Chapter 16
Advanced Techniques for Monitoring the Condition of Mission-Critical Railway Equipment

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ABSTRACT
This chapter provides an overview of advanced techniques for monitoring the condition of mission-critical railway assets. The safe operation of railways depends on a large number of geographically distributed components, each of which has a low cost when compared to the highly complex arrangements of assets found in other industries, such as rolling mills and chemical plants. Failure of any one of these components usually results in a degradation of service in order to maintain safety, and is thus very costly to modern railway operators, who are required to compensate their customers when delays occur. In this chapter, techniques for industrial condition monitoring are reviewed, highlighting the main approaches and their applicability, advantages, and disadvantages. The chapter first makes some basic definitions of faults, failures, and machine conditions. The analysis of faults through methods such as Fault Tree Analysis and Failure Modes Effects Analysis are examined. The field of fault diagnosis is then reviewed, partitioning into the three main areas: numeric/analytical models, qualitative models, and data/history-based methods. Some of the key approaches within each of these areas will be explained at a high level, compared, and contrasted.

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1. INTRODUCTION

Previous work on railway asset condition monitoring is examined. A railway based case study is presented, based on the results of a previous industry/academia collaborative project. The challenges for future research and development are discussed, addressing such topics as information integration, limitations of automatic monitoring and human-machine interaction.

2. A REVIEW OF INDUSTRIAL CONDITION MONITORING TECHNIQUES

2.1 Condition Monitoring Definitions and Capabilities

For the purposes of asset condition monitoring, a failure is defined as any unplanned event which results in an asset being unavailable for its designed purpose.

A fault is a condition of an asset which causes it to deviate from its normal behaviour. This may or may not cause a failure, depending on both the severity of the fault and the functional area of the asset affected by the fault. For example, a loose screw on a luggage shelf may cause rattling in the saloon of a passenger vehicle; this is a fault, because the components are behaving abnormally, but it will not necessarily cause a failure, because it does not stop the train from functioning properly or safely.

An incipient fault is a fault which develops gradually over a period of time. An example might be the loosening of non-threadlocked bolts or screws when subjected to prolonged vibration. Incipient faults are difficult to detect early using automatic methods, and therefore have a tendency to cause failures or only be detected at a late stage of development.

In condition monitoring, the terms fault detection, fault diagnosis and fault identification have distinct meanings. Detection means determining purely whether or not a fault is present in an asset. Diagnosis means to decide what fault may be present. Identification means to determine the severity of the fault.

These capabilities can be added in layers to provide progressively higher levels of condition monitoring. As further layers are added, automated systems can take on more responsibility and gradually improve asset availability by reducing time spent in reactive maintenance, diagnosis and by optimally scheduling maintenance tasks.

The flow diagrams in Figure 1 show how tasks can be split between human maintainers and automated condition monitoring systems for five levels of capability which have been defined as part of the INNOTRACK project (Silmon 2009). Table 1 categorises the capabilities of the condition monitoring system shown in Figure 1.

Currently the most advanced condition monitoring systems available for railway applications have capability level 2. The capability depends partly on the availability of a suitable algorithm or model for the asset being monitored, and partly on the opportunity for analysis or training of the models, which must be done in co-operation with the asset manager.

2.2 Fault Diagnosis Methods

Automated fault diagnosis has been an area of high research activity for several decades. Most of the effort in this field has been focused on industrial processes, such as may be found in the chemical and manufacturing industries. Industrial processes usually have dozens or hundreds of variables and a large, expensive plant which is built as a one-off exercise. This means that investment in fault diagnosis has been higher, because it is a proportionally smaller cost to the operators and yet yields a high return in increased reliability.