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Fault Classification of Rotary Compressors Based on Vibration Signals

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1. Introduction

Condition monitoring of rotary air compressors is crucial to detect and make a diagnosis faults especially in air conditioning [1]. Compressors in air conditioning usually fail due to damage or wear of bearings, leakage from compressor shaft or housing, mechanical damage inside compressor housing. To diagnose the state of a compressor, the method of measuring vibrations is the easiest, most useful, and well-known method. Studies have been actively conducted recently to diagnose compressor failure using vibration signals. Some studies have attempted to classify faults with different causes of failures using machine learning methods. To diagnose a roller bearing failure, a support vector machine (SVM) was used as a classification method for fault detection [2]. Using the condition monitoring results of compressors with different variations in signal measurement, Extreme Learning Machine (ELM), NN (Nual Network), and other classification methods were used [3].

However, previous studies have mainly focused on the development of failure classification techniques, with little development being made of failure simulations, fault detection and failure diagnosis methods used in rotary compressors of air conditioning. In addition, since the air conditioning compressors have not only mechanical failures such as bearing or shaft damage, but also other failure modes, such as changes in the compression ratio or temperature, occur simultaneously in the refrigerant cycle, vibration signals are often caused by the combined failure modes, and thus require the development of a different fault diagnosis method than other mechanical products.

In this study, failure simulation experiment was carried out due to refrigerant cycle problem, changing the speed of compressor fan, motor speed, condenser temperature, etc. and failure simulation test due to mechanical damage caused by wear of actual mechanical parts was performed to produce normal and abnormal data. To characterize the abnormal data, feature extraction was performed by estimating statistical parameters such as mean, variance, skewness, and kurtosis. Support vector machines and artificial neural networks (ANN) were used to detect failure data, and the accuracy and reliability of the two methods were verified.

2. Data collection

The vibration data of the compressor was measured by an accelerometer sensor mounted on a rotary compressor cover. The rotary compressor is connected to other parts of the air conditioner, such as condensers and evaporators. This experiment was performed at two speeds, 34 rps and 69 rps, with normal data having compression ratios between 2.0 and 7.5 for each speed, and out of range data being classified as abnormal data. Figure 1 below shows the acceleration data for each speed.

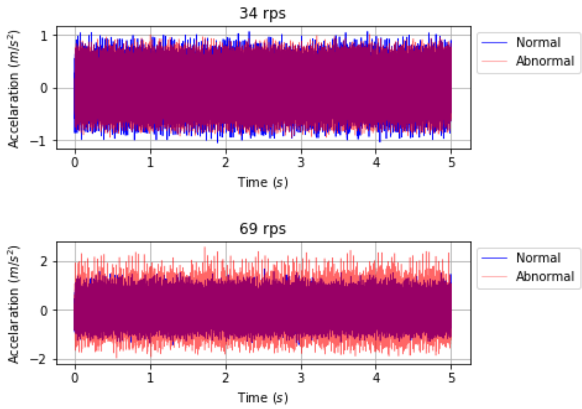

Fig. 1 Acceleration data of compressors

3. Feature extraction

After collecting data, statistical parameters are calculated from the data to extract the characteristics of the normal and abnormal data from the measured signals. Parameters used in data feature extraction include mean, variance, mode, skewness and kurtosis. Feature extraction, performed as the first step in this study, is to use Fast Fourier Transform (FFT) to convert acceleration data from a time domain to a frequency domain. Figure 2 shows the amplitudes of the vibration signals at frequency domain. Compressors operating at 69 rps on the graph tend to have higher frequency values than 34 rps. This can be seen from the numbers of peaks generated by compressors operating at 69 rps. This is because the higher the operating speed of the compressor, the higher the compressor load, resulting in a higher displacement in the compressor cover.

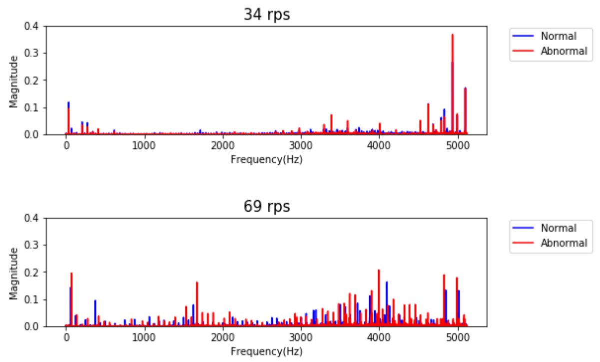

Fig. 2 Data in frequency domain

4. Fault classficiation

As mentioned earlier, failure data may be caused by changes in compression ratio in the refrigeration cycle and by mechanical defects. For compression ratios, the criterion for distinguishing normal from abnormalities is the compression ratio in the range of 2 to 7.5, and above or below this criterion is classified as abnormal data. On the other hand, mechanical defects have characteristics such as amplitude or variance of vibration signals, skewness or kurtosis, so it is necessary to use data-based failure classification methods. In this study, a fault diagnosis method was developed by combining a rule-based limit checking with data-based machine learning methods. SVM and Neural network were used as data-based fault classification methods.

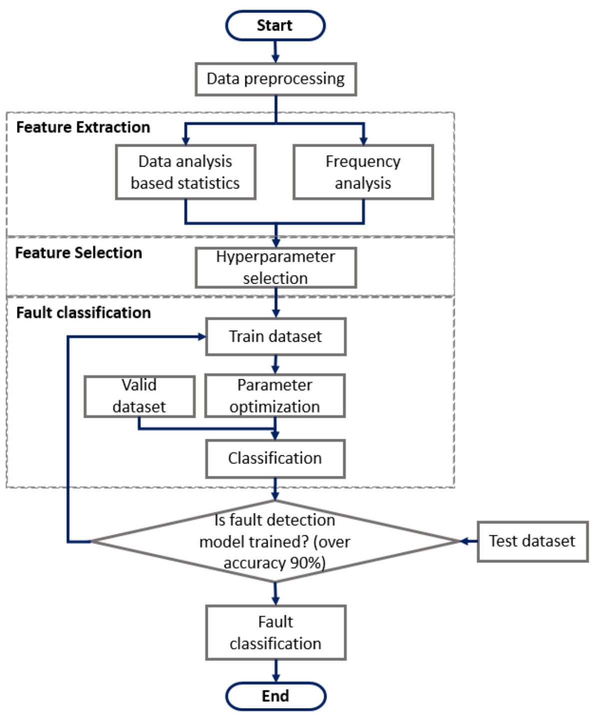

Fig. 3 Flow chart of fault classification

The SVM model represents the linear relationship of kernel function, weight, and bias. Parameters in the SVM consist of generalization parameters and kernel parameters, which are optimized to obtain the accurate SVM model. The second classification model is ANN. The ANN model was built by optimizing the parameters of hidden layers and neurons. The total datasets are divided into training, valid, and test datasets. The training datasets are used to generate fault classification models, valid datasets are used to optimize parameters, and test datasets are used to verify the accuracy of the model. The SVM and ANN models using optimized parameters were compared in terms of the accuracy of the fault classification and found that the SVM method was efficient and accurate in the fault classification.

5. Conclusion

In this study, a failure classification algorithm was developed that combines a rule-based limit checking and machine learning methods using vibration signal data measured from devices simulating compressor failures. The rule-based limit checking is used to analyze failure modes in the refrigeration cycle, and data-based methods such as SVM and ANN are used to analyze failure modes related to mechanical defects. The proposed method enables accurate and reliable diagnosis of compressor failure and is expected to be effective in reducing maintenance costs for the entire air conditioning system in the future.

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