An Intelligence-Based Model for Condition Monitoring Using Artificial Neural Networks

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ABSTRACT

This paper reports a newly developed Condition-Based Maintenance (CBM) model based on Artificial Neural Networks (ANNs) which takes into account a feature (e.g., vibration signals) from a machine to classify the condition into normal or abnormal. The model can reduce equipment downtime, production loss, and maintenance cost based on a change in equipment condition (e.g., changes in vibration, power usage, operating performance, temperatures, noise levels, chemical composition, debris content, and volume of material). The model can effectively determine the maintenance/service time that leads to a low maintenance cost in comparison to other types of maintenance strategy. Neural Networks tool (NNTool) in Matlab is used to apply the model and an illustrative example is discussed.

Keywords: Artificial Decision Making, Artificial Neural Networks (ANNs), Condition-Based Maintenance (CBM), Maintenance Management, Neural Networks Tool (NNTool)

INTRODUCTION

Maintenance cost has become a considerable percentage of operational costs because of the rapid development of technologies and the increasing complexity of machines used in industry (Michalopoulos et al., 2009). For example, the annual cost of maintaining a military jet aircraft is around $1.6 million; approximately 11% of the total operating cost for an aircraft is spent on maintenance activities (Kumar, 1999). Also, each year over $300 billion are spent on plant maintenance and operations by U.S. industry, and it is estimated that approximately 80% of this amount is spent to correct the chronic failure of machines, systems, and people (Latino, 1999). The British Ministry of Technology Working Party report estimated that maintenance cost in the United Kingdom (UK) was approximately £3000 million annually in 1970 (Kelly, 1978).

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Having Enterprise Maintenance Information Systems (EMIS) becomes very important. Therefore, based on maintenance platform using JAVA expert system shell technology, the development of a rule-based intelligent equipment trouble-shooting was proposed (Yao et al., 2006). Literature on enterprise maintenance systems considers EMIS to be composed of Operational Reliability, Maintenance Economics, Human Factors, Maintenance Program, and Maintenance Optimization sub-systems (Grimmelius et al., 1999; Jenab & Zolfaghari, 2008; Yao et al., 2006). In the pertaining literature, several maintenance strategies and architectures have been proposed. These strategies can be categorized into two major classes: with or without preventive maintenance (PM). PM based strategies include:

1. Age-dependent (Pham & Wang, 2000; Sikorska et al., 2011; Ahmad & Kamarudin, 2012).
2. Periodic PM (Liu & Yu, 2004; Oke et al., 2009; Pecht & Jaai, 2010).
3. Failure limit (Love & Guo, 1996; Niu et al., 2009; Gašperin et al., 2011).
4. Sequential PM (Kijima & Nakagawa, 1992; Heng et al., 2009; Ahmad & Kamaruddin, 2012).
5. Repair limit (Dohi et al., 1996; Asif Raza & Al-Turki, 2010).

Machine failures may cause consequences such as machinery damage, production losses, and personnel injury (Orhan et al., 2006; Renwick, 1984). In order to prevent such failures, an effective maintenance policy is required for the plant. Corrective Maintenance (CM) and Preventive Maintenance (PM) are the most common types of maintenance policies. In CM, maintenance calls occur by machine failure, which results in increasing operational costs and risk. In PM, maintenance is performed on a specified-time interval basis to mitigate the chance of the potential failure of the machine. The most critical decision in PM is to determine the appropriate time interval between PM activities (Renwick, 1984). An early maintenance schedule leads to unnecessary overhaul and tear-down, which may be compounded by potential human errors during machine reassembly. On the other hand, a late maintenance schedule may result in damage and unplanned downtime, high costs, and production losses (Renwick, 1984). As result, Condition-Based Maintenance (CBM) is widely used because CBM employs condition-monitoring techniques to verify the condition of the machine for timely action.

Condition monitoring periodically reads data from a feature of a machine in order to assess the criticality of the machine condition, diagnose potential failures, and estimate the remaining lifetime of the machine (Mobley, 1998). Several articles have discussed the advantages of using a condition-monitoring program (Colaiacovo et al., 2000; Lewin, 1995). Although condition-monitoring techniques can analyze features such as vibration, lubricant, thermography, and ultrasound (Pedregal & Carnero, 2006), vibration analysis has been considered more widely in the literature (Márquez et al., 2012; Orhan et al., 2006; Pedregal & Carnero, 2006; Renwick, 1984; Renwick & Babson, 1985). Vibration analysis is a technique used to monitor machine conditions and the trend of deterioration for the purpose of not only reducing maintenance costs, but also decreasing downtime (Renwick & Babson, 1985). The base of vibration analysis is the fact that every system produces vibration while working.

Vibration produced by a machine is small and constant when a machine is working properly. Vibration would present an inconstant trend due to changes in dynamic processes that raise the chance of machine failure. For example, if anomalies such as an imbalance or ear in bearings develops in a rotary machine, the vibration level increases.

A general framework for the risk-based configuration of a safety monitoring system is proposed using a Dynamic Bayesian Network (DBN) (Kohda & Cui, 2006). However, calculations of the conditional state probabilities are complicated and difficult to obtain. An unsupervised algorithm for diagnostics and prognostics in machining processes is discussed (Chinnam &
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