Sterntube Bearing Failures, Alignment or Lubrication?

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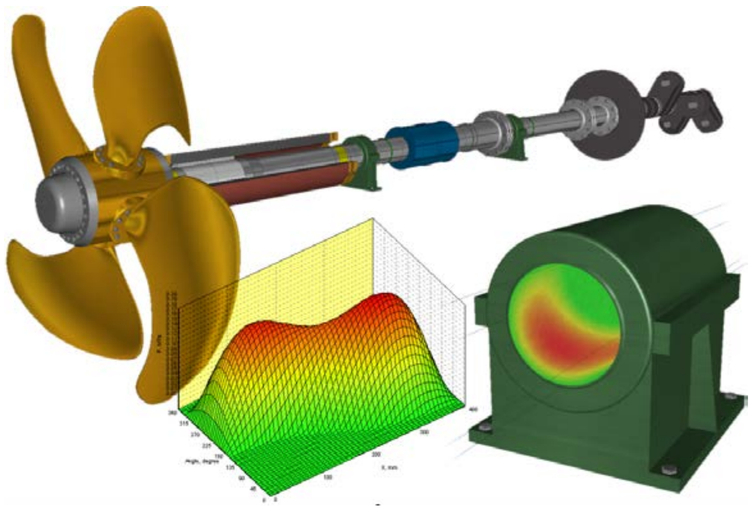

INTELLECTUAL MARITIME TECHNOLOGIES

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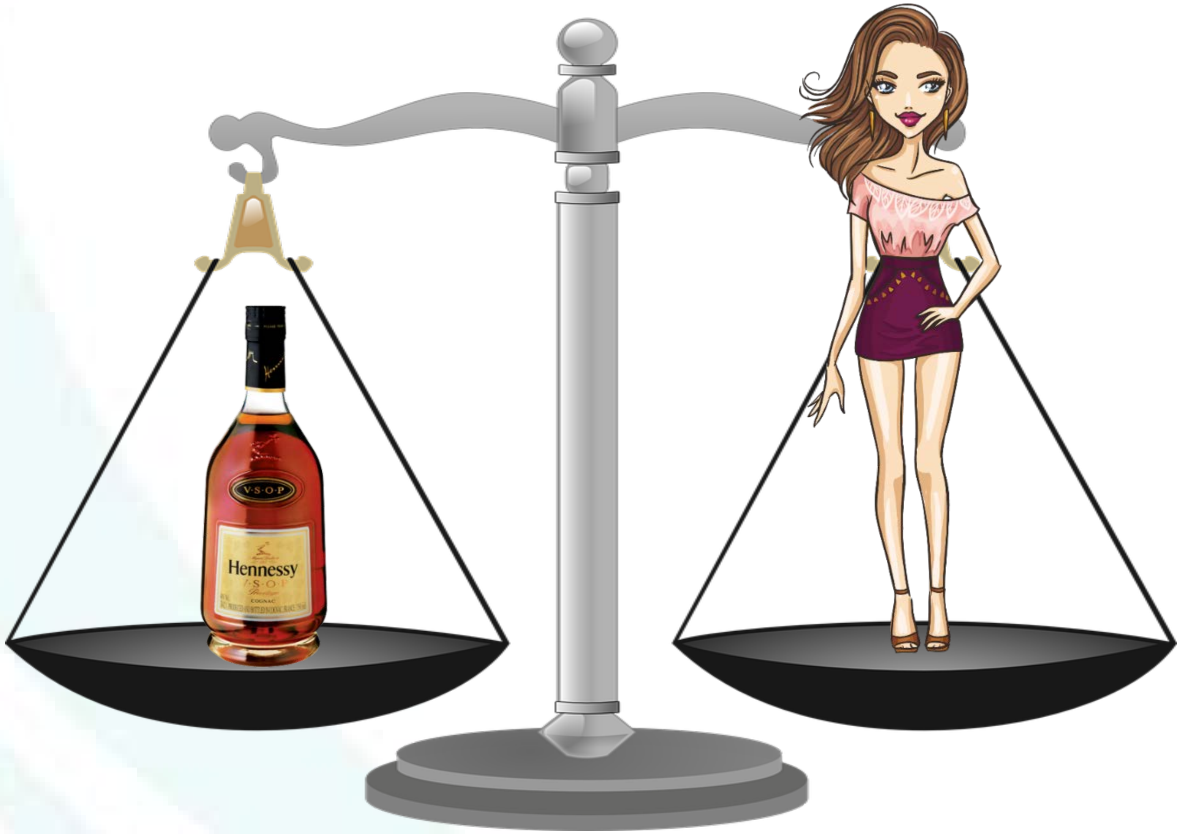
Alignment or Lubrication?

A famous satirist from Odessa was once asked: "*What would be your choice if you put a good brandy on one side of the scale and a beautiful girl on the other*?". The satirist exclaimed in surprise: "*Why put them on different sides*!?"



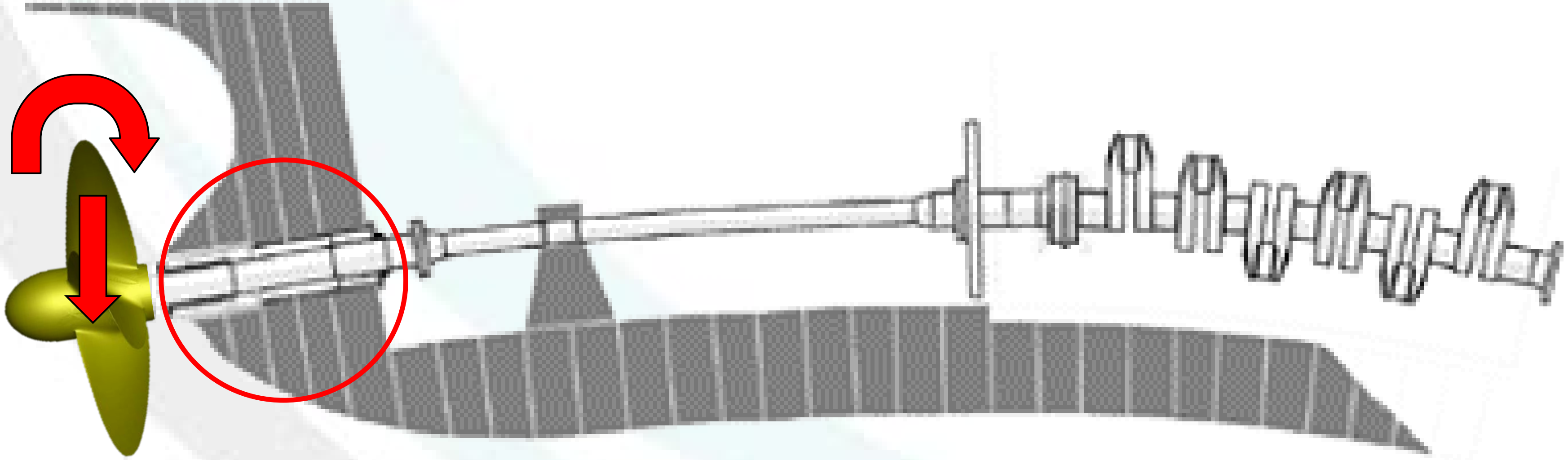
Alignment or Lubrication?: Why put them on different sides!!

They are strongly coupled!

Stern Tube Bearing Mission

A stern tube bearing is at the junction of two environments.

Being a part of the ship's hull and following its deformations, it is exposed by **static and dynamic loads** from the propeller shaft. At the same time, it must fulfill an important mission – **to provide the lubrication** with the minimum friction between bearing bush and journal.



Why does Stern Tube Bearings continue to Fail?

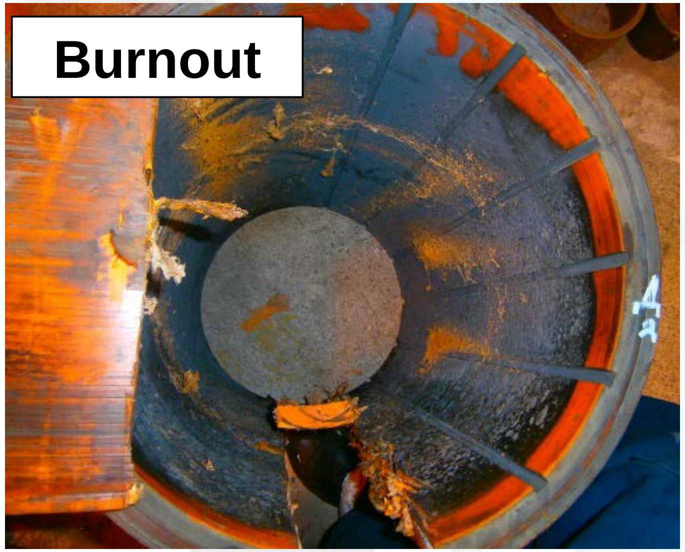
The design of reliable stern tube bearings still a very complicated subject as many years ago.

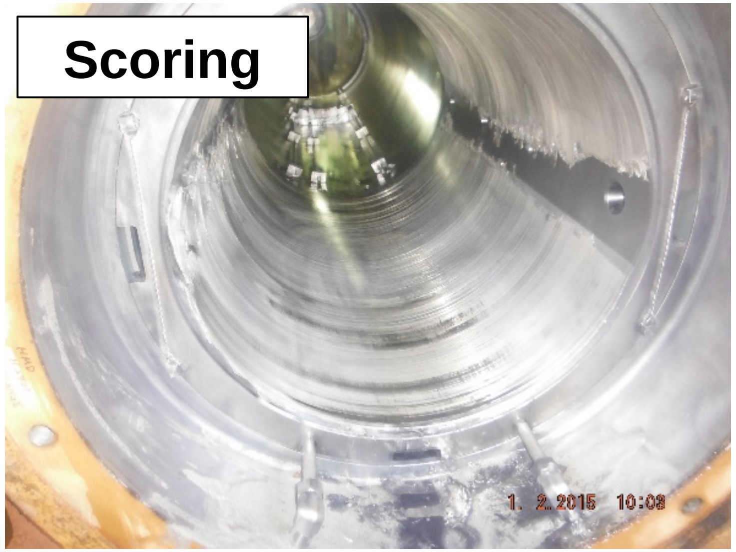
There is no software yet providing the stern tube bearing design based on the unified and rigorous analyses of the shaft alignment, tribology, and whirling vibration in all possible conditions a ship can meet during the operating life.

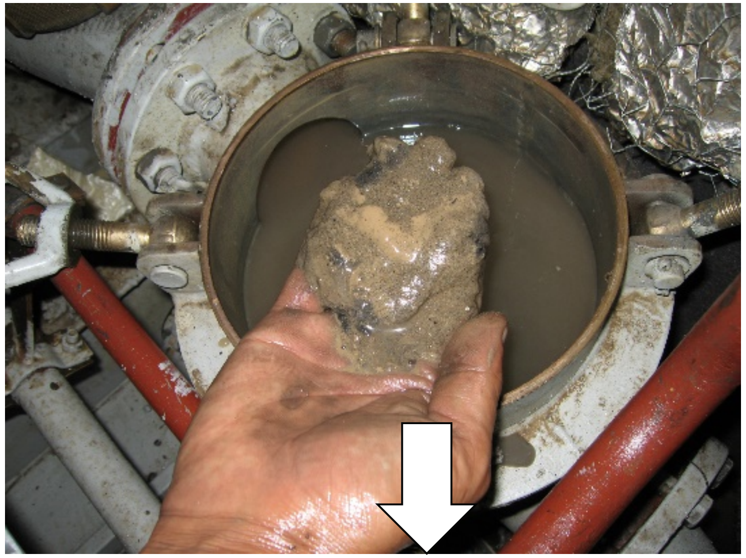
It is a *Key Problem*!

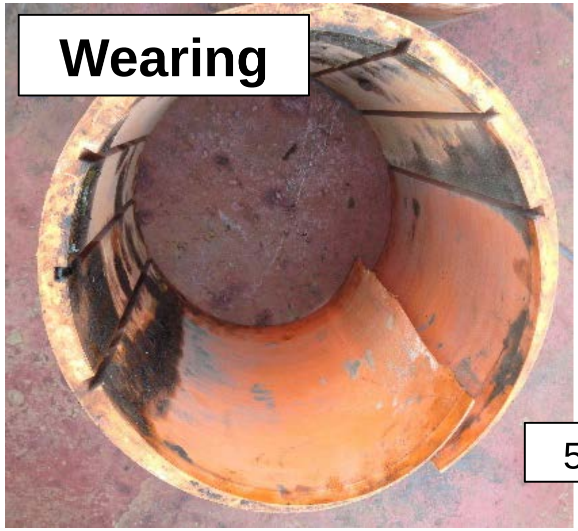
Stern Tube Bearing Failures

What are the typical stern tube bearing failures? They are well known.









Root Causes of Stern Tube Bearing Damage

The main reason is the bad design. Most of the software don’t consider Whirling vibration and Tribology during Shaft alignment design or consider them separately without interdependence!

Beside this, there are other reasons:

- Sharp ship turns at higher speeds, especially for twin-screw ships
- A partially submerged propeller
- Additional bearing loads during ship motions on waves (inertia loads, hull deflections, propeller loads)
- Ice induced whirling vibration
- Transfer from mineral oils to Environmentally Acceptable Lubricants (EALs)
- Trivial errors during implementing the alignment plan (alignment in a dry dock, small accuracy, non-calibrated equipment, alignment in sunny day etc.)

The Stribeck curve

The coupling between shaft alignment and lubrication is expressed by ***Sommerfeld* number** So, that determines the regime of journal bearing lubrication :

$$So = \frac{\mu \omega L D}{R} \left(\frac{D}{\Delta} \right)^2$$

μ – dynamic viscosity, Pa·s

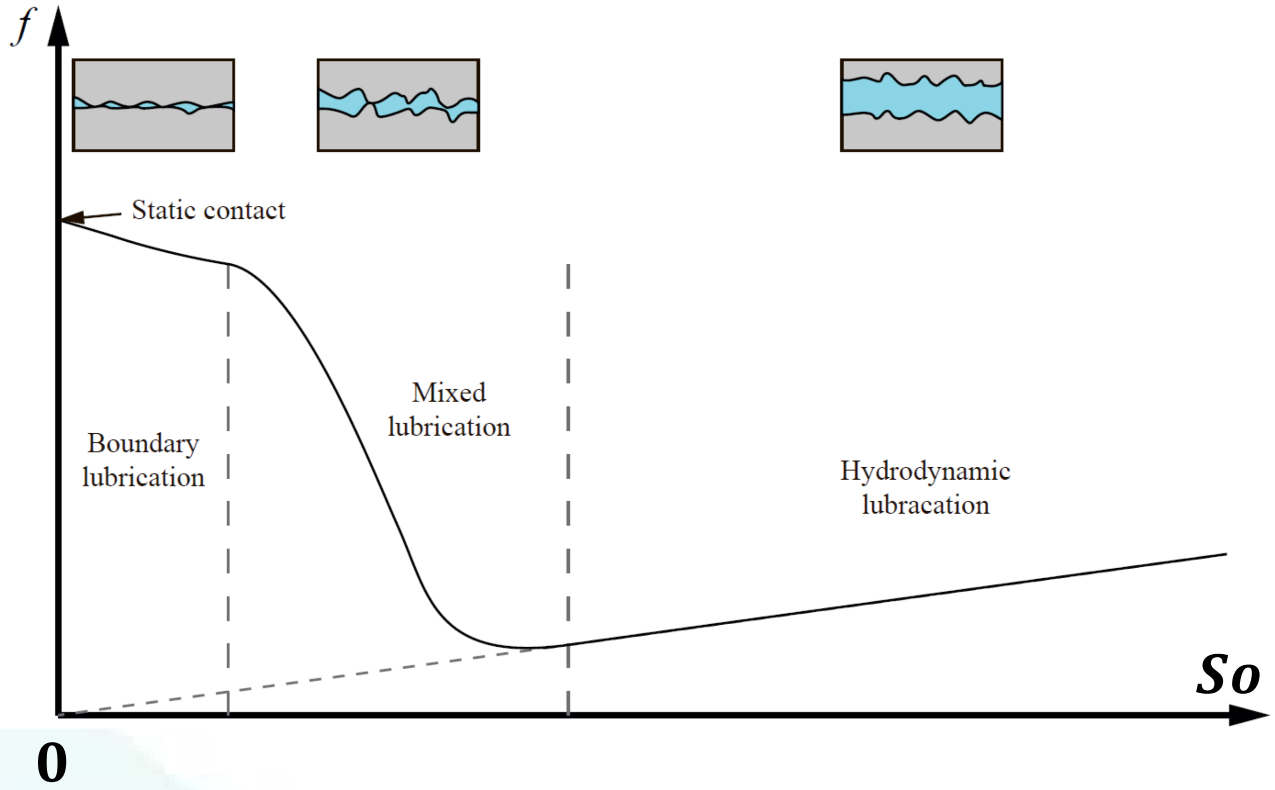
ω – shaft rotational speed, rad/s

R – bearing load, N

L – bearing length, m

D – journal diameter, m

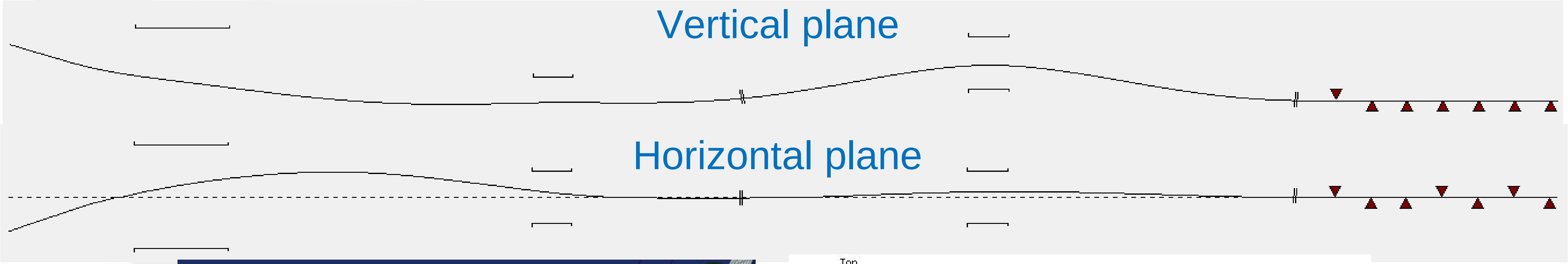
Δ – diametral clearance, m.

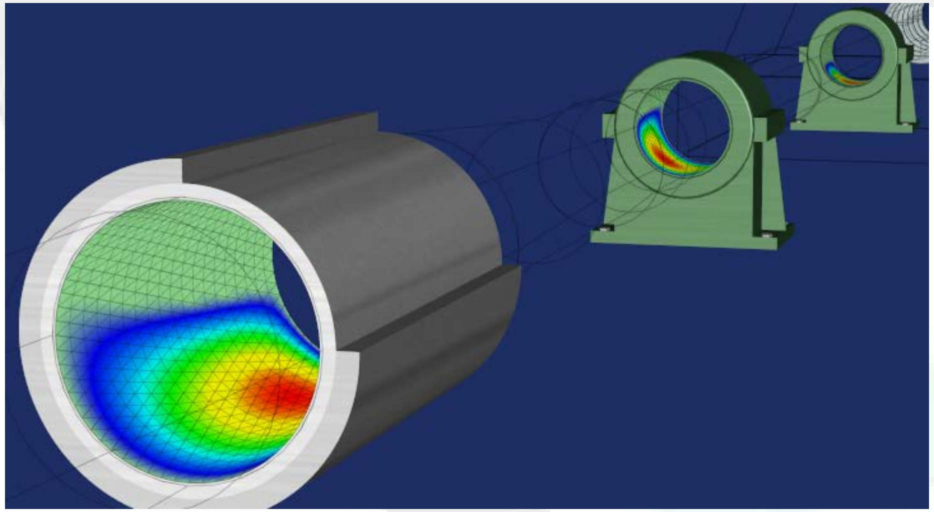


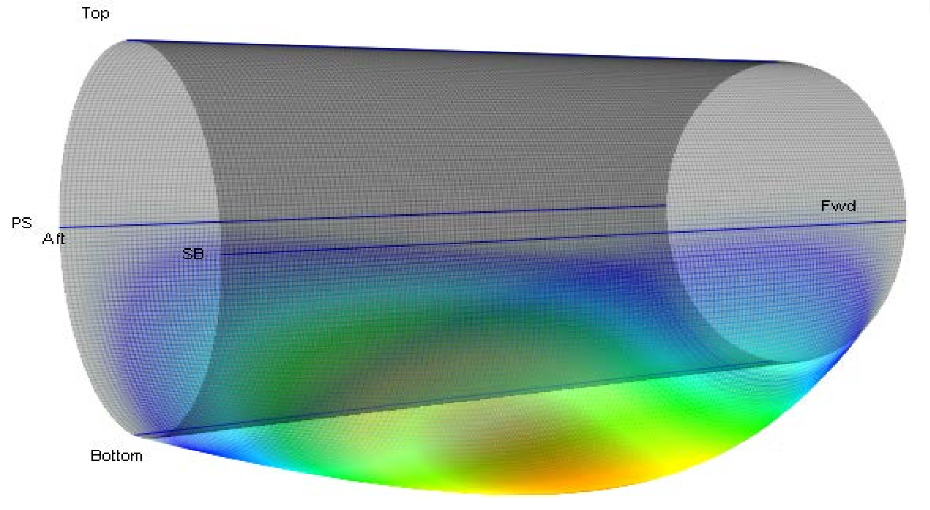
There is a well-founded assumption that stern tube bearings frequently work in mixed or boundary lubrication.

What the Analyses are available now?

The **ShaftDesigner** software provides the **shaft alignment** design together with the tribology analysis of oil and water-lubricated **stern tube bearings** for the different bearing bush forms



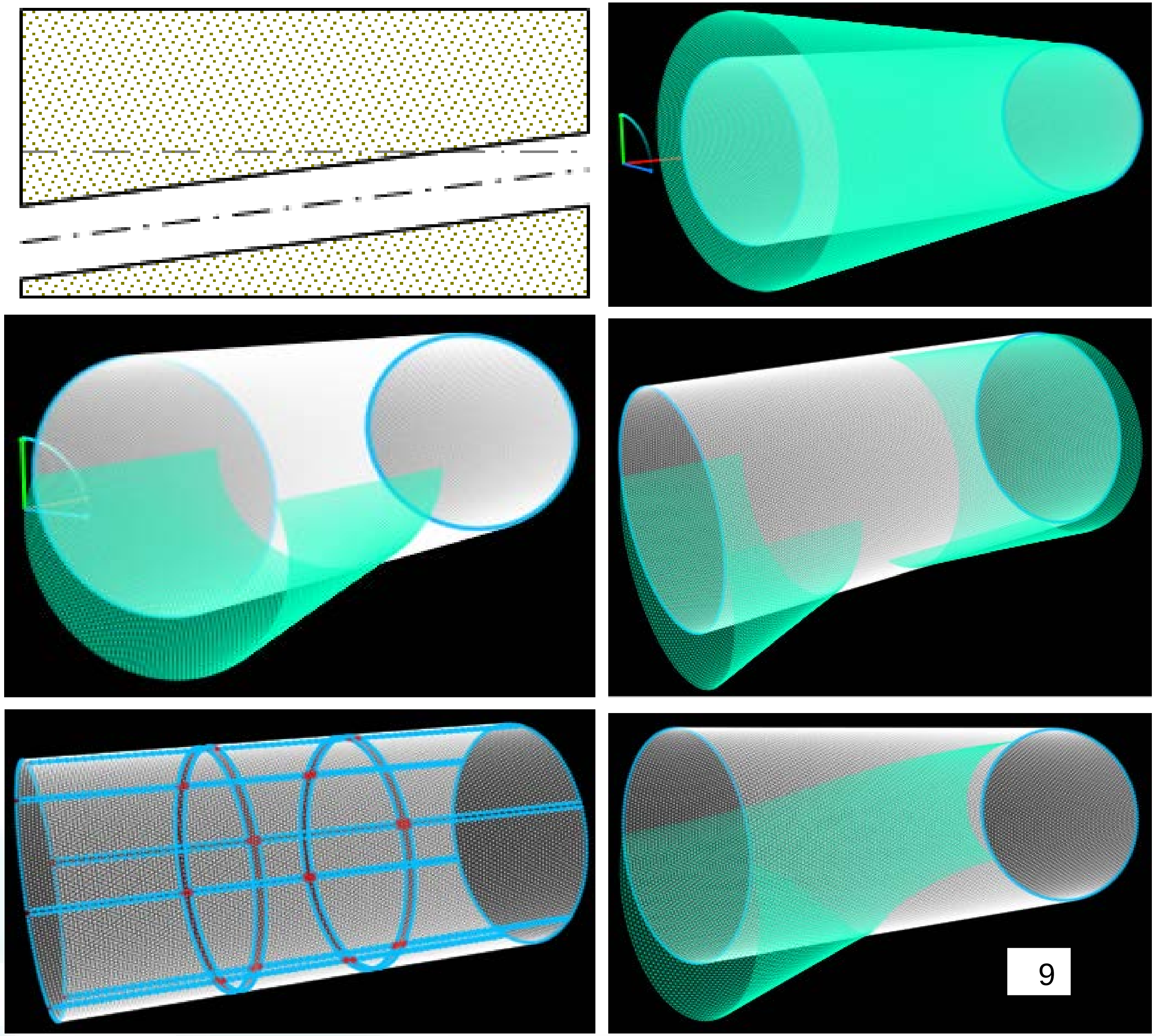




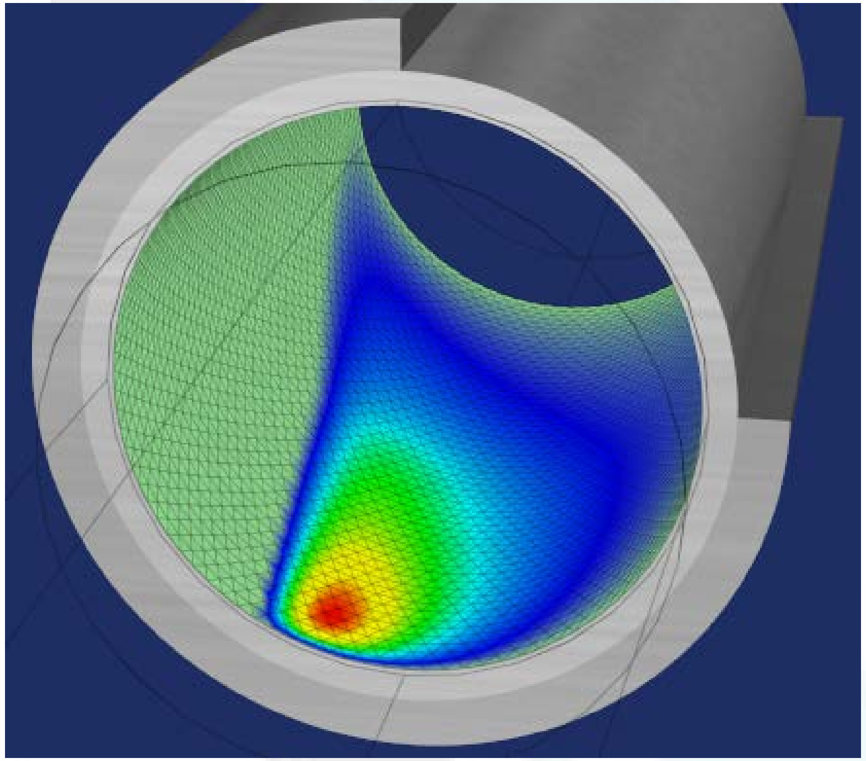
Stern Tube Bearing Forms

The following specific forms or their combinations can be set in the ShaftDesigner:

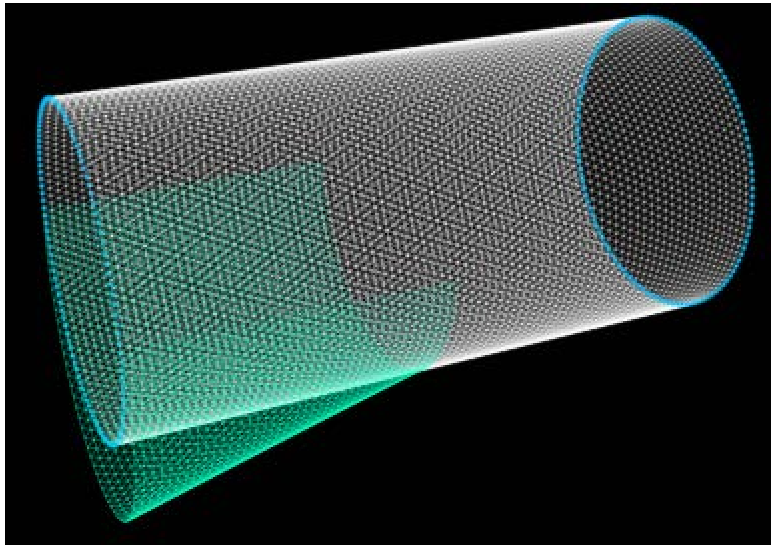
1. Slope boring
2. Eccentricity boring
3. Conicity boring
4. Aft and forward trumped (including double slope)
5. Longitudinal and transverse grooves
6. Bush wear

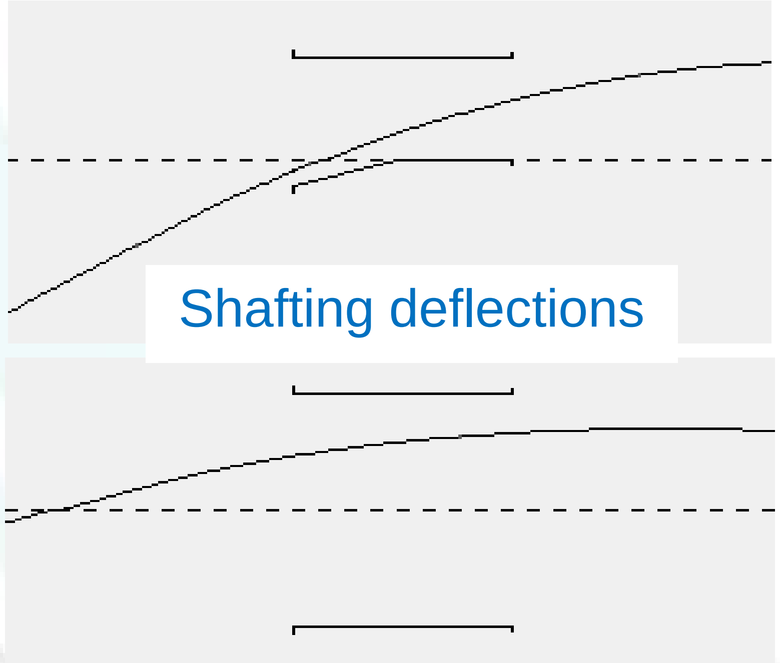


Lubrication of Double Sloped Stern Tube Bearing



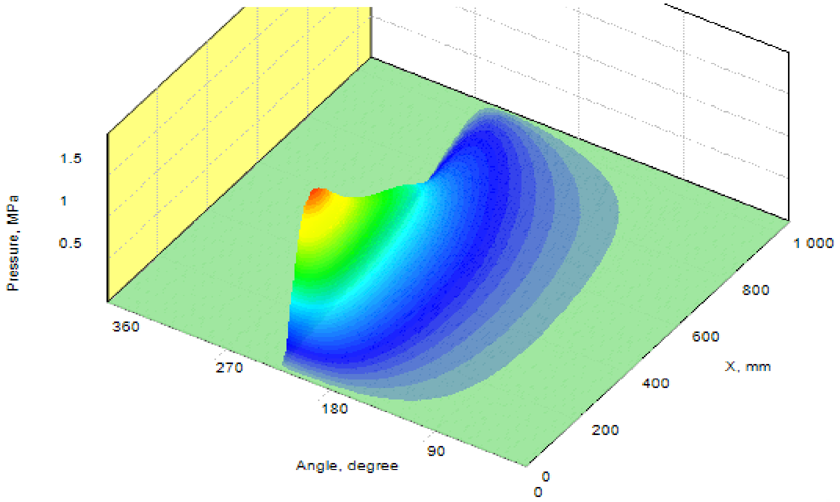
Lubrication pressure



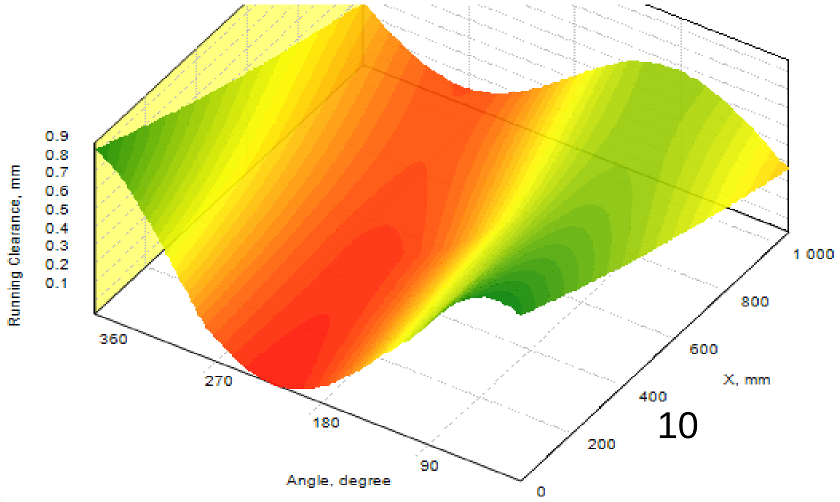


Shafting deflections

Lubrication pressure

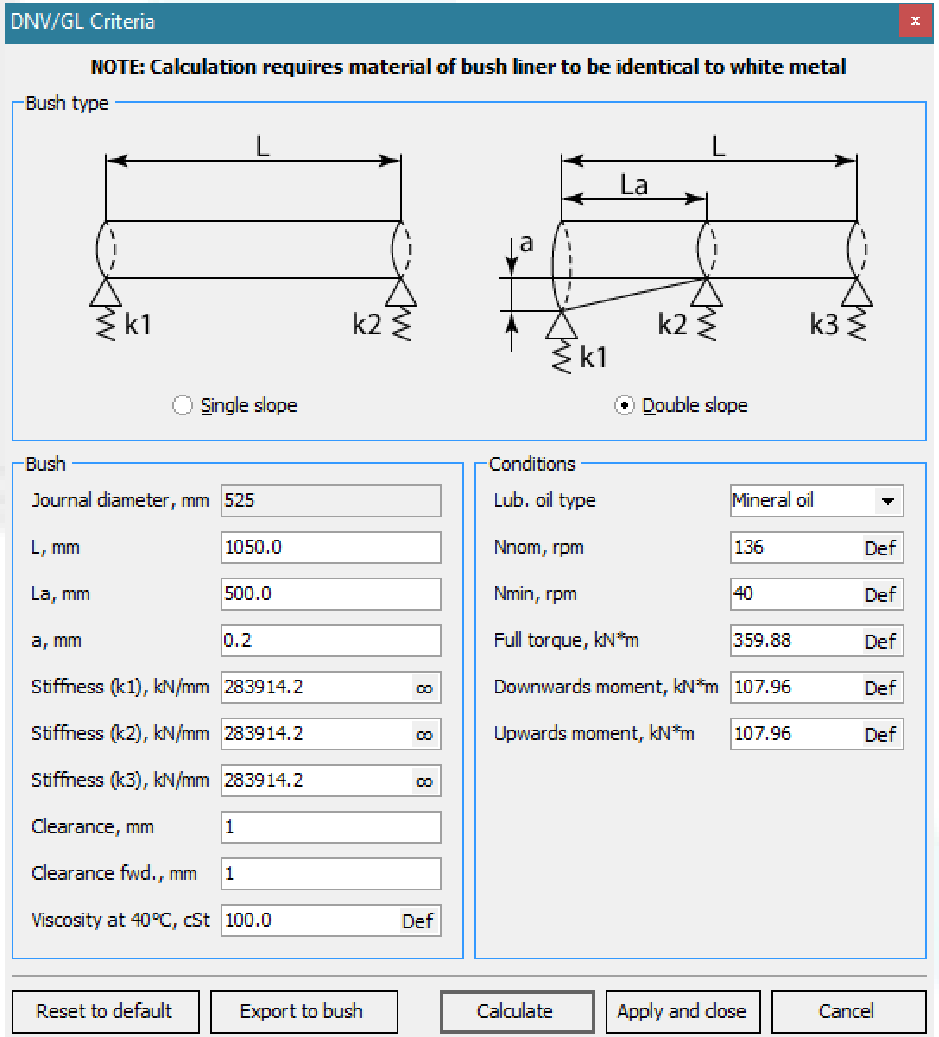


Lubrication film thickness



DNV GL Aft Most Bearing Lubrication Criteria

DNV GL aft most bearing lubrication criteria (Part 4 Chapter 2 Section 4) can be automatically calculated in the ShaftDesigner.



DNV/GL Criteria report - Operation: DNV/GL Criteria

DNVGL-RU-SHIP-Pt4Ch2. Par.2.1.6. Edition January 2018

1. Summary

Criteria	
$n_{0,stat}$ - the minimum shaft speed ensuring hydrodynamic lubrication: Hot static condition, no HD propeller loads, rpm	22
$n_{0,dyn1}$ - the minimum shaft speed ensuring hydrodynamic lubrication: Hot running condition, 15% of full torque downwards, rpm	34
$n_{0,dyn2}$ - the minimum shaft speed ensuring hydrodynamic lubrication: Hot running condition, 40% of full torque upwards, rpm	72
Kinematic viscosity at 40°C, cSt	100.0
Low speed criterion, $n_{min} \geq n_{0,stat}$, (40 ≥ 22)	Fulfilled
Full speed criterion, $n_{full} \geq \max\{n_{0,dyn1}, n_{0,dyn2}\}$, (136 ≥ 72)	Fulfilled

2. Initial Data

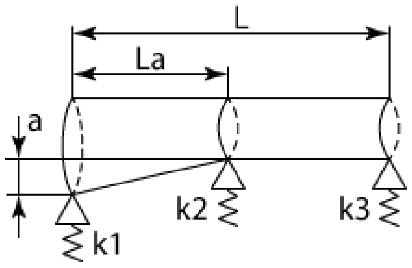
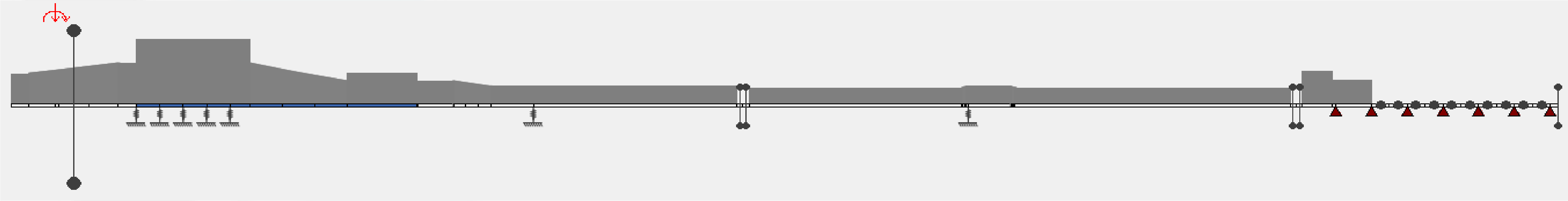


Fig. 1

Whirling Vibration Analysis Based on the Alignment Plan

The forced whirling vibration analysis is based on the shaft alignment design with the multi-support bearing model.



Further Developments to Solve the *Key Problem*

Lubrication:

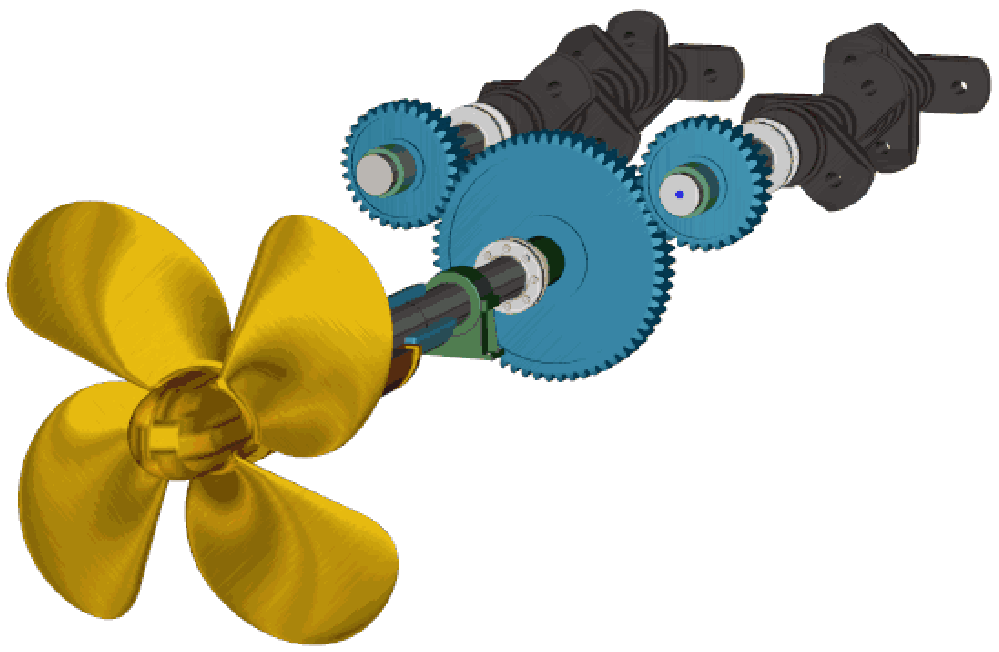
- Calculation of the Stribeck curve for stern tube bearing
- Elastohydrodynamic model of water-lubricated bearings

Whirling Vibration:

- Whirling vibration calculation with a continuous model of bearings
- Dynamic characteristics of lubrication film (stiffness, damping) depending on the shaft alignment parameters

External Loads:

- Considering all possible operational conditions (different ship drafts, speeds, manoeuvres, sea conditions)
- Determining propeller loads using CFD or based on the full-scale onboard measurements at normal operation and maneuvering
- Simulation of shafting behaviour during ship seakeeping



Thank you for your attention!

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