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WCM Vedlikeholdsleder

7.4 Prediksjon / resterende levetid

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Mechanical vibration and shock — Condition monitoring and diagnostics of machines - Prognostics — Part 1: General guidelines

Élément introductif — Élément central — Partie 1 : Titre de la partie

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Introduction

The complete process of Machine Condition Monitoring consists of five distinct phases:

— Detection of problems (deviations from normal conditions);

— Diagnosis of the faults and their causes;

— Prognosis of future fault progression;

— Recommendation of actions;

— Post-mortems.

As far as machine health prognosis is concerned, which demands prophecies of future machine integrity and deterioration, there can be no exactitude in the process requiring statistical or testimonial approaches to be adopted. **Standardisation in machine health prognosis must therefore embody guidelines, approaches, and concepts rather than procedures or standard methodologies**

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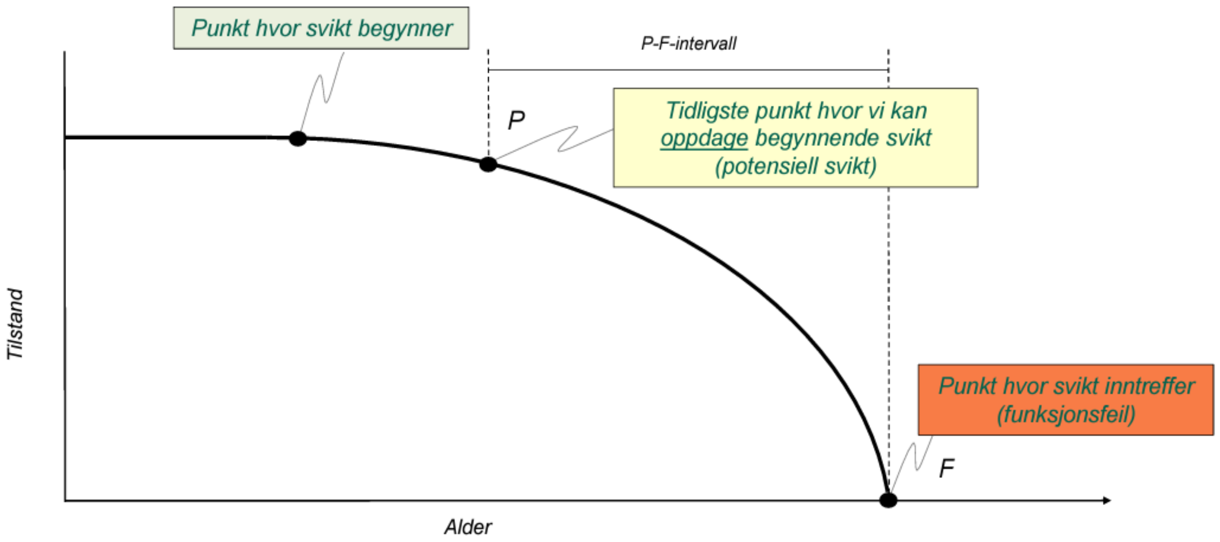
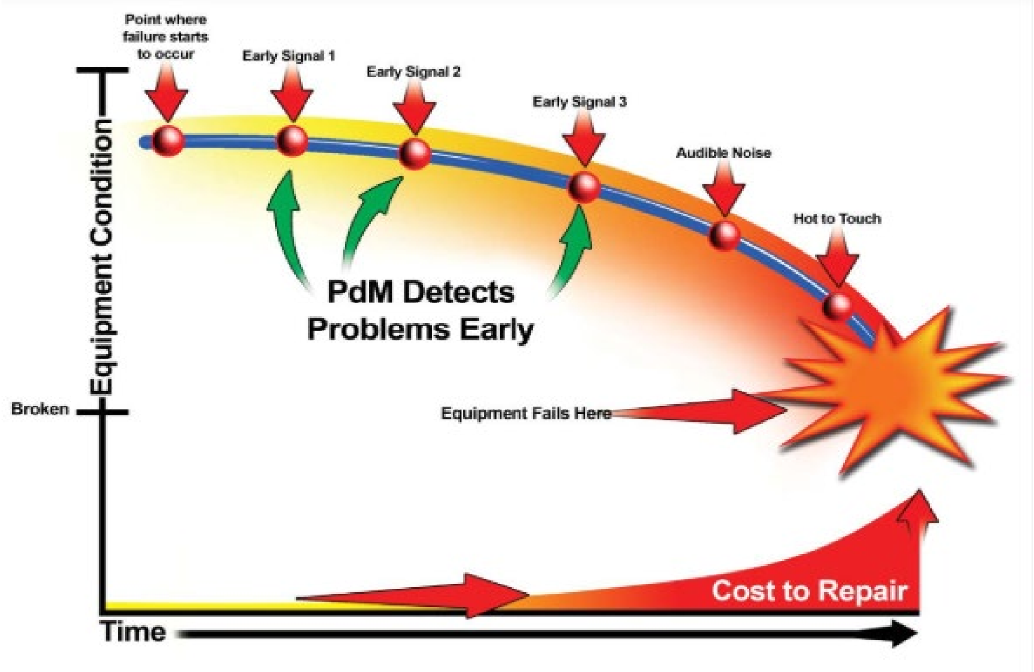
Estimated Time To Failure (ETTF)
An estimation of the period from the current point in time to the point in time where the monitored machine is deemed to be in the failed condition.





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Prognosis Concepts
5.1 Basic Concepts

Prognosis is an estimation of time to failure and risk for one or more existing and future failure modes and is normally intuitive and based on experience. Prognosis is usually effective for faults and failure modes with known, age related or progressive deterioration characteristics the easiest of which is linear. Prognostics are most difficult for random failure modes.

A failure has to be defined in terms of the monitored parameters/descriptors. Monitoring data on its own is insufficient to produce a prognosis. The general conceptual basics of a prognosis process is:

a) define the end point (usually the trip set point);

b) establish current severity;

c) determine/estimate the parameter behaviours and the expected rate of deterioration; and

d) determine the Estimated Time To Failure (ETTF).

It is important to understand that diagnostics is retrospective in nature in that it is focused on existing data at a given point in time.

Influence Factors

Influence factors are parameters that effect the deterioration rate of a failure mode such as temperature, viscosity, clearance, load, speed, etc. Each influence factor can be considered a symptom of an existing failure mode and in Figure 1 is represented by the solid lines that connect existing failure mode trends. Influence factors also have effects on the progression and initiation of other either existing or future faults (Figure 2).

Alert and alarm limits are normally set at a value less than the trip set point. Usually this value is determined based on the maintenance lead time required, however, such alert values should be cognisant of:

1) Confidence level of prognosis;

2) future production requirements;

3) spare parts delivery lead times;

4) maintenance planning lead time required;

5) scope of work required to rectify faults; and

6) trend extrapolation and projection.

7.2 Prognosis Process

7.2.1 General

The generic process involves four basic phases: pre-processing, existing failure mode prognosis, future failure mode prognosis, and post action prognosis. The process is generally sequential as detailed below.

7.2.2 Pre-processing:

1) carry out a diagnosis in order to identify all existing failure modes;
2) identify influence factors between existing failure modes;
3) define failure definition and trip set points for all current symptoms, parameters, and descriptors;
4) determine potential future failure modes, their initiation criteria and failure definition set points;
5) select a suitable failure mode model (Annex D).

7.2.3 *Existing* Failure Mode Prognosis Process:

6) assess severity of all measured failure mode and their parameters/descriptors against their trip set points;

7) project all failure mode parameter and descriptor trends to their trip set points;

8) select the existing failure mode with the shortest ETTF;

9) if possible execute an iterative confirmation process until the confidence in the ETTF is acceptable.

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7.2.4 *Future* Failure Mode Prognosis Process:

10) assess future failure mode initiation criteria and determine most probable future failure modes;

11) determine influence factors between all existing and future failure modes;

12) estimate initiation point, trends, and ETTF for each future failure mode taking into account all influence factors and trip set points;

13) select the most critical future failure mode with the shortest ETTF and develop an “Initial Prognosis” with associated confidence level and validity conditions.

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EXAMPLE CONFIDENCE LEVEL DETERMINATION

PROCESS ACTIVITY STEP	ERROR SOURCES	WEIGHTING	ASSIGNED CONFIDENCE VALUE (%)	RESULTANT CONFIDENCE LEVEL(%)
1	Maintenance History	0.15		
2	Design and Failure Mode Analysis	0.10		
3	Analysis Technique Parameters Used	0.15		
4	Severity Limits Used	0.10		
5	Measurement Interval	0.10		
6	Database Set-up	0.5		
7	Data Acquisition	0.5		
8	Severity Assessment Process	0.5		
9	Diagnosis Process	0.10		
10	Prognosis Process	0.15		
OVERALL CONFIDENCE LEVEL				
Confidence Level = Sum (Weighting * Assigned Confidence Value)				

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Failure Modelling Techniques

C.1 Knowledge Based Models

- symptom/fault
- causal tree
- case based

C.2 Mathematical/Life Usage models

- behaviour
- statistical
- probabilistic
- artificial neural network

C.3 Life Expectancy model

Life duration of individual components in a machine can been estimated with respect of the risk of deterioration during inspection and the risk of failure during operation.

- reliability based
- deterioration based (statistical, deterministic, expert opinion, equations, tests, FEM, damage models)

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C.4 Knowledge based models

— rule-based symptom / fault model

— causal tree model (described in ISO/TC108/SC5/N91 Diagnostics of machines)

— case based reasoning: The principle is to use the similarity between the observed situation and case(s) already known and solved. (Ex: this fault resembles to other cases). This model needs a learning phase based on a good experience that is to say based on several cases well described.

C.5 Mathematical models

— behaviour

The principle is to model the behaviour using physical laws. Modelling can be quantitative or qualitative.

— statistical

A Pareto approach which uses statistical histograms to evaluate the probability of occurrence of one or more failure modes.

C.6 Reliability models

These models provide reliability-related information as probabilistic values with respect to time. Computation on these functions can provide mean time to failure (MTTF) values.

Weibull analysis can be used to take into account failure rate increase when components get old or infant mortality.

Reliability factors can be adjusted with respect to monitoring data and operating conditions. This enables reliability factors to be individualised for a given machine.

C.7 Deterioration models

To estimate the deterioration (damage) initiation and progression (for example wear, cracks, corrosion...).

Can be modelled with several states of deterioration based on previous inspection results on similar machines. These models can be coupled with “good behaviour models” to predict future deterioration.

Eksempel på prediksjon / resterende levetid på Kule- rulle lagre

RUL / ETTF / PREDIKSJON

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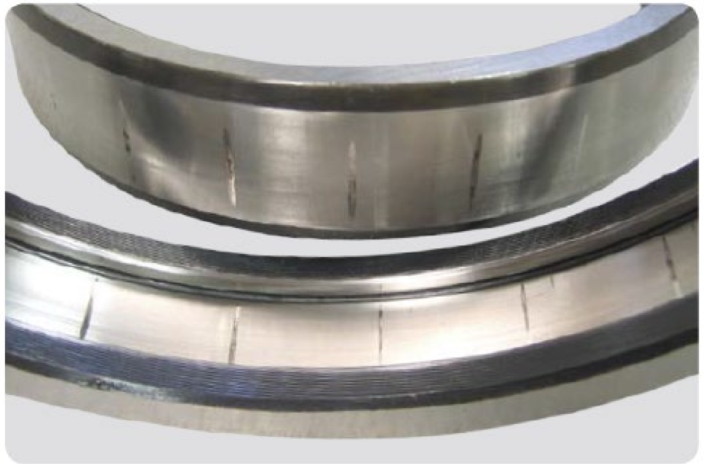
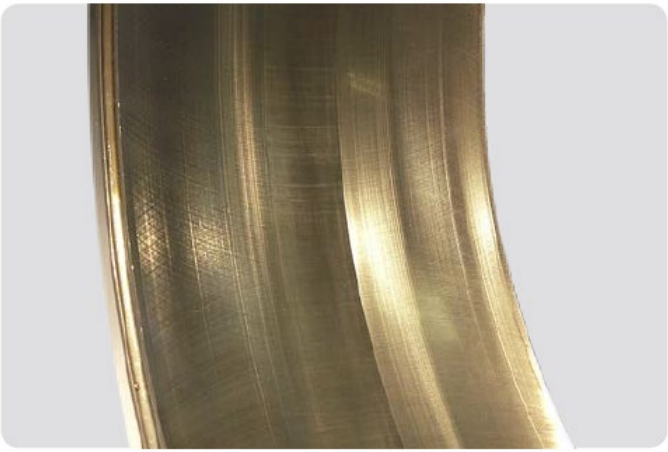
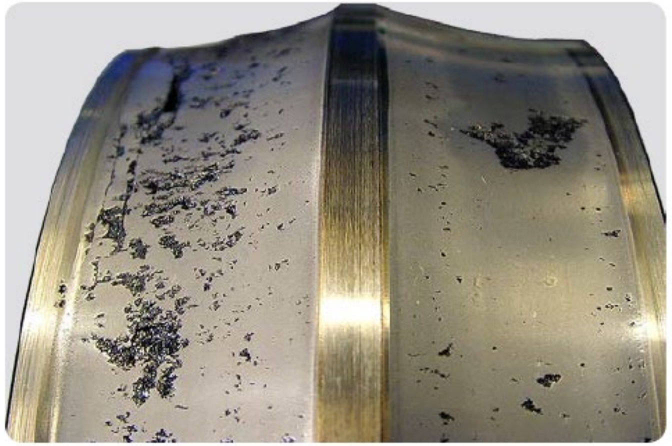


Cylindrical roller bearing inner and outer rings
Exposure to vibrations at standstill, false brinelling marks at roller pitch



Spherical roller bearing outer ring
Abrasive wear of the raceway tracks in an early stage



Spherical roller bearing inner ring
Inadequate lubricant film. Initially, abrasive wear due to contamination, developed into surface distress and spalling.

Cylindrical roller bearing outer ring
Advanced stage of washboarding

Deep groove ball bearing outer ring and ball
Washboarding in the outer ring and dull ball surface

Cylindrical roller bearing outer ring with cage, rollers and grease
Current leakage resulted in burnt grease (black) on the cage bars

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ABB

Motors and Generators

Expected bearing lifetime in Motors

Bearing life

The normal bearing life L_{10h} of a bearing is defined, according to ISO 281, as the number of operating hours achieved or exceeded by 90 % of identical bearings in a large test series under specific conditions. 50 % of bearings achieve at least five times this lifetime.

The nominal bearing life is the lifetime that 90 % of identical bearings achieve or exceed before first signs of material weariness appear. A sufficient grease layer inside the bearing and usage in a correct application are preconditions for a nominal bearing life. By definition, 10 % of bearings can fail before they reach the nominal bearing life. Consequently, bearing life should never be confused with warranty period.

The usual values for bearing lifetime of standard motors are 40,000 h for belt drive and 100,000 h for direct coupling.

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Det er en direkte sammenheng mellom vibrasjonsnivå og levetid på lager!

25% økning i last halverer levetid på et lager. En dobling i belastning reduserer levetiden 8 ganger!

Det er viktig å merke seg at vibrasjon reagerer på en dynamisk kraft på en lineær måte. Unntak inkluderer strukturell resonans, fleksible rotorer, og looseness.

Syv dominerende faktorer som påvirker levetiden til lageret:

1. Turtall på aksling
2. (Design) belastning i lageret (som definert av produsenten)
3. Type lager (kule / rulle / sylindrisk /sfærisk)
4. Faktisk belastning (kraft) påført lageret
5. Smurning
6. Forurensing
7. Drifts temperatur.

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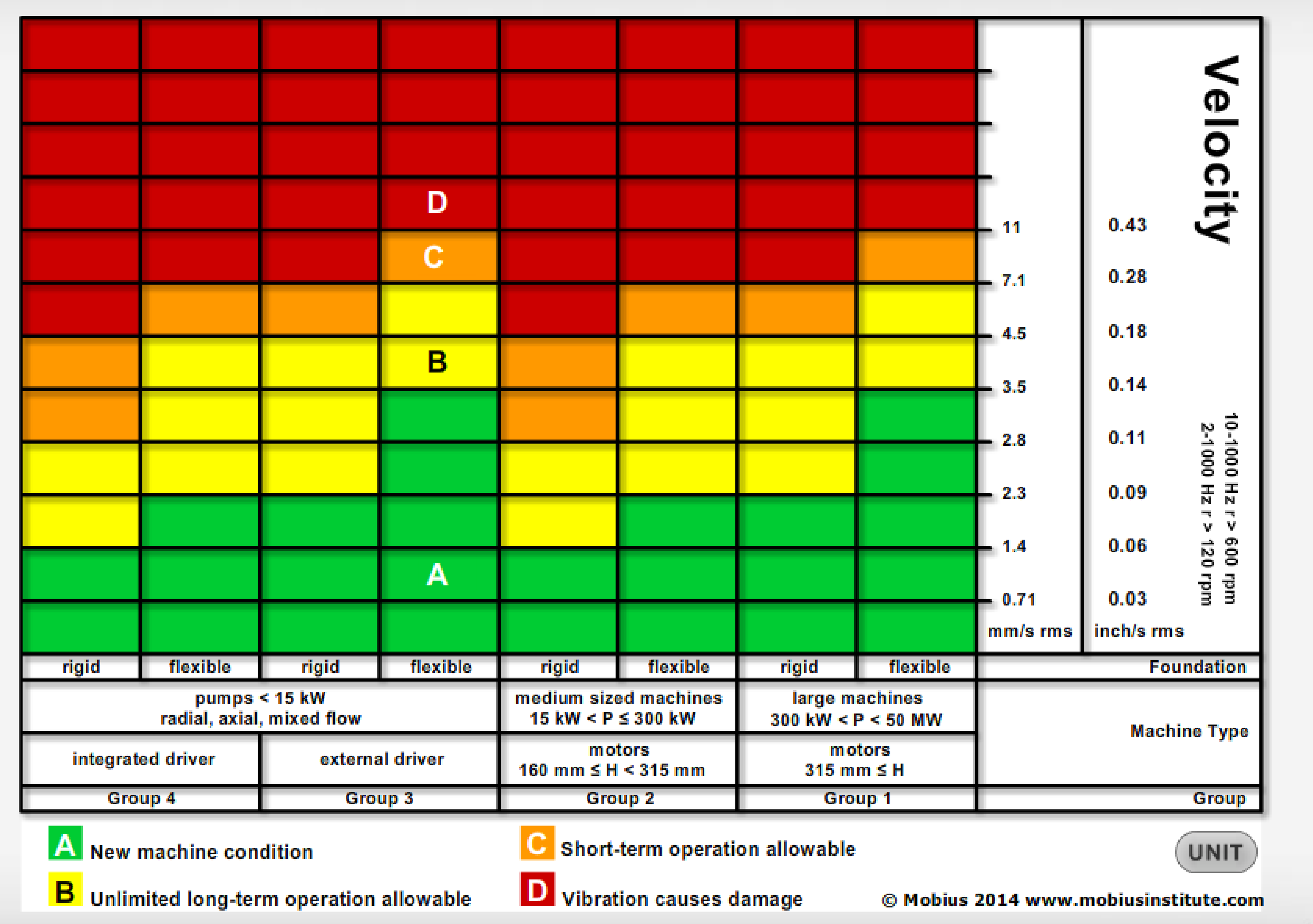

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TABLE 1

IMPACT OF INCREASED LOAD ON BEARING LIFE

	Percentage Life Decrease	
% Load Increase	Ball Bearings	Other Rolling Element Bearing Types[1]
5	14	15
10	25	27
15	34	37
20	42	46
25	49	52
50	70	74
75	81	85
100	87	90

[1] Other rolling element bearing types include cylindrical, spherical, tapered and needle bearings.

TABLE 2

FORCES AND SOURCES OF VIBRATION

Force Source	Type of Force	Reducible
Unbalance	Dynamic	Yes
Shaft Misalignment	Dynamic & Static	Yes
Belt / Drive Tension	Static	Yes, if Excessive Tension is Present
Looseness	Dynamic	Yes, if Excessive Looseness is Present
Rotor Weight	Static	No, Not Normally
Gear Reaction	Dynamic & Static	No
Process Forces	Dynamic & Static	No, Not Normally

TABLE 4

IMPACT OF VIBRATION REDUCTION ON BEARING LIFE

(Assuming dynamic load is the major force component)

	Percentage Increase in Bearing Life	
% Reduction in Vibration	Ball Bearing Types	Other Rolling Element Bearing
5	17	19
10	37	42
15	63	72
20	95	110
25	137	161
30	192	228
40	363	449
50	700	908

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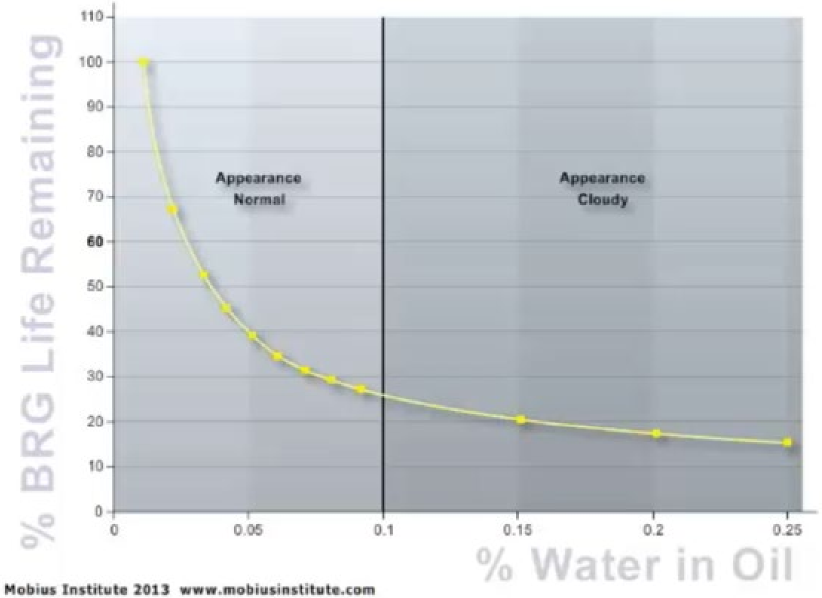
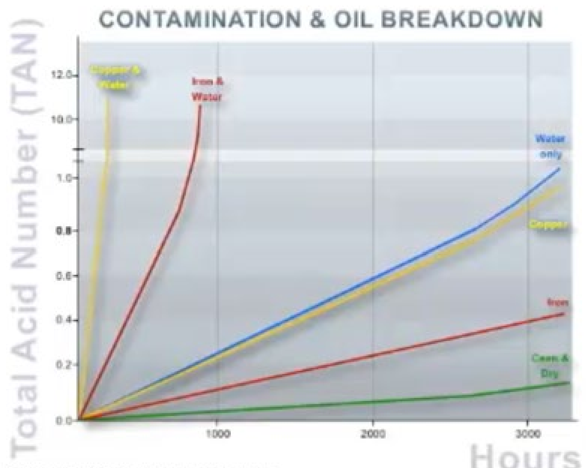
Contaminants that affect the lubricant properties

Before you can even see the water in the lubricant (at **0.1% water in the oil**) the life of the bearing is *already reduced to just 25% of its original life – i.e. a 75% reduction in life.*



Contamination that affect the bearing surface

The worst case scenario is where the oil/fluid is contaminated with water and either iron or copper. The oil/fluid degrades more quickly, in hundreds of hours instead of thousands of hours, and the corrosion will be accelerated, the viscosity will be increased, and deposits will form.



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Colour code	Severity	Prognostic	Recommended action	Code
OK	Acceptable	No reduction in bearing service lifetime	Follow normal maintenance plan	Ok
Notification	Brg wear S1	>20% remaining of L10 bearing life	1) Machine can be operated as normal, follow CM program 2) Consider machine to be acceptable	S1
Warning	Brg Wear S2	<10% remaining of the L10 bearing life	1) Lubricate brg now 2) Follow CM program, 3) start planning	S2
Warning	Brg Wear S3	<5% remaining of the L10 bearing life	1) Replace the bearing at next opportunity 2) Close follow up, 3) Measurement interval <100 hrs	S3
Alarm	Brg Wear S4	<1% remaining of the L10 bearing life	1) Limited use of the machine until repair. 2) Temperature is an important follow up parameter	S4

	Prognostic	Recommendation
Brg wear S1 = >20% RUL of bearing L10 life	The bearing wear has very low energy and **Remaining Useful Life (RUL) can be >20% of L10 bearing life**. For most machines this will be more than 1 year of continues operation. The root cause has a huge impact on the RUL and lack of **lubrication and overload can excalarate the defect dramatically.**	1. If the bearing is grease lubriacted, make sure the lub program is followed. 2. Machine can be operated as normal, follow the normal Condition Monitoring interval.
Brg Wear S2 = <10% of bearing L10 life	The bearing wear has started to develop but we don't expect to see spalling on the raceways. **Remaining Useful Life (RUL) has dropped to <10% of L10 bearing life**. For most machines this can be between 6 months to one year. The root cause has a huge impact on the RUL and **lack of lubrication and overload can excalarate the defect dramatically.**	1. If the bearing is grease lubricated, please add 50% of normal amount of grease asap. 2. Machine can be operated as normal, 3. Plan the repair, order spares etc. 3. Follow the normal Condition Monitoring interval.
Brg Wear S3 = <5% of bearing L10 life	The bearing wear has now significant energy and and we expect there to be spalling or brinelling on the raceways. **Remaining Useful Life (RUL) has dropped to <5% of L10 bearing life**. Probably less than 6 months of operation. **The root cause has a huge impact on the RUL and lack of lubrication and overload can excalarate the defect dramatically.**	1. At this stage we recommend to replace to bearing at next oppertunity even though there are some remaining bearing life. The risk increases and cost of breakdown and loss of production must be considered. 2. Make contact with AMPs Diagnostic center to agree on follow up parameters and interval if the machine needs to be kept in operation. (reduce load etc.) 3. If machine is kept in operation, measurement interval is set to 350 hrs or 2 weeks, which ever comes first. 4. Check maintenance history for the machine. If the bearing wear is considered to be premature, make sure you perform a RCFA of the bearing.
Brg Wear S4 = <1% of bearing L10 life	The bearing defect can now be observed by human sences and the energy is significant. **Remaining Useful Life (RUL) has dropped to <1% of L10 bearing life**. The end is near and risk is high. The root cause has a huge impact on the RUL and lack of lubrication and overload can excalarate the defect dramatically.	1. Stop the machine for repair if possible. 2. Limited use of the machine until repair and close follow up. Temperature is an important follow up parameter. If temperature starts to increase, the breakdown is in progress. 3. Make contact with AMPs Diagnostic center to agree on follow up parameters and ferquency if the machine needs to be kept in operation. (reduce load etc.)

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Takk – det avslutter denne presentasjonen.

Spørsmål?

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