Spectral Ratio Method for Fault Detection in Rotating Machines

J. Dikun, D. Stanelyte, L. Urmoniene

***Abstract*—This study presents the ratio, which is defined between two vibration signals in the spectral domain, to be used in extracting the fault signatures from the signals. These two signals are considered as two different cases of the electric motor of 5 HP in terms of the faulty and healthy motor cases and hence, the comparison between two spectral variations is used as a method to show the fault characteristic. In this manner, the bearing damage of the electric motor of 5 HP are given within the range of 0-4 kHz and its J-curve is presented as an indication of the motor aging.**

Index Terms—**Spectral Analysis, Electric motor, Machinery aging, Fault detection.**

I. Introduction

ELECTRIC motors play very important role in most industrial application. In this manner, safety operation of the electric motors under the different conditions are highly connected with the process reliability. In order to determine the faulty characteristics of the electric motors, there are two important approaches in the literature. One of them is model-based detection, another one is also signal based approach. In the signal-based approach, the most popular method is spectral method, which is based upon the Fourier Transform [1,2]. Nowadays, another popular method is wavelet transform and its different types in usage [2-4]. The wavelet transform based methods or applications are very powerful methods. As an example, Multi-Resolution Wavelet Analysis (MRWA) is in the form of the signal decomposition and hence, the signal to be analysed can be separated to subbands as filter outputs to extract the faulty signal band [3-7]. In addition, Continuous Wavelet Transform (CWT) is another alternative method to indicate the faults. The CWT has an additional property that is defined as redundancy, and hence it is used for the early detection of the faulty cases [3-6].

J. DIKUN, is with Department of Electrical and Mechanical Engineering, Klaipada State University of Applied Sciences, Klaipeda, Lithuania, (e-mail: jeldik@bk.ru).

D. STANELYTE, is with Department of Electrical and Mechanical Engineering, Klaipeda State University of Applied Sciences, Klaipėda, Lithuania, (e-mail: d.stanelyte@kvk.lt).

L. URMONIENE, is with Department of Electrical and Mechanical Engineering, Klaipeda State University of Applied Sciences, Klaipėda, Lithuania, (e-mail: lione.urmoniene@gmail.com).

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Meanwhile artificial intelligence based methods, like neural networks and fuzzy logic approaches are used for the feature extraction of the electric motor current or vibration signals [7-9]. Sometimes, instead of these methods, just statistical calculations can be sufficient to detect the faulty cases by means of the statistical parameter variations [6-11].

In this study, as an alternative approach to the fault detection methods defined in the literature above, a simple calculation defined as a ratio between two vibration signals of an induction motor of 5 HP is introduced and used to extract the faulty case. This study has so many advantages over the other classical methods: One of them is feature extraction in frequency domain and the determination of motor aging curve. In addition, the frequency range that is related with the faulty case can be identified depending on the apriory knowledge [11-15].

II. Power Spectral Density Calculation and Spectral Ratio

The Fourier transform is used to analyse a time-domain signal [1-3]. Nowadays, depending on developing of the fast computers, the Discrete Fourier Transform (DFT) are easily used for the signal analysis.

For a given data of N-samples, the transform at frequency $m\Delta f$ is given by following equation:

$$X(m\Delta f) = \sum_{k=0}^{N=1} x[k\Delta t]\exp(-j2\pi Nmk) \tag{1}$$

Here: Δf - is the frequency resolution,

$X(m\Delta f)$- the DFT of the signal $x(t)$,

The $Y(m\Delta f)$ becomes of the DFT the signal $y(t)$.

The autopower spectral densities (APSDs) of $x(t)$ and $y(t)$ are estimated as below:

$$S_{XX}(f) = \frac{1}{N}|X(f)|^2 \tag{2}$$

Where: $f = m\Delta f$

With the similar way, it is rewritten for the signal $y(t)$, as Syy:

$$S_{YY}(f) = \frac{1}{N}|Y(f)|^2 \tag{3}$$

The statistical accuracy of the estimate in Eqs. (2) and (3) increase as the number of the data points N. Hence, the spectral ratio can be given by the following equality:

$$R(t) = \frac{S_{YY}}{S_{XX}} \tag{4}$$

III. MEASUREMENT SYSTEM AND APPLICATION

In this study induction motor of 5 HP is used for the test motor. After the accelerated aging studies of the motor [1,2], in order to detect and extract the bearing damage signatures, the following data collection system is used as shown in Figure 1. During this procedure, the sampling rate is selected at 12 kHz and cutoff frequency of the low pass filter used in the signal conditioner unit is at 4 kHz. Also, the bandwidth of the accelerometer is 20 kHz.

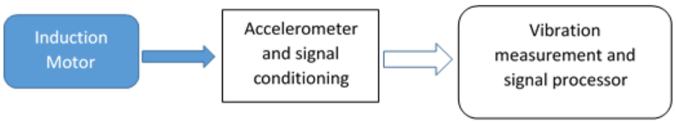
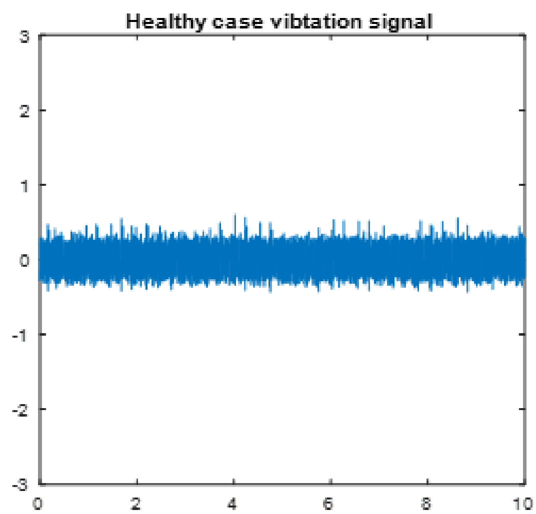
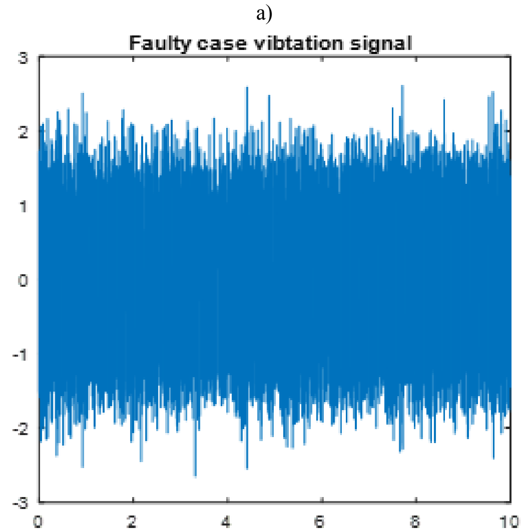


Fig.1. Schematic Diagram for measurement system.

After the accelerated aging tests, motor performance is tested between the healthy motor case (initial case) and faulty motor case (final case) in terms of the vibration signals. In this manner, these vibration signals are given by the following figures, Figure 2 (a) and (b).



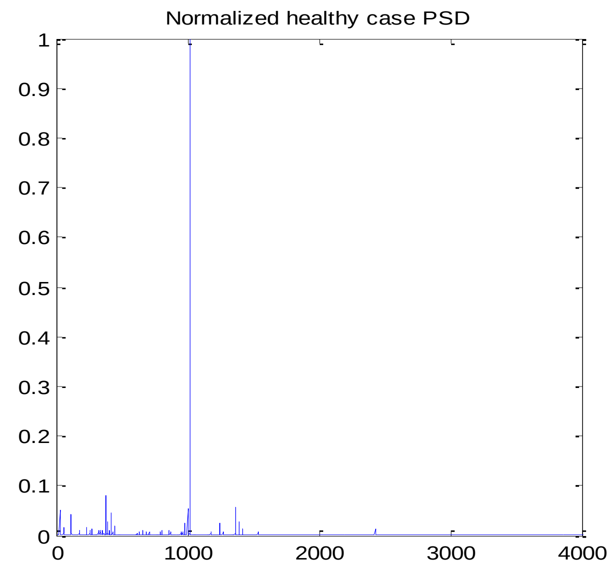
a)



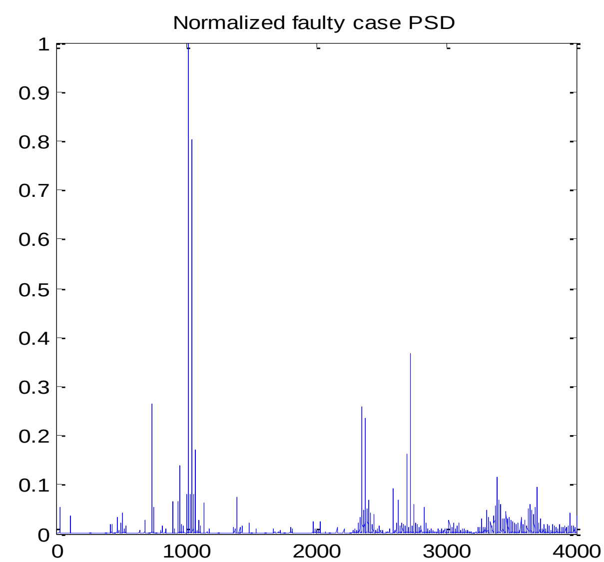
b)

Fig.2. Vibration measurements a) Healthy case, b) Faulty Case.

In addition to the vibration measurements in the time domain, their power spectral density variations can be shown in the frequency domain as follows:



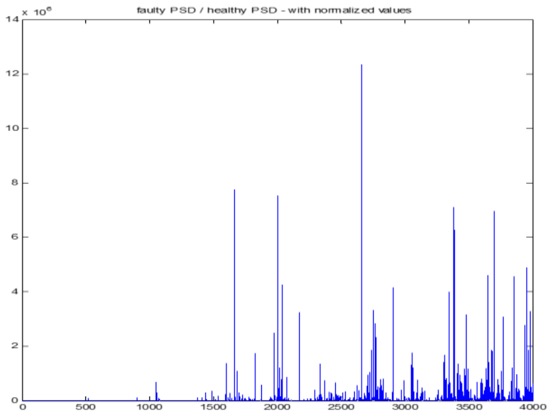
a)



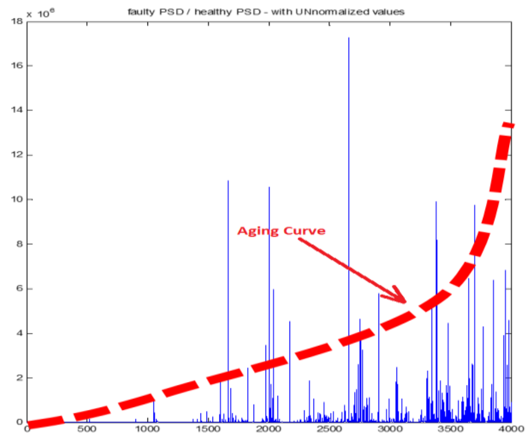
b)

Fig.3. Power Spectral Densities of the Vibration signals a) Healthy case, b) Faulty case.

Comparing the vibration signals, it is seen that there is a increasing in the signal amplitudes and, also, some additional frequencies are appeared between the 2 and 4 kHz as an indicator of the bearing damage occurred at the end of the aging tests. Hence, these are called as the signatures of the bearing damage. After the feature extraction, which is related with the motor bearing damage. On the same data of the power spectral densities, the spectral ration variation that is defined by the Eq. (4) is calculated and it is shown by the following figures as well as aging curve.



a)



b)

Fig.4. Spectral Ratio of the Vibration spectra measurements (a) and aging curve (b).

IV. CONCLUSION

In this study, some characteristics based upon bearing damage of the induction motor of 5 HP was examined and its aging cure was extracted from the experimental data. As seen in the figure (4), the upper critical frequencies of the motor in terms of the safety operation conditions can be indicated at around of the turning point of the aging curve after 3.5 kHz. This is also expected situation because the bearing damage was characterized between 2 and 4 kHz.

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BIOGRAPHIES

Jelena DIKUN Received the BS Degree in Electrical Engineering Science from Klaipeda University in 2010, the MS Degree in Electrical Engineering Science from Klaipeda University in 2012. Currently she is working as a lecturer in Lithuanian Maritime Academy as well as in Klaipeda State University of Applied Sciences. Her primary research interests include electromagnetic radiation, ships' electrical systems, electrical machines and apparatus, electrical measurements technologies.

Lione URMONIENE Received the PhD Degree in Electrical Engineering Science from Kaunas University in 2012. Currently she is working as an Assistant Professor in Klaipeda University as well as in Klaipeda State University of Applied Sciences. Her scientific interests includes oscillated electrical machines, electrical drives, drives control systems and automated drives control systems.

Daiva STANELYTE Received the MS Degree in Informatic Engineering Science from Klaipeda University in 2010. Currently she is a PhD student of Kaunas Technology University at Energy and Thermo Engineering Faculty. At present time, she is working as a head department of Mechanical and Electrical Engineering in Klaipeda State University of Applied Sciences. Her field of scientific research are industry systems automation and energy production, distribution and consumption.