CONDITION-BASED MAINTENANCE

Student's Name

INSTITUTION

INTRODUCTION

Researches in the field of condition-based maintenance (CBM) have been rapidly growing in the recent years. Hundreds of academic papers in this field continue appearing annually in the conference proceedings, journals, and technical reports. This paper reviews and summarizes the recent research developments in condition-based maintenance.

Various researchers have defined condition-based maintenance in various ways. According to Ahmad and Kamaruddin (2012), condition based maintenance refers to a plan for maintaining the systems based not on intervals of time, but on the actual condition of the systems. Ahuja and Khamba (2008) also provide another definition of condition-based maintenance as a maintenance program that recommends maintenance choices based on the information gathered through condition monitoring. The program essentially comprises three major steps that include the acquisition of data, processing of data, and maintenance of decision-making. It should be noted that from the definitions, almost all researchers agree that condition based maintenance is not based on the time interval. CBM relies on the change in the condition or performance of a system as the main reason for executing maintenance. As a result, Al-Najjar (2007), as well as Arunraj and Maiti (2007) point out that the ideal time to execute maintenance functions is influenced by monitoring of the system, subsystem, or component.

Campos (2009) argues that the main purpose of CBM is minimizing the costs related to inspections and repairs by gathering and analyzing continuous or discrete data associated with the condition of the critical components. Bennane and

Yacout's (2012) point of view differs from Campos' (2009) one. Scholars claim that the main objective of CBM is preventing different inconveniences in the system since it acts as a precaution. Bennane and Yacout (2012) argue that condition monitoring could offer sufficient hint on any pending failures that would warrant the planned repairs based on degradation, as opposed to the costly time-reliant repairs or emergencies. As a result, this suggests that there are two perspectives from which one can view the importance of CBM in management: convenience and cost reduction. Nevertheless, CBM might also be costly, or the data might not exist in order to warrant its introduction.

Veldman, Klingenberg, and Wortmann's (2011) study affirm that CBM entails a robust assessment of the financial and reliability maintenance data. Moreover, Tian, Lin, and Wu (2012) add that it needs a clear comprehension of the modes and rates of failure, possible payoffs linked with different maintenance strategies, and asset criticality. Veldman, Klingenberg, and Wortmann (2011) cite the investigations performed on civil aircraft described the failure patterns. In the study, the failure contradicts the belief of the association between operating age and reliability. As a result, it is concluded that a frequent overhaul of a system would improve reliability. Unless there is an overriding failure mode related to age, time-based maintenance does not enhance reliability of the system. In the agreement with Veldman, Klingenberg, and Wortmann (2011), Sharma, Yadava, and Deshmukh (2011) add that there is high possibility of the time-based overhauls to introduce mortality failures in the systems considered stable.

Recent studies have also indicated that the generic architecture for condition-based maintenance is missing and that the present approaches to the design of the CBM systems is

very explicit. Therefore, such researchers as Reimann, Kacprzynski, Cabral, and Marini (2009), as well as Peng, Dong, and Zuo (2010) have posited that every domain field has its own interpretation, which might not be companionable with the needs of other applications. This simply implies that CBM is not suitable for all maintenance areas and need to be utilized only in those areas where the condition-monitoring methods are cost-effective and available.

CONDITION MONITORING

Condition monitoring has been found to be a significant matter in several fields, such as railways, electrical machines, and power delivery. According to Parida and Chattopadhyay (2007), it refers to the process or technique of observing the operating aspects of a machine or a system to predict the need for maintenance before a breakdown. The normal and continued operations of machines are very significant. Recent studies have indicated that condition monitoring becomes increasingly important, especially for energy companies. A sudden shutdown or fault can lead to the financial losses or serious consequences. Companies have to find the methods of minimizing downtime, decreasing the costs of maintenance, and avoiding failures or shutdowns. As a result, machines can be used in an optimal manner with reliable condition monitoring. According to Panagiotidou and Tagaras (2010), condition monitoring differs from the visual scrutiny. It consists of the intricate automated assessments using various condition assessment techniques and tools.

MAINTENANCE STRATEGIES

Muller, Crespo, and Iung (2008) and Kans (2009) note that maintenance frequently adopt some exceedingly publicized

strategies aimed at improving the efficiency of the maintenance function, including total productive maintenance (TPM), condition-based maintenance (CBM), and reliability centered maintenance (RCM). However, some management studies have indicated that some managers do not know what strategy should be used to optimize maintenance; therefore, most maintenance initiatives never materialize (Simões, Gomes, & Yasin, 2011).

According to Jardine, Lin, and Banjevic (2006), maintenance intervention strategies are both technical in nature, as well as a matter of art. In the study conducted by Irigaray, Gilabert, Jantunen, and Adgar (2009), the best practice maintenance strategies are proven to fail within one year. Hao, Xue, Shen, Jones, and Zhu (2010) refer to such failures as a successful failure resulting from the limited knowledge within the organization. Garg and Deshmukh (2006) cite that few internal members of the organization understand where they are moving towards when commencing the maintenance implementation process.

As such, Dragomir, Gouriveau, Dragomir, Minca, and Zerhouni (2009) robustly argue for adopting a holistic approach in the maintenance function of implementing the CBM strategies. Holistic approaches include the assessment of maintenance assets, such as building structures. Castanier, Grall, and Bérenguer (2005) and Campos (2009) also argue that an efficient adoption of CBM essentially requires the performance indicators for developing the systems and components. Researchers note that the assessment of building components must evaluate three significant factors: the physical performance of buildings, failure frequencies, and the preventive maintenance undertaken on the systems. Similar to Castanier, Grall, and Bérenguer (2005), Ahmad and Kamaruddin (2012) point out that the all-inclusive approaches should consist of the performance measurements systems, which act as a tool for delivering the strategic objectives;

the assessment of breakdown maintenance; the assessment of planned schedule maintenance; and the assessment of CBM, where the critical and costly assets are monitored for any degradation.

Ahuja and Khamba (2008) affirm that condition-based maintenance is a non-intrusive method, and the preventing action, which is a repair, is undertaken at the incipient level of failure. Ahmad and Kamaruddin (2012) cite that the hidden failures are frequently present in standby protective devices or units, or rarely used assets. Moreover, the hidden failures might not be evident until there is a need for a proper function of an item. Therefore, condition-based maintenance establishment on the standby units, including protective devices or rarely used machines, would not be efficient because upon startup, the hidden breakdowns could take place. Nevertheless, in order to counter the hidden failures, Ahmad and Kamaruddin (2012) recommend the faultfinding (FF) operations. According to Hao, Xue, Shen, Jones, and Zhu (2010), the faultfinding operations are performed at the planned intervals in order to assess the state of machines or items with dormant functions. A perfect example where condition-based maintenance is not appropriate is an emergency generator, which is often idle until needed.

BENEFITS OF CBM

Kans's (2009) analysis also suggests that time-based maintenance frequently fails in the maximization of service life of every component. The study involves comparing the rates of failure between time-based maintenance (TBM) and CBM. The findings indicate that the components in time-based preventive maintenance are replaced with several hours of useful life remaining. Veldman, Klingenberg, and Wortmann (2011) agree

with Kans (2009). Scholars claim that time-based preventive maintenance wastes resource in that the machine is over-maintained.

According to Kans's (2009) research findings, CBM has highly contributed to sensor technologies, communication technologies, decision support, as well as health and assessment. The use of CBM in these areas focuses on maturing the comprehension of the contributing technologies in order to attain the wider implementation of CBM, especially in the defense and aerospace sectors (Jardine, Lin, & Banjevic, 2006).

Dragomir, Gouriveau, Dragomir, Minca, and Zerhouni (2009) noted that different conditions, signs or indications precede 99% of all machine breakdowns. As a result, by monitoring a system, some actions can be undertaken before failure results in a serious influence on the performance of the organization. Therefore, condition-based monitoring provides an alternative to the preventive maintenance assumption of the age-related mode of failure. In addition, Dragomir, Gouriveau, Dragomir, Minca, and Zerhouni (2009) add that managers could concentrate on the just-in-time (JIT) replacements when using condition-based maintenance. Dragomir, Gouriveau, Dragomir, Minca, and Zerhouni (2009) point out that just-in-time maximizes the life of every component, and it can be facilitated by the intelligent buildings or the development of the automation systems.

Kans's (2009) study presents the use of engineering approach in guiding the development of the integrated/sensor systems (IISS). According to the findings of the study, engineering approach offers clear benefits related to the identification of the overall architectural framework and system requirements for assessing and categorizing alternative architectures. Whereas Kans (2009) efficiently addresses the instrumentation functional aspects in order to offer the rapid system configuration and

flexibility to adapt to the evolving data and sensor needs, including the interrogation of sensor interfaces, sensor types, communication, and multiplexing, Dragomir, Gouriveau, Dragomir, Minca, and Zerhouni (2009) concentrate on a particular structural aspect. Researchers present a novel framework for helping in shifting the time-based maintenance approaches towards the condition-based maintenance procedures. Dragomir, Gouriveau, Dragomir, Minca, and Zerhouni's (2009) propose that a novel approach shows the innovation in the design of integrated micro-electro-mechanical -based multi-parameter sensing.

CHALLENGES OF FACING THE USE OF CBM

Regardless of the benefits of CBM, there are various challenges facing its deployment. Simões, Gomes, and Yasin's (2011) analysis reveals that organizations using CBM are faced with challenges relating to initial cost of implementation. Simões, Gomes, and Yasin (2011) point out that the implementation requires the improved instrumentation of the equipment. Frequently, the cost of effective instruments can be high. As a result, Simões, Gomes, and Yasin (2011) recommend that the implementer should consider the significance of the investment prior to the adoption of CBM.

The second challenge related to the implementation of CBM is that it invokes major changes concerning how general maintenance is performed (Reimann, Kacprzynski, Cabral, & Marini, 2009). It can potentially invoke changes to the entire maintenance in the company. It should be noted that organizational changes can be extremely hard to deal with. In addition, the technical aspect of CBM is not always simple.

CONCLUSIONS

This paper has reviewed the past condition-based monitoring. The maintenance program recommends maintenance choices based on the information gathered through condition monitoring. Almost all researchers agree that condition based maintenance is not based on the time interval. The main purpose of CBM is minimizing the costs related to inspections and repairs by gathering and analyzing the continuous or discrete data associated with the condition of the critical components. CBM has highly contributed to sensor technologies, communication technologies, decision support, as well as health and assessment.

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