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Powertrain performance echoes effective predictive maintenance

By Edward Sullivan and Neville Sachs

Machinery maintenance efforts should begin before a piece of hardware even makes its way to the plant floor.

Maintenance efforts for rotating equipment should start long before the hardware makes its way to the plant floor. Consider the chain of logic between performance and predictive maintenance. Competitive manufacturing plants ensure that rotating equipment is capable of performing at the required levels of precision and accuracy. Achieving the required performance level, in turn, demands that the machinery be as reliable as possible when operators call upon it to help convert raw material into finished goods. The degree of reliability evident on the plant floor is a function of your predictive maintenance program. Addressing the following questions can give you an outline for more effective maintenance, improved reliability and reduced life-cycle cost.

When should we start planning the maintenance for a new piece of machinery?
A. Doing this during the planning stages, before the machine is purchased, helps minimize surprises. Of course, you’re going to start with the vendor’s list of recommended spare parts and maintenance practices. Check vendor references and talk to the maintenance managers responsible for the same or similar machines. Ask how actual maintenance schedules compare with the vendor’s recommendations. Ask for any special suggestions and insights into the machine’s reliability and maintenance needs. Then, be sure to use this information for machine justification.

Do predictive maintenance inspections have to start when the machine is new? Why do we have to be concerned about the condition of a brand-new piece of equipment?
A. The simple answer is to be certain you’ve received what you paid for. Check the machine in great detail as soon as it starts. There’s good data that shows 14% of industrial mechanical equipment has a significant defect when installed (Figure 1). Because of errors made before the machine starts, one in seven will probably require major maintenance before achieving 25% of its design life. Ensure that your machinery is installed and operated correctly by using a detailed equipment acceptance inspection (EAI).

Does this require an expensive, out-of-town consultant bearing all sorts of expensive test gear?
A. Well, you certainly should have a qualified person with lots of skill and experience look at the installation (Figure 2). But it doesn’t have to be expensive and you most likely have access to some qualified people, either in-house or at a nearby supplier.

Keep a few points in mind when developing your EAI. First, its detail should be proportional to the machine’s value. For example, a spared, inexpensive pump whose breakdown won’t be costly doesn’t merit spending a lot of time and money on the inspection. But if a failed, inexpensive pump would cause costly collateral damage, conduct a detailed inspection, including motor current analysis, vibration analysis, infrared scanning and other predictive maintenance measures.

The person conducting the inspection should have a background in detailed testing of similar machines. What gets us in trouble isn't the things we know we don't know; it's the things we think we know, but actually don't. An inspector without a good understanding of how the machine operates shouldn't be inspecting it.

Don't make the machine vendor solely responsible for the EAI. Vendors try to do a good job for customers, but inspector loyalty lies with whoever signs their paycheck. If you're relying on vendor inspection, be certain you've got your own skilled people looking over the inspector's shoulder. Remember, the supplier's representatives inspected and passed the 14% mentioned earlier.

Our machine is installed; the faults revealed during the EAI were corrected. What long-term predictive or preventive inspections should be planned?
A. Oops! We have to step back to the preplanning phase to analyze what might go wrong with the machine. Then, knowing what to look for, we can plan for the needed people and inspection equipment.

Different machines require different inspections and inspection skills. For example, it's unlikely that someone who is good at vibration analysis and diagnosis will also be a qualified certified lubrication specialist who is good at motor current analysis. Planning for your inspections means:

Plan to have qualified, certified people conduct them. This might require hiring skilled vendors or having your technicians trained and tested.

Analyze machines to understand whether they should be monitored manually or with factory-installed transducers and the like.

Good grief! This sounds like it's expensive. Is it really worth it?
A. The answer depends on the cost of a breakdown or a production interruption. Only you know the cost of being unable to supply your customers. Only you can estimate the cost of an environmental incident that an unanticipated breakdown initiates. But several studies have shown that plants with an active PdM program enjoy rotating equipment maintenance costs that are about half of those seen in a reactive plant. Also, the equipment availability in plants using PdM is about 10% higher.

You've convinced me that we should have a PdM program. Where and how do I start?
A. The key to any intelligent maintenance program is understanding the cost of maintenance and the cost of not having a machine available. Many maintenance technicians are parts changers, blindly replacing pieces until the machine operates again. In some places, this is acceptable, but in most competitive, lean manufacturing sectors, this approach leads to plant closures.

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Look at your equipment history and the costs. Develop a 3 X 3 (or 3 X 4) matrix to determine which machines are most critical and demand the most intense inspection. Whether you do the work or outsource the inspection program, whoever sets it up must know where to start and must understand the criticality of each machine. A guideline frequently used as a starting point is machine speed because faster machines tend to deteriorate faster. You can chart machine speed on one axis against cost or process criticality on the other (Table 1). These values indicate which machines most need an inspection program.

Table 1

	Criticality		
Machine speed (rpm)	**Little productive loss**	**Affects half of plant**	**Shuts plant down**
>3,500	3	6	9
1,500 to 3,500	2	3	6
<1,500	1	2	3

What's the second step?
A. The next step, understanding common machine failure modes, starts with your maintenance records and personnel to identify where you spend maintenance money and time on existing machines (Figure 3). These inputs also can alert you as to what to expect with new machinery. Two other information sources are plants with similar machines and independent consultants.

For a small machine, say a centrifugal pump, the areas to check are simple and repetitive: the bearings, alignment, a flowmeter on the discharge line, etc. For complex machines, such as a large turbine-driven gear train, the insights you gather from these inputs are invaluable. The next step is monitoring these points.

Now I know what machines to inspect and how the machines can fail. What's next?
A. It's time to select monitoring tools. The marketplace for predictive maintenance tools is extensive, expensive and can be confusing. Your plant machines may be different from your neighbor's, but many of the predictive tools are the same. Talk to colleagues in local industry, other plants within your company, consultants and vendors. Try to keep your tools:

- Simple. This ensures they'll be used correctly.
- Hardy. Industry-proven tools remain accurate and don't require repeated repairs.
- Expandable. As your inspectors gain experience, you may want to expand your capabilities.

Avoid overbuying toys that won't be used to their capabilities. Too many times we've gone into plants and seen more than $80,000 worth of two-year-old, sophisticated vibration analyzers and the maintenance department doesn't know how to turn them on, let alone use them. It would have been better to spend $10,000 on a basic shock pulse meter or similar tool that could be used weekly.

PdM programs are ongoing and the inspectors' skills are going to require constant updating and expanding. Program continuity requires that each area have multiple qualified inspectors. Shared responsibility eliminates having "Ol' Charlie" announce that he is retiring in a month and taking most of the program with him.

What are the basic predictive techniques used for rotating equipment monitoring and how are they applied?
A. The vast majority of PdM programs are built around vibration analysis to read machine movement and gain understanding of the mechanical forces within the machine.

Vibration analysis monitors overall machine health. Common applications include monitoring bearing condition, plane bearing irregularities, rotational imbalance, base and foundation problems, and problems with motors, belts and couplings.

Oil analysis monitors water, contaminants and fine particulates; and wear particle analysis to determine the source of the larger particles.

Shock pulse monitoring is a relatively simple tool for monitoring the condition of rolling-element bearings and evaluating lubricant film thickness. Ultrasonic bearing monitors do much the same thing.

Infrared imaging locates problems anywhere that temperature variations indicate machine problems. Although IR imaging can detect failing ball and roller bearings, vibration analysis and shock pulse monitoring give earlier warnings.

Strobe lights freeze the motion of moving components and inspect them during operation. They're probably most useful on belt or chain drives and gear sets to view wear and deterioration.

How often should we inspect the machines?
A. Avoid catastrophic or emergency shutdowns by conducting PdM inspections often enough to ensure that critical machine shutdowns can be scheduled. For vibration analysis, install permanent sensors on critical machines -- those that rate between six and nine in the matrix above. Inspect the rest of the machines once a month, unless a critical situation develops.

Establish frequencies for vibration analysis and shock-pulse monitoring according to the guidelines in Table 2. Modify them as necessary after discussing loss of production, the time to restore and maintenance costs. Optimize the inspection routes to reduce travel time.

Table 2

Machine speed (rpm)	Monitoring frequency
>3,500	monthly
1,500 to 3,500	bimonthly
<1,500	quarterly

Inspect slower-speed machinery that might require extensive, expensive repairs two or three times as often as an inexpensive pump that can be readily spared. Conduct oil analysis for large machines twice a year; some critical hydraulic systems might need more frequent monitoring. Use infrared imaging on electrical connections and switchgear annually, but quarterly on critical V-belt drives. An inspector should keep a strobe light close at hand when checking rotating machinery.

These PdM program guidelines can pay for themselves eight- to tenfold. But educate your inspectors. In addition to the fancy tools, give them an adjustable wrench, a pair of pliers, a stethoscope and strobe light -- and ask them to use them. You'll probably more than double the return.

Your inspection program should issue reports that include repair priorities, such as A = immediate corrective action is needed, B = repair within three weeks and C = schedule the repairs. Have operators shut equipment down as soon as possible after detecting a fault so defective parts can be sent to inspectors for failure analyses. This helps them better understand their capabilities and helps the plant understand what must be done to prevent future failures.

Edward Sullivan is senior reliability specialist and Neville Sachs is CEO of Sachs, Salvaterra & Associates Inc., Syracuse, N.Y. E-mail them at reliable@twcny.rr.com.