Predictive Maintenance (PdM) & Proactive Maintenance (PAM)
Predictive Maintenance (PdM)

- Also known as Condition-Based Maintenance.
- Uses non-intrusive testing techniques, visual inspection and performance data to assess machinery condition.
- Replaces arbitrarily timed maintenance tasks with maintenance that is scheduled when warranted by equipment condition.
The mortality of machinery

The plot of typical machinery life spans is shown in the so-called bathtub curve. Among collections of equipment, there is a rather high incidence of early failures, called infant mortalities. Most equipment that survives infancy will continue to perform with few failures occurring. In time, however, the failures begin to increase until the last of the group succumbs.
Benefits of Predictive Maintenance

• Helps reduce cost and improve reliability:
  – Frequency based preventive maintenance can be delayed if PdM monitoring shows it is not necessary yet;
  – Equipment with indicators of probable failure prior to scheduled PM activity are identified and scheduled for maintenance prior to failure;
  – Equipment with conditions that if not repaired will lead to catastrophic failure are detected and repaired at a fraction of the catastrophic failure repair cost.
• Improves mean-time-to repair due to prediction of failure
• Reduces inventory levels due to the avoidance of premature parts replacement and the ability to predict parts requirements
• Improves loading of resources and provides reduced overtime levels due to reduced emergency maintenance
• Gives the engineer/technician insight into the location and cause of the impending failure, reducing diagnosis time if the equipment is permitted to run to failure
Steps for a PdM Program

1. Select equipment for PdM
2. Choose optimum monitoring methods
3. Set up a PdM process
4. Measure condition periodically
   - Collect data
   - Record data
   - Do trend analysis
5. Determine acceptable condition limits
   - Machine baseline measurements
   - Fault located
   - Correct fault
   - No fault located
   - Acceptable
     - Inside limits
     - Outside limits
   - Unacceptable
     - Perform condition analysis
Methods to Assess Condition of Systems/Equipment

• Includes intrusive and non-intrusive methods
  – Vibration Analysis
  – Tribology and Lubrication
  – Thermal Imaging and Temperature Measurement
  – Flow Measurement
  – Electrical Testing and Motor Current Analysis
  – Leak Detection
  – Valve Operation
  – Corrosion Monitoring
  – Process Parameters
  – Visual Observations
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Vibration Monitoring and Analysis

• One of the most commonly used techniques.
• Helps determine the condition of rotating equipment and structural stability in a system.
• Applicable to all rotating equipment; e.g., motors, pumps, turbines, compressors, engines, bearings, gearboxs, shafts, etc.
• Conditions monitored: wear, imbalance, misalignment, mechanical looseness, bearing damage, belt flaws, cavitations, fatigue, etc.
From steam trap faults and valve leakage to compressor problems, ultrasonic detection can be used to find a variety of problems that generate ultrasonic signatures.

• Typical hand-held ultrasonic detector
Passive (Airborne) Ultrasonics

- Airborne ultrasonic devices operate in a frequency range of 20kHz- 100kHz and heterodyne the high frequency signal to the audible range to allow the operator to hear changes in noise associated with leaks, corona discharges, and other high frequency events.
- Examples include bearing ring and housing resonant frequency excitation caused by insufficient lubrication and minor defects.
Infrared Thermography (IRT)

- Application of infrared detection instruments to identify pictures of temperature differences
- It is a non-contact technique
- Attractive for identifying hot/cold spots in energized electrical equipment, large surface areas such as boilers and building walls, and other areas where “stand off” temperature measurement is necessary.
Lubricant and Wear Particle Analysis

• Is performed for three reasons:
  – To determine the mechanical wear condition
  – To determine the lubricant condition
  – To determine if the lubricant has become contaminated

• There are a wide variety of tests that will provide information regarding one or more of these areas.

• Standard analytical tests include: visual and odor, viscosity, % solids/water, spectrometric metals, infrared spectroscopy, particle counting, analytical ferrography, etc.
Non-Destructive Testing (NDT)

- **Radiography (or X-Ray):**
  - Detection of deep-surface defects.
  - One of the most powerful NDT techniques available in industry.
  - Depending on the strength of the radiation source, can provide a clear representation of discontinuities or inclusions in material several inches thick.
  - Applicable to metal components including weld points.

- **Ultrasonic Testing (Imaging) (UT):**
  - Detection of deep sub-surface defects
  - Alternative of complementary technique to radiography.
  - Based on the difference in the wave reflecting properties of defects and the surrounding material
  - Applicable to same components as X-Ray testing. Specialized applications for plastics or composite materials are common.
  - Preferred method over radiography due to expense and safety precautions required by radiography.
• **Magnetic Particle Testing (MT):**
  – Detection of shallow sub-surface defects.
  – Useful during localized inspections of weld areas and specific areas of high stress or fatigue loading
  – The major advantage is its portability and speed of testing.
  – Applicable to materials that conduct electric current and magnetic lines of flux.
  – Most effective in welded areas.

• **Dye Penetrant (DP):**
  – Detection of surface defects in non-porous materials.
  – Allows large areas to be quickly inspected.
  – Simplest NDT technique in which to gain proficiency

**Hydrostatic Testing:**
– Method for detecting defects that completely penetrate pressure boundaries.
– Typically conducted prior to delivery or operation of completed systems or sub-systems that act as pressure boundaries.
– Applicable in components and assembled systems that contain fluids or gases.
Electromagnetic Induction Testing or Eddy Current Testing:

– Provides a portable and consistent method for detecting surface and shallow sub-surface defects in metal components, such as cracks, seams, holes or lamination separation).

– A set of magnetizing coils are used to induce electrical currents into the component being tested.

– Used for monitoring the thickness of metallic sheets, plates and tube walls. Also coating thickness.

– In more production oriented applications, this technique can determine material composition, uniformity and thickness of materials being produced.

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Most Commonly Used PdM Techniques

- Vibration monitoring → rotating equipment
- Oil analysis → detect residual metal particles
- Thermography → identifying plant “hot spots”
- Shock pulse measurement → bearings
- Ultrasonics X-ray scanning → spot leaks and faults
Proactive Maintenance (PAM)

• Improves maintenance through better design, installation, maintenance procedures, workmanship, and scheduling.

• Employs the following basic techniques to extend machinery life:
  – Specifications for new/rebuilt equipment
  – Precision rebuild and installation
  – Failed-Part Analysis (FPA)
  – Root-Cause Failure Analysis (RCFA)
  – Reliability Engineering
  – Rebuild certification/verification
  – Age exploration
  – Recurrence Control
Failed-Part Analysis (FPA)

• Involves visually inspecting failed parts after their removal to identify the root causes of their failures.

• More detailed technical analysis may be conducted when necessary to determine the root cause of a failure.

• Example: Failed-bearing analysis provides methods to categorize defects such as scoring, color, fretting, and pitting and to relate those findings to the most probable cause of failure.
Root-Cause Failure Analysis (RCFA)

Proactively seeks the fundamental causes that lead to facility and equipment failure.

Goals are:

• Find the cause of the problem quickly, efficiently, and economically
• Correct the cause of the problem, not just its effect
• Provide information that can help prevent the problem from recurring
• Instill a mentality of “fix forever”
Age Exploration (AE)

• Provides a methodology to vary key aspects of the maintenance program to optimize the process.
• The AE process examines the applicability of all maintenance tasks in terms of:
  – Technical content: Review tasks to ensure that all identified failure modes are addressed and that the existing tasks produce the desired amount of reliability
  – Performance interval: The task performance interval is continuously adjusted until the rate at which resistance to failure declines is determined.
  – Task grouping; Tasks with similar periodicity are grouped together to minimize time spent on the job and outages