Advancement in Reliability and Maintenance:

Condition Monitoring, RCM, MIS, CMMS, TPM & Kaizen, heuristic approach

NILESH PANCHOLI
B.E. (Mech.), M.E. (Mech.), Ph. D.
Email: *nhpancholi@gmail.com*
www.nileshpancholi.com

Condition Monitoring

Today’s paradigm

Condition Monitoring:

– In house maintenance staff

  Qualified personal who know the equipment

  Regularly scheduled maintenance

– Often reactive

  React to break down events

Future paradigm

Condition Monitoring:

- Use of technology to measure
  Heat
  Vibration
  Sound
  Electrical output
  Other . . . if you can measure it, you can monitor it

- Operate equipment with known status or condition
  Predict impending failures
  Comparing baseline data to measurements that fall out of tolerance
  Eliminate break down events

And in many industries

The future paradigm is now . . .

Technology is in use today . . .

- Power generation
- High speed rail lines
- Steel mills
- Tunnel and surface mining
- Warehousing and distribution
- Truck transportation
- Paper mills
- Printing
- Agriculture, food processing
- Critical components and “balance of plant”

Equipment and services

- Use of technology to measure
  - Heat
  - Vibration
  - Sound
  - Electrical output of any kind
  - Others
  - Manual and automated
- Service support
  - Equipment selection & implementation
  - Equipment operation
  - Maintenance and repair service

Equipment and service categories

- Manual
  Hand held
- Semi automated
  Combination
- Fully automated
  Mounted sensors
- Computer based - monitor via hard wire and remote monitoring via phone or internet
- Service support
  Dispatched after witness of impending failure

Periodic condition monitoring

Data collectors/analyzers

collect, store and trend vibration and process data to facilitate detection, analysis and correction of machine problems.

Inspection systems

automate the machine inspection process and enable collection, storage and review of machine condition and plant process data.

On-line systems

On-line systems use permanently installed sensors to collect vibration and process data, 24/7, and alert personnel to important changes in machine condition.

Protection system is a digital, modular, scalable hardware and software solution that provides integrated machinery protection, condition and performance monitoring from a single source.

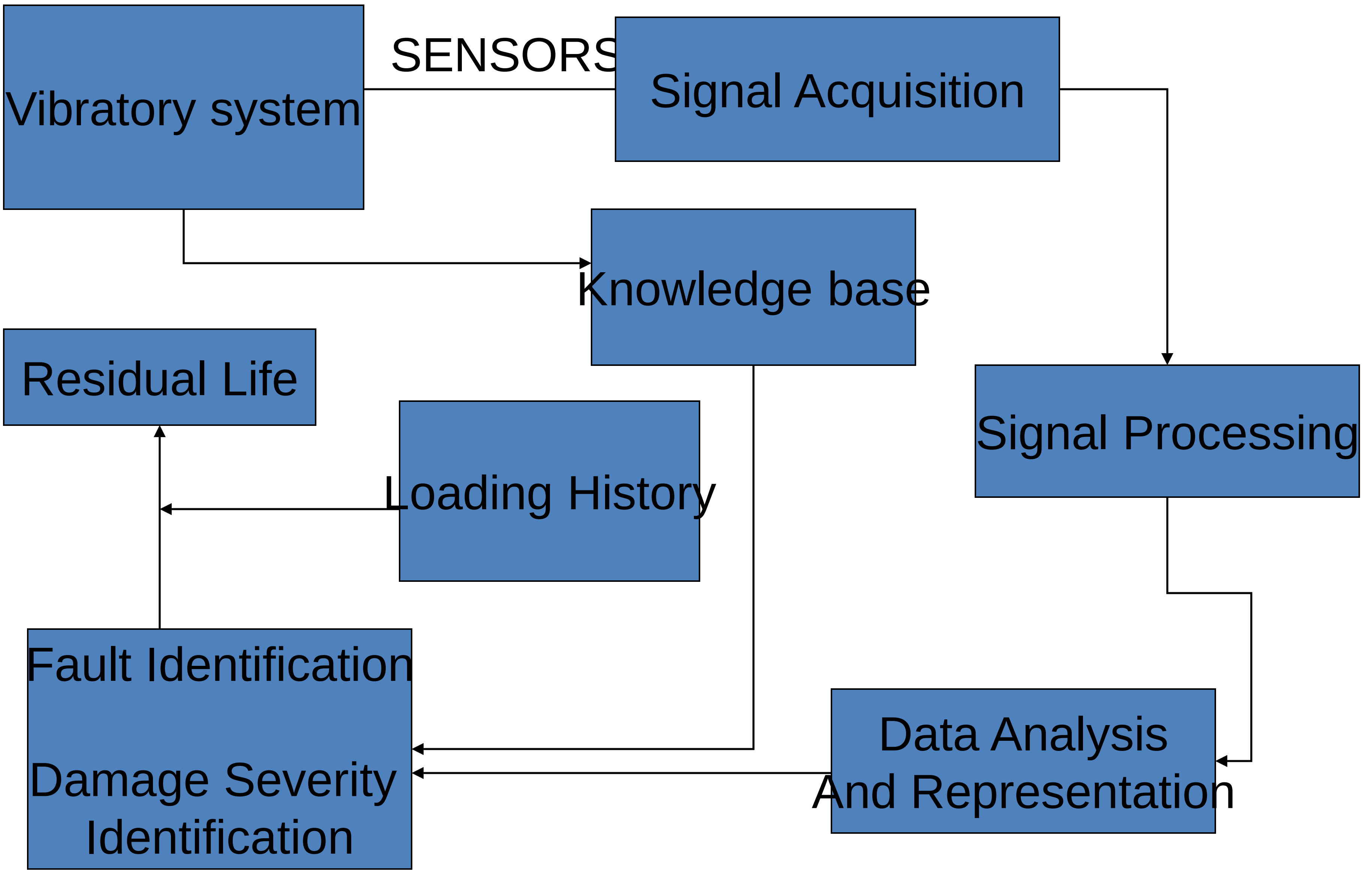
Benefits . . .

- No surprise break downs
- Increased “up time”
- Reduced need for “back up” equipment
- Minimize maintenance resource
  - Possible outsource when needed
- Minimize on hand parts supply

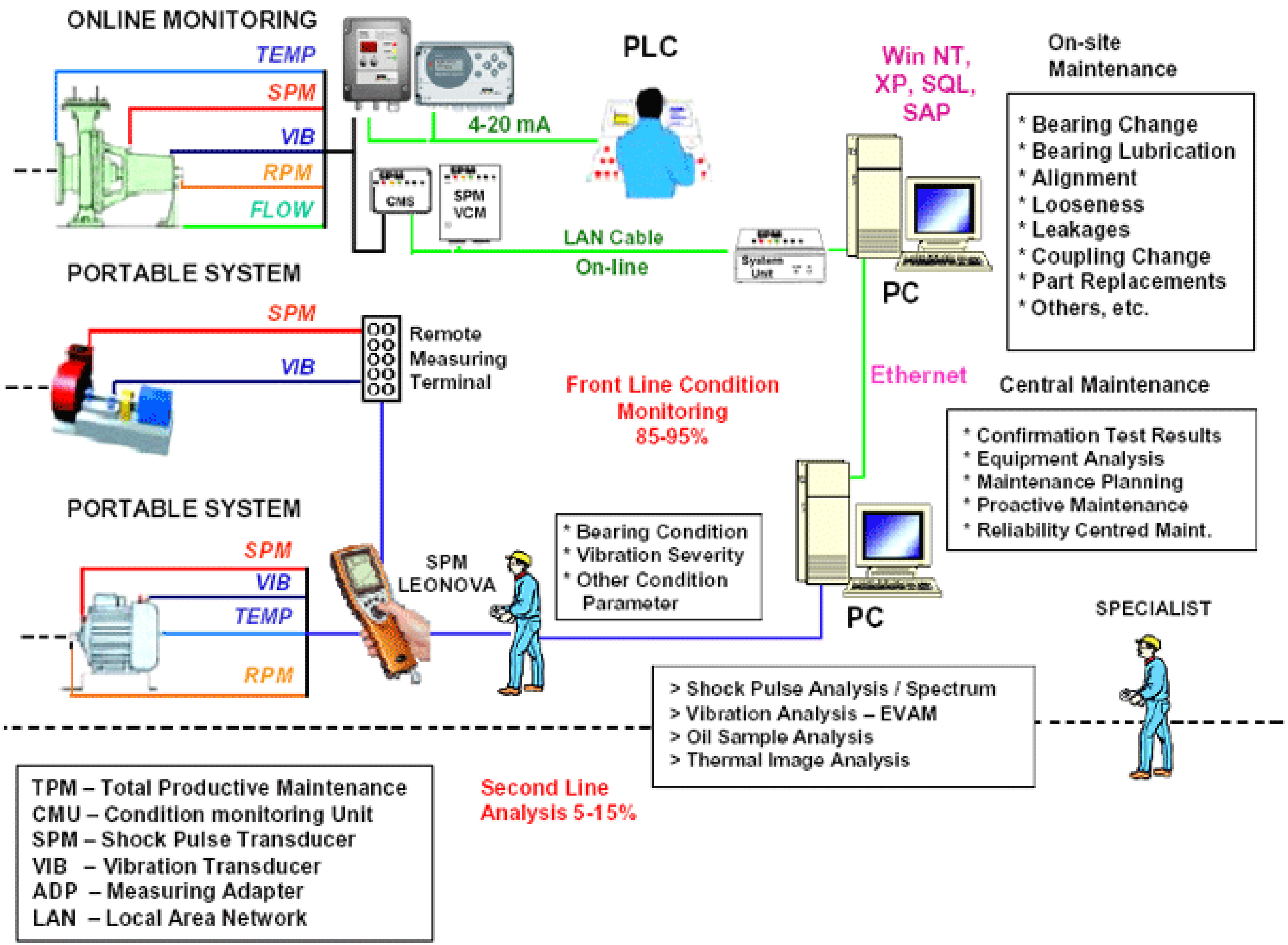
Recommendations . . .

- Understand your process
- Understand the complete list of available tools
- Work with experienced personnel
- Implement only what is practical

CONDITION MONITORING - Process



Condition Monitoring System Diagram



Condition Monitoring – Types
WDM, SPM

WEAR PROCESS MONITORING TECHNIQUES

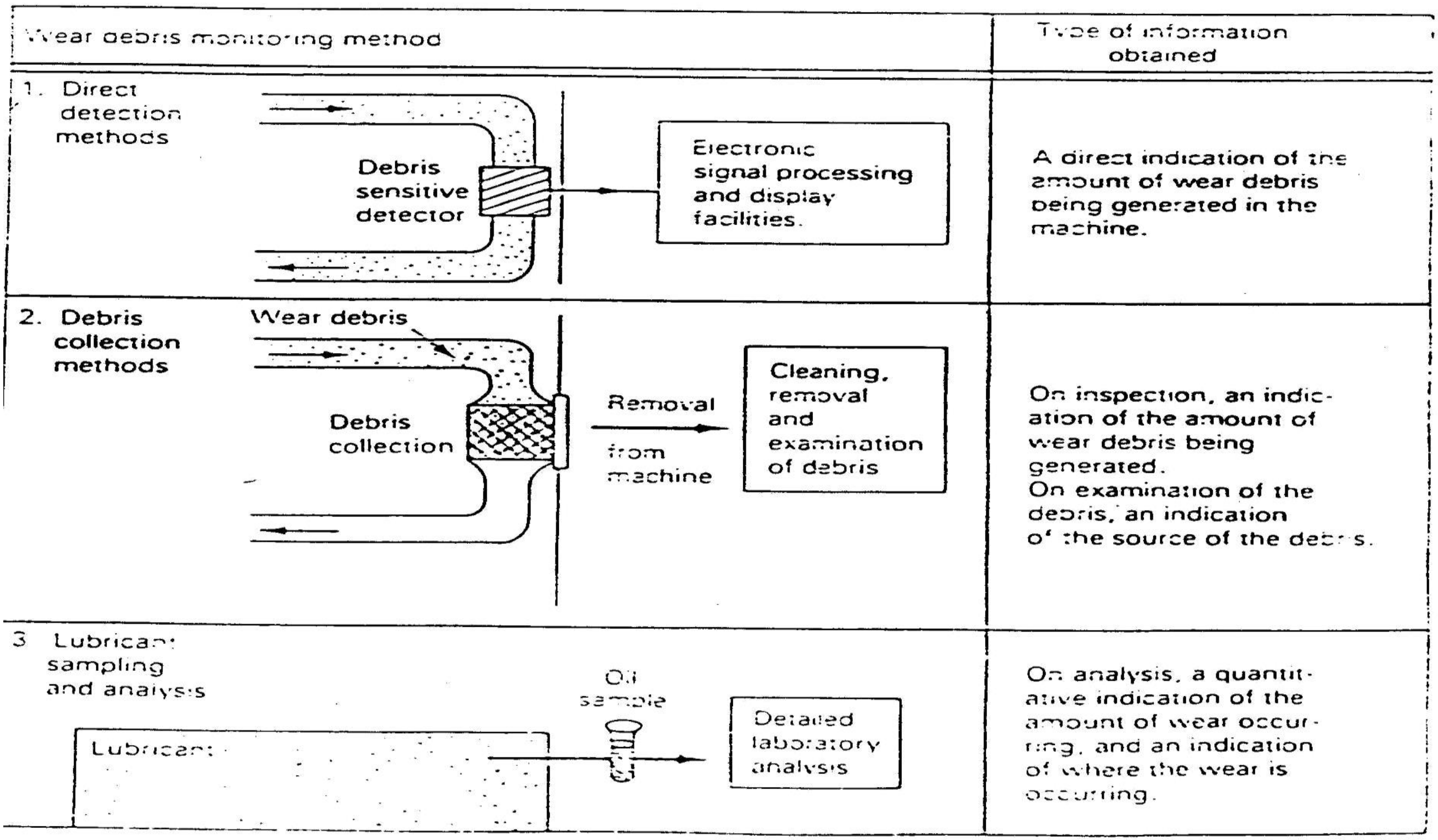


FIG. 2 WEAR DEBRIS MONITORING METHODS

Shock Pulse Method

The *Shock Pulse Method* (**SPM**) is the only successful monitoring technique specialising on rolling element bearings by determining accurate information on:
the mechanical state of the bearing surfaces
the lubricating condition thoughout the bearing life-time.

What is Shock Pulse?

Shock pulse method is a signal processing technique used to measure metal impact and rolling noise such as that found in rolling element bearings and gears. Much more refined than other high-frequency measurements, shock pulse is widely used as a basis for predictive maintenance. Rolling element bearings are the most common measurement for shock pulse, but this technique has other applications including gear condition, compressor condition, and other applications where metal-to-metal contact is a source of wear

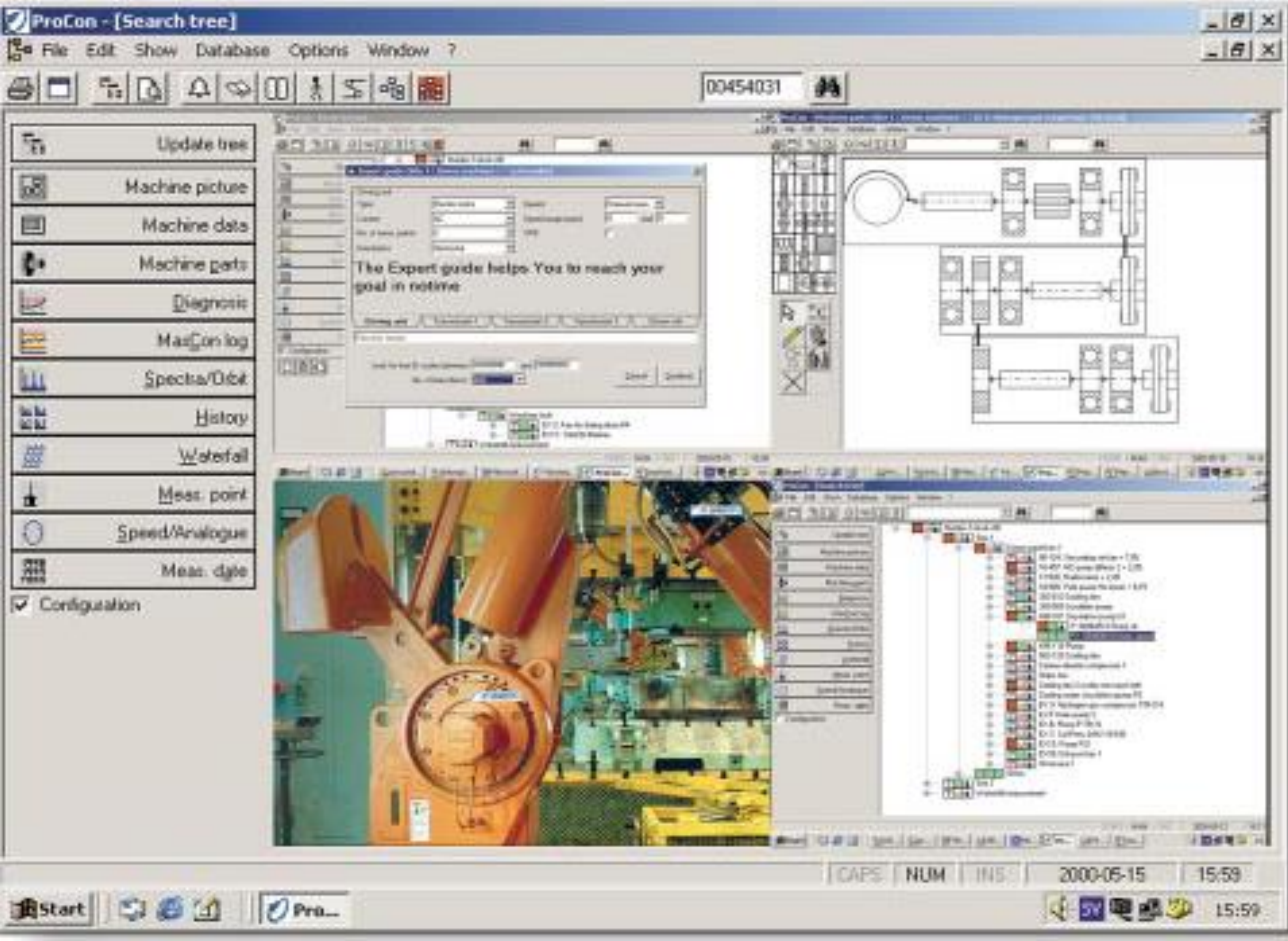
- When two pieces of metal in motion contact each other, two interrelated yet distinct processes occur. On initial impact, a shock or pressure wave develops and quickly propagates through the metal. This shock pulse is in the ultrasonic frequency band and typically occurs around a center frequency of 36 kHz. The amplitude of the shock pulse is relative to the velocity of the impact. As the signal expands from its point of origin, it is dissipated by carbon and other imperfections in the metal. This shock or pressure wave can be measured using the shock pulse method.

- As the impact continues to develop, the metal surfaces are compressed and deflected. As the objects recoil, the metal components rebound and continue to flex for a number of cycles until the energy is dissipated. This second phase of the collision is vibration and its frequency depends on the shape, mass, stiffness, and dampening of the metal. Shock pulse method filters out this phase of the collision, as the magnitude of the vibration is structure and material dependent.

Case Study

sr. no	Equipments	V.I	D. C	DPT	MPI	UT	Replica	Hardness
1	Rotor	X			X	X	X	X
	Rotor bore							
	Gland area	X		X	X			
	Journal	X	X	X	X	X		
	Disc	X			X	X	X	X
	Lacing Wire	X						
	Satellite Strips	X		X				
		X					X	X
2	Turbine casing							
	Casing	X	X	X	X		X	X
	Casing welds	X		X	X			
	Inlet nozzle chamber	X		X			X	X
	Flanges	X		X	X			
	Parting plane fasteners	X	X		X	X	X	X
3	Turbine internals							
	Liner	X	X		X			
	Diaphragms	X	X	X	X		X	X
	Gland Housing	X	X	X	X			
	Steam Flow Path	X	X					
4	Blades							
	Overall surface	X		X	X	X		
	Tangential/ Axial Blade							
	Blade To Blade Attachment Hub Area	X		X	X	X	X	X
	Stationary Blades	X	X	X	X	X		

Different Condition Monitoring Techniques Useful on Different turbine Equipments



ProCon - [Search tree]
File
Edit
Show
Database
Options
Window
?
00454031
Update tree
Machine picture
Machine data
Machine parts
Diagnosis
MasCon log
Spectra/Orbit
History
Waterfall
Meas. point
Speed/Analogue
Meas. date
Configuration
The Expert guide helps You to reach your goal in notime
CAPS
NUM
INS
2000-05-15
15:59
Start
Pro...
15:59

- Advanced turbine fault diagnostics system:
  - Detection of eccentricity change in coupling,
  - Blade failure,
  - Bearing instability,
  - Steam whirl,
  - Rotor crack,
  - Rotor rubbing,
  - Temporary rotor bow,
  - Loose bearing pedestal,
  - Inclined position of bearing,
  - Electrical run-out,
  - Mechanical run-out,
  - Loose stator core in generator,
  - Change of imbalance at shutdown,
  - Radial bearing damage,
  - Inter turn short circuit in generator rotor, etc.

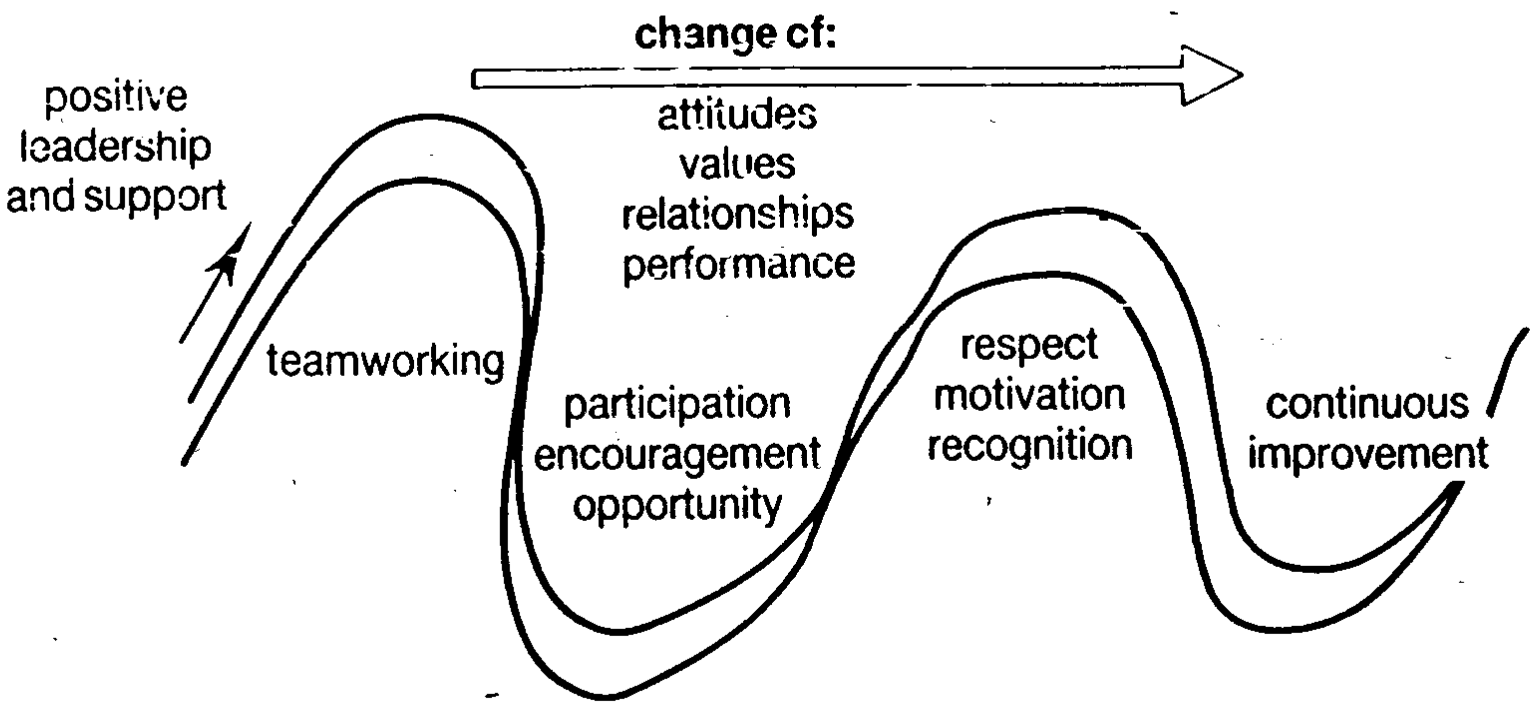
TPM & Kaizan

Introduction to TPM

What is TPM ?

- Total Productive Maintenance (TPM) is both
  - a philosophy to permeate throughout an operating company touching people of all levels
  - a collection of techniques and practices

    aimed at maximizing the effectiveness (best possible return) of business facilities and processes



The TPM philosophy

It is a Japanese approach for

- Creating company culture for maximum efficiency
- Striving to prevent losses with minimum cost
  - Zero breakdowns and failures, Zero accident, and Zero defects etc
- The essence of team work (small group activity) focused on condition and performance of facilities to achieve zero loss for improvement
- Involvement of all people from top management to operator

Table Five Fundamental TPM Development Activities

Five TPM Activities	Goals	Division	Level
Autonomous Maintenance	• Eliminate six major losses and raise overall equipment effectiveness through small group activities • Educate workers in equipment-related knowledge and skills • Improve equipment, change workers' approaches, and revitalize the workshop	Production	Operators
Equipment Improvement	• Eliminate six major losses and maximize overall equipment effectiveness • Master improvement methods for maximizing equipment effectiveness	Production	Managers
Quality Maintenance	• Ensure 100% product quality by establishing and maintaining conditions for zero defects	Production	Managers and operators
MP System-building	• Create a system ensuring that information and techniques gained through in-house TPM activities are reflected in the design of machine tools sold outside the company	Machine tools plant	Engineering
		Tools and bearings plants	Production engineering
Education and Training	• Educate workers in equipment-related knowledge and skills • Improve and expand maintenance skills	TQC promotion office	TPM administration

Measuring Effectiveness of Facilities

The effectiveness of facilities

– is its best possible return generated

Overall facilities effectiveness (OEE) =

%Availability x %Performance x %Quality

- Breakdown losses
- Set-up and adjustment losses

- Idling and minor stoppage losses
- Speed losses

- Scrap and rework losses
- Start-up losses

$$\textbf{\%Availability} = \frac{\text{Loading time} - \text{Breakdown \& Setup loss}}{\text{Loading time}} \times 100$$

Where loading time

= planned production/operation time – breaks – planned maintenance time

$$\textbf{\% Performance} = \frac{\text{Quantity produced}}{\text{Time run} \times \text{Capacity/Given time}} \times 100$$

or

$$= \frac{\text{Time run} - \text{Minor stoppages} - \text{Reduced speed}}{\text{Time run}} \times 100$$

% Quality =

$$\frac{\text{Amount produced} - \text{Amount defects} - \text{Amount re-processed}}{\text{Amount produced}} \times 100$$

or

$$= \frac{\text{Time run} - \text{Defect time} - \text{Re-processing time}}{\text{Time run}} \times 100$$

Example 1

A medium volume manufacturing facility with a capacity of producing 2 parts/minute actually produced 800 parts in a planned running 2 shifts of 8 hours each. It had breaks and scheduled maintenance for 40 minutes and also faced 40 minutes breakdowns and 1 hour 20 minutes for changeover and adjustment. Number of rejects and re-works were 10 and 6 parts respectively. Calculate its overall effectiveness

Planned production time = 2x8 hrs. = 960 minutes

Loading time = 960-40 (breaks & scheduled maintenance) = 920 min.

Down-time =40 (Breakdowns) + 80(Changeover & adjustment)= 120

$$\%\textbf{Availability} = \frac{\text{Loading time – Down time}}{\text{Loading time}} \times 100 = \frac{920 - 120}{920} \times 100 = \mathbf{87\%}$$

Example 1 (Contd.)

$$\textbf{\%Performance} = \frac{\text{Quantity produced}}{\text{Time run x Capacity/given time}} \text{x100} = \frac{800}{(920-120)\text{x2}} \text{x100} = \textbf{50\%}$$

$$\textbf{\%Quality} = \frac{\text{Amount produced – Amount defects – Amount re-work}}{\text{Amount produced}} \text{ x 100}$$

$$= \frac{800 - 10 - 6}{800} \text{ x 100} = \textbf{98\%}$$

Overall effectiveness (OEE) = 0.87 x 0.5 x 0.98 x 100 = **42.6 %**

Example 2

A chemical plant was expected to run for 120 hours/week continuously with production capacity of 2400 metric tones /hour. At the end the week it produced 220,000 tones together with a waste of 3000 tones. It had120 minutes breakdowns and 460 minutes changeover and adjustment. Calculate plant overall effectiveness.

Planned production time = 120 hrs/week = 7200 minutes

For continuous production, breaks and scheduled maintenance = 0

Therefore, loading time = 7200-0 = 7200 min.

Down-time = 120 (Breakdowns) + 460(Changeover & adjustment) = 580

$$\%Availability = \frac{\text{Loading time – Down time}}{\text{Loading time}} x100 = \frac{7200 - 580}{7200} x100 = 92\%$$

Example 2 (Contd.)

$$\%Performance = \frac{\text{Quantity produced}}{\text{Time run x Capacity}} x100 = \frac{220,000}{(6620)x(2400/60)} x100 = 83\%$$

$$\%Quality = \frac{\text{Amount produced – Amount waste}}{\text{Amount produced}} x\ 100$$

$$= \frac{220,000 – 3000}{220,000} \text{ x } 100 = 98.6\%$$

Overall effectiveness = 0.92 x 0.83 x 0.986 x 100 = 75.3 %

RELIABILITY CENTRED MAINTENANCE

BRIEF REVIEW ABOUT RELIABILITY CENTRED MAINTENANCE

INTRODUCTION

- Reliability Centered Maintenance is an analytical process that determines optimum maintenance requirements for physical assets in their operating context. It is based on preserving the functions of physical assets using knowledge of failure characteristics of the asset in a particular operating environment.

DEFINITION

- Reliability Centered Maintenance can be defined as "an approach to maintenance that combines reactive, preventive, predictive, and proactive maintenance practices and strategies to maximize the life that a piece of equipment functions in the required manner." RCM does this at minimal cost. In effect, RCM strives to create the optimal mix of an intuitive approach and a rigorous statistical approach to deciding how to maintain facility equipment.

- **ADVANTAGES OF RCM**

  The advantages offered by RCM are as under: -

- Greater safety and environmental integrity.
- Improved operating performance.
- RCM was developed to help airlines draw up maintenance programme for new types of aircraft before they enter service.
- Greater maintenance cost-effectiveness**.**

- **DISADVANTAGES OF RCM**
- The disadvantages of RCM are as under: -
- Can have significant startup costs associated with staff training and equipment needs.
- Savings potential is not an organization if its breakdown is greater than 25 % of management workload.

THE RCM PROCESS

The basic steps in developing a formal RCM analysis are:

- 1. Define the major systems and components. The user defines the systems. Where systems are extremely complex and this complexity makes analysis difficult, the user may opt to define subsystems as a means of organizing the problem into manageable pieces.
- 2. For each system, define all "functions" of that system.
- 3. For each of those functions, define the possible "functional failures" that could occur (i.e., what could go wrong that would prevent the system function from occurring).
- 4. For each functional failure, define all possible "failure modes" (i.e., each equipment failure could be the cause of the functional failure).
- 5. For each failure mode, state whether it would be due to improper operation, improper maintenance, or both.

CMMS

CMMS Definition

Computer systems that schedule, track and monitor maintenance activities and provide cost, component item, tooling, personnel and other reporting data and history.

CMMS systems can often be interfaced with production scheduling and cost systems, and may be used to follow preventive maintenance policies.

Essential Factors in a CMMS

Creation of a Preventive Maintenance Program

Collection of Equipment Data to trigger Privative Maintenance

Track Tools, Spares, Parts, etc

Create work orders that list the information required to plan the job

Track moving spare parts

Handle contract purchasing with vendors

CMMS, Best Practices and Compliance

Best Practices	
Total Productive Maintenance (TPM)	**Reliability Centered Maintenance (RCM)**
Operational philosophy based on integrating equipment maintenance into the manufacturing process. Workers understand the way they perform their duties impact the equipment they operate.	Analytical Process to determine optimum maintenance to increasing equipment uptime and Overall Equipment Efficiency (OEE) by reducing breakdowns resulting in lower total cost of ownership of the equipment.
The main purpose is to eliminate any loss caused by maintenance activities and avoid downtime that is unplanned.	It uses Failure Modes, Effect and Criticality Analysis (FMECA) to pinpoint the maintenance required to avoid critical failures.