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On condition based maintenance policy

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Abstract

In the case of a high-valuable asset, the Operation and Maintenance (O&M) phase requires heavy charges and more efforts than the installation (construction) phase, because it has long usage life and any accident of an asset during this period causes catastrophic damage to an industry. Recently, with the advent of emerging Information Communication Technologies (ICTs), we can get the visibility of asset status information during its usage period. It gives us new challenging issues for improving the efficiency of asset operations. One issue is to implement the Condition-Based Maintenance (CBM) approach that makes a diagnosis of the asset status based on wire or wireless monitored data, predicts the assets abnormality, and executes suitable maintenance actions such as repair and replacement before serious problems happen. In this study, we have addressed several aspects of CBM approach: definition, related international standards, procedure, and techniques with the introduction of some relevant case studies that we have carried out.

Keywords: Condition-based maintenance; Predictive maintenance; Prognostic and health management

1. Introduction

In general, maintenance is defined as all technical and managerial actions taken during usage period to maintain or restore the required functionality of a product or an asset. There have been various classifications of maintenance policies. Simply, maintenance policies can be divided into breakdown maintenance and preventive maintenance. Some references, e.g. Erbe et al. [11] identified maintenance types in detail. In our study the maintenance policy is classified into three types: breakdown maintenance (corrective maintenance), preventive maintenance, and Condition-Based Maintenance (CBM). In the breakdown maintenance, the maintenance action is taken after some problems such as breakdowns in a product are found while the preventive maintenance periodically checks a product with a certain interval in order to prevent the abnormality of the product. The CBM may be similar to the preventive maintenance in the sense that its goal is to prevent product abnormality in advance before abnormality occurs. Note that some previous works put the CBM method under the preventive maintenance policy with the Time-Based Maintenance (TBM) method. However, the CBM approach is different from the time-oriented approach of preventive maintenance. It focuses on the prediction of degradation process of the product, which is based on the assumption that most abnormalities do not occur instantaneously, and usually there are some kinds of degradation process from normal states to abnormalities [12]. Hence, unlike breakdown maintenance and preventive maintenance, the CBM focuses on not only fault detection and diagnostics of components but also degradation monitoring and failure prediction. Generally, CBM can be treated as a method used to reduce the uncertainty of maintenance activities and is carried out according to the requirements indicated by the equipment condition [27]. Thus, the CBM enables us to identify and solve problems in advance before product damage occurs. In industry systems, any product damage can lead to serious results. In this respect, the CBM is very attractive method for the industry operating high-valued assets.

Until now it has been difficult to achieve effectiveness of maintenance operations because there is no information visibility during product usage period. However, recently, with emerging technologies such as Radio Frequency IDentification (RFID), various sensors, Micro-Electro-Mechanical System (MEMS), and wireless tele-communication, and Supervisory Control And Data

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Acquisition (SCADA), Product Embedded Information Devices (PEID) are expected to be rapidly used for gathering and monitoring the status data of products during their usage period. Advancements in information technology have added accelerated growth in the CBM technology area by enabling network bandwidth, data collection and retrieval, data analysis, and decision support capabilities for large data sets of time series data [29]. Under the new environment, we can gather the product status and usage data related to distributing route, usage conditions, failure, maintenance or service events, and so on. These data enable us to diagnose the degradation status of the product in a more exact way. Therefore, using this information gives us new challenging issues for improving the efficiency of product maintenance operations. We can make a diagnosis of product status, predict products abnormality, and execute proactive maintenance, i.e. do CBM.

Since a critical failure or degradation of the product during its operation can seriously damage the belief of customers on the product reliability, the maintenance enhancement for preventing this kind of failure or degradation in advance has precedence over any other things in a company. For this purpose, recently lots of manufacturing companies are trying to adopt new technologies and get more accurate real-time information regarding product status during its usage period. As diverse information becomes available, the CBM approach to use them for preventing a critical failure or degradation in advance has been highlighted. Although most machine maintenance today is still either purely reactive (fixing or replacing equipment after it fails) or blindly proactive, world-class companies are moving forwards towards 'predict-and-prevent' maintenance [19], which is very similar to the goal of CBM. From this perspective, this study will deal with several aspects of CBM. Although there have been some literature review works on CBM, this study has some different features compared to previous works: First, this study deals with various aspects of CBM based on the survey of relevant previous works. It contains its definition, advantage and disadvantage, procedure, related standards, diagnostics and prognostics methods, and so on. Second, this study refines the definition of CBM considering several aspects of CBM, e.g. procedure and its advantage, and clarifies the difference between diagnostics and prognostics. Finally, this study addresses some discussion issues when implementing CBM based on several CBM case studies that we have carried out.

This study is organized as follows. First, in Section 2, we address the definition, related international standards, and previous studies associated with CBM. Furthermore, we introduce relevant case studies that we have carried out until so far. In addition, we make a discussion about the implementation of CBM approach. Finally this study is concluded with the discussion on contributions and limitations in Section 3.

2. Several aspects on condition based maintenance approach

2.1. Definition

The term, CBM, is often used with other terms such as Predictive Maintenance (PdM), Prognostic and Health Management (PHM), on-condition maintenance which comes from the U.S. Department of Defense and Department of Energy, online monitoring, or risk based maintenance. Actually, the concept of CBM was first introduced by the Rio Grande Railway Company in late 1940s and initially it was called predictive maintenance [29]. There are various definitions on the concept of CBM. Bengtsson [3] shortly described it as preventive maintenance based on performance and/or parameter monitoring and the subsequent actions. According to British Standard, CBM is defined as the maintenance policy carried out in response to a significant deterioration in a machine as indicated by a change in a monitored parameter of the machine condition. According to the definition of Kothamasu et al. [21], CBM is a decision making strategy where the decision to perform maintenance is reached by observing the condition of the system and/or its components. These definitions address the goal of CBM, but they have the limitation in describing the CBM procedure. On the other hand, Butcher [4] defined CBM as a set of maintenance actions based on real-time or near real-time assessment of equipment condition, which is obtained from embedded sensors and/or external tests & measurements taken by portable equipment. This definition includes technical aspect of CBM compared to previous ones, but lack of the descriptions on CBM goal.

In this study, we define CBM as a maintenance policy which do maintenance action before product failures happen, by assessing product condition including operating environments, and predicting the risk of product failures in a real-time way, based on gathered product data.

2.2. Advantage and disadvantage

In general, there are lots of stakeholders during asset lifecycle. For example, owner of asset, operators (users), external agents (maintenance service provider), regulators related to health and safety (government), and so on. From each viewpoint, the interests and objective of CBM will be different.

We can think of what the advantages and disadvantages of CBM approach are. Until so far, there are lots of advantages of CBM reported in previous works or from industries. Amongst them, first and foremost, the CBM gives us prior warning of impending failure and increased precision in failure prediction. Thus, it can effectively reduce the product failure compared to other approaches. From the viewpoint of product safety management, the CBM is useful for the product types where safety is considered important since it can increase safety by detecting problems in advance before serious problems occur, which leads to the improvement of customer satisfactions due to the high quality assurance. Hence, the CBM makes maintenance service providers avoid the risk cost due to the dissatisfaction of product quality. In general, by the maintenance contract, a maintenance service provider usually has the responsibility for keeping the quality of product in a customer during the warranty period. Hence, the CBM is very attractive for the maintenance service provider.

Furthermore, it allows end users to perform better planned maintenance, reduce or eliminate unnecessary inspections, and