Dynamic Positioning Committee
Marine Technology Society

THRUSTERS

Reliable Prediction of Steerable Thruster Systems Based on Condition Measurements

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Wärtsilä Ship Power

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0. Agenda

1. Introduction
2. The thruster system
3. Design aspect of mechanical systems
4. Reliability of steerable thruster based on field analysis
5. Conclusions

1. Introduction

Reliability is the ability of the equipment unit to perform its stated duty without a forced (unscheduled) outage in a given period of time

By William E Forsthoffer (Reliability optimization through component condition monitoring and root cause analysis)

1. Introduction

- Scope
  - Combined use of CMS and reliability engineering for improvement of total life cycle operation
- Why is it important
  - Better understanding of system and component characteristics, based on service measurements
  - Find underlying factors for improvement
  - Provide effective ways to support expected system behavior
  - Serve as a basis for maintenance programs and life cycle costs
- What do we want to achieve
  - Better prediction of maintenance, reliability and availability
  - Better design for improved overall performance and reduced maintenance
  - Improved availability
  - Better understanding of system behavior

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2. Thruster System *What can go wrong*

- Seal damage: water content in lub. oil
  reduces the life time of bearings and gears with 50%
- Inadequate lubrication: due to late filter / oil change
- Overloading of the thruster
- External impacts

- Eventually this leads to early wear of gears and bearings
- Wear particles spread through the unit and affect other "healthy" components

THE HEALTH OF THE THRUSTER SLOWLY BUT STEADILY DETERIORATES

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2. Thruster System *Results of malfunctions*

- Unplanned maintenance / repairs
- Replacement parts
- Loss of redundancy (Class)
- Docking

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2. Thruster System

Development CMS

Today

Alarms →

- pressure
- temperature
- level

Tomorrow

Monitoring →

Early detection of deteriorating components:

- vibrations
- moisture
- particles

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Result -> signals:

- detect early changes
- make trend line

Future

Diagnostics / prognostics

- combine signals, remaining lifetime
- database

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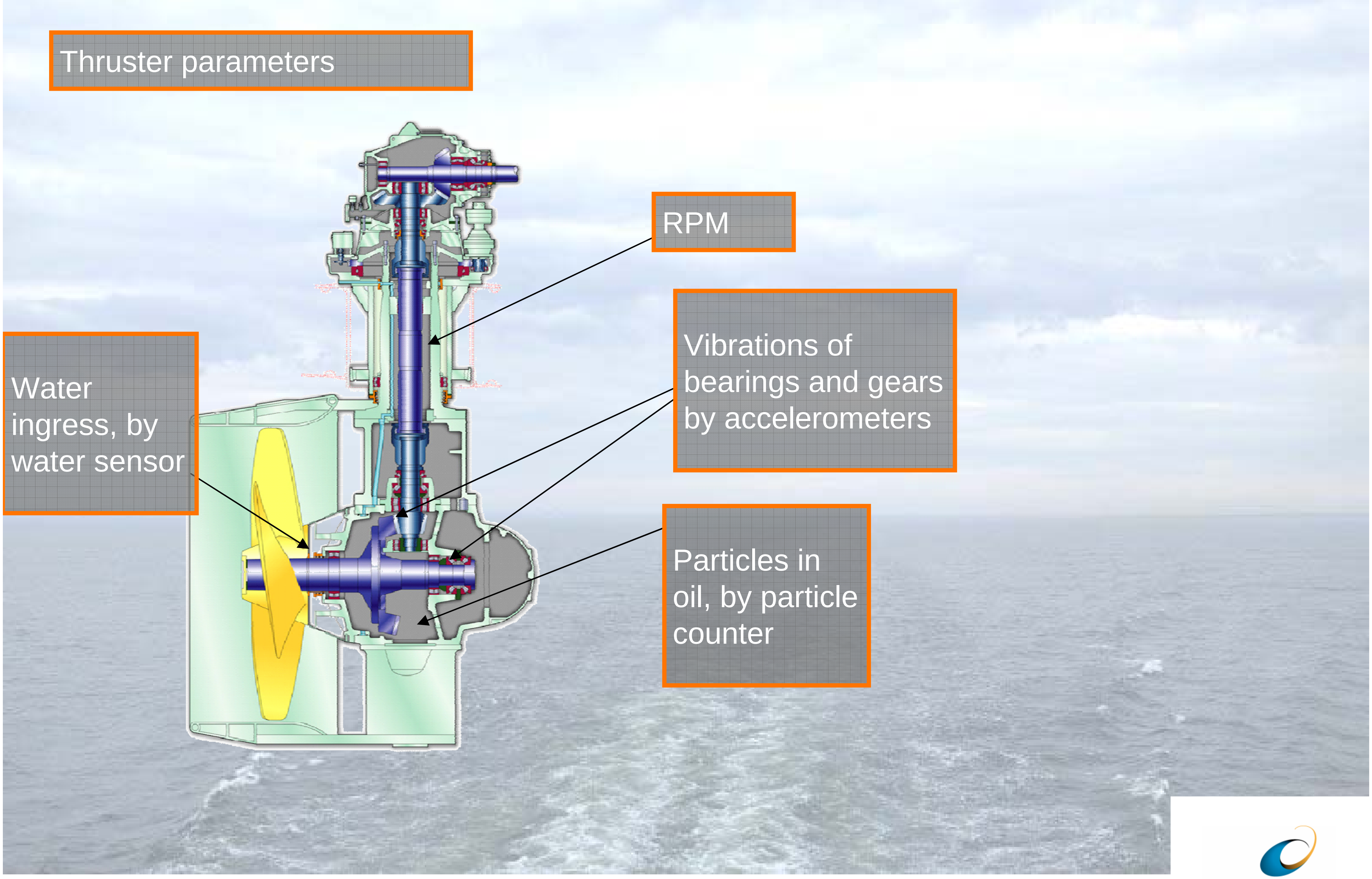
2. Thruster System

Monitoring what….



2. Thruster System

Monitoring what….

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3. Design aspects of mechanical systems

Failure Mode Effect and Criticality Assessment (FMECA):

- Clear vision on the various ways equipment may fail -> intrinsic and exogenous failure processes.

- Room for subjective assessment of criticality and the effect of maintenance interventions.

Quantitative decision support:

- Quantified analysis of the various maintenance strategies**:**
  - Functional failures and repair activities as realisations of chance processes.
  - Characterised by a probability distribution (mean and spread in failure and repair time).

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3. Design aspects of mechanical systems

Set-up FMECA

Functional decomposition → Evaluation of each failure mode → Compensating provision and corrective action → Address criticality

Functional decomposition
- System
- Assembly
- Component

Evaluation of each failure mode
- Cause
- Effect
  - Local
  - System

Compensating provision and corrective action
- Redundancy
- Material, hours

Address criticality
- Probability
- Severity

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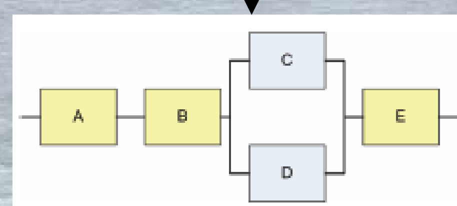
3. Design aspects of mechanical systems

Set-up Quantitative decision aproach

FMECA → Expand FMECA → Set up model → Visualize by figures

Expand FMECA:
- Mean time to failure
- Spread
- Repair time

Set up model:
- Block diagrams



Visualize by figures:
- Costs
- Maintenance interventions
- Failure analysis

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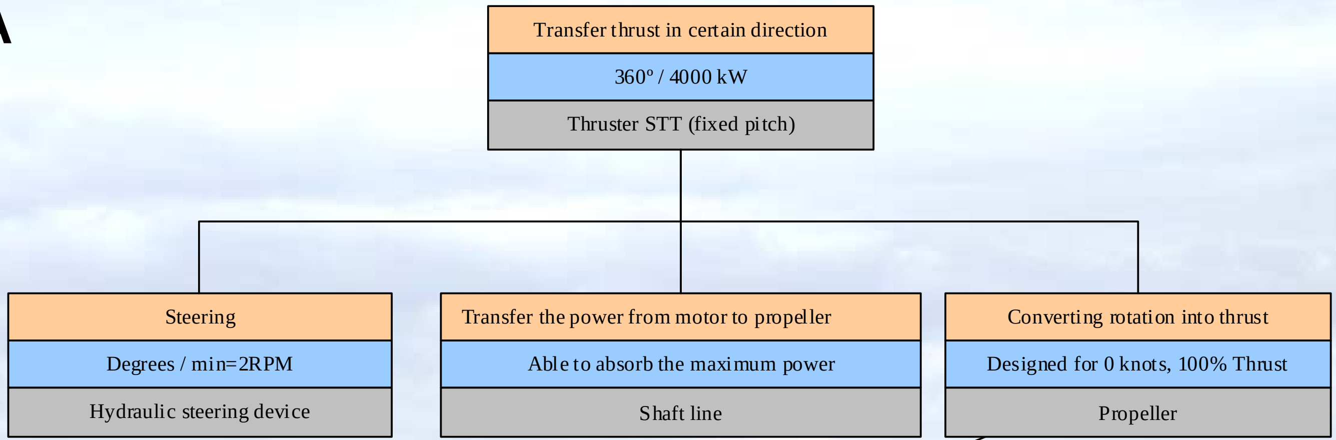
3. Design aspects of mechanical systems

Result FMECA



Level	Module	Failure Mode	Local Effect	System effect	Probability	Severity				Score	Failure Cause
						Saf.	Env.	Op.cap.	Cost		
B3	**Propeller**	Broken blade	No more thrust	System has lost main function	1	2	2	16	16	16	Extreme external events

System/Assembly	Score
Bearings	32
Gearset PGB	16
Propeller	16
Shaft	16
Steering gearbox	16

Score = Prob. x Sev.(highest)

Probability: 1,2,3,..5

Severity: 1,2,4,..16

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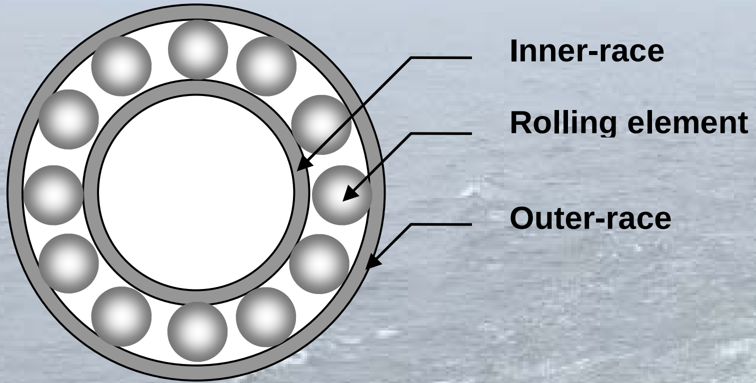
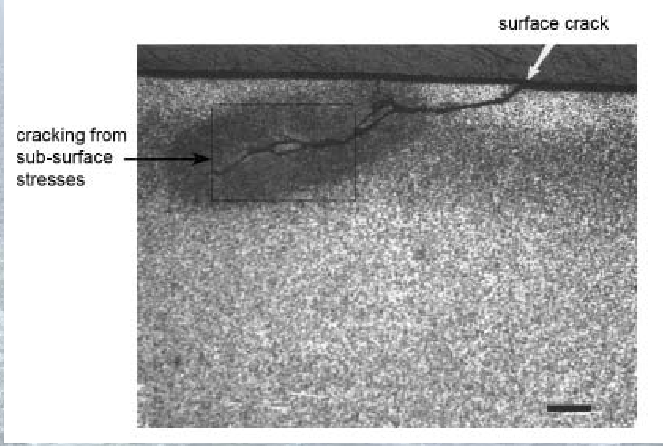
3. Design aspects of mechanical systems

Information Failure Modes Roller bearings

- Failure mode: Fatigue damage
- Failure mechanism: Spalling, brinelling
- Failure cause: Heavy prolonged load, excess speed, shock load, excessive vibration

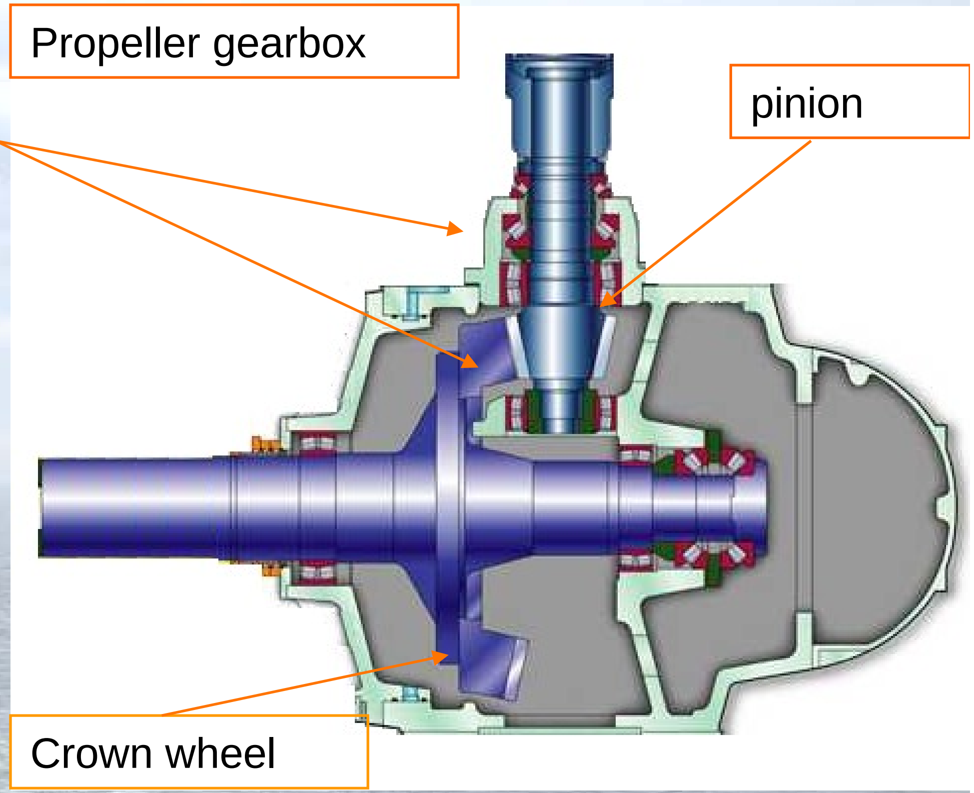




3. Design aspects of mechanical systems

Optimal design criteria:

- Pinion supported by roller bearings at both sides
- Separate axial and radial bearings
- Precise and stable tooth contact pattern under variable loading (thrust)
- Teeth are finish-machined after hardening



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3. Design aspects of mechanical systems

Selection and parameters gears and bearings

Min. 25.000 h lifetime: full continuous load

- Separate bearings for axial and radial load
- Bearing load depends on: torque and thrust
- Double sided support by anti-friction bearings near gearwheels
  - → less deformation
  - → higher lifetime
- Effect of load profile
- Oil contamination / water ingress / temperature

Infinitive lifetime

4. Reliability based on field analysis

Results Quantitative Approach:

- Failure analysis
- Reliability and availability prediction
- Maintenance prediction
  - Preventive
  - Corrective
  - Condition based

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Gears and bearings

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4. Reliability based on field analysis

Results Quantitative Approach:

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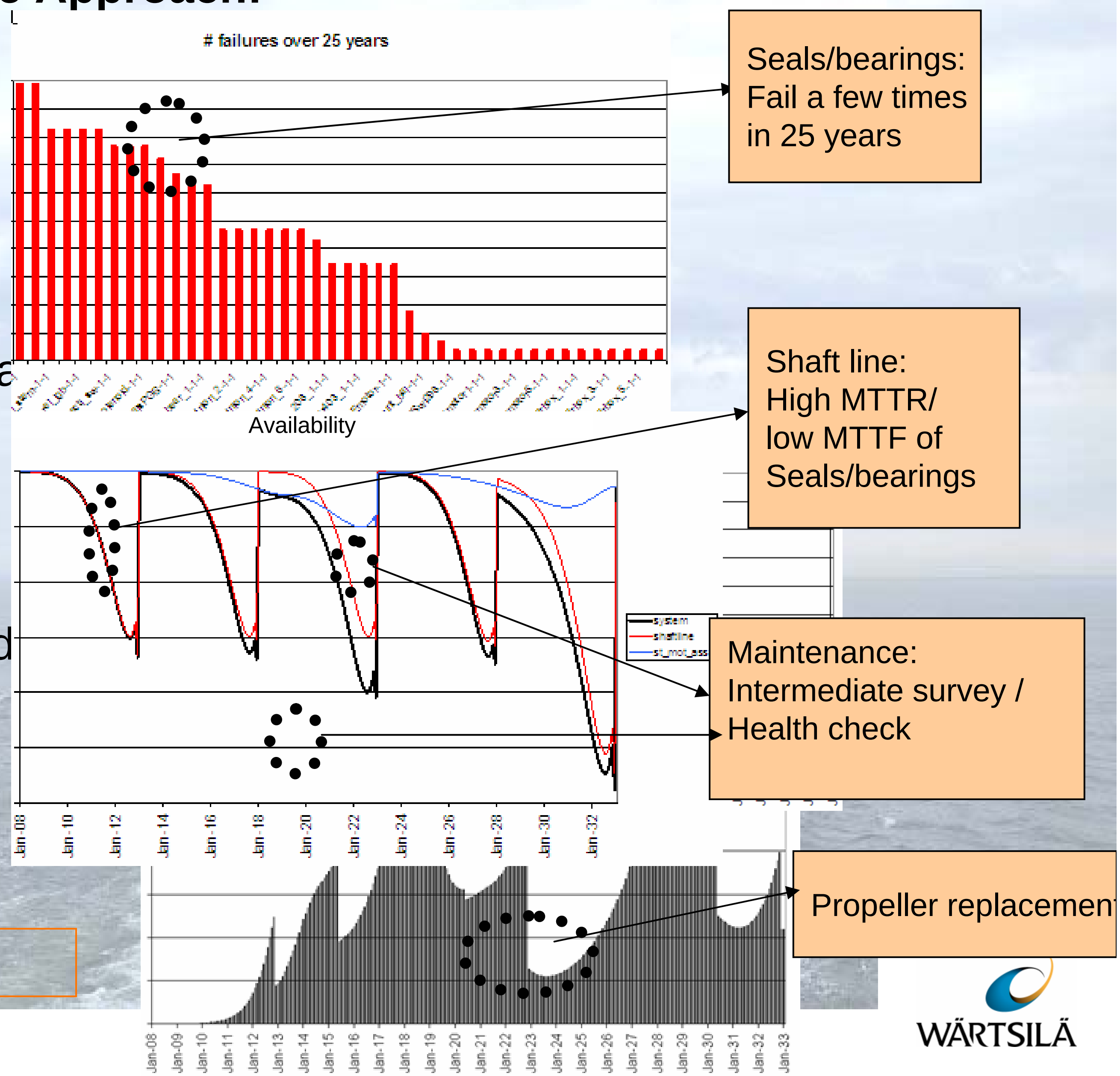
Gears and bearings



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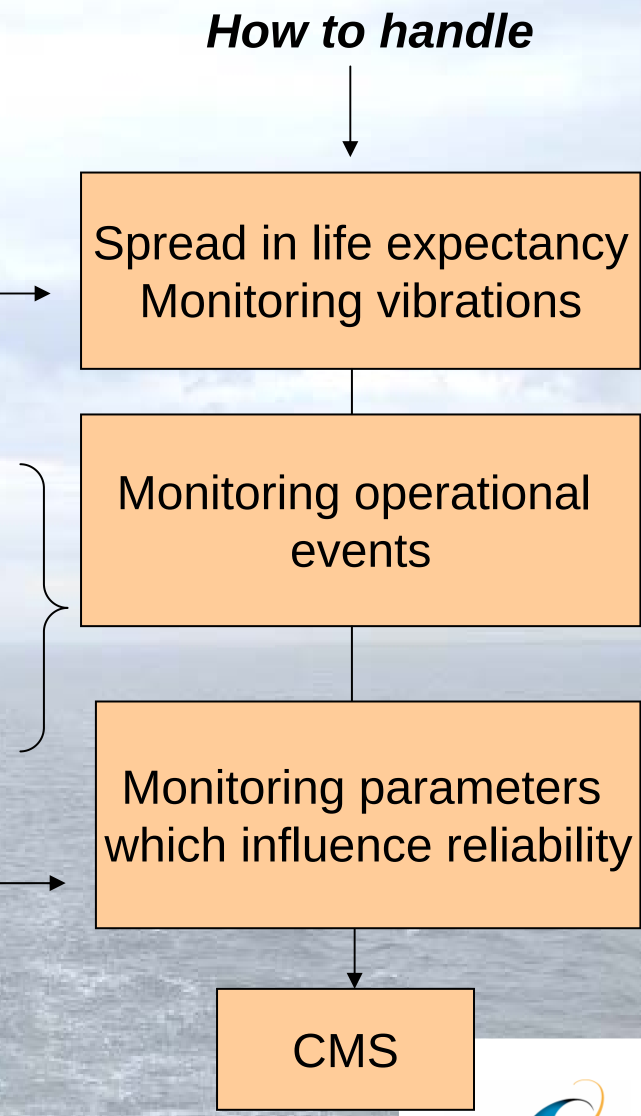
4. Reliability based on field analysis

Field information related to failures:

- Slowly progressing failures:
  - Wear-out
  - Fatigue
- Event determined failures:
  - Operator using machinery outside operating envelope
  - Maintenance interactions
  - External reason
- Stochastic failures (suddenly happening):
  - Reliability
  - Human factors in production (manufacturing failure)



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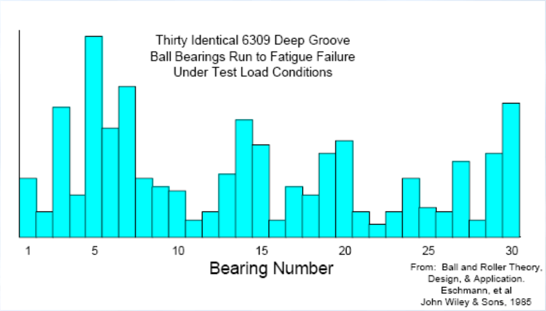
4. Reliability based on field analysis

Reliability combined with condition monitoring

Lifetime expectation:

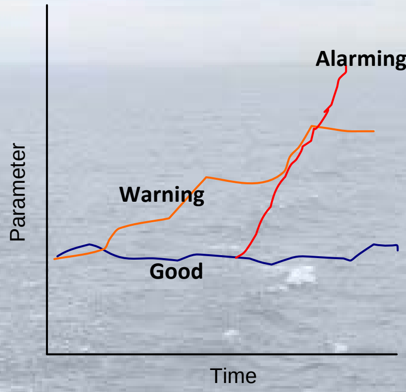
For lifetime expectation a statistical approach is needed:

- Wear-out of bearings is random-> life can only be made in terms of *expected reliability*.
- Use Weibull distribution as an estimate for bearing life



Solution:

- Measurement of performance and health of system
- Real-time trending and monitoring of parameters which influence reliability



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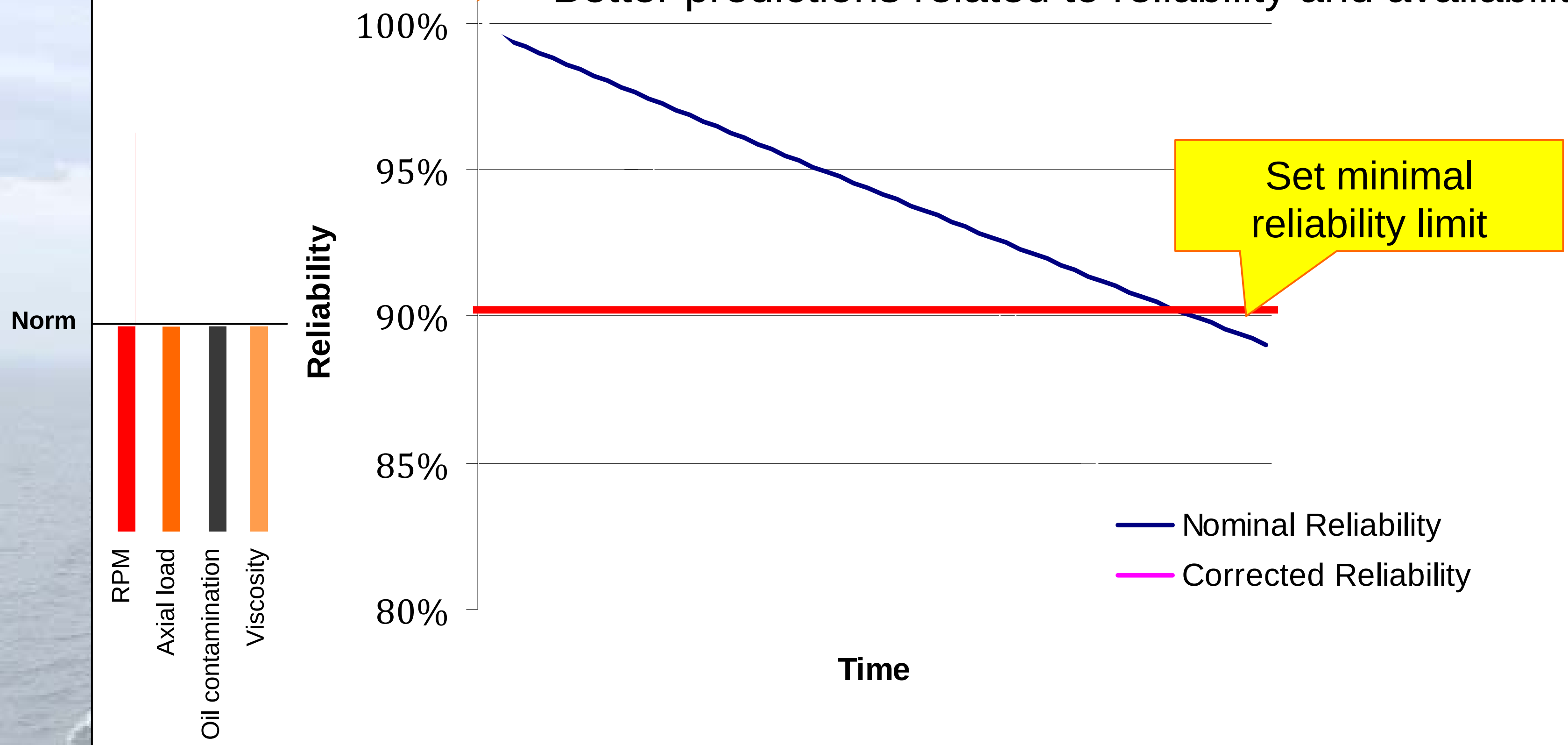
4. Reliability based on field analysis

Result of combination

- Correlation of information as input to perform CBM
  - Evaluate qualitative and quantitative approach
  - Better understanding of system behavior
  - Better predictions related to reliability and availability



5. Conclusions

CMS, CBM

From Condition Monitoring to Condition Based Maintenance:

- Give a *condition* of components or system
- Minimize the possibility of the *consequence of damage*
- Possibility of *adjusting maintenance intervals*, depending on the results of CMS
- Better understanding of *component / system behavior*, this can be used for better *predictions for reliability and availability*
- Eventually this approach allows to perform *condition based maintenance*

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6. End

Questions?