An Effective and Portable Electronic Stethoscope for Fault Diagnosis by Analysing Machine Running Sound Directly

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Machine sound is a typical kind of non-stationary signal which carries information regarding the operating conditions of the machine. In the past, human ears have been used for detecting any abnormality occurring in a machine as this method is simple and fast. However, the audible range of human hearing is broadband and has a low signal-to-noise ratio, making the method inefficient. The invention of the Fast Fourier Transform (FFT) for vibration-based machine fault diagnosis has helped to increase the efficiency of diagnosis. However, FFT fails to detect the transitory characteristics of signals that are fault-related. Moreover, the cost of a FFT based analyser is expensive and the accessibility of a wired transducer is limited. Therefore, we are proposing the use of the hearing method again — not with a pair of human ears, but with an electronic stethoscope. We use Continuous Wavelet Transforms (CWT) to remove the noise from raw machine running sound signals and to detect non-stationary impulses generated from the impacts of defective components. The method of Trajectory Parallel Measure (TPM) is then used for fault detection and classification. From the results of the tests on a number of similar types of gas engines, the concept of the electronic stethoscope has been found to be feasible and promising. This electronic stethoscope uses CWT and TPM to diagnose faults by analysing the machine running sound directly.

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1. INTRODUCTION

Machine sound has been used for machine condition monitoring and fault diagnosis for hundreds of years. Before the invention of vibration analysers and oil analyses, human hearing was the main source for method of diagnosing machine abnormalities during operation. Such a method is valid provided that the sound generated by the impacts of a defective component is different audibly from the sound of a 'healthy' machine, and the background noise generated by the environment is insignificant. However, due to the broadband limitation of the human audible range, the low signal-to-noise ratio (SNR) of human ears, and the different subjective opinions given by human experts, the method of human hearing is somewhat unreliable for fault detection. Therefore, vibration-based fault diagnosis, which is less dependent upon the interpretation of human experts, has become popular in industry. Usually, the vibration levels generated by various components of a machine reflect the 'health' of the machine. A defective machine will be characterised by substantial changes in the vibration-based power spectrum compared with a 'healthy' one. Modern vibration analysers are capable of detecting machine faults, which exhibit periodic fault symptoms, from their fault-related spectra. However, the costs of vibration-based analysers are high, and the procedures for using them in fault diagnosis are time- and labour-intensive. These, coupled with the limited accessibility of wired transducers, has made industry search for a cheaper, simpler to use, and portable alternative for the use of fault diagnosis. Here, we propose a new type of machine fault diagnostic system which can detect both stationary and non-stationary impulses directly from machine running sound. This system not only functions as simply as the human hearing method, but also diagnoses faults as reliably as the conventional vibration analysers. In this paper, we propose the innovative concept of an "electronic stethoscope". It is expected to be a portable, simple-to-use, low-cost and fast-to-process fault diagnosis system. With the success in implementing such a system, the requirements of hiring experts in fault diagnosis and purchasing expensive vibration analysers, and the difficulty of installing wired transducers in confined spaces, can be eased. In general, the process of fault diagnosis involves the collection of sensor data, the extraction of vital features for fault detection, and the classification of faults.[1] In the design of the electronic stethoscope, we have used Continuous Wavelet Transforms (CWT) for noise removal and fault-related feature extraction, and the chaos-based Trajectory Parallel Measure (TPM) for the classification of machine running conditions.