Targets and benefits of condition monitoring development

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Something about the “facts” in condition monitoring

Challenges in Maintenance - same slide could have been used 10, 15, 20 years ago and also in future

- keeping processes and machinery in good running order with high OEE during whole life cycle with optimum costs
  - high costs due machinery failures in process facilities are mainly due to cost of lost production
  - process and machinery are kept up and running when they are needed with the capacity planned with desired product quality
  - planned shutdowns short
  - maintenance of processes and machines are done during operation when possible (or in planned shutdowns)
- proper maintenance with optimal operation of processes
  - **conditions promoting problems** and failures are avoided
  - processes and machines are restored to condition to meet requirements during operation or in planned shutdowns to avoid small stoppages and unplanned shutdowns
- despite proper preventive maintenance actions and keeping operating conditions optimal it is a statistical fact that failures occur
  - time based maintenance practices alone will not be effective way to prevent unplanned shutdowns

Based on condition monitoring and inspections a proper Condition Based Maintenance solution can be built ➔ corrective actions can be planned and executed during operation or in planned shutdowns before major breakdown and possible secondary damages happens.

Something about the “facts” in condition monitoring

Basics of condition monitoring – always the same

- most failures give some warning of the fact that they are about to occur.
  - identifiable conditions which indicate that a functional failure is about to occur or is in the process of occurring

Root cause is probably not an UFO?

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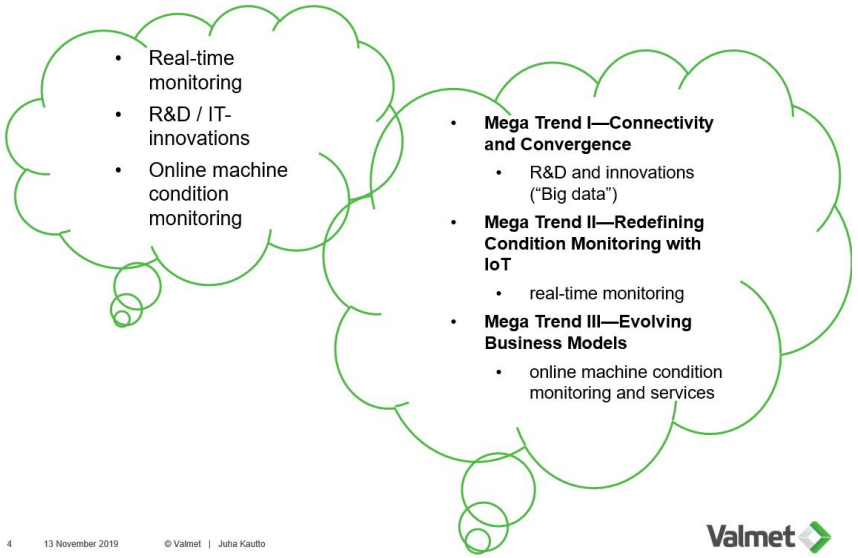
Something about the “facts” in condition monitoring

Global trends in Condition Monitoring

- Ability to monitor the condition of assets 24/7/365 from any location – almost anything can be measured
- How do we champion that?
- What do we do with all this data?
  - Condition data needs to be processed into condition information of machines
  - Condition information needs to be processed into maintenance actions
  - Knowledge = experience, skill, expertise, capability…
    - How to restore the condition? - What, how, when?
    - How to avoid failures to happen again?
    - Etc.
- Lack of technical resources for analysis/diagnosis - partnership and collaboration??
- Lack of trust in prediction capabilities of technology to monitor machine condition
- How about sharing knowledge above to others?
- Many of the **challenges in maintenance remain the same also in future**



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Something about the “facts” in condition monitoring

Targets of Condition Monitoring / Maintenance

- **Unplanned shutdowns/downtime not allowed** because of machinery failures, but also other ”possible” causes of downtime must be avoided
- **Shortening planned shutdowns**
  - Example (production “worth” of 1 milj. EUR / day)... Shortening shut downs 4 hours à + 150 kEUR
- **Lengthening the time between shutdowns**/downtime
  - This is CBM... maintenance and repairs only when needed… improves also availability…
- **”Standardized” failure finding tasks** and maintenance actions during operation
- **Guiding maintenance**
  - up-date prority lists for ”short unplanned” stoppages” (condition monitoring responsibility...)
  - up-keep shutdown plans (constant review of plans)
  - etc.
- **Avoiding failures and unplanned shutdowns**
  - Eliminating conditions that promote failures (very important when improving OEE and profitability)
- **Improve maintenance**
  - Eliminating recurrent failures (allowed only once...)
  - Design machines so that monitoring during operation is possible (target: everything must be Condition Based)
  - Improving maintainability (modular design, accessibility, etc.)
  - Lengthening service intervals (materials, lubrication, etc.)

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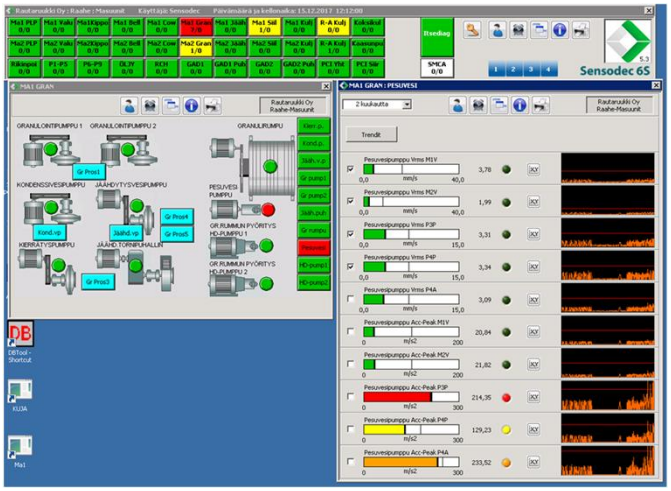
Something about the “facts” in condition monitoring

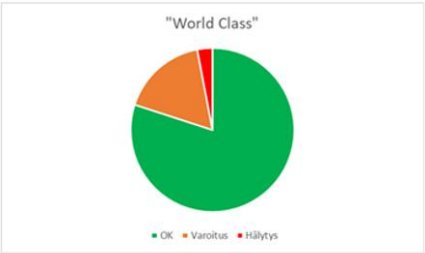
Failures are rare

- despite proper preventive maintenance actions and keeping operating conditions optimal it is a statistical fact that failures occur – what is “normal”?
- Typically >80% of machines are “healthy”
- Only few-% has some failure developing
- Same should be seen in Condition Monitoring systems too… but…
  - Sometimes Condition monitoring systems looks “like a Christmas tree”
  - Due to above lots of time is used just to find out deviations
  - Systems that are planned to help analyst by detecting changes “automatically” are not doing their “job”…
  - Of course good examples exists… In many cases condition monitoring development will help…

Failure distribution %

	Failure	Deviation	Normal	Total
Process 1	1,06 %	11,70 %	87,23 %	100,00 %
Process 2	5,83 %	8,52 %	85,65 %	100,00 %
Process 3	0,00 %	10,59 %	89,41 %	100,00 %
Process 4	2,63 %	7,89 %	89,47 %	100,00 %
Process 5	3,28 %	3,28 %	93,44 %	100,00 %
Total	2,65 %	9,33 %	88,02 %	100,00 %





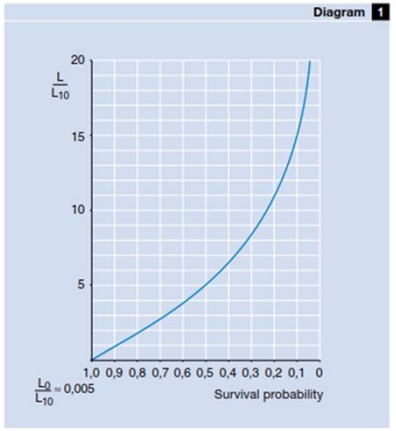
How machines fail

Failures are rare – simplified example calculation based on “basic rating life” of bearings

- despite proper preventive maintenance actions and keeping operating conditions optimal it is a statistical fact that failures occur – what is “normal”
- 90% of bearings will last >>L10 ajan
- 10% bearings will fail < L10
- L10 = 60000h (7 years = rating life)
- If we have 100 bearings
  - 10 bearings will fail in 7 years
  - 1 – 2 bearing failures / year is ”normal” based on their rating life
- 50% of bearings last longer than 5 times their rating life
- Above mentioned ”facts” are only based on basic bearing rating life...
  - **Operatig conditions and lubrication etc. Has effect on ”service life” of bearings**

$$L_{10} = (C/P)^p$$

Operating Condition	Minimum L10 Life (Hours)
Intermittent operation during day, service interruptions acceptable	8,000
Intermittent operation during day, reliability important	12,000
Continuous 1 shift operation	20,000
Continuous 2 shift operation	40,000
Continuous 24 hour operation	60,000
Continuous 24 hour operation reliability important	100,000



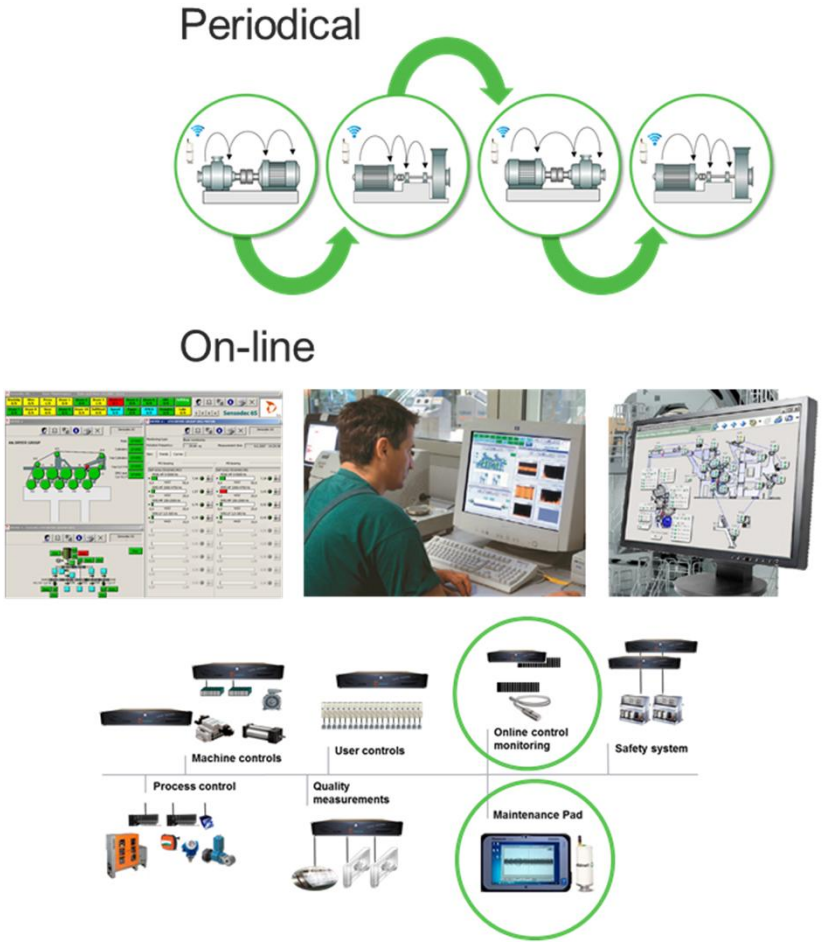
Because failures are random, continuous condition assessment and monitoring is inevitable to find out machines with progressive failure modes

Current situations on site

In what “level” is your condition monitoring program?

Three “levels” of Condition Monitoring can be found

- Level 1: Reactive maintenance with longer “time to react” based on Condition Monitoring
  - Example a paper machine with 44 bearing failures in drying section in 5 years – still “happy” because any of the failures has lead to unplanned shutdown
- Level 2: Detection of failures and elimination of root causes
  - When finding out root cause nearly all of above mentioned bearing failures can be avoided
- Level 3: Condition Monitoring “itself” deliver value for the organization
  - following “normal conditions” instead of failures
  - “anticipating” problems and failures
  - following “conditions that promote failures”
  - close co-operation with maintenance and operation
  - targets set based on “requirements” from management, production
  - etc…



Current situations on site

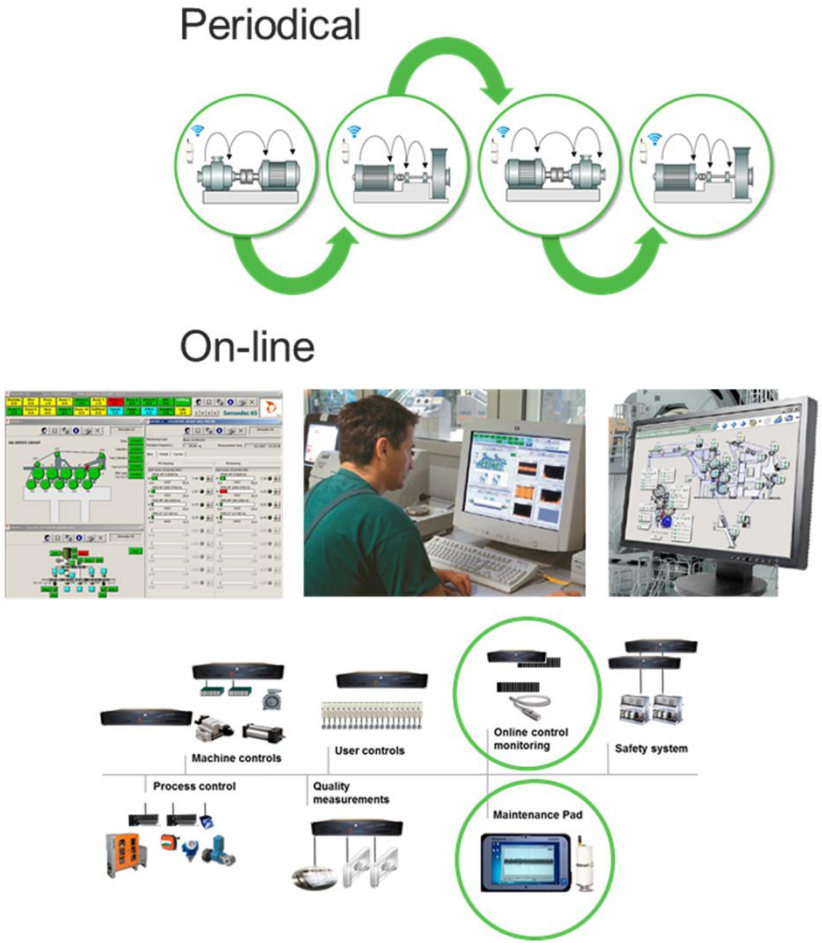
In what “segment” your organization belongs?

Segment 1: No or low/limited competence/experiences in condition monitoring
- low maintenance knowledge – relies to “old fashioned” maintenance practises also development of those are needed also
- don't realize the possibilities of preventive and predictive maintenance practises - often still thinks that everything is ok
- might think that condition monitoring is the key to success (all problems cleared when condition monitoring are in place)
- might have some tests and pilots done with condition monitoring but those have not succeed – because daily maintenance practises in use doesn’t support condition based approach

Segment 2: Some level competence in condition monitoring but limited expertise
- quite often organization doesn’t realize the situation on their own – “might think that they have the best condition monitoring ever seen”
- can be quite satisfied when some failures found beforehand but still lots of failures leading to unplanned shutdowns occurs
- can be “difficult” to “know what is not known”

Segment 3: High competences and expertise in condition monitoring
- significant improvements of availability and reliability achieved by condition monitoring and condition based maintenance practises
- realizes the situation where they are and knows that they don’t know everything
- eager to learn more and interested in new technologies and solutions

Segment 4: Low competence in condition monitoring but have outsourced condition monitoring
- service provider do or do not have proven “track record”
- may or may not have significant improvements of availability and reliability achieved
- either Segment 1, 3 or 3 above?

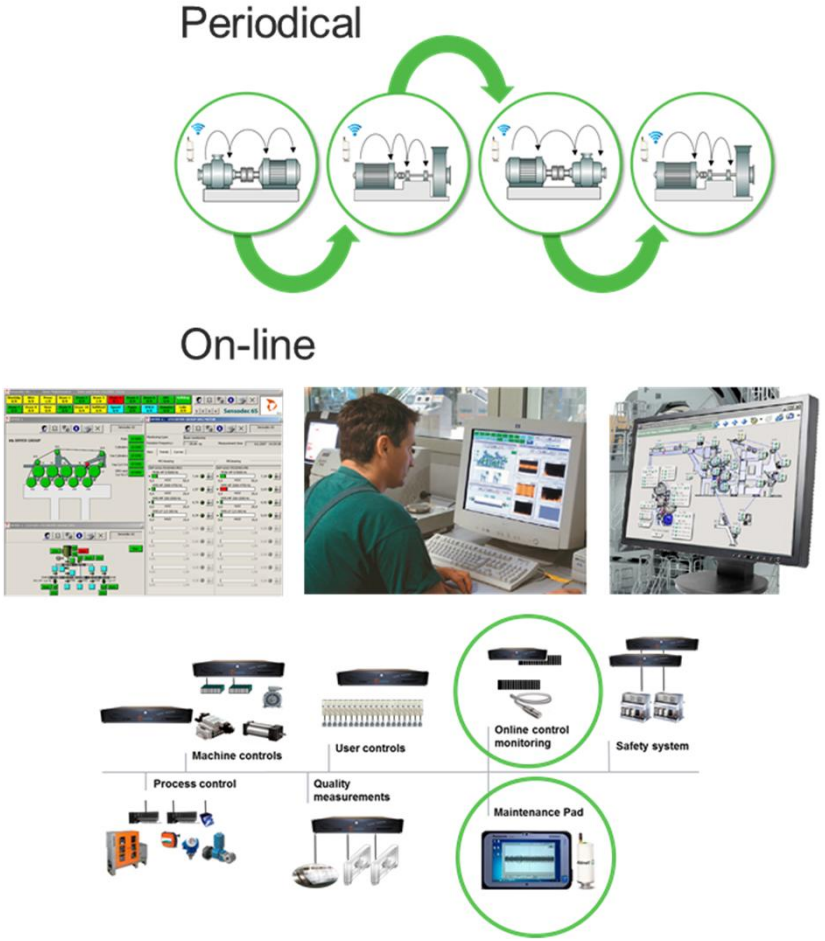


How to “succeed” with condition monitoring?

- **Know what is ”normal” – follow deviation from normal**
- **Know how machine/components ”fails to be normal”** – what ways and why not + what are failing components?

For failures:

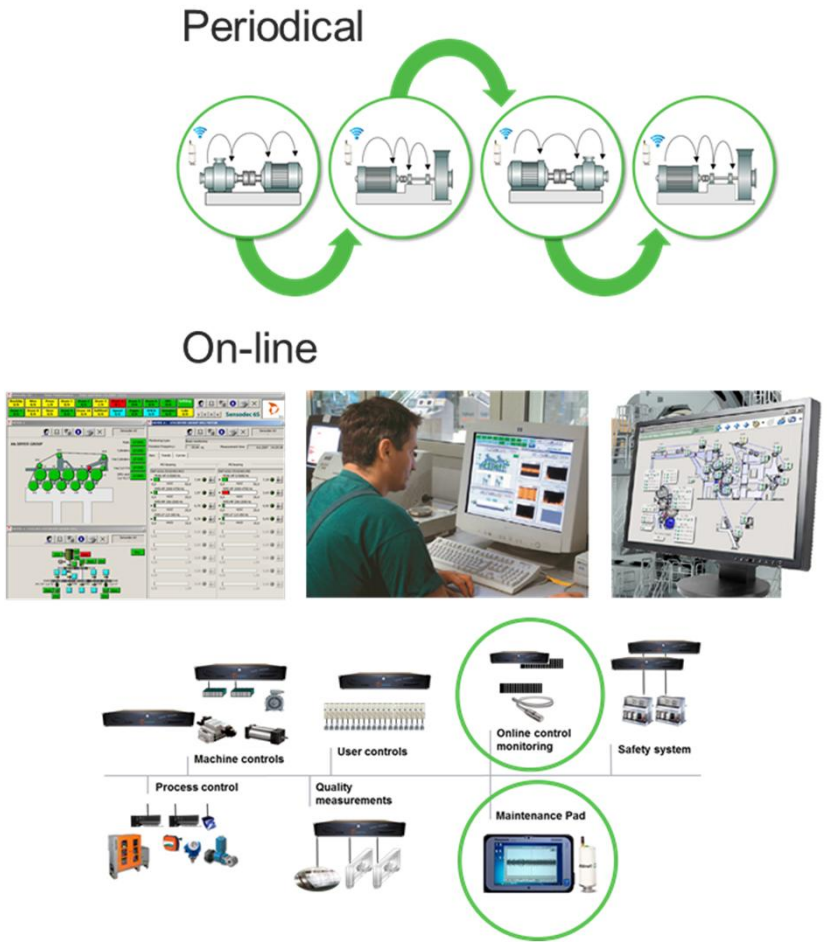
- Estimate possible and probable failure modes and P-F curve
- What are **symptoms of failure** in each failure mode
- What **should be followed** to able to detect probable failures - symptoms of failure in each failure stage
- Use correct measurement and follow-up parameters
- **Set-up and up-keep alarm limits**
- Fine-tune condition monitoring system (trend scales,alarm limits etc.)
- Be sure that Condition Monitoring system is in operation and works correctly



Planning of Condition Monitoring

Before we can select or define suitable methods to manage failures we need to identify which is critical, which failures can occur and how to predict or prevent them

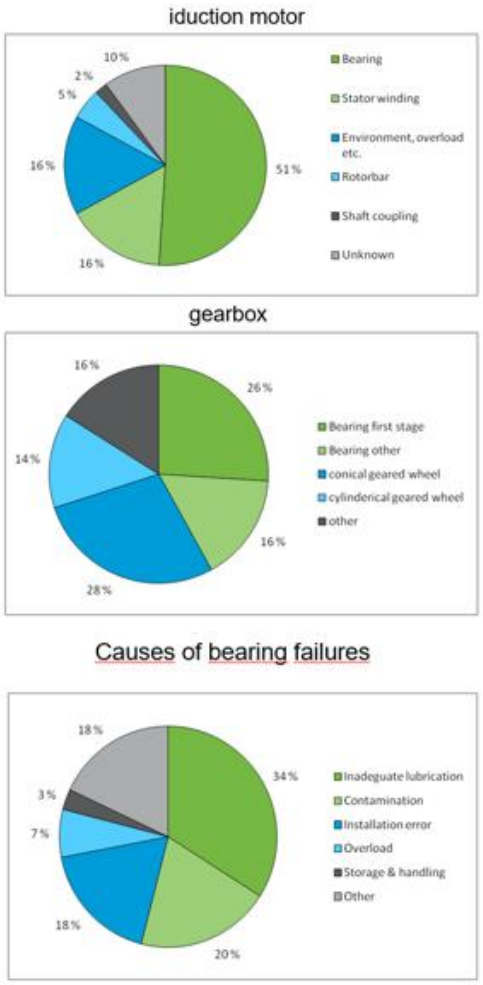
- Criticality analysis **(What is critical to production?)**
- Most probable failing machine components causing shutdown are analyzed **(What is critical for critical machine?)**
- Potential fault mechanisms **(How critical machines fail?)**
- How to predict or prevent potential failures **(What are suitable methods (condition monitoring methods)?)**
- Probable rate of failure propagation defined **(What is time interval from point where failure begins and is detectable to breakdown?)**
- Rate of failure propagation defines the interval for inspection and/or measurement needed, **What kind of systems is needed (on-line, periodical, etc.)?**



Fundamental truths don’t change

”... You can’t analyze what you don’t know or understand...”

”... Condition monitoring requires understanding of processes and machinery components and their influence...

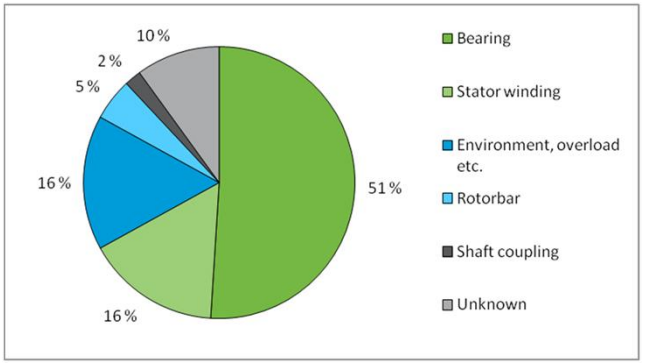


Most of the problems still appear as bearing faults

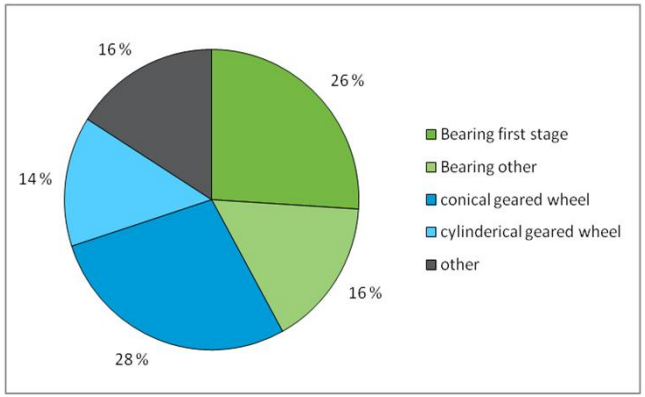
In rotating machinery (with rolling bearings) most of the problems appear as bearing failures

- 60-70% of all rotating machinery problems are due bearing faults (if rolling bearings) – this does not mean that bearings are the weak part but all forces goes through bearings
- about 60 % of the rolling bearing faults are due inadequate lubrication, false lubricant or contaminants in lubrication (next slide)
- 20 - 30% of faults are caused by residual unbalance and poor alignment
- Rest are caused by overload, environment and operation (most of the overload failures are caused by operation of the machine)

Typical motor failures (low voltage)

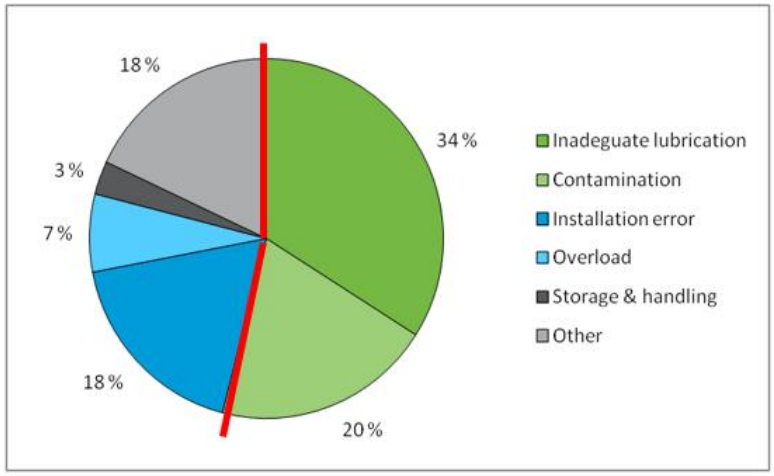


Typical gearbox failures



Typical causes of failures / how to detect those

Typical causes of bearing failures



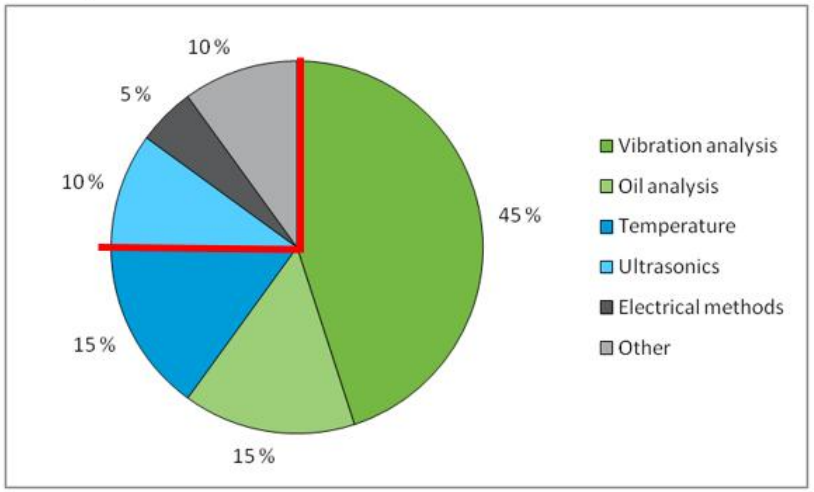
”rule of the thumbs”

- 80% of machines are always ok
- 2-3 (max. 5%) has some failure in progress

It is ”easy” to be Condition Monitoring specialist:

- If you have to estimate ”root cause” ... First ”always” say lubrication... You can’t go very much wrong way...

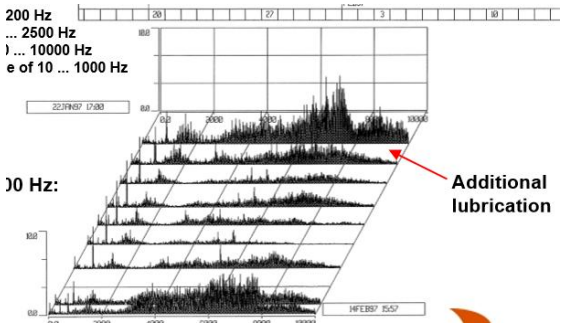
How possible failure mechanisms are identified



How to prevent failures

Some “tips”

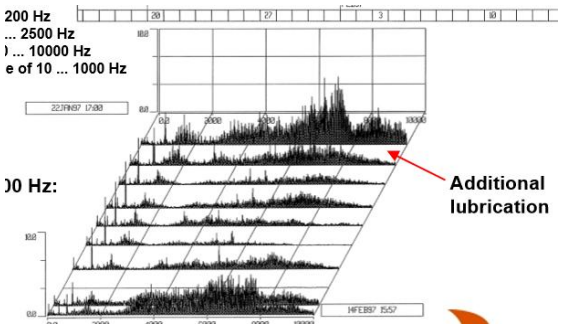
- It is not only doing condition monitoring but you have to plan corrective actions to maintain machine in good running order
- conditions promoting problems or changes in processes and equipment operational behavior are detected early enough
- full benefit of condition monitoring can be achieved when failures can be prevented
  - This is done by targeting condition monitoring actions to causes of failures and conditions that promote failures
- Target is to move operation and maintenance towards more condition-based approach
  - role of condition monitoring from follow-up of failures (reacting) towards approach where failures are avoided



Damages Detected with Condition Monitoring

Goals of Condition Monitoring

- Maintain and improve availability
  - Prevent operational and ambient conditions causing deterioration and failures
  - Predict incipient failures and follow failure propagation
  - Estimate failure progress and time to maintenance to prevent and eliminate unplanned shutdowns
  - Guide service and maintenance actions to planned shutdowns or maintenance and services tasks to be done during operation when possible
- Maintain and improve process efficiency
- Know when problems arise to be able to act before major problems

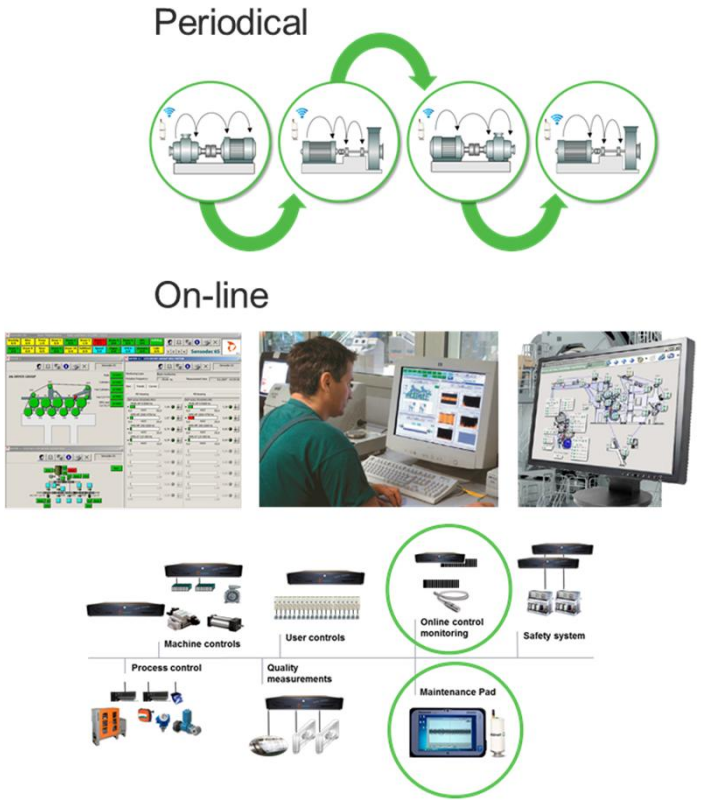


Damages Detected with Condition Monitoring

Condition Monitoring development

Targets / Basis

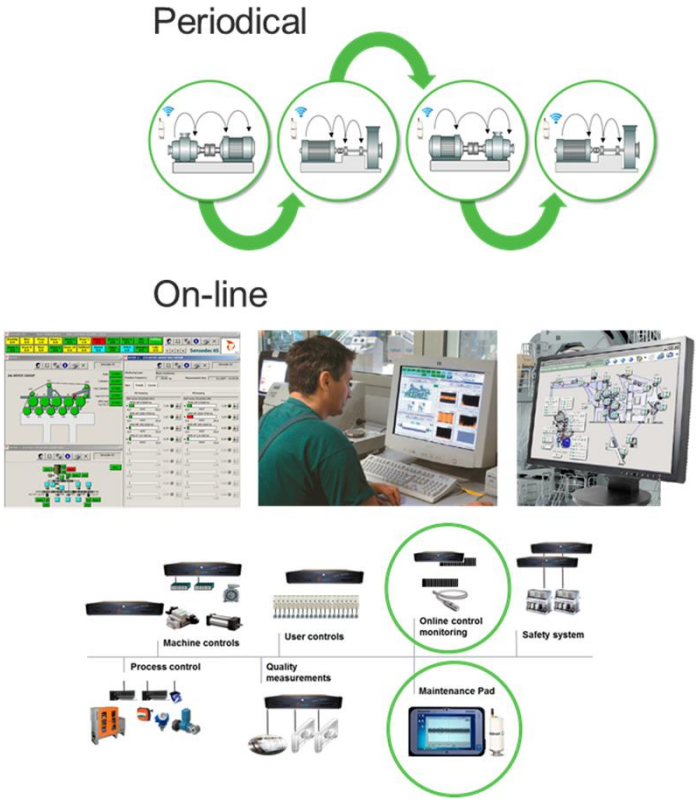
- Critical machines connected to on-line condition monitoring system
- Periodical condition Monitoring based on routines defined, planned and executed in defined intervals to reliably detect problems and machinery failures in early stage
  - enough time to plan and execute maintenance actions well before there is an effect to production
  - to have failures and failure mechanisms in control
  - to avoid unplanned shutdowns by maintenance actions guided by condition monitoring
  - to shorten shutdowns by detailed planning of actions required guided by condition monitoring
  - to lengthen time between shutdowns by more accurate knowledge of current condition of assets
- To achieve targets, condition monitoring provides basis for operation and maintenance planning for high availability and productivity of critical assets
  - methods and practices based on process and machine criticality, probable failures and failure modes
  - follow-up parameters used on technical characteristics of process and machinery in question
  - measurement and inspection intervals based on probable rate of failure propagation
  - analysis, diagnosis and prognosis based on qualified expertise and experience of machinery in question
  - efficient reporting routines defines basis of up-to-date and full-time knowledge of machinery condition
- How to achieve targets:
  - probable failure modes analyzed and their symptoms defined
  - follow-up parameters defined based on probable failure modes
  - methods used that can reliably detect changes in equipment operational behavior
  - measurements an inspections performed in shorter interval than the fault develops into operational problems
  - problems may appear during machine's total life-cycle à constant trending of symptoms is necessary



Condition Monitoring development

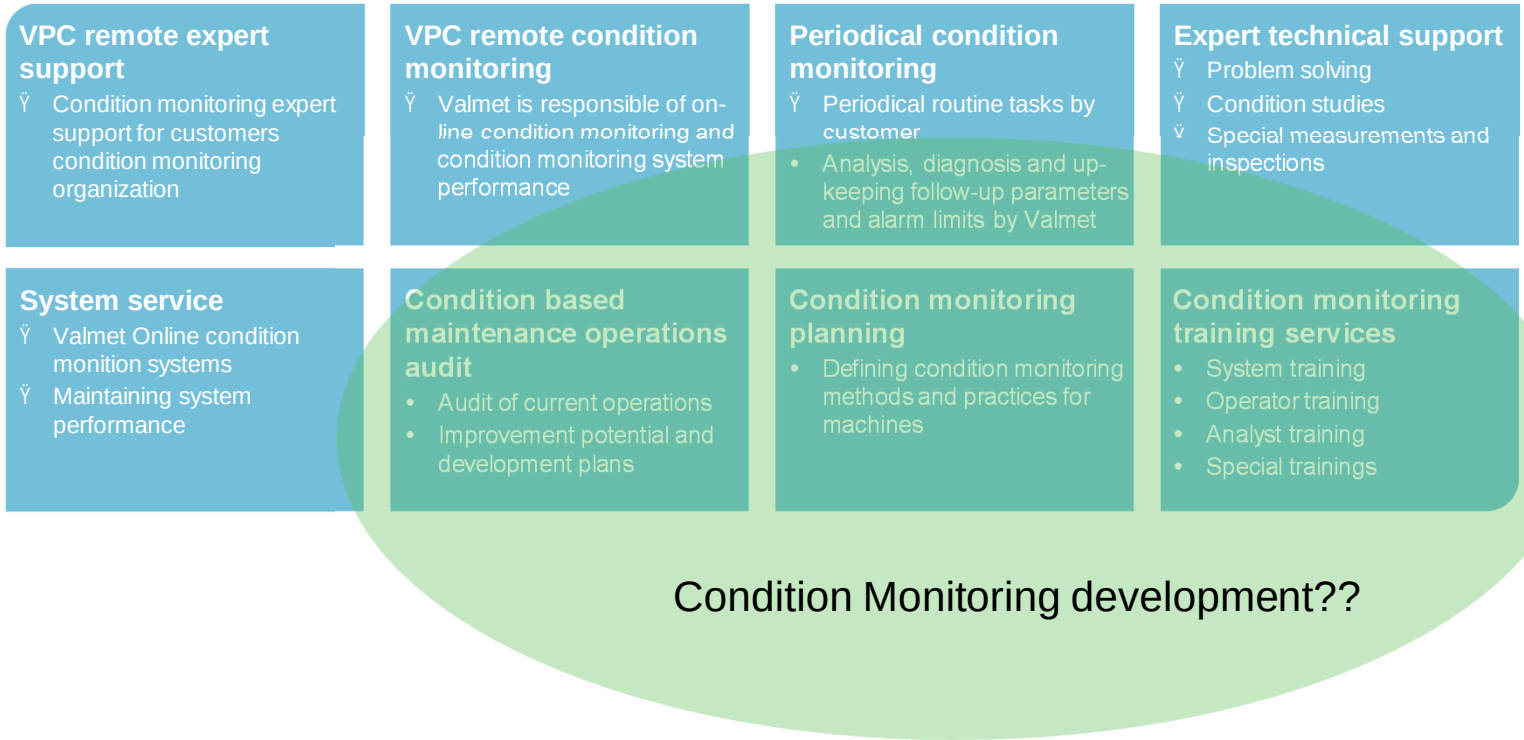
Contents

- Phase 1: Condition Monitoring Audit
  - analyze potential for improvements in condition monitoring and Condition Based Maintenance actions
  - evaluate current failures and failure rates realized to failure rates possible to achieve with comprehensive Condition Monitoring and Condition Based Maintenance practices
  - define plan to develop condition monitoring practices and maintenance towards more Condition Based approach
  - evaluate training and education needs
  - audit is done by experienced and competent condition monitoring expert in co-operation with customer
- Phase 2: Condition monitoring planning
  - Condition monitoring practices tailored to process and machinery in question
    - Condition monitoring practices based on probable operational problems and failure modes
    - Inspections to support condition monitoring of assets (not so called “Operator Driven” tasks)
  - Solution is planned by experienced and competent condition monitoring expert in co-operation with customer
- Phases 1 and 2 are reported and evaluated and forms basis of continuous co-operation in future – Condition monitoring plan is revised and updated on constant basis
- Phase 3: Condition Monitoring in practice
  - Condition monitoring
    - condition data by periodical and/or on-line measurements and inspections are done on site by trained personnel
    - analysis and diagnosis of results are done and reports on assessment prepared to plan and execute needed maintenance actions
    - follow up and development of condition monitoring activities



Asset reliability - condition monitoring

Valmet condition monitoring solution is customized from service modules



Condition monitoring planning (1/2)

Defining condition monitoring methods and practises for machines

Included:

- Selection of machines for condition monitoring
- Determination of monitoring methods
- Recommended measurement systems and instrumentation (on-line/periodical)
- Determination of measurement points (on-line/periodical)
- Recommended intervals for periodical measurements (and inspections)
- Measurement and follow-up parameters recommended
- Preliminary condition monitoring plan

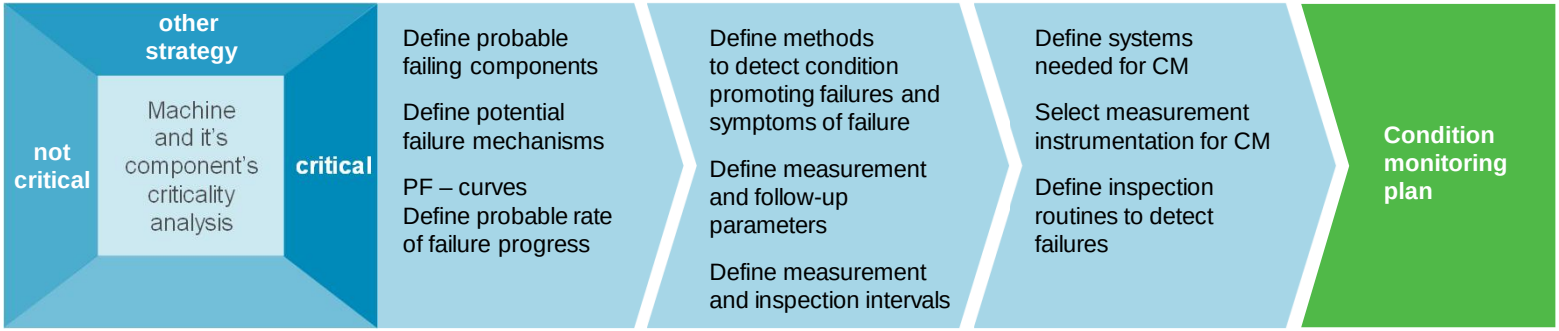
Condition monitoring “plan” includes following:

- selection of machines to on-line and periodical condition monitoring
- probable failing mechanisms and how to detect those
- monitoring methods needed
- measurement systems and instrumentation (on-line/periodical)
- recommended measurement and follow-up parameters
- schedule for on-line, periodical measurements and inspections
- requirements for practical organization of condition monitoring operation
- requirements for documentation, reporting and follow up of measurements
- co-operation requirements for condition monitoring and maintenance operations

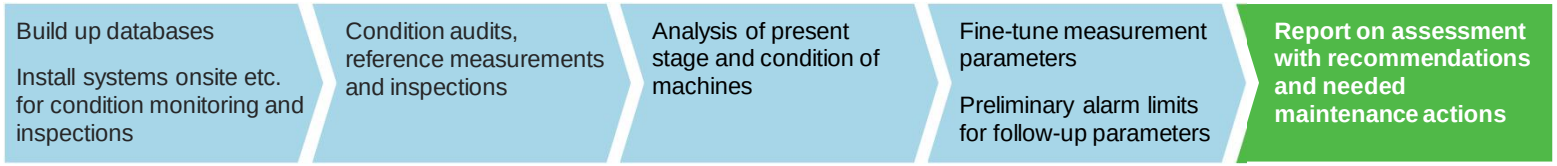
Condition monitoring planning (2/2)

”Flow charts” – tasks in planning and implementation phase

Included: Condition monitoring plan



Additional services: Condition monitoring implementation

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