Asset Management Questions

Are 'On-condition maintenance' and 'run-to-failure' the same thing?

References:

A. US DoD Report AD-A066579 Reliability Centered Maintenance, Nowlan and Heap, Dec 1978
B. International Electrotechnical Vocabulary (IEV)
C. Navair 00-25-403 Guidelines for the Naval Aviation Reliability Centered Maintenance Process
D. Hare, Masters, Kennedy; The Funding Battle: Defending the Maintenance Budget of a Government Owned Utility Business, ICOMS 2013

Introduction

There is a view that condition based maintenance represents the repair or replacement of equipment when its condition is such that it no longer achieves its functional specification, which is essentially operating the equipment until it functionally fails. Whereas predictive maintenance represents the assessment of equipment condition by the collection of data that represents it's potential for future failure and intervenes to restore equipment through repair or replacement to avoid functional failures.

This paper addresses the oft stated belief that there is no difference between maintenance based on the assessed condition of an item (a process termed "condition monitoring") and the maintenance of an item that degrades to the point of breaching functional requirement limits. A comparison between "condition monitoring" and "predictive maintenance" shall also be made.

An application of the role of condition monitoring in determining preventive task frequencies shall also be assessed to test the validity of this statement.

Implications

Managing asset related risk usually requires that equipment is monitored in some manner such that interventions can be achieved prior to equipment functionally failing. Such interventions must of course be cost effective in managing the consequences of those functional failures such as:

- Commercial or other loss through non delivery of product or service, where defective products or materials result or a service is not provided in either a timely manner or at all;
- Increased cost and down time due to secondary damage to the equipment itself and associated systems either functionally or geographically related;
- Increased cost of more extensive repair schemes where simple repair limits are passed and hence more extensive repair or replace solutions are required for return to service and;
- Increased logistics costs associated with unplanned failures that will likely occur at inconvenient times and caused increased unavailability due to the effort required to assemble resources and undertake the work often in unusual circumstances with what is available at the time.

Technical Facts

Condition monitoring is one of three forms of preventive maintenance defined in the seminal document on Reliability Centered Maintenance by Nowlan and Heap. The other forms are hard time or fixed life for wear out characteristic type equipment and failure finding tasks for equipment that has a hidden function and the failure mode is not amenable to management by either condition monitoring or hard time maintenance actions.

There is no mention of predictive maintenance which is a term introduced in the late 1980s and extended with the application of prognostics. Arguably both are a variation on "condition monitoring" where the assessment of various information that defines the "condition" of the equipment is related to failure potential which is either human or machine interpretable to define a required response.

Condition monitoring tasks are described as follows in a direct quote from Nowlan and Heap

> Scheduled inspections to detect potential failures are commonly termed *on-condition tasks*, since they call for the removal or repair of individual units of an item "on the condition" that they do not meet the required standard. Such tasks are directed at specific failure modes and are based on the feasibility of defining some identifiable physical evidence of a reduced resistance to the type of failure in question. Each unit is inspected at regular intervals and remains in service until its failure resistance falls below a defined level - that is, until a potential failure is discovered. Since on-condition tasks discriminate between units that require corrective maintenance to forestall a functional failure and those units that will probably survive to the next inspection, they permit all units of the item to realize most of their useful lives.

This position has been maintained in the latest International Electrotechnical Standards as published in the IEV

> ***IEV 192-06-07 - condition-based maintenance***
>
> *preventive maintenance based on the assessment of physical condition*
>
> *Note 1 to entry: The condition assessment may be by operator observation, conducted according to a schedule, or by condition monitoring (192-06-28) of system parameters*

This can be compared to statements regarding operate (run) to failure as noted firstly in Nowlan and Heap,

> Where safety consequences are not involved, any applicable task must be cost-effective, and this condition is usually difficult to satisfy unless the failure has operational consequences. Once again, the design often emplys redundancy to limit the number of items subject to such failures. As a result, there are tens of thousands of items on complex equipment for which scheduled maintenance provides no advantage. Since such items cannot benefit from preventitive maintenance, they are left in operation until a functional failure occurs. This strategy permits each unit to realize its maximum useful life.
>
> Items that cannot benefit from scheduled maintenance are characterized by two properties:
>
> - Such items have no hidden functions; hence a failure is evident to the operating crew and will therefore be reported and corrected.
> - The failure is one that has no direct adverse effect on operating safety.

and also in the IEV which defines a failure as follows:

> ***IEV 192-03-01 failure, <of an item>***
>
> *loss of ability to perform as required*

However, not withstanding the comments above, the key to the effectiveness of a condition monitoring task compared to a "run to failure scenario" can be the quantitative risk based assessment of the two approaches. This is explained in the following worked example at Figure 1.

Condition Monitoring and Predictive Maintenance

There is no definition for predictive maintenance in the IEV, arguably from an International Standards view (ISO or IEC) it does not exist. However, some public domain definitions are:

Those activities involving continuous or periodic monitoring and diagnosis in order to forecast component degradations so that as-needed, planned maintenance can be performed prior to equipment failure." ***http://reliabilityweb.com/tips/article/definition_of_predictive_maintenance/***

Predictive maintenance (PdM) techniques are designed to help determine the condition of in-service equipment in order to predict when maintenance should be performed. This approach promises cost savings over routine or time-based preventive maintenance, because tasks are performed only when warranted. ***https://en.wikipedia.org/wiki/Predictive_maintenance***

Clearly these definitions are indistinguishable from "condition monitoring" as defined in the international standards and described by Nowlan and Heap at Reference A. More likely, usage of predictive maintenance represents marketing hype for technology based condition monitoring such as vibration analysis, thermography, wear debris analysis etc. operating beyond normal human senses.

Prognostics extends the concept of condition monitoring from a single reject condition based on risk of failure in the time between monitoring sessions to a more exact understanding of the remaining "useful" life, This requires significantly more data and knowledge of failure characteristics than the simple condition monitoring approach offered in the worked example. Suffice to say that prognostics is itself and advance form of condition monitoring and hence reflects the disconnect in myth 9.

Prognostics is an engineering discipline focused on predicting the time at which a system or a component [1] will no longer perform its intended function.[2] This lack of performance is most often a failure beyond which the system can no longer be used to meet desired performance. The predicted time then becomes the remaining useful life (RUL), which is an important concept in decision making for contingency mitigation. ***https://en.wikipedia.org/wiki/Prognostics***

Worked Example

Reference C, Navair-00-25-403, provides guidance on quantitative methods to assess condition monitoring task frequencies. By comparing the cost of undertaking a condition monitoring task versus not doing any task at all and running to failure, the clear difference between the two approaches can be demonstrated.

The diagram below is from Reference A and defines the boundary conditions necessary to the determination of an effective condition monitoring task and its frequency.

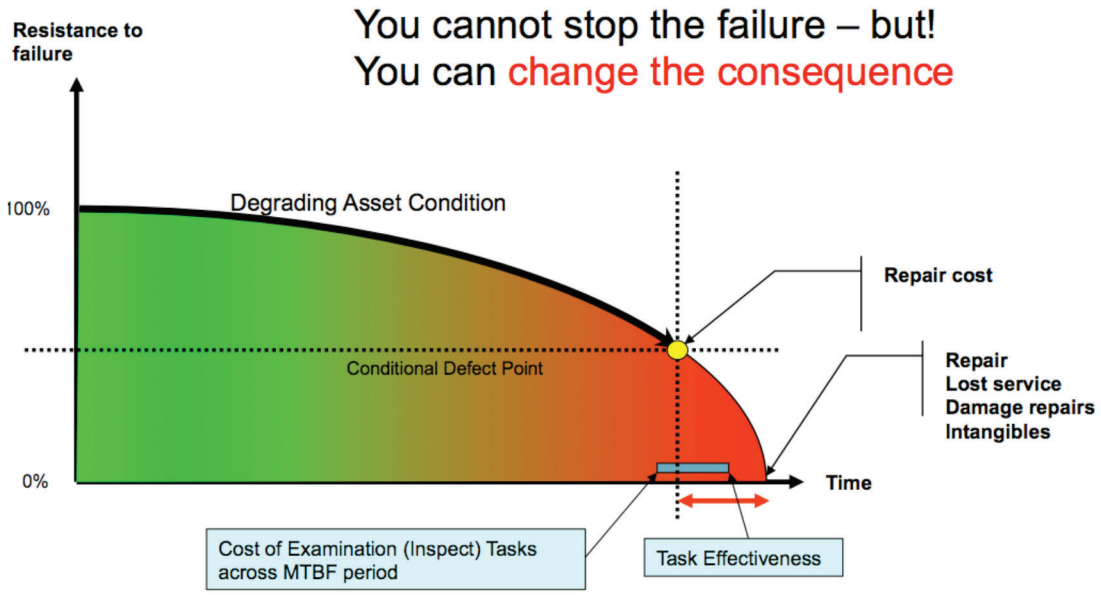

Figure 1: Condition monitoring model

Provided six validity characteristics are met, a condition monitoring task can be determined for certain equipment, otherwise the equipment should be run to failure (functional). These characteristics are:

1. The equipment is a random failure pattern item.
2. The warning period between Conditional Defect Point and Functional Failure is usable to undertake a planned maintenance response.
3. There is a defined Conditional Defect Point that is measurable or can be assessed in a consistent manner.
4. The warning period must be less than 20% of the Mean Time Between Failure (MTBF).
5. The task effectiveness of the staff undertaking the task can be accurately determined.
6. A cost effective task period exists.

The resulting formula for determining optimum condition monitoring task period is provided in Reference C and shown at Figure 2 as follows:

Where T = warning Period
θ = Task Effectiveness
Task period = T/n

$$n = \frac{\ln\left[\frac{\frac{-MTBF}{T} * C_i}{(Cnpm - Cpf)*\ln(1-\theta)}\right]}{\ln(1-\theta)}$$

Figure 2: Condition monitoring task frequency assessment

The resultant curve that defines that optimal point is shown in the following graph, which demonstrates how the equivalent of "run to failure" (i.e. cost curve rises rapidly past the lowest cost task period point at 5.5 months), wil generate significant additional cost versus application of the condition based maintenance approach. This curve is shown at Figure 3.

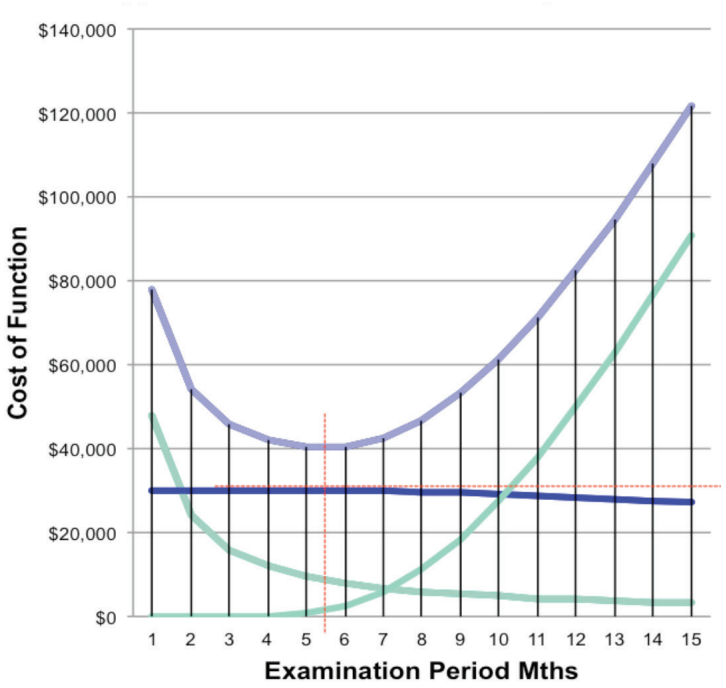

Figure 3: Condition monitoring task optimisation

Conclusion

On condition maintenance is clearly a proactive preventive maintenance task that balances the cost of the task with the cost of not doing the task. Cost of not doing a task relates to a "run to (functional) failure" decision. Quite clearly the two failure conditions are different, condition monitoring is searching for a "conditional failure" point that represents the need for maintenance intervention to prevent the losses of a "functional failure" that may result from a "run to failure" policy for that equipment in that context of operations.

Hence the belief that "That 'On-condition maintenance' and 'run-to-failure' is the same thing!" is confirmed as a myth.

ASSET MANAGEMENT COUNCIL

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