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Fault diagnosis using Rough Sets Theory

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Abstract

The fault diagnosis on diesel engine is a difficult problem due to the complex structure of the engine and the presence of multi-excite sources. Usually, one method of fault diagnosis can only inspect one corresponding fault category. In this paper, a new method, Rough Sets Theory, is used to diagnose the valve fault for a multi-cylinder diesel engine. Through the analysis of the final reducts generated using Rough Sets Theory, it is shown that this new method is effective for valve fault diagnosis. Rough Sets analysis requires discretizing the fault condition attributes. However, in practice, some of the limits of these attributes are unknown. A new discretization method has been created and the method is found to be suitable for discretizing the attributes without a priori knowledge.

Keywords: Fault diagnosis; Rough Sets Theory; Discretization

1. Introduction

Fault diagnosis on machinery has been well researched [1]. There are many effective methods that are used to diagnose accurately and quickly a certain category of faults [2]. For instance, large-scale centrifugal compressor can be diagnosed by holospectrum technique [3]. However, up to now, it is difficult to diagnose more than one category of faults. This is especially so in diagnosing the dynamic characteristics of reciprocating machinery, such as reciprocating compressor and diesel engine. This is due to the complex structure of the reciprocating machinery. Although many methods can be used to determine specific fault category, such as broken valve and cracked crankshaft [4], the results obtained from such fault specific method are not easy to interpret. There is a need to have a method that can diagnose more than one category of faults in a generic manner. In this paper, a method based on Rough Sets Theory is proposed and implemented.

Z. Pawlak (Poland) first proposed Rough Sets Theory in 1982. This theory has been developed and used in many domains, such as medical diagnosis [5], stock market forecast [6], fault diagnosis in engineering domain [7], decision making for bank manager [8] and some other uses [21].

The advantage of Rough Sets Theory is that it needs neither additional information about the data nor is it necessary to correct the inconsistencies manifested in data. Instead, rules generated are categorized into certain rules or possible rules.

In this paper, the Rough Sets Theory [9] is used to analyze the decision table composed of attributes

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extracted from the vibration signals, which are collected from a 4135 diesel engine. The remainder of this paper is organized as follows. The characteristics of vibration signal of diesel engine will be analyzed in Section 2, then Rough Sets Theory is introduced in Section 3. The attributes field is established in Section 4, which is used to compose the decision table. A new discretization method, more suitable to discretize continuous attributes without a priori knowledge, is proposed in Section 5. The diagnosis results using Rough Sets Theory are discussed in Section 6 and at the end of this paper, conclusions based on the aforementioned analysis are given.

2. The Characteristics of vibration signals for a 4153 diesel engine

There are many surveillance methods [2,10] proposed to monitor the condition for a diesel engine, based on the processing of the vibration signals. Due to the complex structure and multi-excite sources that exist in diesel engine, the vibration signals collated from the engine surface have the following characteristics:

- Presence of a number of self-exciting vibration and forced vibration in the diesel engine that is running. Therefore, the width of spectrum in frequency domain is very large.
- The vibration signals in the time domain are more complex compared to a large-scale rotational machinery, which is a pure sine curve.

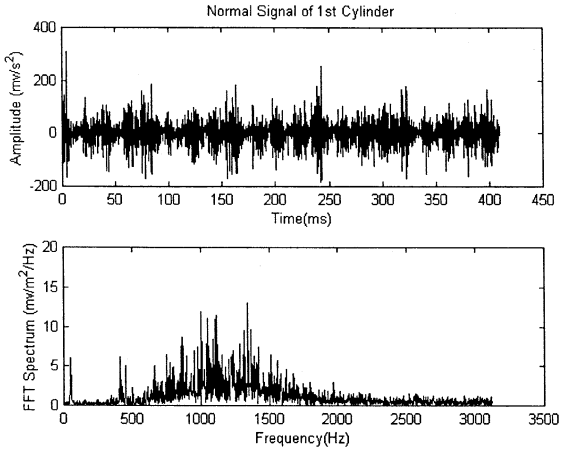

Fig. 1. Normal state (sample point 1).

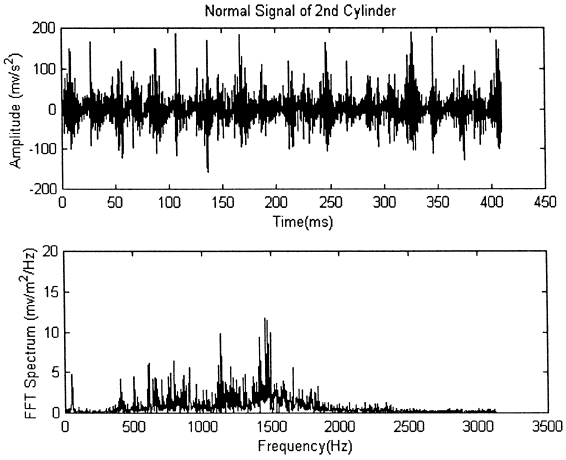

Fig. 2. Normal state (sample point 2).

- In a diesel engine, such as 4135 engine, the stroke cycles are fixed. Therefore, the time series appear periodical. However, in every period, there exist many other periodical vibrations within the stroke cycle.

In Figs. 1–12 some vibration signals, collected from a 4135 engine surface, are presented. The parameters of 4135 diesel engine are:

Rated Engine Power: 80 hp,
Rated Engine Speed: 1500 rpm,
Four states are studied in this paper. They are,

- Normal state
- Intake valve clearance is too small

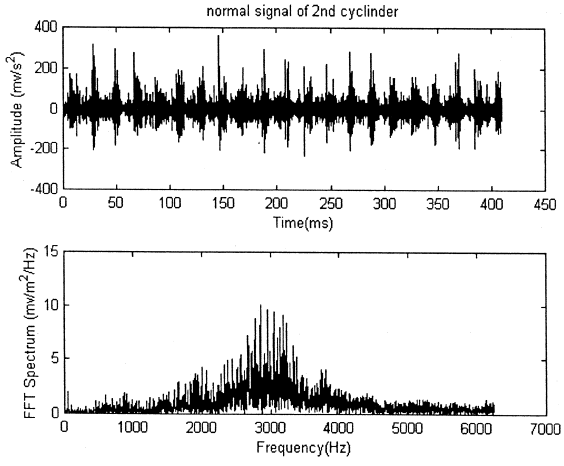

Fig. 3. Normal state (sample point 3).