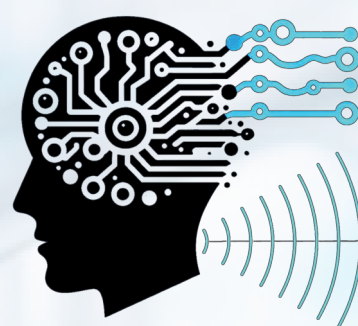


BUDOWA ALGORYTMÓW ŚLEPEGO PRZETWARZANIA SYGNAŁÓW, OPARTYCH NA GEOMETRYCZNEJ STRUKTURZE INFORMACJI, ORAZ ICH ZASTOSOWANIE W METROLOGII I DIAGNOSTYCE MASZYN

Development of blind signal processing algorithms based on the geometric structure of information and their application in metrology and machine diagnostics

PhD. MSc Eng.
Dariusz Mika



Assoc. Prof. PhD.
Jerzy Józwik



PhD. MSc Eng.
Paweł Pioś



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Institute of Technical Sciences and Aviation,
The Univ. College of Applied Sciences in Chelm, Poland

ABSTRACT

The paper presents the concept of using a Blind Source Separation (BSS) algorithms to diagnose localized faults in rolling element bearings. These bearing faults usually result in strong harmonics of the fault frequencies along with sidebands in the spectrum of the vibration signals. We have shown that separation of vibration signal components containing these fault frequencies enables more effective bearing diagnostics. We have used linear BSS algorithms as well as nonlinear version. The conducted experiment showed an increase in the effectiveness of fault detection for all types of simulated bearing damages. Achieving this goal will enable the construction of an expert system for diagnosing the condition of technical devices based on the analysis of the vibro-acoustic signal generated by the operating device.

INTRODUCTION

Rolling element bearings (REBs) are one of the most widely used elements in machines and their failure one of the most frequent reasons for machine breakdown. They are widely used in motors, gas turbines, pumps and many other machines. This has prompted a great deal of research on vibration-based diagnostics of REBs over the last few decades, and the area is now quite well understood, with a number of powerful diagnostic techniques available. The main idea of the presented method is to extract and identify source components related to the occurring bearing damages in the complex vibration signal. For this purpose, the authors used blind source separation methods (BSS). BSS is one of the most interesting and developing areas of signal processing. It is based on solid theoretical foundations and has many potential applications. BSS has become the subject of researches in many fields of science, especially biomedical engineering, medical imaging, speech recognition, remote detection, communication systems, geophysics, economics and audio-visual systems [3]. BSS techniques basically do not use learning data or a priori knowledge of the parameters of researched systems.

PROPOSED METHODOLOGY

Each mechanical device is the source of vibro-acoustic signal referred to as a complex diagnostic signal which is the composition of signals coming from a number of individual sources. Component signals can be identified with particular components of the devices or the processes occurring in the device which are their sources. Each mechanical process is the source of a single component signal in a complex diagnostic signal. In the device, in which one element is not working properly, an appropriate component should appear referred to as a failure signal. Extraction and identification of the component coming from the source of a failure in a complex diagnostic signal can be used to diagnose the failure. The measured vibration signals x_i treated as a multi-channel mixed signal are processed by the BSS algorithm, which results in statistically independent source signals s_i . These signals are then processed using standard methods for identifying damages of a given type. The proposed idea is schematically presented in Figure 1. The ideal situation would be to obtain pure signals generated by individual damages as a result of separation. Such separated damage signals would be much easier to analyze using currently used damage identification methods. The proposed approach was tested in the experiment described below.

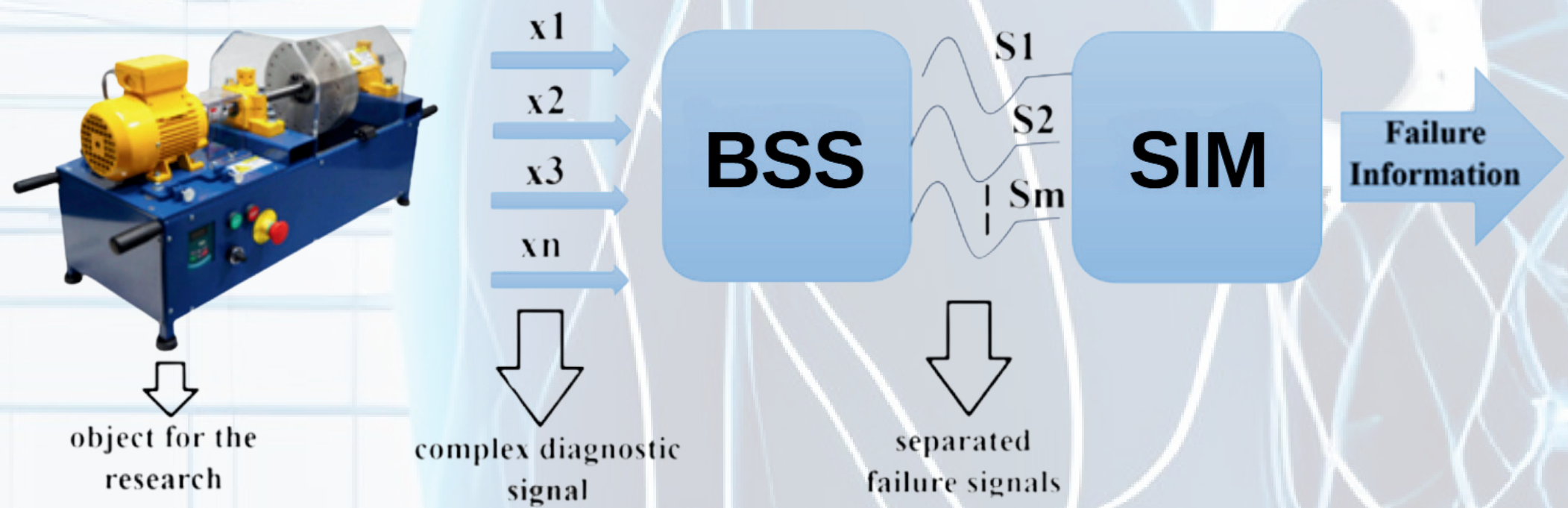


Fig. 1. Block diagram showing the operation of a diagnostic expert system based on BSS and ANN techniques.

EXPERIMENT

The measurement station is shown in Figure 2. The station consists of a rotating machine, a signal analyzer, and a set of vibration sensors. Damage to the outer and inner race of a rolling bearing was simulated in the rotating machine. Three three-axis vibration sensors placed on the bearing housings and located as shown in Figure 2 were used.

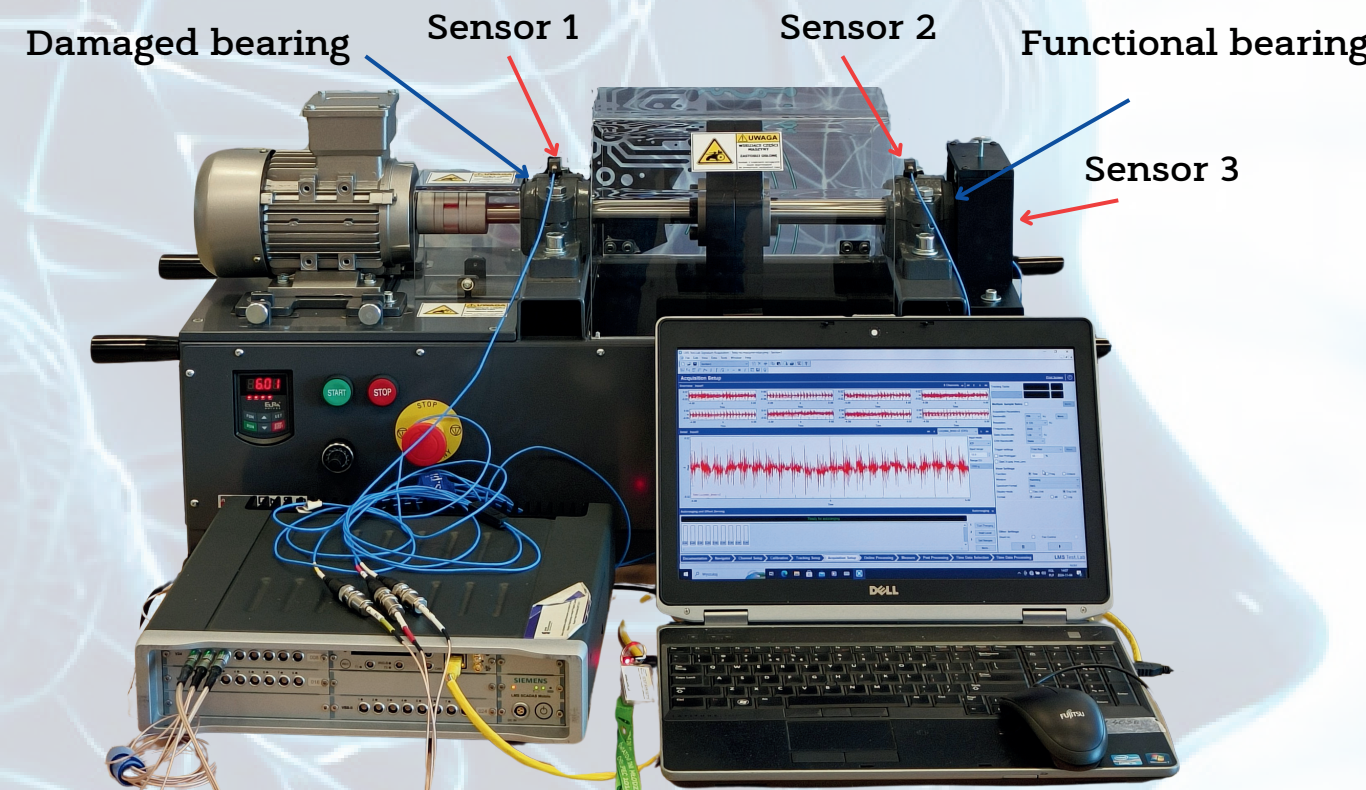


Fig. 2. Measurement station. Arrows indicate the damaged bearing and the location of three triaxial vibration sensors.

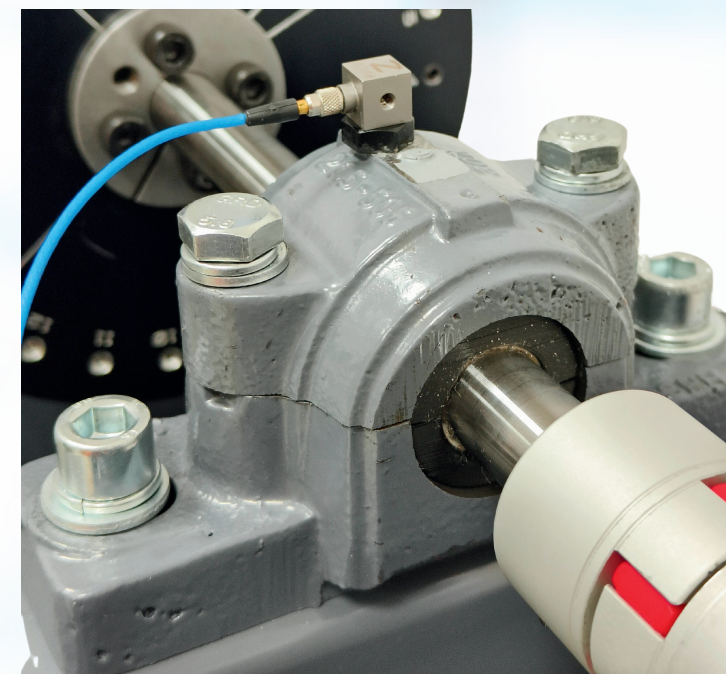


Fig. 3. Triaxial sensor placed on the bearing housing with a simulated fault.

In the case of simultaneous simulation of two types of damage, an envelope analysis was performed on both the measured signals and the source signals after separation. The figure 4 shows the results of the analysis of an example of the measured signal. The envelope spectrum shows peaks corresponding to the characteristic frequencies of both types of damage, i.e. BPFO and BPFI. As a result of using nonlinear ICA, the source signals originating from both types of damage were separated. Figures 5 show the envelope spectrum of the separated signals. In both cases, only one of the characteristic damage frequencies was observed, corresponding to the damage of the outer and inner race, respectively. The analyses carried out confirmed the increase in the effectiveness of damage detection when using BSS methods for separating source signals (failure signals). When using linear algorithms, an increase in effectiveness was observed in relation to standard methods by 6%, and when using the nonlinear BSS algorithm (MISEP) by 10%.

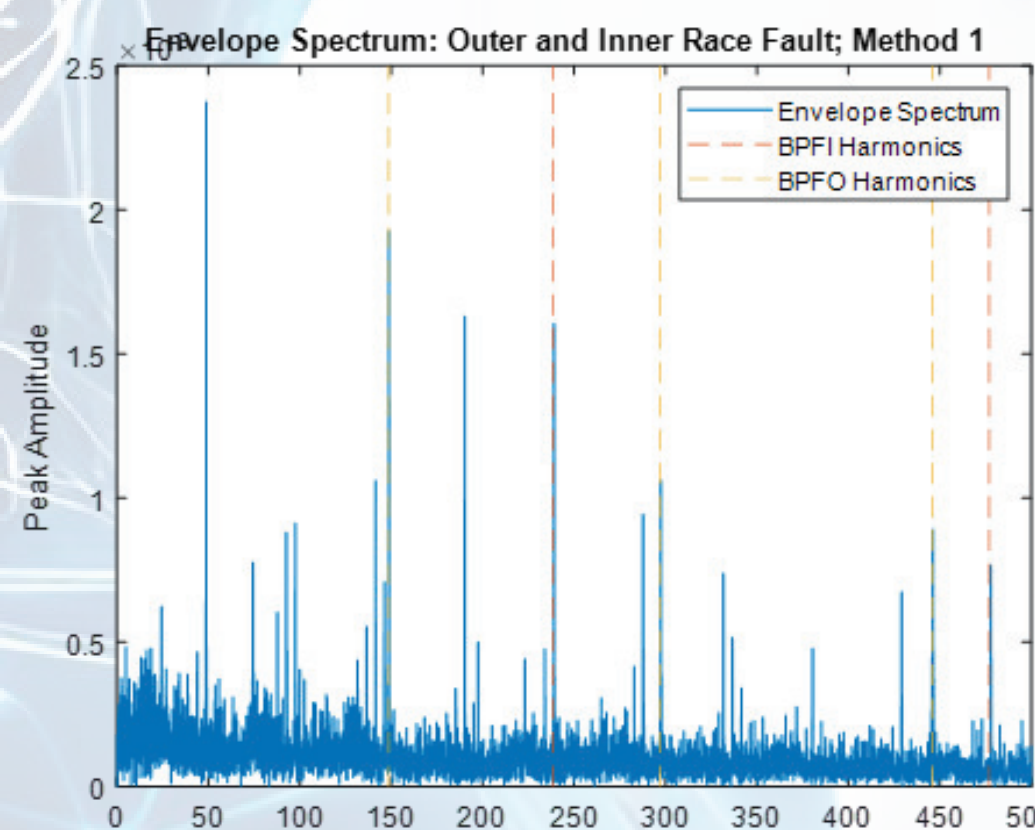


Fig. 4. The envelope spectrum of the selected signal measured in the case of simultaneous damage of the outer and inner race of the bearing. The characteristic peaks of BPFO and BPFI occurring simultaneously are visible.

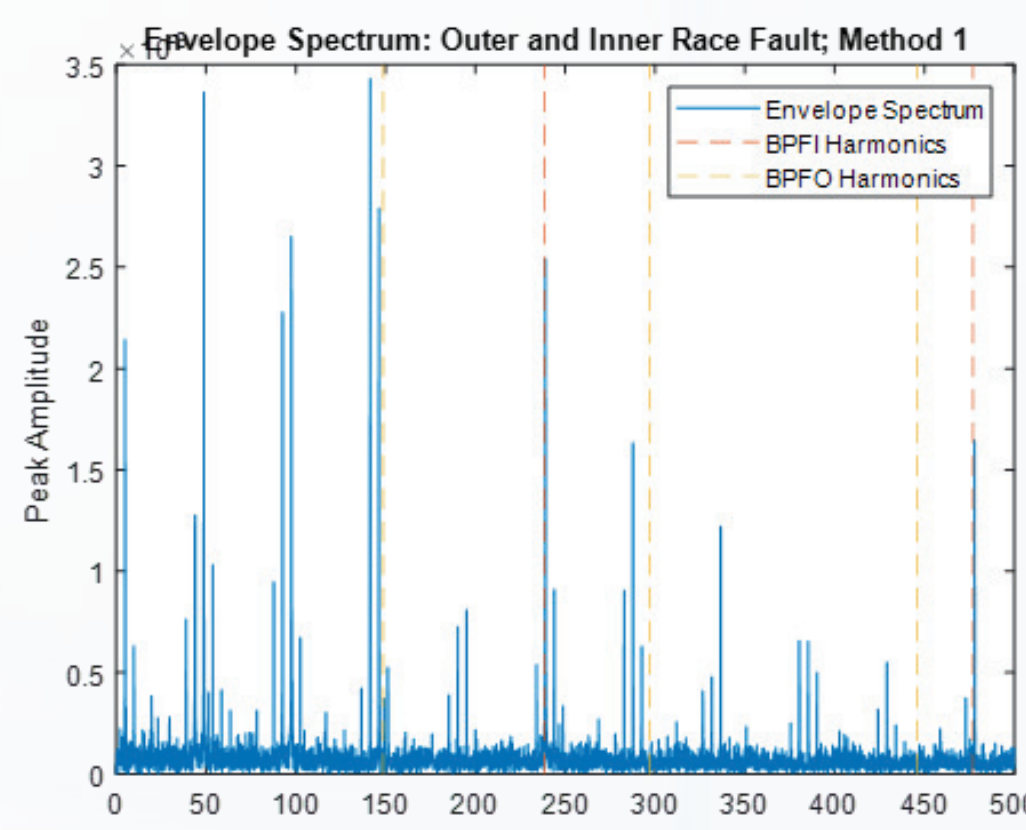


Fig. 5. Envelope spectrum of the source signal separated using nonlinear ICA. Only the spectral peak corresponding to the characteristic frequency of BPFI corresponding to the damage of the inner race was identified.

CONCLUSION

The presented idea the use of Blind Source Separation techniques in the diagnostics of rolling bearings. The theoretical part presents information related to the basic damages of rolling bearings. The frequencies associated with these damages are defined. A methodology for the use of BSS methods is proposed and an experiment is carried out on a real machine. In the experiment, the measured vibration signals were subjected to the action of both linear and nonlinear BSS algorithms. The separated signals were then subjected to standard methods of identifying bearing damages. The obtained results showed an increase in the effectiveness of damage identification by 6% for linear BSS algorithms and 10% for nonlinear BSS algorithms.