Predictive Maintenance

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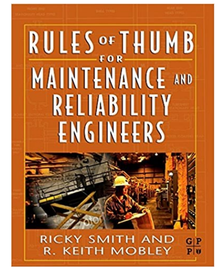

Like preventive maintenance, predictive maintenance has many definitions. To some predictive maintenance is monitoring the vibration of rotating machinery in an attempt to detect incipient problems and to prevent catastrophic failure. To others it is monitoring the infrared image of electrical switchgear, motors and other electrical equipment to detect developing problems. The common premise of predictive maintenance is that regular monitoring of the actual crafts condition, operating efficiency and other indicators of operating condition of machine trains and process systems will provide the data required to ensure the maximum interval between repair and minimize the number and cost of unscheduled outages created by machine train failures.

Predictive maintenance is much more. It is the means of improving productivity, product quality and overall effectiveness of our manufacturing and production plants. Predictive maintenance is not vibration monitoring or thermal imaging or lubricating oil analysis or any of the other nondestructive testing techniques that are being marketed as predictive maintenance tools. Predictive maintenance is a philosophy or attitude that, simply stated, using the actual operating condition of plant equipment and systems to optimize total plant operation. A comprehensive predictive maintenance management program utilizes a combination of the most cost effective tools, i.e. vibration monitoring, thermography, tribology, etc., to obtain the actual operating condition of critical plant systems, and based on this actual data, schedules all maintenance activities on an "as needed" basis.

Including predictive maintenance in a comprehensive maintenance management program will provide the ability to optimize the availability of process machinery and greatly reduce the cost of maintenance. It will also provide the means to improve product quality, productivity and profitability of our manufacturing and production plants.

Predictive maintenance is a condition driven preventive maintenance program. Instead of relying on industrial or in plant average life statistics, i.e. mean time to failure, to schedule maintenance activities, predictive maintenance uses direct monitoring of the crafts condition, system efficiency and other indicators to determine the actual mean time to failure or loss of efficiency for each machine train and system in the plant. At best, traditional time driven methods provide a guideline to "normal" machine train life spans.

The final decision, in preventive or run to failure programs, on repair or rebuild schedules must be made on the bases of intuition and the personal experience of the maintenance manager. The addition of a comprehensive predictive maintenance program can and will provide factual data on the actual crafts condition of each machine train and operating efficiency of each process system. This data provides the maintenance manager with actual data for scheduling maintenance activities.

A predictive maintenance program can minimize unscheduled breakdowns of all crafts equipment in the plant and ensure that repaired equipment is in acceptable crafts condition. The program can also identify machine train problems before they become serious. Most equipment problems can be minimized if they are detected and repaired early.

Predictive maintenance utilizing vibration signature analysis is predicated on two basic facts: (1) all common failure modes have distinct vibration frequency components that can be isolated and identified and (2) the amplitude of each distinct vibration component will remain constant unless there is a change in the operating dynamics of the machine train. These facts, their impact on machinery and methods that will identify and quantify the root cause of failure modes will be developed in more detail in later chapters.

Predictive maintenance utilizing process efficiency, heat loss or other nondestructive techniques can quantify the operating efficiency of plant equipment or systems. These techniques used in conjunction with vibration analysis can provide the maintenance manager or plant engineer with information that will enable them to achieve optimum reliability and availability from their plant.

Several nondestructive techniques are normally used for predictive maintenance management: vibration monitoring, process parameter monitoring, thermography, tribology and visual inspection. Each technique has a unique data set that will assist the maintenance manager in determining the actual need for maintenance.

How do you determine which technique or techniques are required in your plant? How do you determine the best method to implement each of the technologies? If you listen to the salesmen for the vendors that supply predictive maintenance systems, his is the only solution to your problem.

How do you separate the good from the bad? Most comprehensive predictive maintenance programs will use vibration analysis as the primary tool. Since the majority of normal plant equipment is rotating, vibration monitoring will provide the best tool for routine monitoring and identification of incipient problems. However, vibration analysis will not provide the data required on electrical equipment, areas of heat loss, condition of lubricating oil nor other parameters that should be included in your program.

There are a wide variety of predictive techniques or technologies that may provide benefit to a facility or plant. In most cases, more that one of these technologies will be needed to provide complete coverage of all critical assets and to gain maximum benefits from their use.

The typical technologies that have been successful utilized by facilities and plants are included in Table 4.1.

Monitoring Techniques	**Use**	**Problem Detection**
Vibration	Rotating machinery, e.g., pumps, turbines, compressors, internal combustion engines, gear boxes	Misalignment, imbalance, defective bearings, mechanical looseness, defective rotor blades, oil whirl, broken gear teeth
Shock pulse	Rotating machinery	Trends of bearing condition
Fluid analysis	Lubrication, cooling, hydraulic power systems	Excessive wear of bearing surfaces, fluid contamination
Infrared thermography	Boilers, steam system components, electrical switchboards and distribution equipment, motor controllers, diesel engineers, power electronics	Leaky steam traps, boiler refractory cracks, deteriorated insulation, loose electrical connections, hot or cold firing cylinders
Performance trending	Heat exchangers, internal combustion engines, pumps, refrigeration units and compressors	Loss in efficiency, deteriorating performance trends due to faulty components
Electrical insulation tests, e.g., megger tests, polarization index, surge comparison testing, rotor impedance testing, DC high potential testing	Motor and generator windings, electrical distribution equipment	Trends of electrical insulation condition, turn-to-turn and phase-to-phase short, grounds, reversed coils or turns
Ultrasonic leak detectors	Steam hydraulic and pneumatic system piping	Leaking valves, system leaks
Fault gas analysis and insulating liquid analysis	Circuit breakers, transformers and other protection devices	Overheating, accelerated deterioration trends, hostile dielectric
Protection relay testing and time travel analysis	Circuit breakers, transformers and other protective devices	Deteriorating or unsafe performance
Stereoscopic photography, hull potential measurements, diving inspections	Underwater hull	Corrosion, fatigue cracking trends, hull fouling trends
Material (non-destructive) testing, e.g., ultrasonics, eddy current, borescopic inspections	Hull structure, shipboard machinery and associated piping systems and mechanical components	Corrosion, erosion, fatigue cracking, delaminations, wall thickness reduction
Signature analysis, time domain and frequency domain	Rectifiers, power supplies, inverters, AC and DC regulators, generators	Degraded solid state circuits and other electrical components
Wear and dimensional measurements	Sliding, rotating and reciprocating elements	Excessive wear and proximity to minimum acceptable dimensions which affect performance

Table 4.1 Visual Inspections

Visual inspection was the first method used for predictive maintenance. Almost from the inception of the industrial revolution, maintenance technicians performed daily “walk-downs” of critical production and manufacturing systems in an attempt to identify potential failures or maintenance-related problems that could impact reliability, product quality and production costs. A visual inspection is still a viable predictive maintenance tool and should be included in all total plant maintenance management programs.

Setting Up a PM/PdM Program

Setting us an effective preventive / predictive maintenance program is not a trivial exercise. A logical, methodical approach must be used to ensure that the tasks, intervals and methods selected will provide a level of maintenance that will support reliability and optimum life cycle of the facility’s assets.

The process should be predicated on a criticality analysis that defines the relative importance of each asset. Obviously, the more critical assets will receive more attention and effort than less critical assets. The first step in the process is to determine the maintenance requirements for those assets that are to be included in the preventive maintenance program. Based on the criticality analysis, you may elect to omit some of the less critical assets. The assessment of need should include three tasks:

- Conduct a Simplified Failure Modes and Effects Analysis (SFMEA). A SFMEA identifies the more common failure modes for classes of assets, e.g. compressors, fans, etc. This information should be used to develop specific preventive maintenance tasks, i.e. inspections, testing, etc., that will detect these failure modes before they result in an emergency or breakdown.

- Conduct a Duty-Task Analysis. Duty-Task Analysis is used to determine the specific maintenance activities, interval, skills, and materials that are needed to properly maintain assets. The process uses a combination of engineering design analysis and information derived from the vendor's Operating and Maintenance manual or similar sources

- Review Asset History. For existing assets, this step should include a thorough evaluation of their maintenance and reliability history. As a minimum, this part of the assessment should include and evaluation of equipment history from the CMMS. Other available records, such as downtime reports and safety investigation documents, should also be reviewed.

Without infinite resources, you will not be able to include all assets in the preventive/predictive maintenance program. Therefore, the next step is to determine the specific assets that will be included. Obviously, the criticality analysis should be the dominant tool for this determination, but the following steps should confirm it:

Inventory Assets and Equipment. The primary intent of this task is to verify that all assets and equipment have been identified and included in the criticality analysis. There is a tendency to overlook critical assets, such as the infrastructure, e.g. electric power distribution, compressed air, etc., that can have a major impact on plant performance. A sub-set of this task is to establish a plant-wide asset identification methodology that will be used as part of the preventive maintenance program and is also essential for CMMS implementation.

Appraise Asset Condition. When starting an effective preventive maintenance program, it is essential to know the current condition of all assets in the plant or facility. This is normally accomplished by performing Condition Assessments. In addition to the information derived from the condition assessment, this step should also answer the following questions:

- Can it be easily maintained in its present condition? If not;
- Can it be upgraded to maintainable condition? If it can;
- How can it be taken out of service and how much will it cost? If it cannot be;
- What alternatives are there to choose from?

Choose Assets to be Included in the Initial Program. The change process is generally more effective when you start small and build the program over time. Initially, the preventive maintenance program should concentrate of the most critical assets. As a rule, this initial effort will address the top quartile (25%) of critical assets, as determined by the criticality analysis. Use early successes to justify and sell program expansion, but always remember the preventive maintenance program cannot be considered world-class until all critical assets are included.

Using the knowledge gained in the preceding steps, determine the organizational requirements for the upgraded preventive/predictive maintenance program. This step should include an accurate determination of:

Effort-hours required to implement and maintain the program. This task should define the total craft effort-hours, by craft line and skill level, required to execute the activities identified by the duty-task analysis.

Supervision-hours required to effectively manage the craft workforce. Adequate supervision is an absolute requirement for effective preventive / predictive maintenance.
Planning-hours required to effectively supporting the preventive maintenance activity.
Support-hours required to effectively support the program. It is important to provide clerical, material handling and other support for the maintenance organization to prevent overloading the planners, supervisors and other line managers.

Effort-hours required to write or modify preventive maintenance task lists, work orders, maintenance procedures and other documentation that is needed to support the upgraded program.

Materials required to support the program must also be identified. This task should include a determination of items that should be stocked, minimum-maximum stocking levels, and other information required for the Materials Management function.

Facilities required supporting the program. This task should include a determination of where to locate and configure shops, tool rooms, MRO inventories, training, and other facilities that are required to support an effective preventive maintenance program. Predictive tools needed to support the program. Data collectors, analysis software, infrared cameras, etc. will have to be acquired, as well as training for technicians. Consideration should be given to requiring technicians to gain and hold a certification in the various predictive disciplines.

A fundamental requirement of Reliability Excellence is changing the reactive environment that has permeated most organizations for the past decades. A key part of the change is clear, definitive policies and procedures that define how the maintenance organization will perform its day-to-day activities. This step should establish clear, concise definition, principles and concepts that will govern the operation of the maintenance function. It should include:

- Roles and responsibilities for all functional groups, e.g. maintenance manager, supervisors, planners, schedulers, and technicians
- Job descriptions for all employees that clearly define their contribution to a world-class organization. Job descriptions should minimize the use of generic descriptions, such as "and other responsibilities as defined."
- Expectations that clearly establish a vision of what the final objectives of the change process will be.

Using the resultants from the preceding steps, present the plan to plant or facility management. The presentation should be in a format that addresses the financial benefits that the enhanced preventive/predictive maintenance program will generate for the facility. If the business plan is presented in terms that facility management can accept, approval and at least general support and commitment should be automatic. This commitment is essential. Without at least general commitment, you will not have the budget and support needed to implement an effective preventive/predictive maintenance program.

After the initial startup of the program, a long-range plan to upgrade critical assets to improve the ability to effectively maintain their operating condition should be developed. This may require modifications; rebuilds and other non-preventive maintenance activities design to restore the asset condition to a maintainable level or to simplify the ability to perform effective maintenance.

The modified organizational structure, preventive maintenance requirements and maintenance work culture established to support the preventive maintenance program will require re-training of the workforce. This training will be needed at all levels, from maintenance manager to the junior craftsperson in the organization.

Source: Rules of Thumb for Maintenance and Reliability Engineers (Elsevier Publishing) by Ricky Smith CMRP and Keith Mobley