CONTINUOUS CONDITION MONITORING

Modern Diagnostic Systems Ensure Early Failure Detection and Damage Prevention

By Jost A. Anderhub

One of the greatest challenges facing plant owners and machine operators involves increasing the availability of production machinery within the scope of their day-to-day work, without using additional resources for maintenance measures. To pull off this balancing act, over the past 70 years three different maintenance strategies have been devised and pursued. The following examines the different principles, along with their suitability for use in day-to-day practice; and provides answers to the challenges involved in the efficient maintenance of sophisticated industrial machinery.

The "first generation" (1940 to 1950) of maintenance was neither strategic nor efficient, the motto being "run it until it breaks down." Machines were acquired redundantly in some cases, and switched over if one broke down. If this dual investment was not possible and a fault occurred; the corresponding production section was shut down in order for the laborious search to find the cause and for its repair to begin. The level of technical personnel required for this, the tying-up of storage capacity and capital, as well as the loss of production that had to be taken into account were accepted.

Preventive Maintenance

Until the mid-1970s, the concept of "preventive" maintenance was practiced. On the basis of manufacturer's directions, error logs and personal experiences, the operational lives of machines and their components were estimated and, on this basis, calendar-based maintenance schedules were drawn up. The objective was to use components for as long as possible, in order to inspect or to replace them in good time before an expected damage occurred. The deadline for inspecting or overhauling was calculated on the basis of the said factors (manufacturer's directions, error logs). Using this calendar or operating time-based approach, it was — at the planning level, at least — possible to roughly coordinate production and maintenance shutdown times. Figure 1 illustrates the time chart that fits this maintenance program.

Preventive maintenance signaled an initial step in the direction of long-term maintenance organization and, for a large number of components and machine types, this strategy could be employed successfully.

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Suddenly Failing Components

For the bulk of large-scale industrial machines, it transpired, however, that this preventive approach was not suitable in practice; since a large number of unscheduled downtimes and instances of capital damage still occurred, caused by components failing suddenly. The mean time to repair (MTTR) even became longer compared with previous years; as often the stock of spare parts had also been reduced, and the production of new parts and their supply used up precious production time.

To find out the reason for the vast discrepancy between planning and reality, United Airlines of the U.S.A. examined the life cycles of complex machines and their components over a lengthy period of time. Since the aviation industry has been the driving innovator of quality testing and management since it first came into being, the results of this study are still frequently quoted today, and provide the basis for a large number of modern-day maintenance concepts, including that of "reliability-centered maintenance." See Figure 2.

The results of this investigation prove that the time of failure cannot be predicted in 89% of all components and machines studied. This is because a direct relationship exists between component operational life and component failure probability in only a minority of the objects studied. If we examine the theoretical, expected life cycle of components as a whole, there is the time of premature failure, a long phase of failure-free operation and, finally, a wear-related increase in the failure probability toward the end of

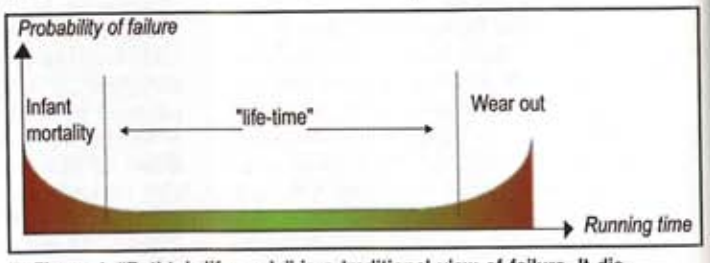

Figure 1. "Bathtub life cycle" is a traditional view of failure. It displays a high failure risk after machine start-up and increase of failure rate toward end of component lifetime caused by wear.

the life cycle. This life cycle has been graphically depicted and has come to be known as the "bath tub life curve."

It transpired, however, that the "bath tub life curve" can only be applied in the case of a mere 4% of the machines studied. Although the overwhelming majority (68%) also exhibited the phase of premature failure, after completing

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this phase, it was possible the life cycle would end at a nonpredictable point in time.

Offline Monitoring

The arrival of modern automation technologies in the '80s also extended to tools for maintenance. This development started out with mobile measuring instruments for measuring vibrations and temperatures, which, to this day, are still being used worldwide and in thousands of applications. What is known as "snapshot" or "offline" monitoring made it possible for the very first time to receive information about the condition of machines. Despite that, only a very short operating period was recorded. With periodic repetition, it was possible to detect the onset of failures and to initiate corresponding measures aimed at damage prevention.

At this juncture, the difference between "failure" and "damage" should be briefly explained. "Failures" denote behavior patterns of components (or machines) that deviate from the specification, e.g., because of stiffness, corrosion, abrasion or leakage. Failures such as these necessarily do not have to render the operation of the machine impossible. They can, however, be measured — meaning that they can also be recorded. The term "damage" denotes the final functional breakdown of a component or a machine, which renders further operation no longer possible.

For maintenance engineers, the time between the initial detection of the failure and the occurrence of damage is of particular interest. This is because this period of time can be referred to as the "advance warning period" before an instance of damage occurs. In the case of a worn car tire, this advance warning period can, depending on the style of driving, be several thousand miles or kilometers. In industrial everyday life, continuous observation of the developing failure and the timely shutting down of the machine shortly before the damage occurs helps to prevent many lost hours of operation.

This important advance warning period is mostly depicted in what is known as a "P-F-interval." In this case, "P" stands for "potential failure" (initial failure detection) and "F" stands for "functional failure" (time of damage). If the task is to exploit the life cycle of components to the max, it is necessary to record all the relevant measuring data precisely and reliably — which allow the duration of the period from "P" to "F" to be ascertained.

In the case of a car tire, this entails measuring or performing a visual check of the tire surface every 62 mi. (100 km) driven, in order to detect whether the canvas of the tire body is already visible. If this check — be it for machine operation or as in the case of the car example — is not performed on a regular basis, the failure is allowed to develop unchecked into what might possibly be a severe instance of damage.

For this reason — in order for the application of the P-F interval to lead to the desired results — it is essential that a reliable and periodic check of all the components is carried out, so that failures are detected early and the resulting damage is avoided.

Offline monitoring systems can only satisfy these requirements to a limited extent. If the monitoring or "snapshot" intervals selected are too long (Figure 2), failures may only first be detected in what is an already highly developed stage, and the advance warning periods are dangerously short. If monitoring period is too short, time is wasted in frequent and unnecessarily frequent data collection and analysis (Figure 2).

Online Condition Monitoring

Systems for the continuous monitoring of the condition of machines and components (online condition monitoring) offer significant advantages, in this regard. These advantages not only impact on the production efficiency, but also on the safety of humans, the environment and machinery. This is because the continuous checking of the behavior of components allows the onset of failures to be reliably detected at an early stage, which in turn extends the period of time available for planning and implementing the necessary repairs. Setting the monitoring system sensitively and activating an automatic machine stop when damage occurs reduces the probability of capital damage and consequential damage dramatically. As a result, it is possible to realize highly efficient and extremely low-risk machine operation at the same time.

Whereas in the past, redundant machines and — in the event of damage occurring — a changeover to a sister machine was mentioned, today, what were formerly redundantly designed machine lines are integrated ever-more frequently into the operative production chain. Continuous monitoring of these machines is becoming increasingly popular and, in many cases, is proving to be a quantifiable, worthwhile investment.

Numerous examples have been published, which prove that even six-figure investments in modern diagnostic systems have paid for themselves within a matter of a few months. Frequently, the period of time for the evaluation and approval of such an investment is considerably longer than the actual payback period, once the system has been installed and is in operation.

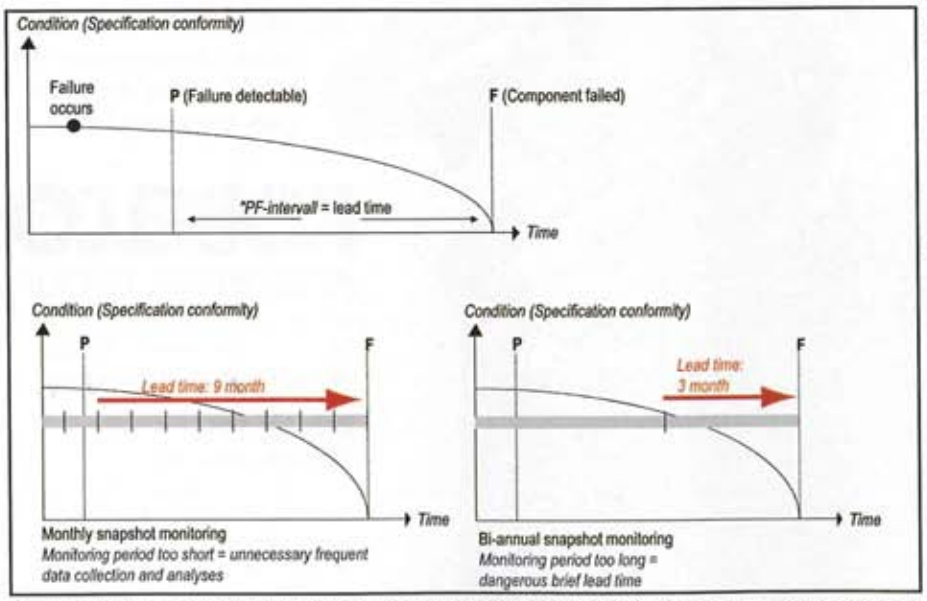

Figure 2. The "PF-Interval" describes the advance warning period prior to damages. The longer this lead time is, the more efficient are the responses to the impending damage.

Summary

All in all, it is possible to state that "trial and error" methods can no longer be justified in today's industrial world, and the number of installations of specialized expert systems is set to grow rapidly. This is not only because of the requirements exacted by the global markets, but also because of the market availability of systems that satisfy the high standards in terms of the safety and reliability of machine operation. ■

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