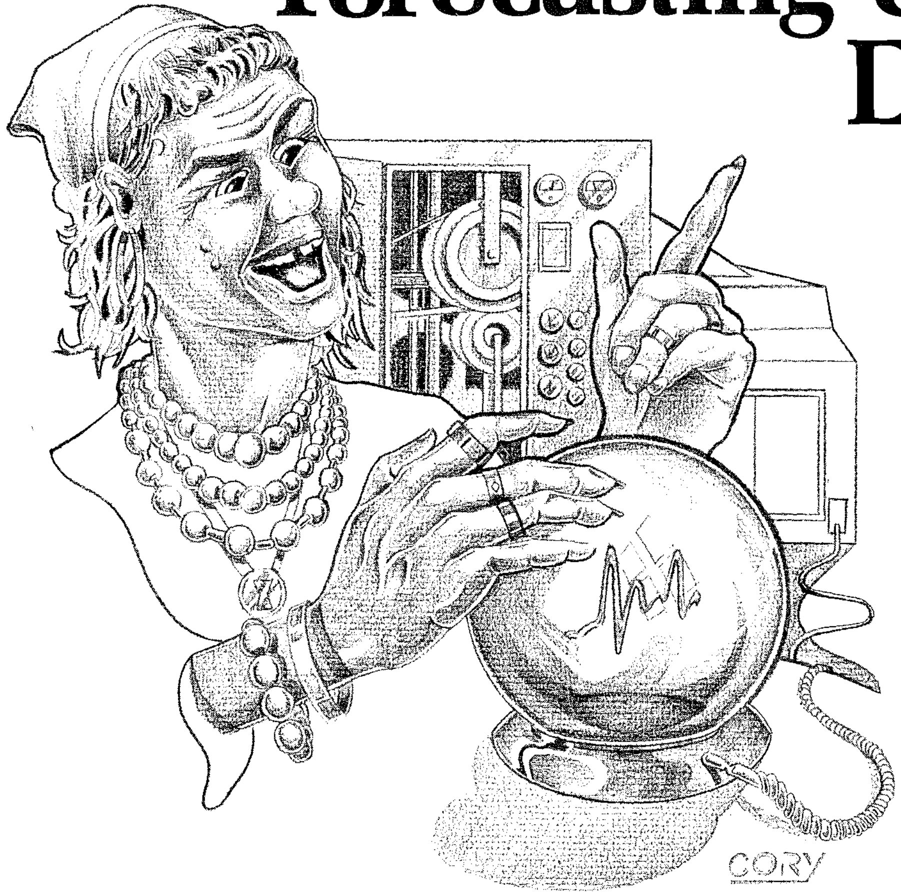
Predictive Maintenance–Forecasting Upcoming Downtime



Predictive maintenance determines if your machines are operating efficiently, and if problems can be expected in the future. It tells you when to expect downtime without disrupting the operation of the machine or altering it in any way.

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THE DOWNTIME DILEMMA

Knowledge of your equipment's future saves money. If you know when downtime will strike, costs can be minimized in planning the purchase of replacement parts, in predicting equipment downtime, in determining manpower requirements for repair, or for reassigning production workers while the equipment is out of operation. On the other side, if no problems are revealed, no maintenance work is performed and operating plans can be made accordingly. Either way, you save.

The concept of predictive maintenance is not new, but recent economic developments and technological advances are leading many companies to take another look. The spiralling costs of replacement parts, labor, energy, and production losses when a system fails to perform at peak efficiency are some reasons for this fresh look. New instrumentation is also making it easier to analyze the performance of a machine while it is operating. New devices to sense, monitor, control, and record the operating characteristics of a machine produce data previously difficult, if not impossible, to acquire. New instrumentation also contributes to the ability of less-trained personnel to interpret and effectively use the data produced during predictive maintenance tests.

To date, the electrical field has taken the lead in applying the principles of a predictive maintenance program. Most people ac-

Reprinted from PRODUCTION ENGINEERING April 1978

quainted with maintenance as practiced in the electrical field are familiar with the equipment and tests for insulation resistance, low resistance, and absorption. They are also familiar with such concepts as insulation breakdown, continuity, absorptivity, and phase unbalance. Each test—alone or in conjunction with others—provides an insight into the relative electrical health of a particular piece of equipment. For instance, using the insulation resistance test shows if the resistance-to-ground is changing.

As an example, assume that a large motor, during initial tests to establish a baseline "signature" or performance profile, had a resistance-to-ground of 20 megohms. Six months later the same motor is monitored and a new reading taken. If the reading is unchanged, the motor is considered to be in excellent health. If the resistance-to-ground decreases, however, the motor has undergone an adverse change that in time could result in failure. This non-destructive test required minor disassembly and the knowledge gained—when used properly—results in both dollar and manpower savings. Continued monitoring of this motor permits predictability of future failure, thereby eliminating the destruction of equipment, unnecessary operational downtime, and extensive maintenance overtime. The value of this type of testing is that it is quick, precise, economical, and results in no untimely disruption to the work cycle.

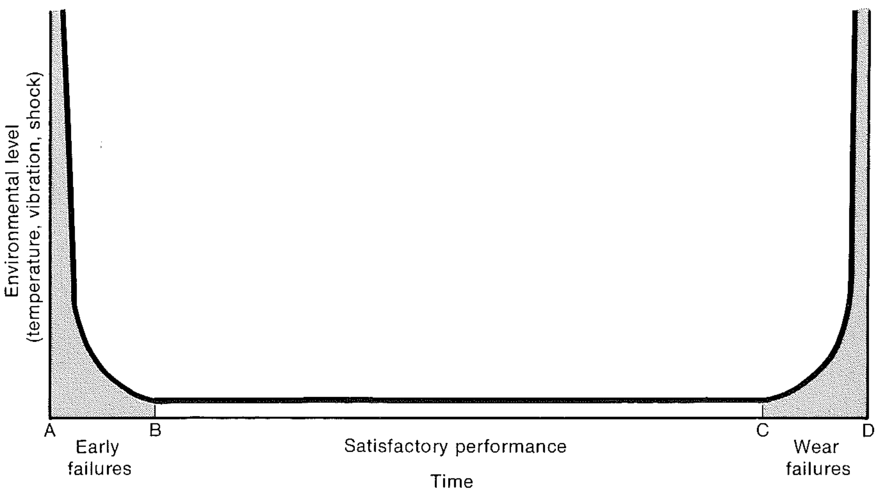
On the mechanical side, there are two common approaches used today:

■ Preventive maintenance—a time-based program in which equipment is inspected or maintained on an assumed cycle based on the prediction that the piece of equipment will wear out in a finite period.

■ Breakdown maintenance—based upon the concept of letting a piece of equipment run until it shuts itself down. There are, of course, many variations to each of the programs.

A better method is vibration testing and analysis. This ap-

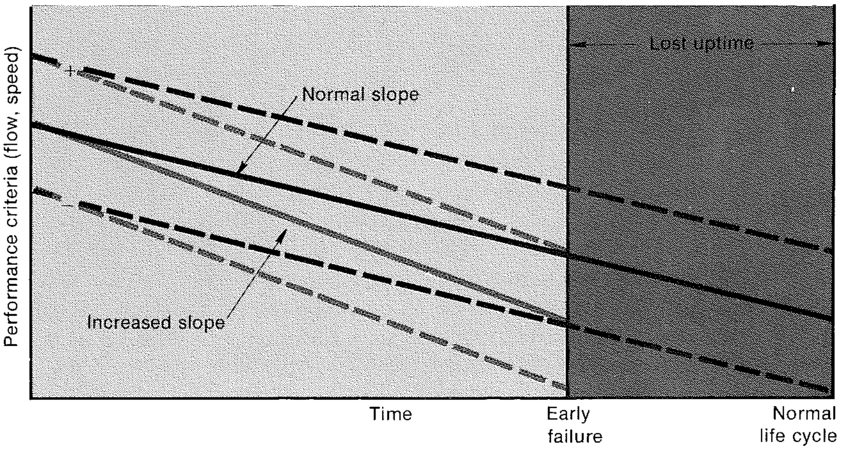
At either end of the equipment's lifeline . . . the majority of failures occur



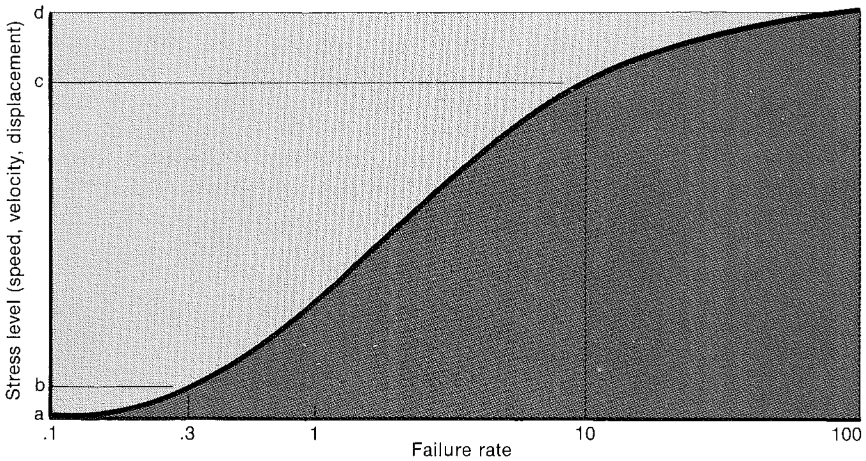
Are your machines getting pushed?

When the early failures are weeded out after the initial start-up, the equipment is expected to follow a normal trend over its life cycle. This figure depicts the effect of altering a critical parameter (such as speed, flow, temperature, etc.) on the performance history of a piece of equipment.

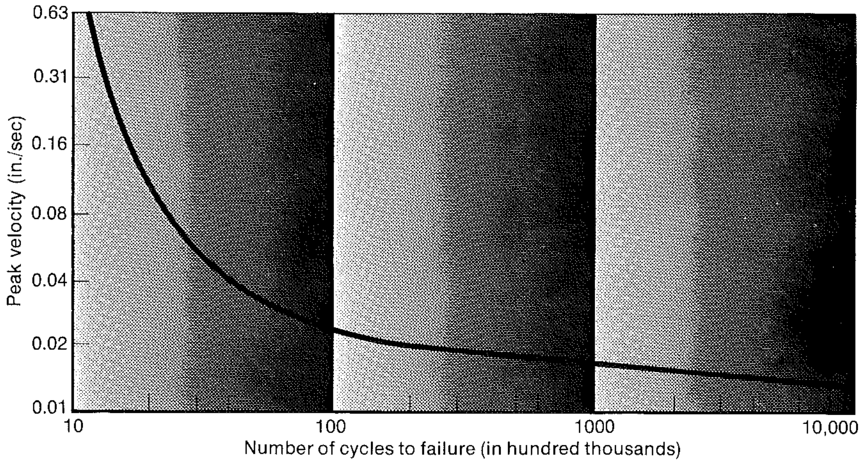
The black line marked normal represents the nominal performance to be expected from a piece of equipment. The plus (+) or minus (−) black lines show the acceptable range above and below this slope due to variations in manufacturing and installation tolerances. The line slopes due to the normal degradation of equipment. The colored lines show the increased slope and subsequently decreased life cycle when specified limits are exceeded. These limits could be increased vibration, increased acoustic and/or temperature levels, or a host of other variations.



As stress levels increase . . . so does the failure rate



The SN curve: As peak velocity of vibrating elements goes up . . . the number of cycles to failure goes down



proach has been practiced for many years with varying degrees of success. The concept is no more complicated than the routine electrical tests mentioned previously. Like electrical testing, it does require a working knowledge of the basic engineering principles. At least to get started, the best approach is for production maintenance to call in consultants for advice on setting up proper testing and analysis procedures.

But this addition to your shopfloor shouldn't be viewed with anxiety. Mechanical predictive maintenance is simply the next logical step in the chain of development of vibration testing or analysis. An important aspect of mechanical predictive maintenance is that the evaluation is taken while the equipment continues to operate. Thus, determining future downtime need not be a source of downtime itself.

Predictive maintenance

A predictive maintenance program can be implemented during the design or engineering phase of your new equipment, or during installation, startup, and full operation. Significant benefits can accrue to the user in each stage—but the earlier, the better.

In the design or engineering phase, parameters can be specified relative to the vibration limits of the equipment and its components. Proper specification of these limits can significantly improve the equipment's operating characteristics. It also eliminates controversy as to equipment acceptability during startup. Such specifications are routinely accepted by electrical engineers. For example, no electrical engineer would permit the acceptance of an electric motor with a low insulation resistance since this usually indicates near-term problems. Potential capability tests are routinely conducted in all stages of the life cycle on electrical equipment.

Vibration specifications are no different. Excellent standards exist today for every type of equipment regarding allowable vibration limits. Ignoring these standards will lead to premature problems and less-than-desirable performance. Vibration is as important a parameter for mechanical equipment as any of the electrical parameters mentioned previously are for electrical equipment.

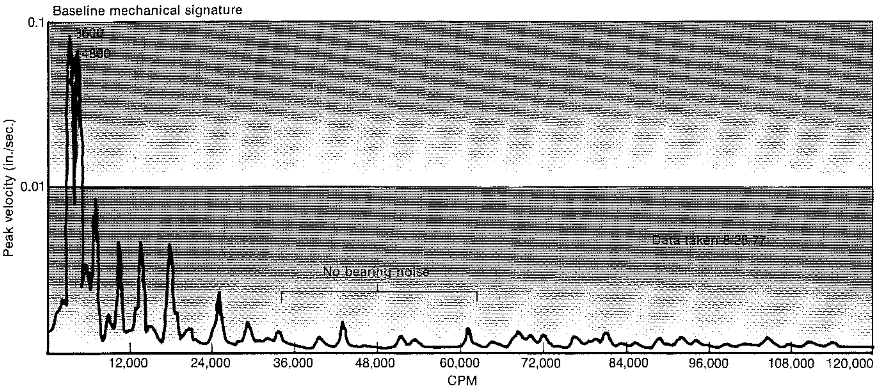
During the startup phase of a new system, it is conceivable that defective pieces of equipment will be encountered.

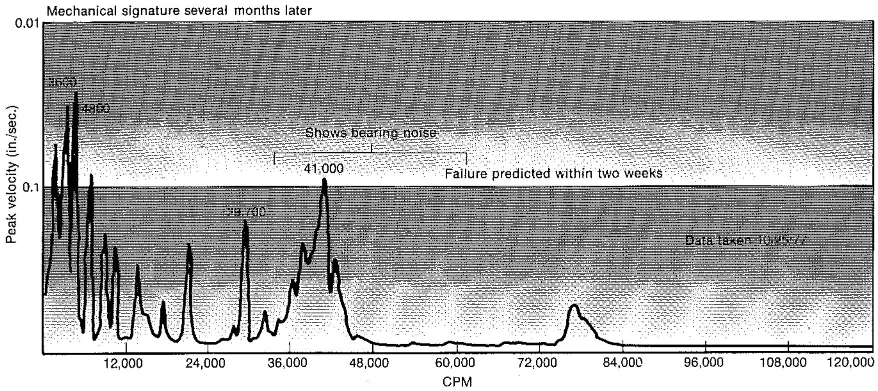
The failures uncovered during the equipment startup period can be attributed to many factors. They can be due to manufacturing defects, incorrect installation procedures, design deficiencies, or shipping damage . . . to name a few. Once these have been resolved, the machine enters a longer period where it operates properly. This will continue through the normal life cycle of the equipment until components of the equipment begin to wear out.

The cause for vibration analysis needs no better advocate than the "SN curve." This curve shows you the number of cycles the equipment can withstand prior to failure. The SN curve is not a theory, but is based on experiences throughout industry, including original equipment manufacturers and the automotive industry. The cycles to failure depend upon the magnitude and the number of cycles as plotted against time.

Is your equipment healthy?

These two signatures show how the current and relative changes in a machine's condition are determined. The signatures were taken from the same machine, but several months apart. The first signature was taken when the machine was healthy. The second was taken after bearing deterioration had begun. When this latter signature was taken, there were no observable signs of trouble. While there are more complicated analyses that you can use, these readily tell you of the machine's changes over a period of time. Comparing these mechanical signatures helps you predict a shortened life cycle for the bearing.





Any piece of equipment will eventually fail when exposed to enough stress enough times. There are many means of extending the life cycle of equipment. One is to simply build massive equipment, so that it withstands high vibration levels for extended periods. Because few companies want to pay for these massive units, this is rarely considered a viable alternative. A reasonable one, however, is designing equipment within good engineering guidelines that minimize the magnitude of response as well as the number of cycles.

In most instances, this means you'll have to do more advance planning when specifying new equipment. Vibration parameters should be specified as part of the acceptance criteria. For example, permissible vibration due to foundation problems, manufacturing defects and poor assembly techniques can all be determined and set down in the equipment specifications. Using these parameters, the acceptance of equipment is clear.

Signature analysis

The heart of predictive maintenance is signature analysis. A signature can best be explained by comparing it with an electrocardiogram (EKG) of the human heart. A doctor seeing an individual's EKG for the first time can develop some important conclusions. The one thing the doctor cannot do with a single EKG, however, is to determine the relative condition of the heart. However, if he takes several EKG's over time, the doctor can assess a malfunction in the heart and the rate of improvement or deterioration.

Both the doctor and the vibration engineer require their data in real time; that is, the graph must represent the actual state of health of the person or equipment under evaluation at that precise moment. The instrumentation used—transducer, signal conditioner, oscilloscope, and recorder—perform the same function. It's the overall frequency content that differs. The doctor is looking at a low frequency response up to two times a normal heart rate. The vibration engineer, through the attenuators of his instrument, can look at frequencies up to 1,200,000 cycles per minute. This wide range of response allows the vibration engineer to evaluate all aspects of the system simultaneously—the floor, the base structure or mount, the bearings, the motor, and the rotating elements, both internal and external.

" Determining future downtime need not be a source of downtime itself "

An equipment signature analysis is used in the same way as an EKG. There are characteristics in a machine's signature, just as in an EKG, that point to normal or abnormal operating conditions. However, to determine the relative change within a piece of equipment, it is necessary to view the signature in relation to previous signatures on the same equipment.

Using signature analysis as a part of predictive maintenance helps assure that only *necessary* maintenance work is done. Maintenance people can readily determine when equipment is functioning properly and can delay routine maintenance if appropriate.