Condition-Based Maintenance

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Abstract

A well-implemented condition-based maintenance (CBM) regime requires management support, data analysis to determine cost-effective monitoring points and a knowledgeable and disciplined maintenance organization. The main objective of CBM is to ensure that assets fulfill their mission most cost-effectively.

Keywords: Condition-based maintenance, reliability-centered maintenance, preventive maintenance, failure mode, computerized maintenance management system.

Introduction

Condition-based maintenance (CBM) is a management philosophy that posits repair or replacement decisions on the current or future condition of assets (Raheja, Llinas, Nagi, & Romanowski, 2006); it recognizes that the change in the condition and performance of an asset is the main reason for executing maintenance (Horner, El-Haram, & Munns, 1997). Thus, Horner et al. noted that we determine the optimal time to perform maintenance from actual monitoring of the asset, its subcomponents, or parts. They also stated that condition assessment varies from simple visual inspections to elaborate automated checks using a variety of condition monitoring tools and techniques.

The objective of CBM is to minimize the total cost of inspections and repairs by collecting and interpreting intermittent or continuous data related to the operating condition of critical components of an asset (Knapp and Wang, 1992). Knapp, Javadpour, and Wang (2000) argued that monitoring, where cost-effective, could provide adequate notice on pending failures, which would allow for planned repairs based on asset degradation, as opposed to costly time-based (fixed intervals) repairs or emergency breakdowns. In some instances, however, CBM might not be cost-effective, or data might not exist to justify its introduction.

Raheja, Llinas, & Nagi (2000), on the other hand, argued that current approaches to CBM system design are extremely specific and that a generic architecture for CBM is missing. Thus, they claimed that each domain area has its interpretation of CBM that may not be compatible with the requirements of other applications. However, CBM does not apply to all maintenance assets, and we should only apply it where condition monitoring techniques are available and cost-effective (Horner et al., 1997).

CBM requires a robust analysis of reliability and financial maintenance data (Crespo Márquez & Sánchez Herguedas, 2004). Furthermore, it requires an unambiguous understanding of failure modes and rates, asset criticality, and potential payoffs associated with different maintenance strategies. Moubray (2001) cited studies done on civil aircraft describing patterns of failure that contradicted the belief of a relationship between reliability and operating age. He noted that this belief led to the idea that frequent overhauls of an asset would increase its reliability.

According to Moubray (2001), unless there is a dominant age-related failure mode, time-based overhauls do not improve the reliability of complex items. He further noted that it is highly possible that a time-based overhaul would introduce infant mortality failures in otherwise stable systems.

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The Benefit of Monitoring Asset Performance

Wood (1999), as well as Moubray (2001), argued that time-based preventive maintenance (PM) often failed to maximize the service life of each component; in many instances, the components were being replaced with many hours of useful life remaining. PM tasks, based on hard time intervals, waste a lot of resources (Tsang, 1995); that is, often the plant or building is over-maintained (Mann, Saxena, & Knapp, 1995).

Bloch and Geitner (1983), noted that certain signs, conditions, or indications precede 99 percent of all machine failures. Therefore, by monitoring an asset, action can be taken before it has a serious effect on the performance of the organization. Thus, condition-based monitoring offers an alternative to the assumption of age-related failure mode. Moreover, with condition-based monitoring, managers can focus on just-in-time (JIT) replacement. According to Wood, JIT replacement maximizes the life of each component and is facilitated by building automation systems (BAS) or intelligent buildings.

Maintenance Strategies

Coetzee (1999) observed that maintenance management often implement some highly publicized strategy towards increasing the efficiency of the maintenance function such as reliability-centered maintenance (RCM), total productive maintenance (TPM), condition-based maintenance (CBM), computerized maintenance management systems (CMMS), auditing systems and so on. However, most managers do not know what the right regime for optimizing maintenance is. As a result, most efforts do not materialize.

Intervention strategies are not only technical; they are also a matter of art (Heckscher, Eisenstat, & Rice,1994). According to Hecksher et al., best practice strategies fail within a year or so. They labeled this phenomenon *successful failure*, which results from limited know-how within the organization: few internal members understanding what they are moving towards when they start an implementation process (Heckscher, et al.).

As a result, Coetzee (1999) argued for a holistic approach within the maintenance function to implement CBM. A holistic approach would include the evaluation of the maintenance assets, including building structures. Shonet (2003) argued that effective implementation of CBM requires the development of performance indicators for building components and systems. He noted that the evaluation of building components should assess (1) the physical performance of building systems, (2) the frequency of failures of building systems, and (3) actual preventive maintenance (PM) carried out on the systems.

Likewise, a holistic approach should also include performance measurement systems as a tool for delivering strategic objectives, such as the implementation of a balanced scorecard process (Letza,1996); the evaluation of breakdown (BD) maintenance, where the run to failure philosophy prevails; the evaluation of planned schedule maintenance, where planning and scheduling methodologies are rigorously applied; and the evaluation of CBM, where critical and costly assets are monitored for degradation (Amari and McLaughlin, 2004). Degradation is a process where system parameters gradually worsen.

The application of CBM requires the use of certain analytical tools, such as failure mode, effect, and criticality analysis (FMECA) and RCM to determine the likelihood of failure and how failure would occur; as well as a reliable information tool (i.e., CMMS) to capture and track repairs and associated costs of the assets under consideration.

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FMECA is a systematic process for identifying all possible ways in which failures of an element can occur and RCM is an approach for identifying the most applicable and cost-effective maintenance task for asset elements (El-Haram & Horner, 2002). Thus, El-Haramand Horner noted that the RCM process evaluates each failure to determine its consequences if any, as well as each consequence, to determine applicable and cost-effective maintenance tasks.

Failure is when an asset, component, or element cannot fulfill its mission. For many assets, however, certain symptoms (soft faults) often occur before total failures, such as excessive vibration, abnormal heat (Knapp et al., 2000), solid contents in oil, and so on. Sensors capable of detecting pre-failure signals can provide alerts and alarms notifying the asset operator of the potential of an impending failure. For other assets, failure (hard faults) may occur instantaneously and cannot be predicted; generally, these failures are exogenously generated.

CBM is a non-intrusive technique, and the actual preventive action (repair) is taken at the incipient failure level (Tsang,1995). Tsang noted that hidden failures are often present in standby units, protective devices, or infrequently used assets. Hidden failures are not evident until the time when the proper function of the item is needed.

Thus, a CBM regime on standby units, such as protective devices, or infrequently used assets would not be effective, since upon startup hidden failures could occur. However, to counteract, hidden failures Tsang (1995) recommended faultfinding (FF) tasks. FF tasks are performed at scheduled intervals to check the state of assets or items with dormant functions. A typical example is an emergency generator that is generally idle until needed.

According to Sherwin and Al-Najjar (1999), if downtime is very expensive, inspection and condition monitoring are not the best overall maintenance policies unless the combined age to failure distribution of the various failure modes of an asset, or component, has a large variance such that the standard deviation is greater than or (nearly) equal to the mean.

Determining CBM Failure Point

Determining when a failure mode has been initiated and predicting the time remaining for complete failure requires reliable data and effective algorithms. Moreover, making decisions on the appropriate maintenance response to CBS alerts or alarms requires a disciplined maintenance organization.

Many maintenance organizations equipped with CBM do not effectively respond to alerts and alarms. However, some CBM systems are integrated into the CMMS, so that a work order is automatically generated when signals from a monitored point trigger alerts or alarms. This is particularly suited for continuous process plants where failure and downtime can be extremely costly.

Alarms

A key requirement for successful implementation of CBM is a low incidence of false alarms and quick and reliable detection of faults (Buswell &Wright, 2004). Buswell and Wright noted that an International Energy Agency (IEA) project indicated that abrupt faults could be easily detected; degradation faults, on the other hand, had to be quite large before detection was unambiguous. The study also noted that it is possible to balance robustness and sensitivity. Increasing sensitivity results in early warning of faults but may increase the incidence of false alarms (Knapp, Javadpour, & Wang, 2000). However, the condition-

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based monitoring industry leaders have applied quality control type techniques in the detection of machine faults; thus, providing increased protection from false alarms, as well as from missed faults (Mann et al., 1995).

Conclusion

The introduction of CBM without managerial support at all levels, appropriate data and analysis, reliable data, and effective algorithms. disciplined and knowledgeable maintenance staff is unlikely to achieve desired results.

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