation (2)

$$z(t) = \sqrt{x(t)^2 + y(t)^2} \cdot e^{j\beta} = E(t) \cdot e^{j\beta} \; . \qquad (2)$$

was found analytical signal, which absolute value is demodulate (envelope) of original signal. In formulation (2) E(t) is envelope of signal, x(t) is original signal after band-pass filtration and y(t) is Hilbert transformation of this signal [3]. Frequency spectrum of demodulate signal is in figure 5. For elimination of mirror part of frequency spectrum which develops after demodulation is need for low-pass filtration with cutt off frequency bigger then half of width of band band-pass filtering.

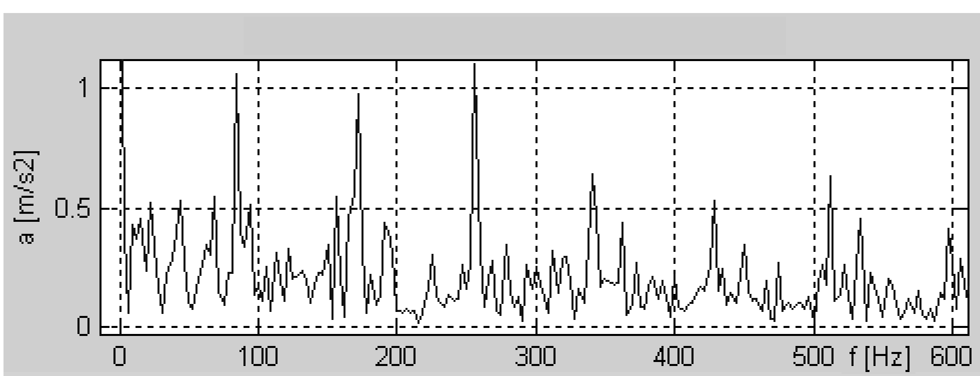

Figure 5: Envelope spectrum of vibration signal

For better results conserning appearance and expliciteness of results is often executed averaging. Because there is no point in time averaging in our case, it was done a frequency averaging from 30 measured intervals of signal [2]. Result of averaging along with final result of experiment is shown in figure 6.

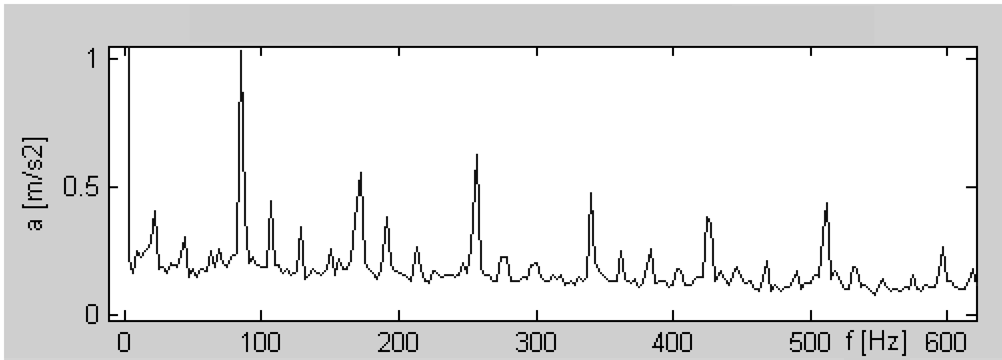

Figure 6: Envelope spectrum of vibration signal after averaging

For comparison there is in figure 7 shown an envelope spectrum measured with multianalysator Pulse.

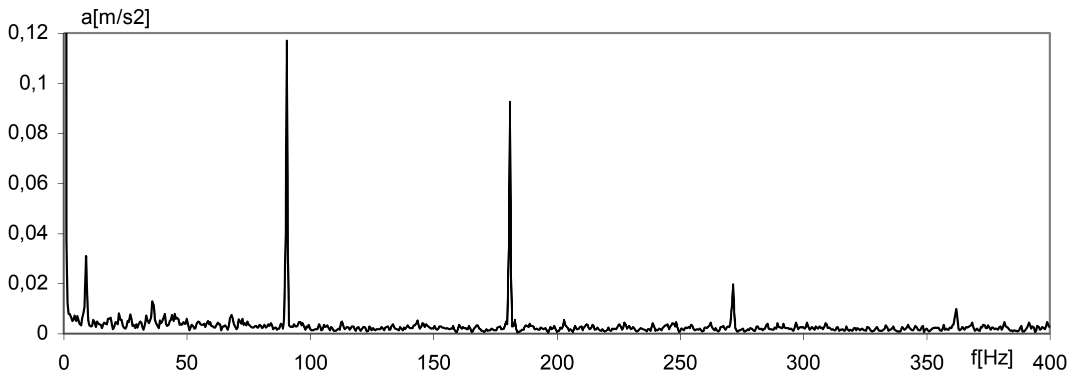

Figure 7: Envelope spectrum of vibration signal from MA Pulse

As you see, results are equal in typical frequency pointing failure of outer ring. Amplitude of specified harmonic componets is not important for determining of condition of bearing. Failure of bearing (for example pitting) is verified by presence of typical harmonic components.

3. CONCLUSION

There was verified posibility and veracity of results of envelope analysis realized in Matlab environment in this text. In other research will be examined posibility of using an EMAT transducer for realization of envelope analysis in rolling element bearing nondestructive testing. Because bearing during its failure produces typical signal characterized by series of very narow impulses, there is a assumption of very wide frequency spectrum of this signal. There we can find a large advantage against low frequency realization with aid of accelerometers, which is decrease of disturb signal. It increases sensitivity of envelope analysis, which is very important for much earlier recognition of bearing failure. Then we can find there a relative analogy between proccesing by accelerometers and EMAT transducer. Because EMAT transducer is basically coil, so with joining capacitor we can achieve amplifying of signal with aid of resonance effect similar with mechanical resonance effect in low frequency band. Envelope of measured signal with EMAT sensor will then be calculated with procedure verified in this text.

ACKNOWLEDGEMENT

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