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As part of a recent reliability program, a U.S. lumber plant held a series of machine reliability and vibration technology seminars for its maintenance staff. Afterward, a newly trained maintenance technician identified 10 of the plant's most trouble-prone machines and began a one-person campaign to repair them.

Employing condition monitoring equipment for vibration analysis and operational deflection shape, he first tested Machine No. 1 and quickly discovered a resonance problem at the current machine operating speed. Then he detected that Machine No. 2 was out of alignment by a quarter of an inch. He arranged for repairs to be made on both machines. Over the next few months, he diagnosed serious problems in the eight remaining machines and initiated repairs on them as well. Within six months, the technician had saved the lumber plant $1.5 million, based on previous maintenance expenditures and downtime costs associated with the 10 problem machines.

Although dramatic short-term savings are unusual, reliability programs can have a major financial impact over the long term. The most effective programs emphasize training, precision repair skills, and a proactive approach on the part of maintenance and other departments.

For companies planning or implementing a reliability program, there are six important steps for improving the reliability of production equipment.

1. Train top managers, maintenance technicians, and other personnel regarding reliability issues.

Ideally, reliability training should involve every department level in a plant, including top management. The plant manager and key department heads should receive training on basic reliability concepts and on how reliability programs affect the bottom line. Managers and supervisors need to understand how to implement reliability programs, and how to monitor and document results. Also, maintenance managers and technicians need to acquire the specific skills necessary to perform precision maintenance. See accompanying section "A Wealth of Training Options."

Early in the training process, participants from the various departments must reach agreement on program goals and on the meaning of reliability. Broadly defined, reliability consists of maximum functionality from bearings and/or machines with a low incidence of failure at the lowest possible cost. But terms like "maximum functionality" and "lowest possible cost" have different meanings in different plants and even within different departments of the same plant. Program participants should formulate their own definition of reliability reflecting the realities of a particular industry and plant environment.

Equally important is defining failure. The meaning of failure can vary from industry to industry, and even from department to department within the same plant. For example, consider a pump that fails and is quickly replaced with a standby unit without interrupting production. Maintenance might regard this event as a failure because it involves an unanticipated pump repair. The production department, on the other hand, might not term it a failure because there was no loss of production. It is important, therefore, to reach a plant-wide consensus on what constitutes failure. A sample definition might be: Failure occurs when a bearing or machine fails to meet 100 percent of its functional requirements during regularly scheduled operating times. Under this definition, the pump replacement would constitute a machine failure. Agreed-upon definitions and program goals should be documented and made available to key managers, maintenance supervisors and staff, machine operators, and other interested parties.

2. Employ condition monitoring equipment to track bearing and overall machine health.

Condition-based maintenance is a critical component of most reliability programs. Condition monitoring technologies include temperature and vibration monitoring, infrared thermography, ultrasonic noise detection, and operational deflection shape. Employed properly, these technologies can identify bearings or machines on the verge of failure and enable the scheduling of necessary repairs.

The use of vibration monitoring in particular has increased dramatically over the past 10 to 15 years. Vibration devices, linked with trending software, can quickly pinpoint changes in bearing or machine conditions. Current advancements include wireless systems and industrial decision support software. Moreover, vibration amplitudes can be a good indicator of overall maintenance effectiveness; high amplitudes are often a sign of poor maintenance practices.

Although an important tool, condition monitoring alone cannot guarantee precision maintenance. In fact, some condition monitoring practices can even be counterproductive. For

example, consider a plant that sets a vibration alarm limit of 0.3 in/sec for its industrial fans. A fan that registers 0.29 in/sec will pass the plant's vibration test, but it still may run roughly and fail prematurely. The alarm limit in this case is a minimum requirement for operation, not a precision specification. To avoid this problem, always establish two sets of vibration criteria—an upper alarm limit that signals imminent trouble and a lower precision specification. In this case, the precision specification might be as low as 0.06 in/sec. Fans and other machines maintained to precision specifications have a much longer life expectancy than those maintained to alarm-limit specifications.

3. Conduct failure analysis by inspecting failed machine components.

To an alert maintenance staff, failed machine components can provide valuable information. For example, small indentations in bearing raceways and rolling elements usually indicate an ineffective sealing arrangement, whereas an OD surface that has a worn, mirror-like appearance indicates that the bearing was spinning in the housing. Other telltale evidence includes flaking, smearing, and abnormal wear patterns.

With proper training and experience, maintenance technicians can learn to recognize these signs and diagnose machine problems. In more difficult cases, machine components can be returned to the manufacturer for expert analysis.

4. Pinpoint the root cause of machine problems.

Distinguishing the root cause from various side effects and symptoms often requires careful analysis. For example, a bearing installed on an oversized shaft eventually will run hot, causing the bearing lubricant to degrade. A cursory examination of the bearing arrangement might point to the degraded lubricant as the cause of failure. More careful analysis, however, would determine the actual cause the oversized shaft.

Once the source of a problem is identified, the maintenance staff can target its efforts effectively and begin corrective action. After corrective action is taken, the results should be verified to confirm the findings of the root cause analysis.

5. Practice proactive maintenance by making precision repairs.

A cement producer used a proactive approach recently in repairing a large induced-draft fan with a history of problems. The fan, driven by a 2600 hp dc motor, evacuates hot gases from a cement kiln. Temperatures in the application typically reach 650 F. Although the fan had a speed rating of 1200 rpm, for many years it operated at 1100 rpm because of a serious vibration problem. The reduced fan speed limited the kiln to only 80 percent of capacity. During planned maintenance every March, the fan□s bearings were replaced regardless of condition and the fan was balanced, but the vibration problem persisted.

Finally, as part of a new proactive maintenance program, the plant arranged for a series of highly accurate bearing position measurements to be taken using infrared technology. Readings were taken in both the cold and hot-running state. Analysis showed that thermal growth during fan operation caused misalignment of as much as 0.040 in. between the fan and the motor. Based on these measurements, the fan and motor were realigned to account for thermal growth. Subsequently, the fan was brought up to its full operating speed of 1200 rpm without an increase in vibration. Kiln capacity and throughput also increased. In addition, during the next shutdown period, the fan's bearings were inspected and did not require replacement, saving labor and bearing costs.

6. Establish key performance indicators to monitor program success.

Key performance indicators are the hard data used to gauge a reliability program's effectiveness. There is no single, all-purpose indicator that works in every situation. Instead, program supervisors should select one or more key indicators that are well suited to a particular industry or plant environment.

Petrochemical plants, for example, typically have standby machines and redundant equipment, which are brought online quickly in the event of failure. Machine availability levels of 99 percent or higher are the norm. Here, gauging the effectiveness of reliability programs simply on the basis of machine availability data would be difficult. Annual repair costs or mean time between failures would be better indicators of a program's effectiveness.

Paper manufacturers, on the other hand, rarely have redundant paper machines. If a machine

fails, production halts until the machine is repaired and returned to service. When failures occur, availability levels drop. Here, machine availability would be an excellent measure of reliability. It also might be appropriate to have a variety of key performance indicators for auxiliary and ancillary equipment. **MT**

Information supplied by SKF USA Inc., 1510 Gehman Rd., Kulpsville, PA 19443; (888) SKF-2000; fax (215) 513-4736. For information on training programs, contact SKF Reliability Maintenance Institute, SKF Industrial Services Center, 4392 Run Way, York, PA 17406; (717) 751-2900; fax (717) 751-2901

A Wealth of Training Options

Training opportunities now exist for reliability-minded employees of every skill level and job description. These include one- and two-day management seminars for executive-level staff covering machine reliability impact and program oversight. Also offered are courses for mid-level managers who directly supervise plant millwrights and mechanics.

Maintenance department employees, meanwhile, can choose from a variety of skills courses. These range from week-long introductory courses covering bearing fundamentals to advanced courses focusing on specific applications, such as centrifugal pumps, paper machines, and continuous casters. Other courses provide hands-on training on alignment, balancing, and using the latest condition monitoring equipment, techniques, and software.

In addition to offering public seminars, some training providers will hold seminars at the client's facility on request. These on-site seminars, intended for employee groups of various sizes, can be custom-designed to address the host company's specific operational concerns.

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