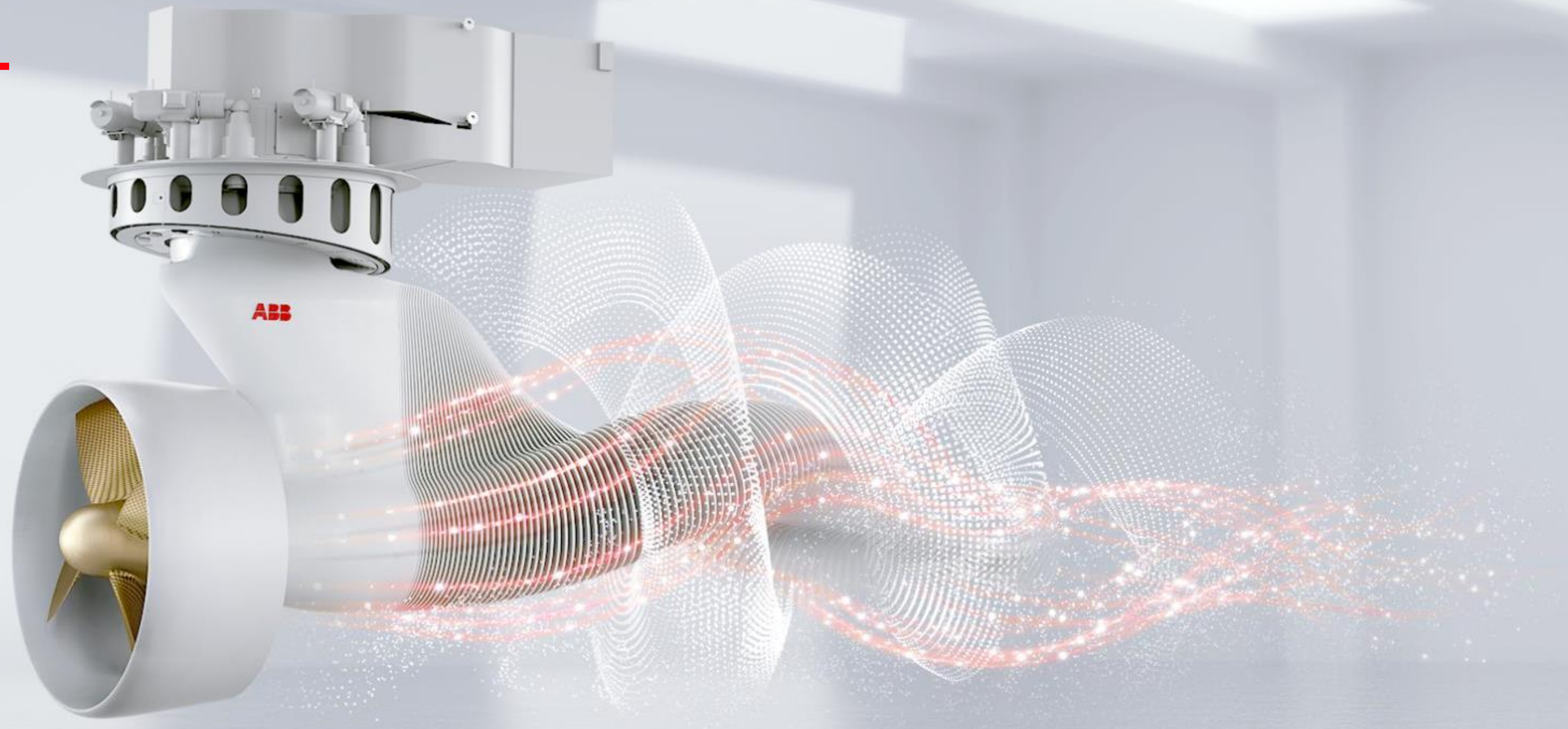

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# Shaftline Bearing lifetime calculation

## Background

Sami Palokangas, Azipod ® X/V Technology Manager

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"This ABB presentation is preliminary and not final and as such non-binding.
It is tendered for discussion only, does not constitute a term to contract and ABB can, without notice, make any change in ABB’s own discretion“



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# Azipod® bearing arrangement and affecting forces

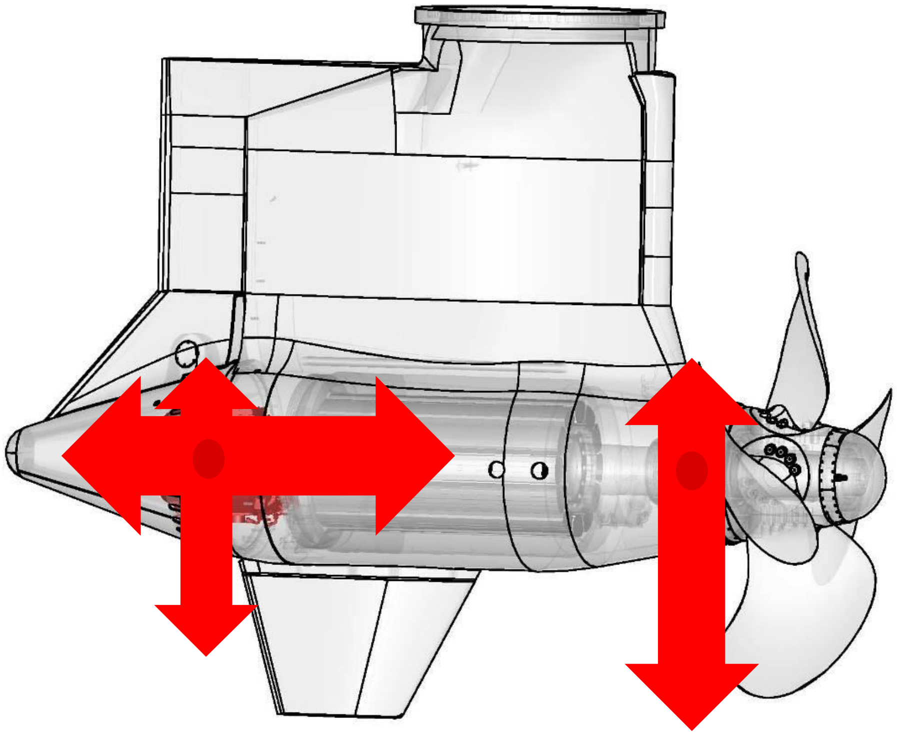
## NDE-Bearing

Axial Forces

- Propeller Thrust force

Radial Forces

- Shaftline weight
- Magnetic pull
- (Propeller side forces)



## DE Eng Bearing

Radial Forces

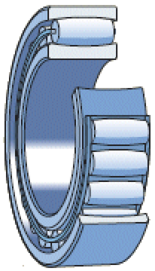
- Shaftline weight
- Propeller side forces
- Magnetic pull

# Azipod® Bearing types

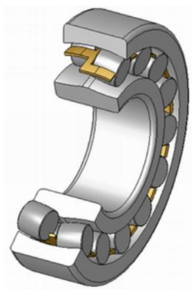
Roller Bearings

Rollertype Radial Bearings

Toroidial roller bearings



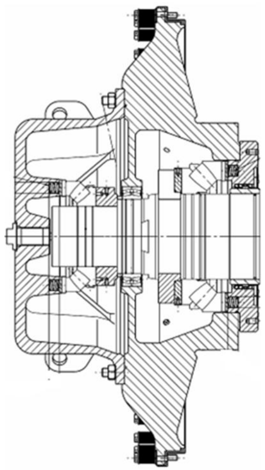
2- row spherical roller bearings



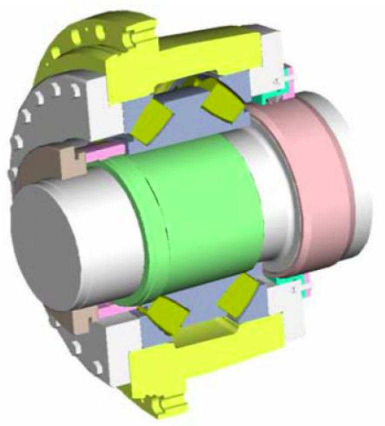
Cylindrical Roller bearings

Rollertype Thrust Bearings

3-row thrust Bearing Unit

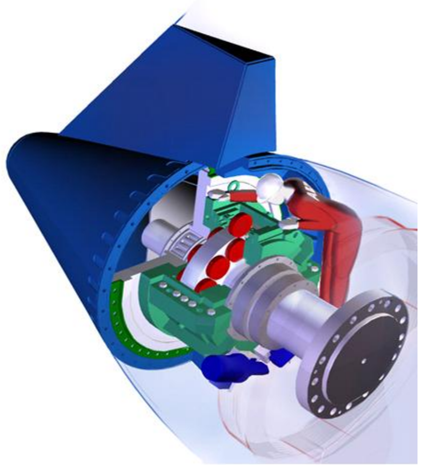


2-row thrust Bearing Unit



Slide Bearings

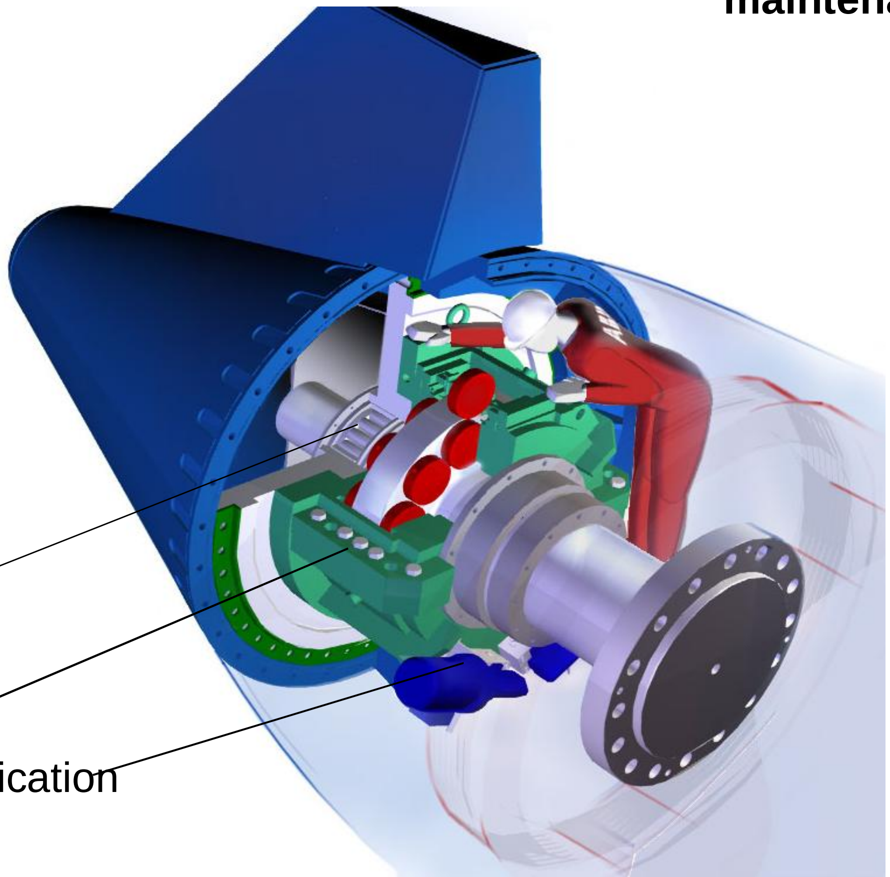
Slide Thrust bearing For Open water Applications



Slide Thrust bearig For Heavy Ice Operation

# Hybrid thrust bearing concept

Designed to be robust with **minimum maintenance cost**



Well known and proven Technologies:

Non-drive-end radial **roller** bearing

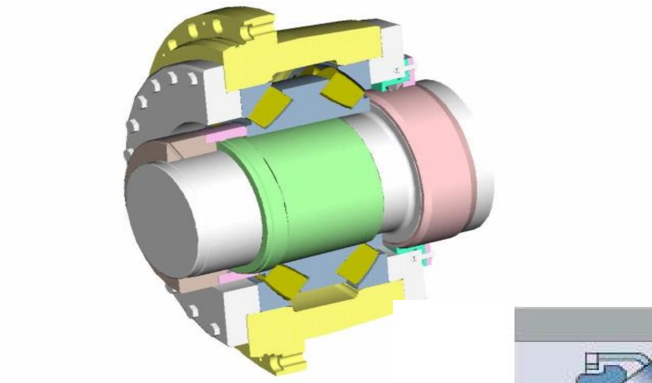
**Slide** thrust bearing

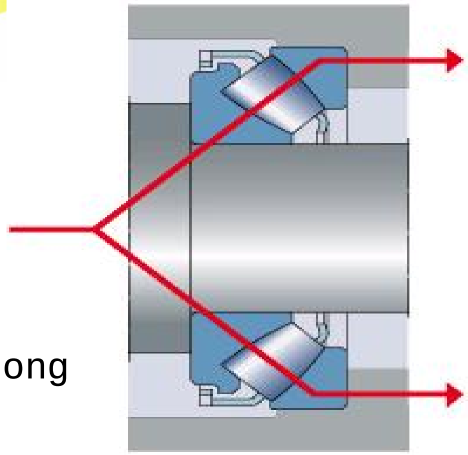
Redundant lubrication

Thrust pad change inside Azipod unit does not require dry-docking.

Patent pending

# Main Features: Roller bearing vs. Slide bearing





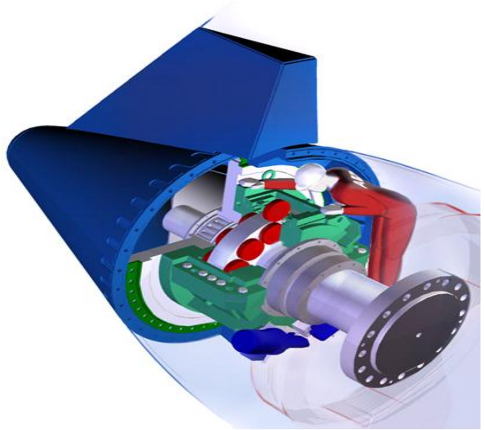
-Thin oil film

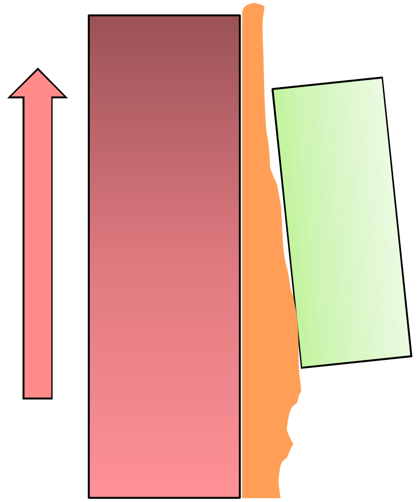
-High surface pressure

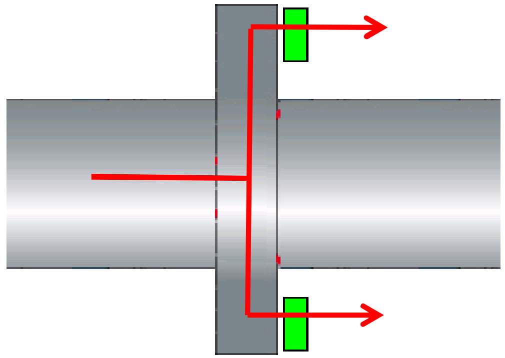
-Dimensioning based on fatigue

-Failure process can take long time

-Radial load partly carried by same bearing







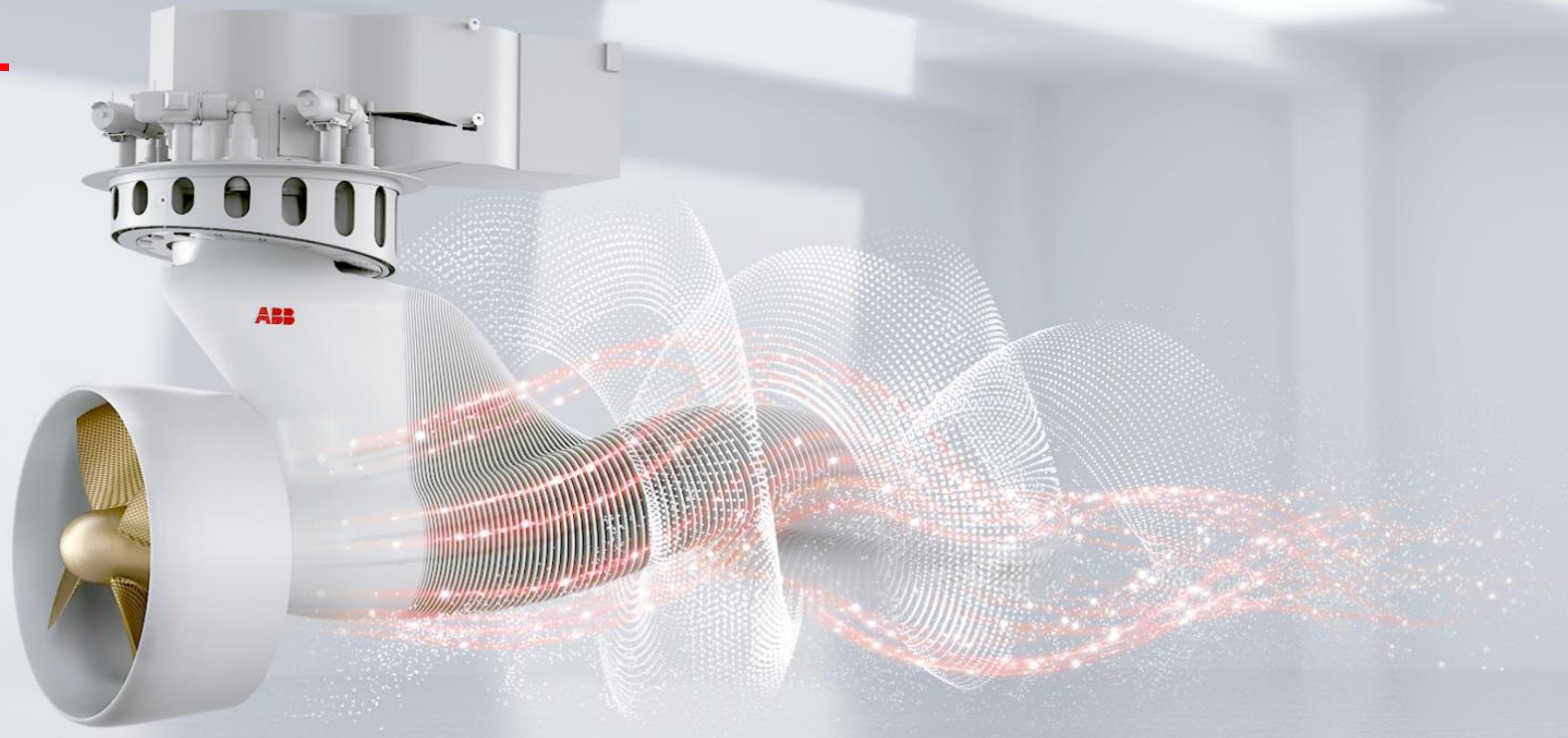
-Thick oil film

-Low surface pressure

-No fatigue

-Sliding surface may damage rapidly if oil film disappears

- Radial load load carried by separate bearing



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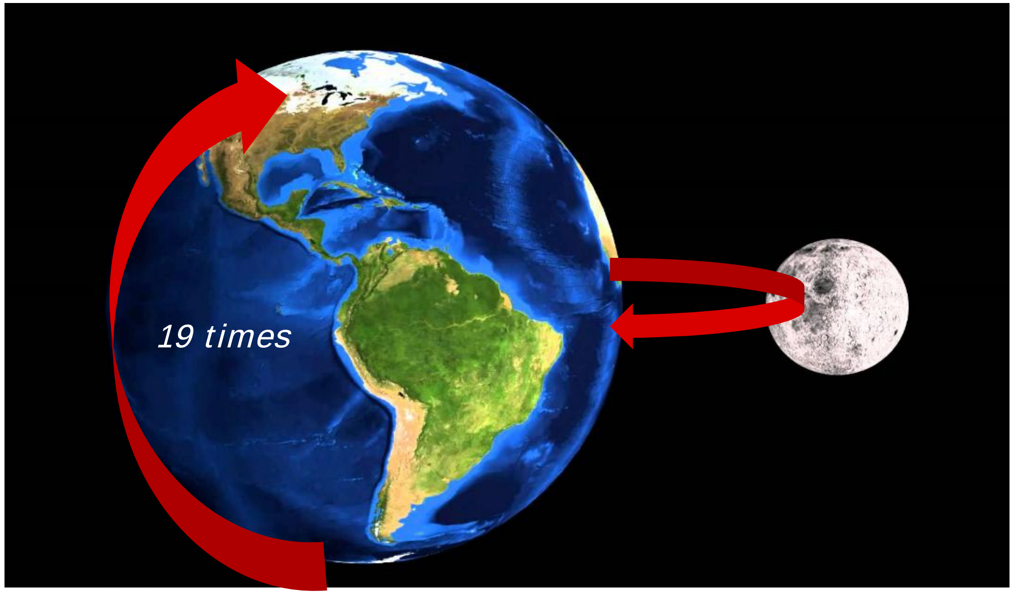
# Bearing lifetime and dimensioning

## Roller Bearings

Sami Palokangas, Azipod ® X/V Technology Manager

# Why to use roller bearings in Azipod®

- Low friction (low heat losses)
- Low start up torque
- Zero speed operation
- Wear down close to zero
  - 650mm shaft 140rpm
  => 150 000 km relative motion per year
- Limited space available
- Reversible rotation
- High stiffness
- Low radial clearance




*During 5 years dry-dock interval:*
*To Moon and back or 19 times around the world*



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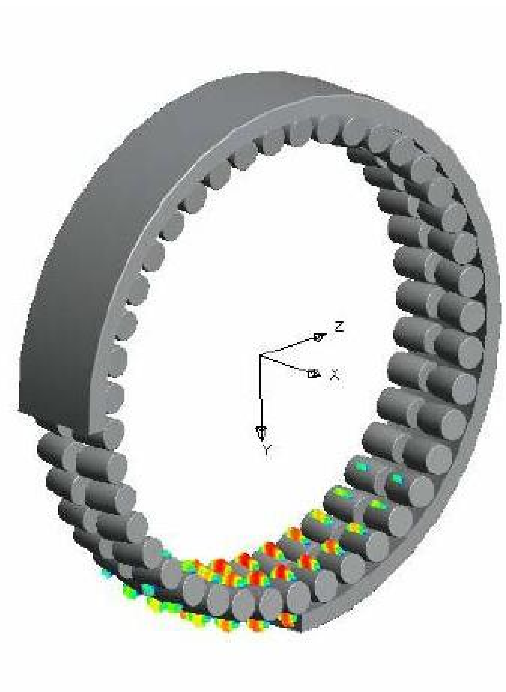
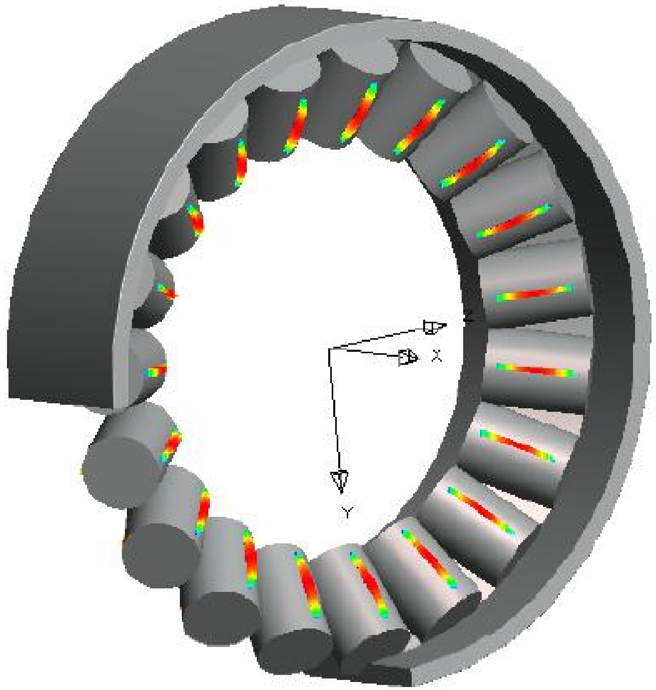
# Rolling contact

## Basis for Dimensioning

- Line contact
- Very high contact pressures
  - typically 1500 MPa (=> 15000 bar)
- High sub surface shear stress
- Lifetime calculation is based on fatique



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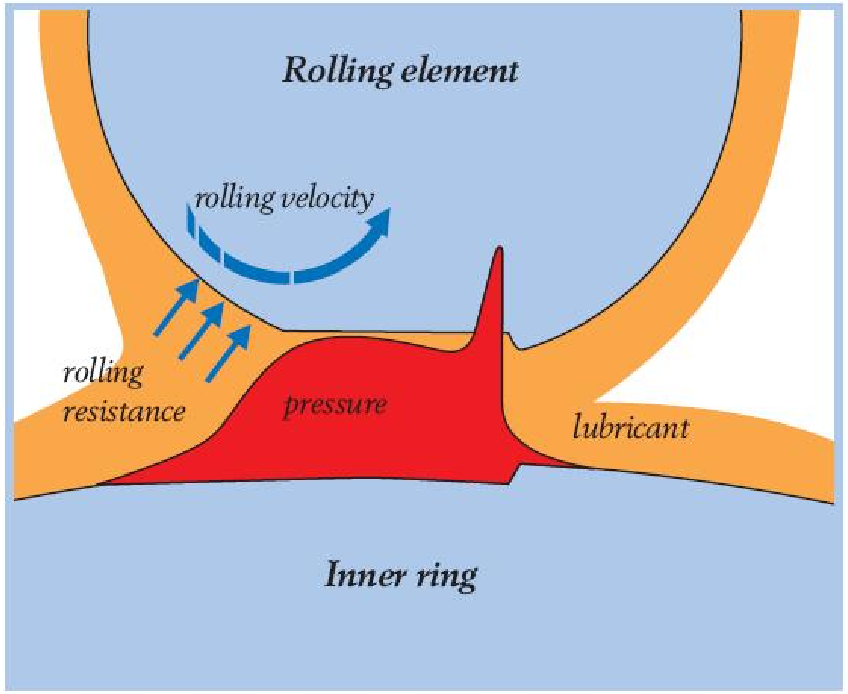
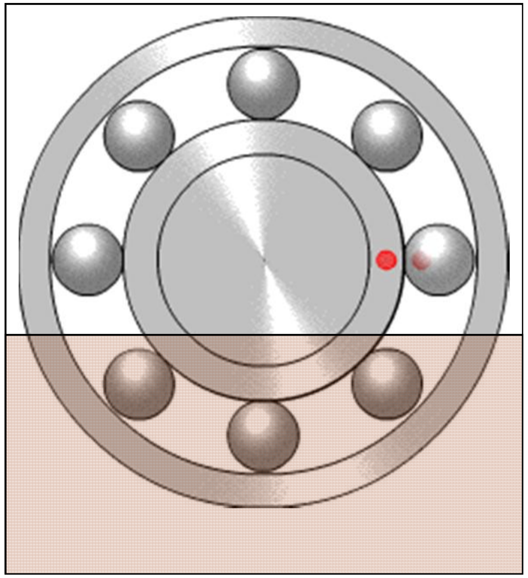
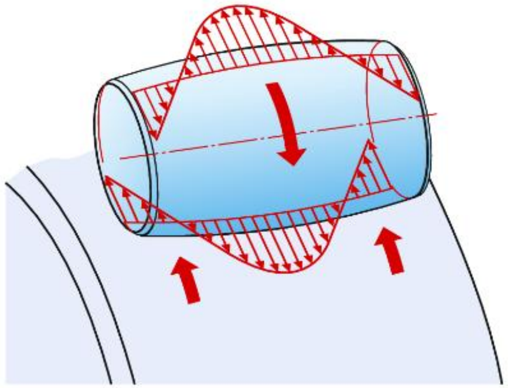
# Elastohydrodynamic Lubrication




Lubricant film thickness and pressure distribution in an elastohydrodynamically lubricated contact.
The large tail in the pressure at the inlet of the contact produces a resultant moment opposite to the rolling direction.





*By Guillermo Morales Espejel, Tribology & Lubrication, SKF Engineering Research Centre, Nieuwegein, the Netherlands.*

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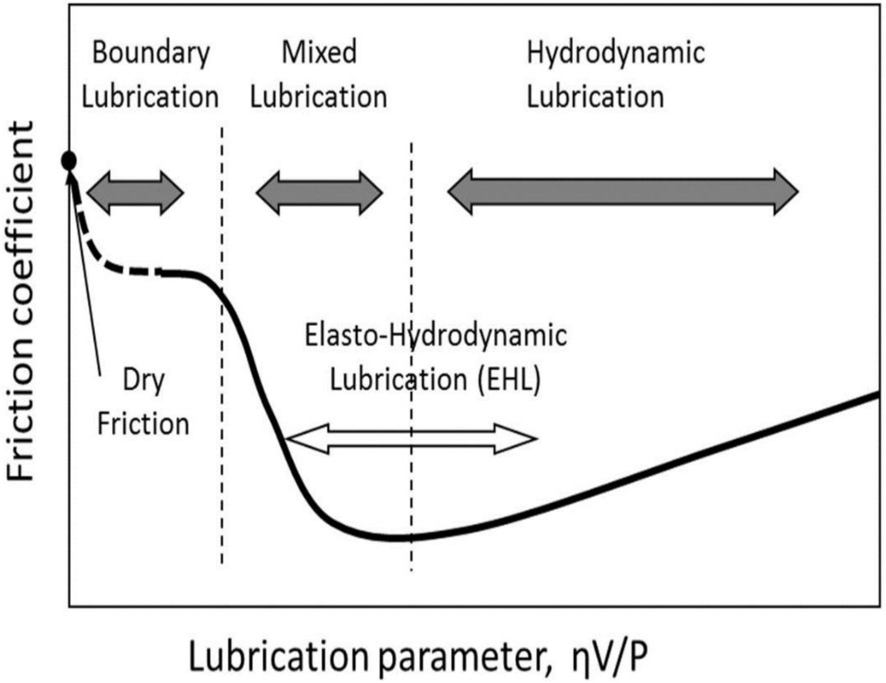
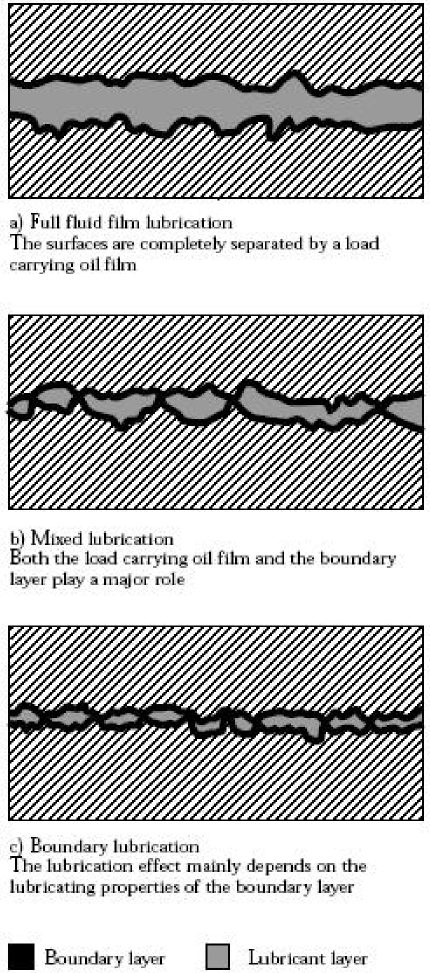
# Lubrication Condition




Full fluid film lubrication: The surfaces of the components in relative motion are separated by lubricant film.

Mixed lubrication: Where the lubricant film gets too thin, local metal-to-metal contact occurs, resulting in mixed friction.

Boundary condition: If the lubricant contains suitable additives, reactions between the additives and the metal surfaces are triggered at the high pressures and temperatures in contact areas. The resulting reaction products have a lubricating effect and form a thin boundary layer.



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# Basic bearing lifetime L10

L10 is the nominal rating life in millions of revolutions which is reached or exceeded by at least 90% of a large group of identical bearings

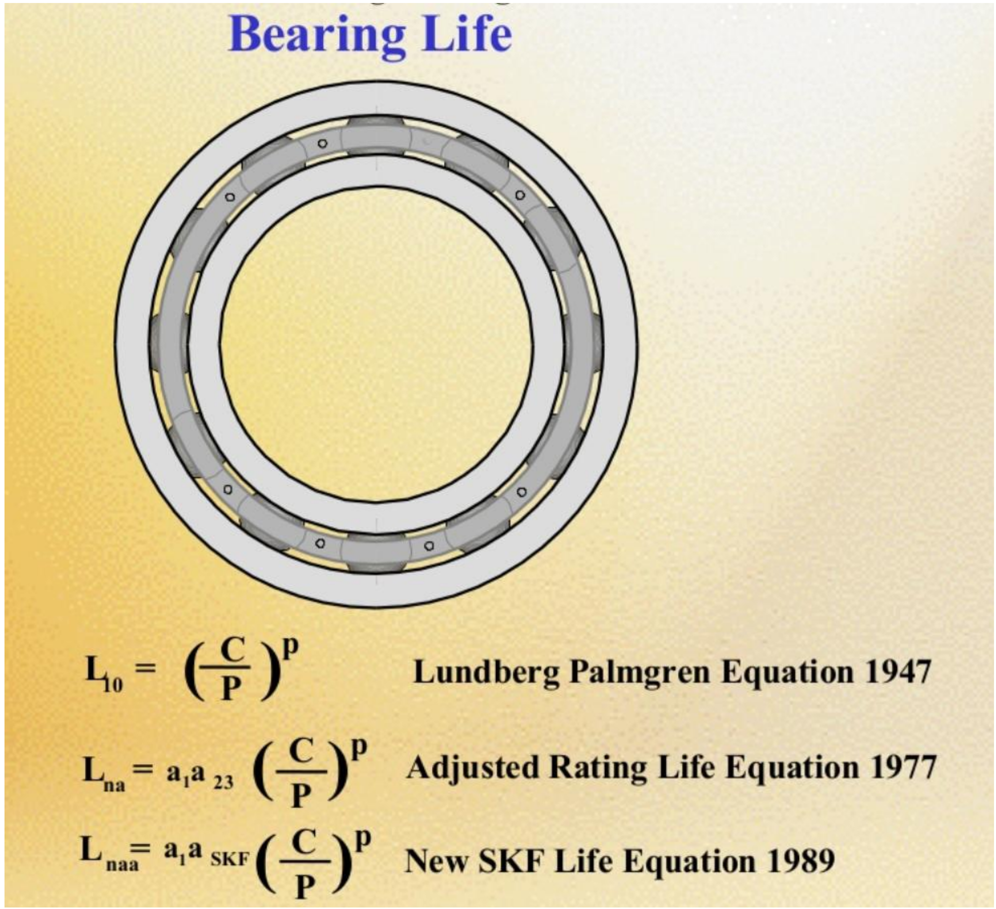
C = Dynamic load rating

P = Equivalent dynamic load

P = Life exponent

p = 3 for ball bearings

p = 10 / 3 for roller bearings




=> ISO 281:2007





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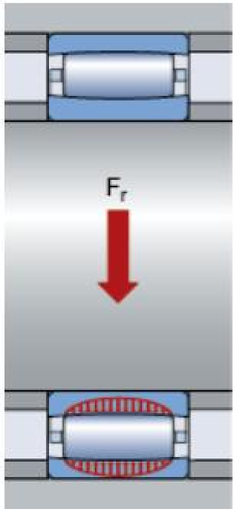
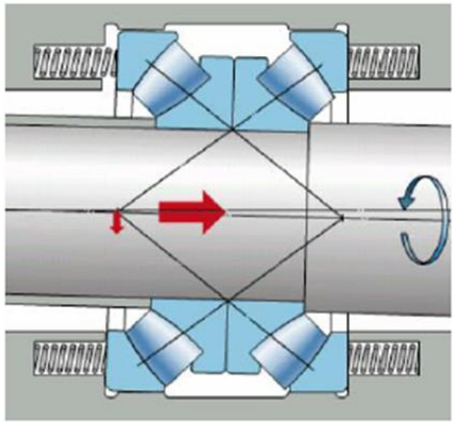
# Equivalent Dynamic Load

- In Toroidal bearings only radial force is relevant




- In Roller Thrust Bearings both Axial and Radial Forces have to be taken into consideration in dimensioning



## Bearing Life

**Equivalent Dynamic Bearing Load**

$$P = X F_r + Y F_a$$

Where :

X = Radial Load Factor

Y = Axial Load Factor



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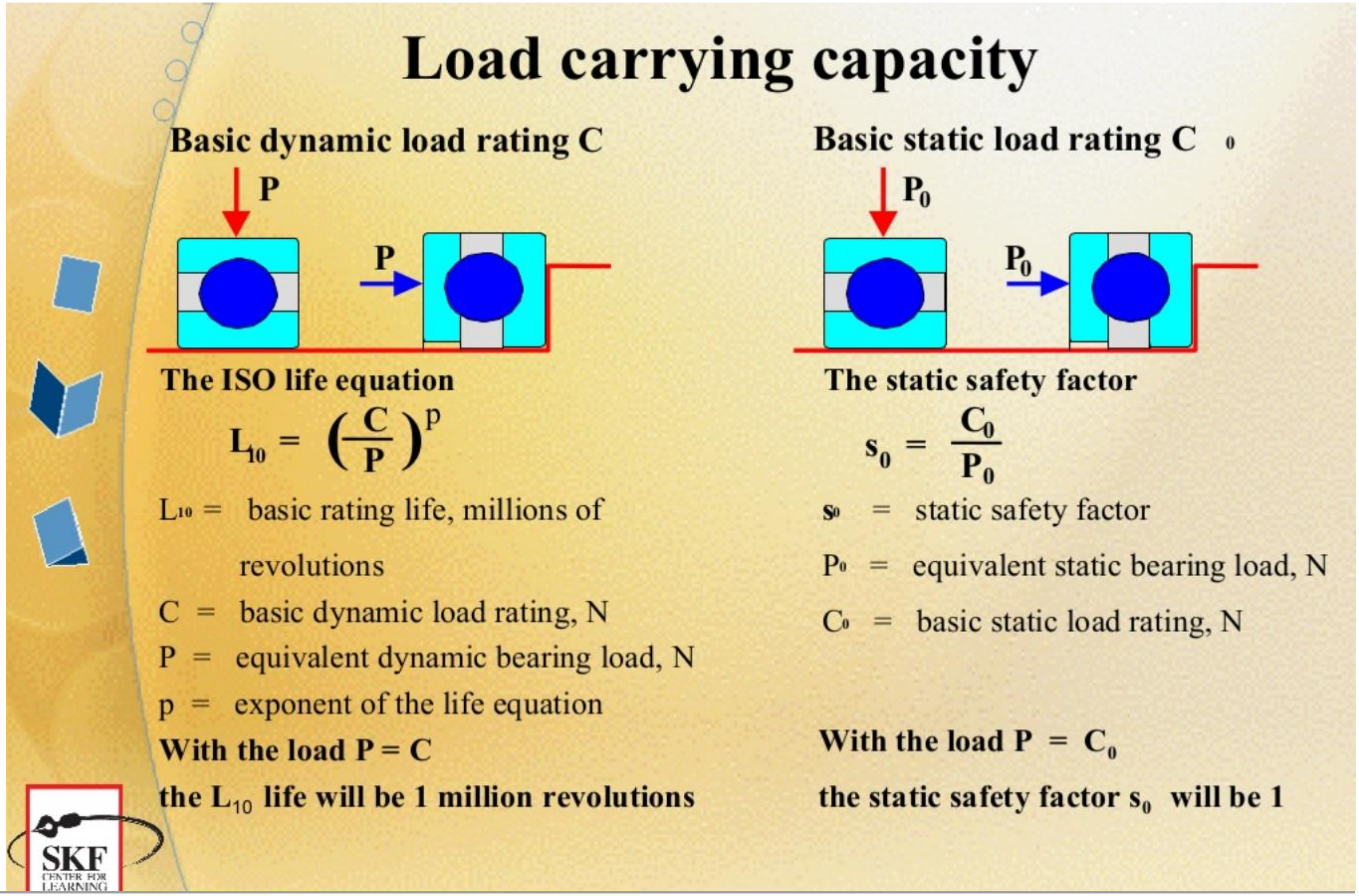
# Load Ratings

## Dynamic vs. Static

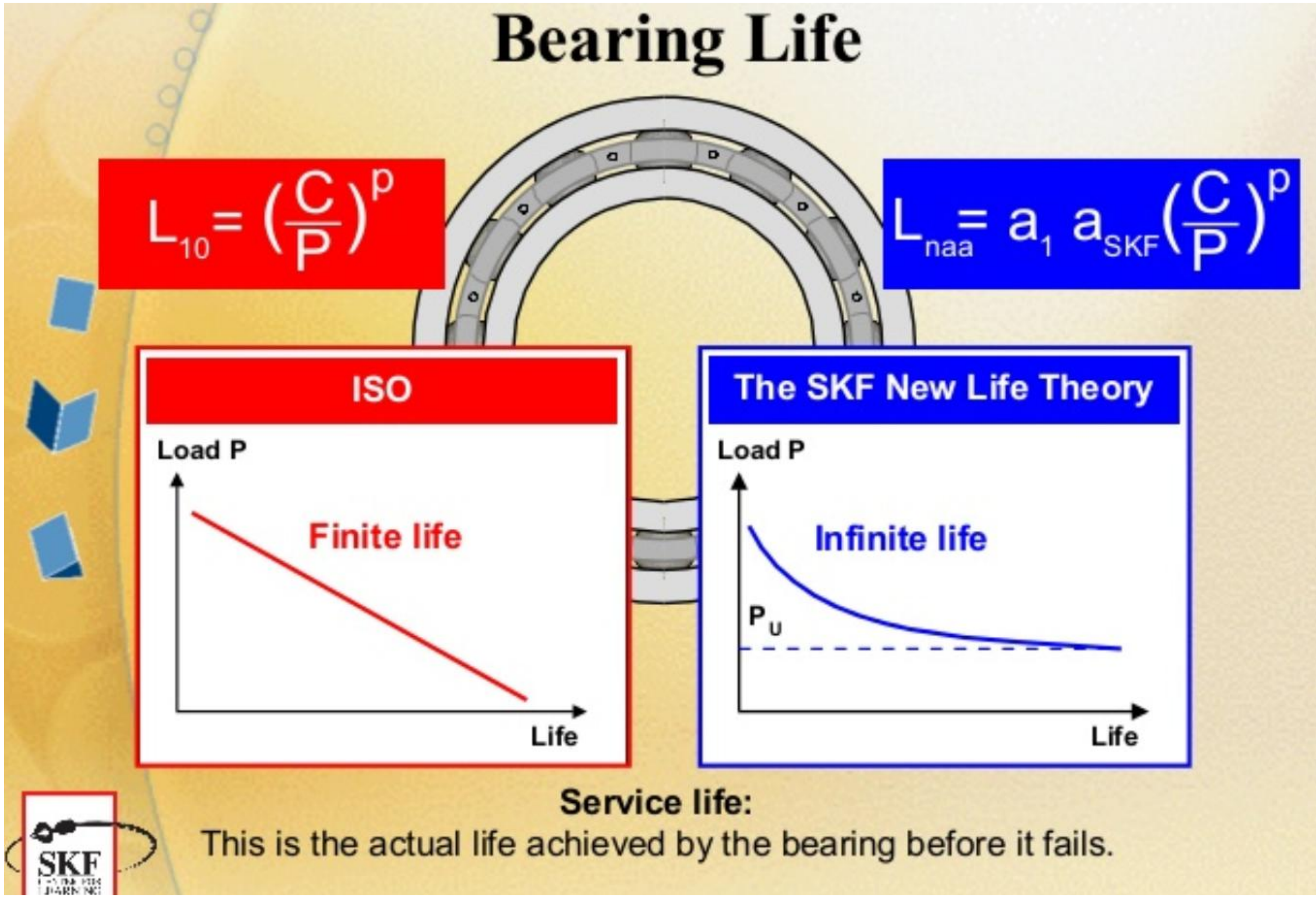
Basic dynamic calculations typically define the bearing size in open water vessels.

Static safety factor is checked against shock loads, which are important dimensionig factor especially in Ice operation.



# ISO281:2007

- Since ISO 281 was published in 1990, additional knowledge has been gained regarding the influence on bearing life of contamination, lubrication, internal stresses from mounting, stresses from hardening, fatigue load limit of the material, etc
- New method takes these conditions into consideration.



# Affecting factors

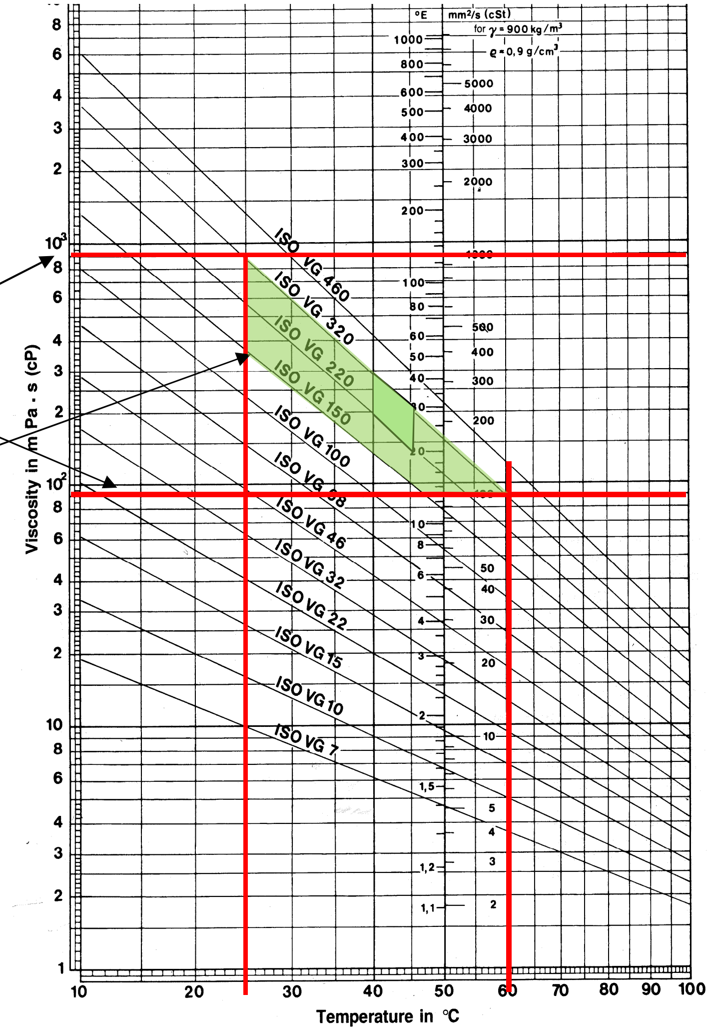
## Viscosity

cSt limits 100 - 1000 $mm^2/s$

Recommended area

Normal operating area

Temperature range 25°C - 60°C



# Affecting factors

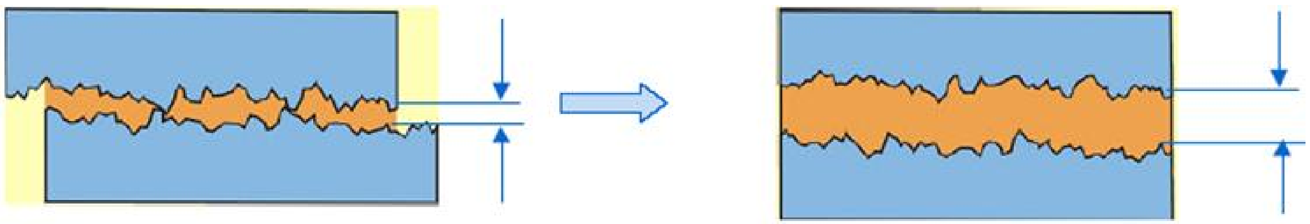
## Viskosity Ratio κ (kappa)

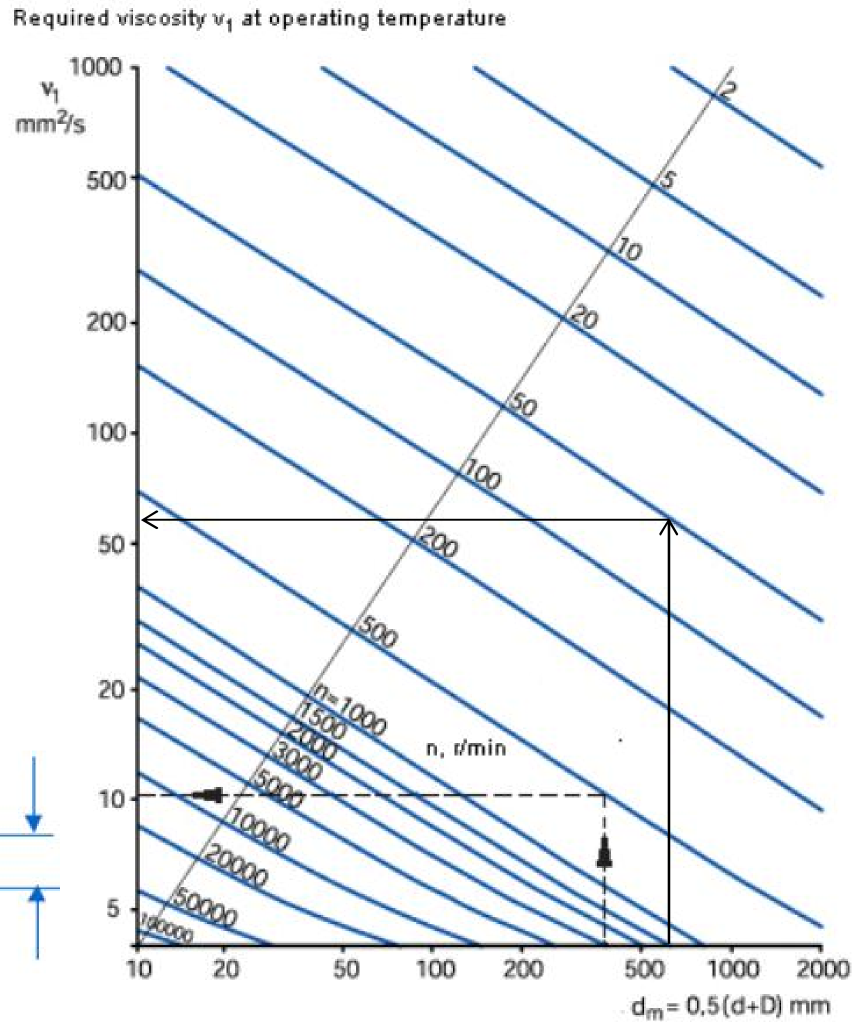
K tells the lubrication condition.

Adequate lubrication is considered when κ >1

$$\kappa = \frac{\nu}{\nu_1}$$

| | | |
|---|---|---|
| κ | = | viscosity ratio |
| ν | = | operating viscosity of the lubricant [$mm^2/s$] |
| $\nu_1$ | = | rated viscosity depending on the bearing mean diameter and rotational speed [$mm^2/s$] |





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# Affecting factors

## Contamination

Contamination factors for SKF bearings.

| Condition | Factor $\eta_c$ [1] for bearings with diameter $d_m$ < 100 | $d_m \ge 100$ mm |
|---|---|---|
| **Extreme cleanliness**<br>Particle size of the order of the lubricant film thickness<br>Laboratory conditions | 1 | 1 |
| **High cleanliness**<br>Oil filtered through an extremely fine filter<br>Conditions typical of bearings greased for life and sealed | 0,8 ... 0,6 | 0,9 ... 0,8 |
| **Normal cleanliness**<br>Oil filtered through a fine filter<br>Conditions typical of bearings greased for life and shielded | 0,6 ... 0,5 | 0,8 ... 0,6 |
| **Slight contamination**<br>Slight contamination of the lubricant | 0,5 ... 0,3 | 0,6 ... 0,4 |
| **Typical contamination**<br>Conditions typical of bearings without integral seals,<br>coarse filtering, wear particles, and ingress from surroundings | 0,3 ... 0,1 | 0,4 ... 0,2 |
| **Severe contamination**<br>Bearing environment heavily contaminated and<br>bearing arrangement with inadequate sealing | 0,1 ... 0 | 0,1 ... 0 |
| **Very severe contamination**<br>Under extreme contamination, values of $\eta_c$ can be outside the<br>scale resulting in a more severe reduction of life than predicted by the equation for $L_{nm}$ | 0 | 0 |

# Afecting factors

## Water content

Roller bearings are more sensitive to water than slide bearings

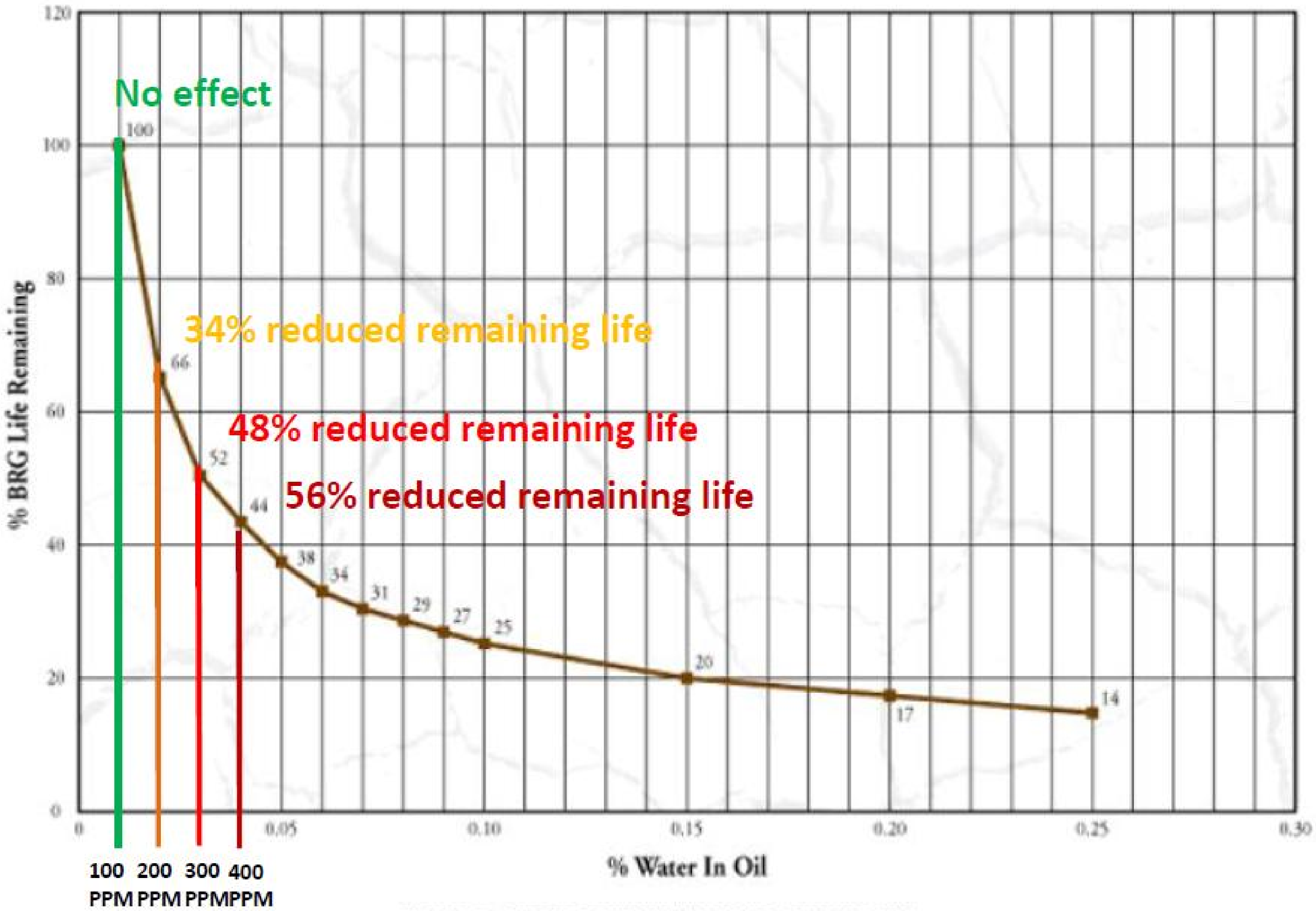


FIGURE 2. WATER CONTAMINATION VS. BEARING LIFE




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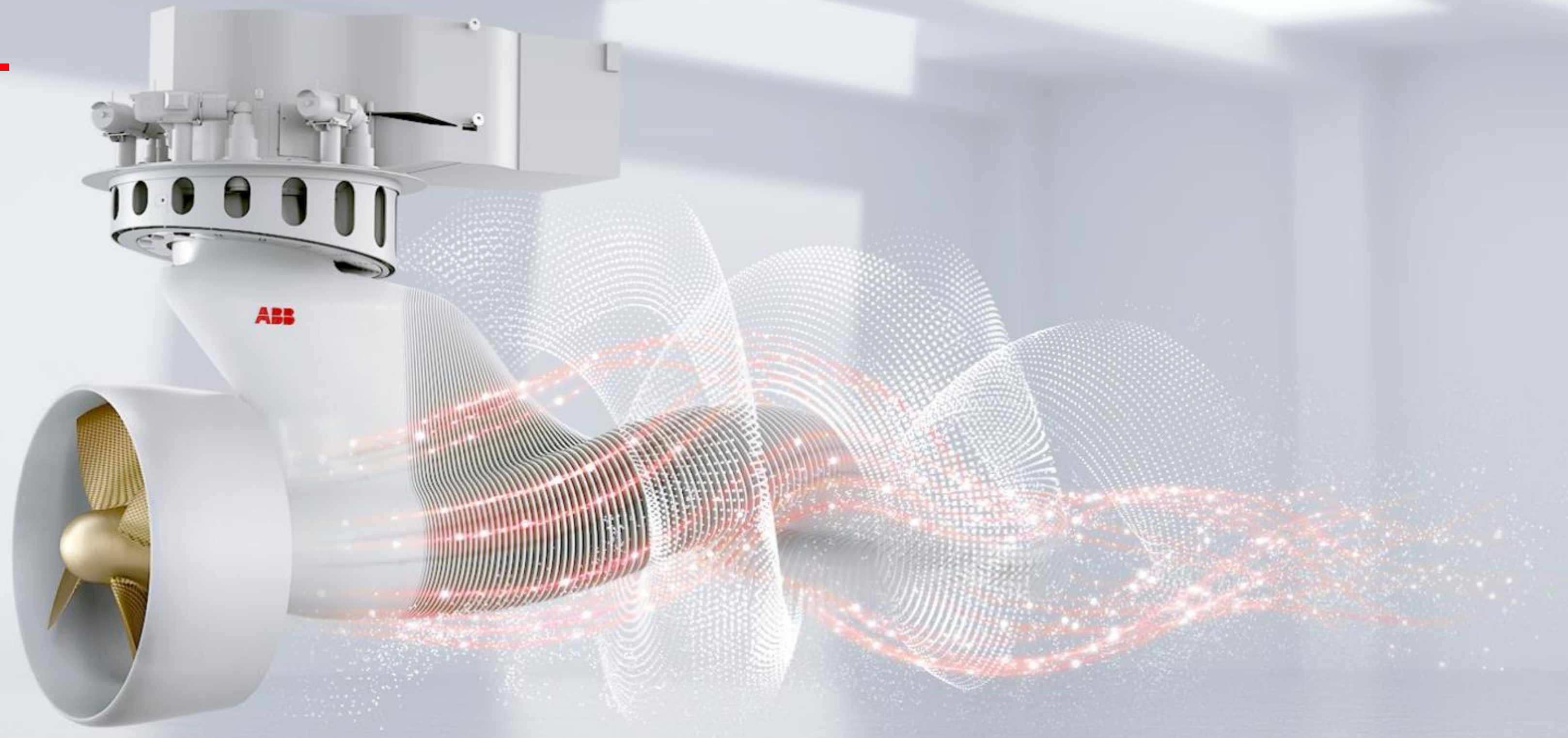


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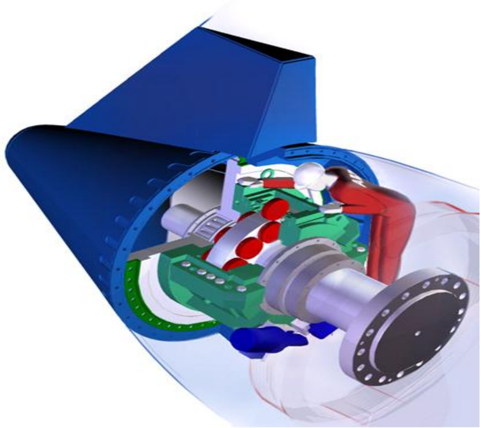
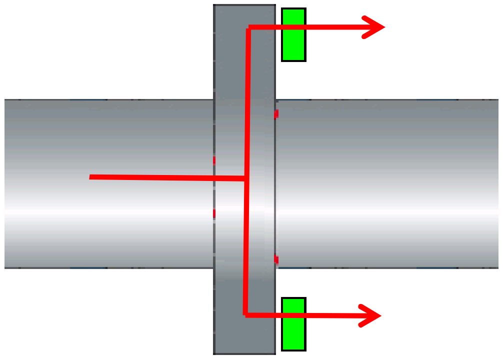
# Bearing lifetime and dimensioning

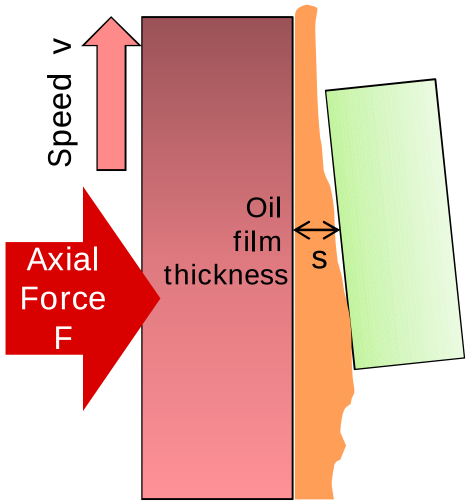
## Slide Bearings

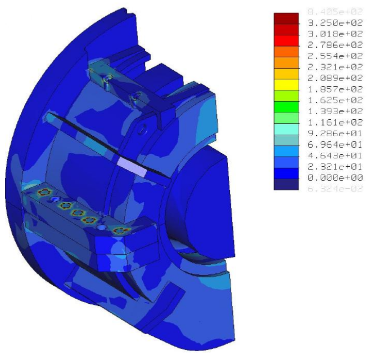
Sami Palokangas, Azipod ® X/V Technology Manager

# Dimensioning principle of Axial Slide bearing







Dimensioning is based on:

1. Hydrodynamic lubrication
   - As long as there is oil film between surfaces there is no wear.
   - Dimensioning has to be sufficient to ensure lubricating film in every operating condition.

2. Shock Loads & Static strenght
   - Need to have enough sliding surface area to withstand compression loads from normal operation and possible shock loads.
   - All Mechanical parts of the bearing needs to withstand all loads from normal operation and also from rare special conditions.

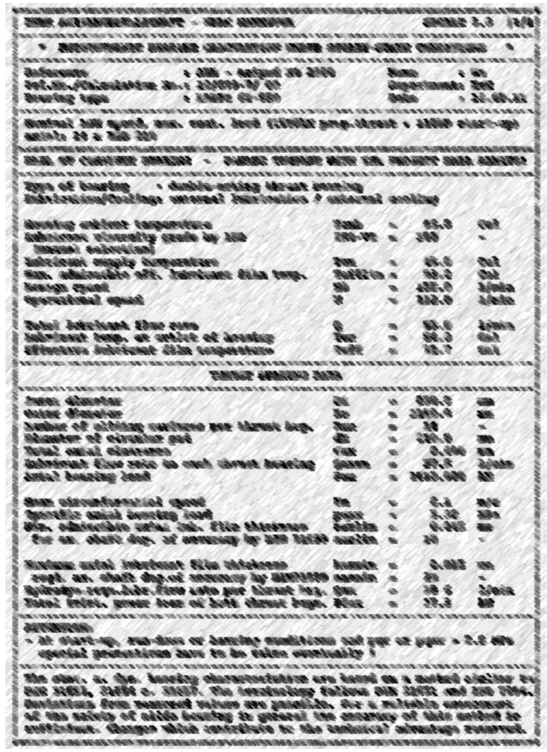
# Hydrodynamic calculation of slide thrust bearing

## Start information for calculation

Green = positive effect    Red = Negative effect

| # | Main Input Value | Effect on oil film Thicker the better | Effect on temp. Lower the better |
|---|---|---|---|
| 1 | Sliding speed | | |
| 2 | Axial force by propeller | | |
| 3 | Start-up force | | |
| 4 | Oil viscosity grade | | |
| 5 | Oil IN temperature | | |
| 6 | Oil Flow | | |
| 7 | Shaft movements in dynamic situations | | |

Hydrodynamic calculation





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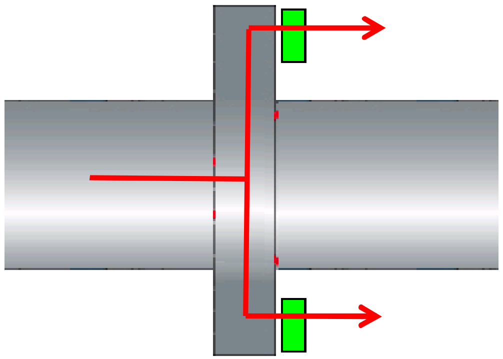
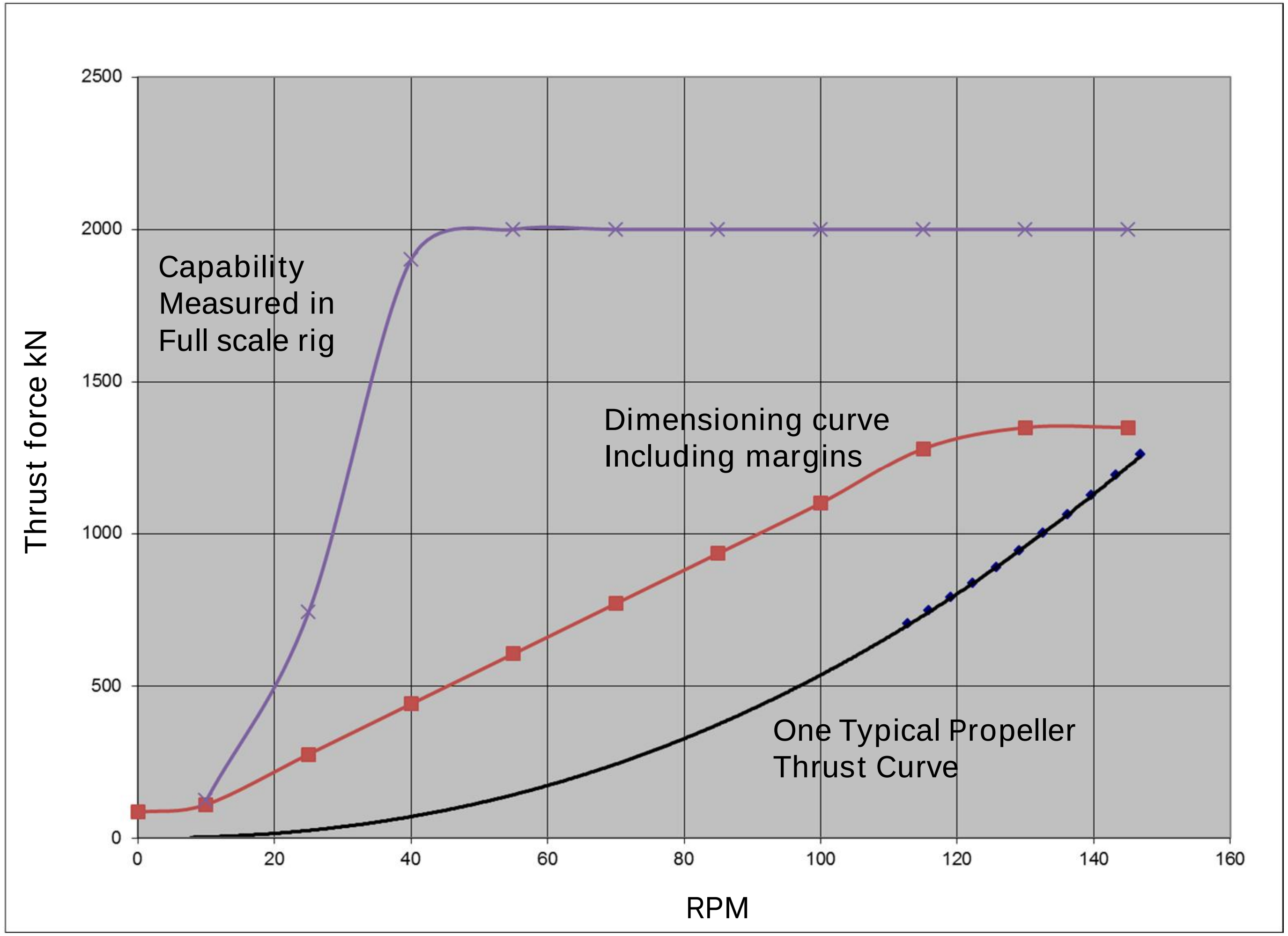
# Axial slide bearing

## Dimensioning

Dimensioning
vs. measured
performance









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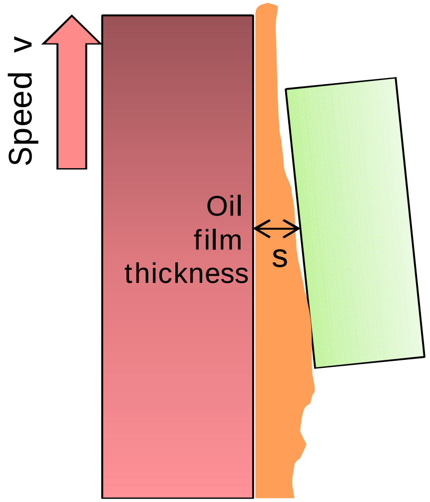
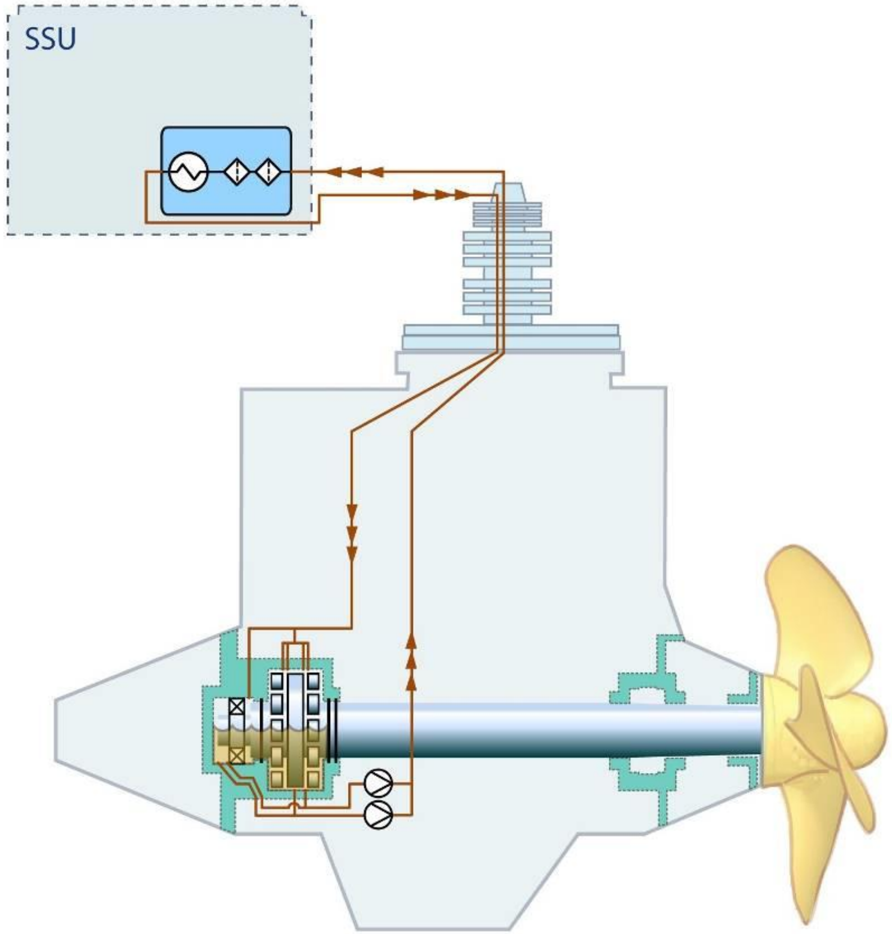
# Affecting factors

## Hybrid Thrust Bearing Unit

- Rolling bearing oil film thickness is typically 0.2-1 µm
- In slide bearing the oil film thickness is typically 20-30µm: more robust against contamination and water content
- In ABB Hybrid Thrust bearing unit, roller bearing and slide bearing utilize same oil and same oil circulation. Therefore the roller bearing defines the cleanliness and water content requirement.
- However, also in slide bearing particles can cause scratches on sliding surface.



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