Fault Diagnosis of Rotating Machinery based on Acoustic Emission using PARAFAC-Source Separation

Anindita Adikaputri Vinaya[1], Dhany Arifianto[1]

Abstract – A common technique of vibration spectrum analysis is used for fault diagnosis of rotating machine in industry. The technique, however, requires a significant man power and has the risk of the direct measurement of vibration signal. This paper presents a remote maintenance technique based on acoustic emission of rotating machinery. The mixing matrix and the source signals are estimated using PARAFAC source separation by performing PARAFAC decomposition algorithm, permutation, and capon beamforming. This proposed technique prove the suitability and effectiveness of acoustic emission technique to diagnose Ball Pass Frequency of The Outer Race (BPFO) defect and misalignment coupling motor to pump.

Index Terms – Vapor-liquid equilibria, 1-butanol, 2-methyl-1-propanol, glycerol, water.

INTRODUCTION

Rotating machine is an important component in the industry. Fault diagnosis of rotating machine is a great importance. Vibration spectrum analysis is commonly used in the industry for fault diagnosis of machinery. [1]. However, the technique requires a significant man power and has the risk because of the direct measurement of vibration signal. On the other hand, the rotating machine has an acoustic emission. Vibration and acoustic signals have the same parameters such as amplitude, phase and frequency. In order to minimize the risk of direct measurement, diagnosis technique using acoustic emissions in rotating machine need to be developed.

The defect in rotating machine is known based on the instantaneous frequency when a machine is running [2]. And misalignment defects can be caused due to an error manufacturing, inadequate installation, and lack of lubrication. Many cases of bearing fault was found in the motor on the outer race [3]. Misalignment defect can be found in severe place in rotating machinery such as when pump and motor are coupled. When the defect is misalignment because of coupling, it can be diagnosed by the appearance of the first three harmonics [3].

In the real plant, there are many machines that will emit sound mixed with each other and accompanied by the presence of background noise. Therefore, in order to obtain the signal from the machine required signal processing to separate the mixed signals into its components. Blind Source Separation (BSS) is a method used to separate the mixture of signals without knowing much information about the signal sources and mixing processes [4-5].

In order to solve separating problems, Nion in 2010 used Parallel Factor (PARAFAC) decomposition to reduce the complexity of JAD algorithm. This method has good performance in solving problems related to the separation of the speech signal [7]. This study aims to determine the performance of PARAFAC-source separation method in separating the mixture. The sound signal is mixed in convolutive mixing in PLTU Unit 6 Paiton, East Java. The outlook of this study is technique can be used as consideration for detecting the condition of the machinery.

MATERIAL AND METHOD

PARAFAC was introduced in 1970 and widely used for wireless communication, sensor processing, food technology and BSS. PARAFAC decomposition based on multiway analysis with trilinear model which is the expansion of Principal Component Analysis (PCA) method used bilinear models. This model modifies a mixed signal x to the rank of three-way matrix [6]. In this study, we want to separate the mixture using PARAFAC-source separation with Capon beamforming algorithm. It is based on cross reduction in underdetermined case [6]. For more details, here are the steps of the process of separating mixed signals with PARAFAC-source separation:

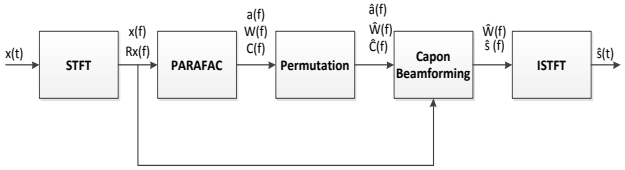

Figure 1. Separating process using PARAFAC-source separation

In order to verify the effectiveness of the proposed method, we conducted experiments designed to separate four major machine parts of rotating machine: motor drive-end (s1), motor nondrive-end (s2), pump drive-end (s3), pump nondrive-end (s4) with three microphones in a power plant PLTU Paiton unit 5.

RESULT AND DISCUSSION

After separating, the signals in time domain will be transformed in frequency domain for detecting faults. The signals also will be compared with vibration signals.

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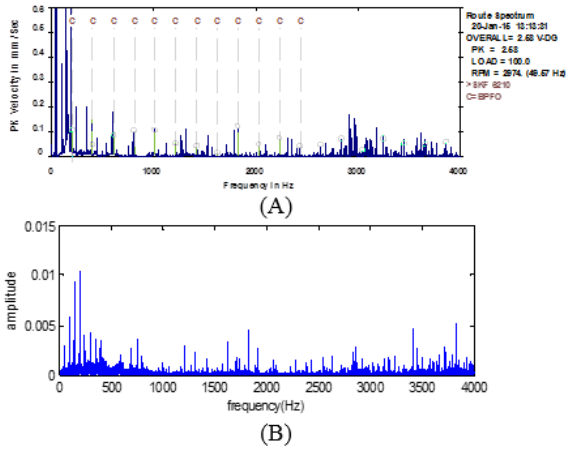

Figure 2. BPFO defect in motor non drive end based on vibration spectrum (a) and estimated signal (b)

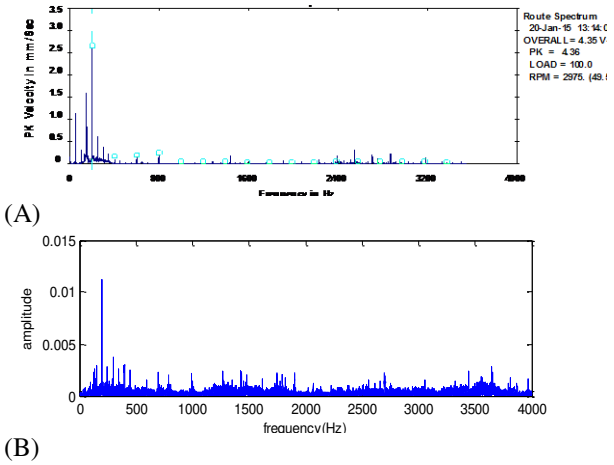

Figure 3. Misalignment defect in pump non drive end based on vibration spectrum (a) and estimated signal (b)

Based on figure 3 and 4, there are bearing and misalignment defects. Ball Pass Frequency of The Outer Race (BPFO) can be seen where there is vibration and acoustic signal harmonics marked with dashed lines along frequencies as shown in figure 3. Misalignment can be identified from the appearance of 3 harmonics at low frequencies as shown in figure 4. It is in accordance with the analysis of the defect characteristics to the machine [3].

The comparison of dominant frequency between the vibration signal and an acoustic signal estimation can be seen in Table 1. Based on table 1, PARAFAC method can separate mixed signals with minimal error is 0.014% on the estimated signal 3.

Table 1. Frequency instantaneous comparison in vibration and estimated acoustic signal

Source	Frequency Instantaneous(Hz)		Error
	Vibration Signal	Estimated Signal	
s1	203.01	198.53	2.21%
s2	202.55	198.59	1.95%
s3	198.62	198.59	0.014%
s4	198.30	198.59	0.14%

CONCLUSION

Separation of mixed signals on the pump has been conducted using tensor decomposition PARAFAC model in power plant PLTU Paiton unit 5. The separation using tensor decomposition methods with PARAFAC model has compatibility with vibration analysis, so that they can be used to diagnose machinery defects. The pattern of sound signal can be characterized by a dominant frequency or instantaneous frequency, and the signal spectrum. Based on the results that have been obtained, the machine has ball pass frequency of the outer race (BPFO) defect and misalignment coupling motor to pump.

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