Ministério da Educação

UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

Campus Curitiba

What do we (think we) know about grease lubrication?

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AGENDA

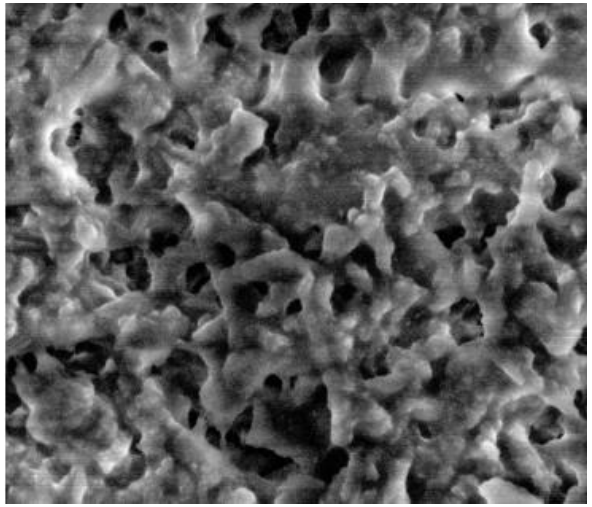
1. What do we know about grease lubrication
    - Film thickness
    - Friction
2. Case study: Curve rail lubrication
3. Case study: Rolling bearings

1. WHAT DO WE KNOW

Lubricating grease – Concept

- **Composition**
  - 65 - 95 % base oil (mineral, synthetic or vegetal)
  - 5 - 35 % thickener (soap, non soap, synthetic, organic)
  - 0 - 10 % additives (EP, AW, VM, CI, etc…)

Sponge

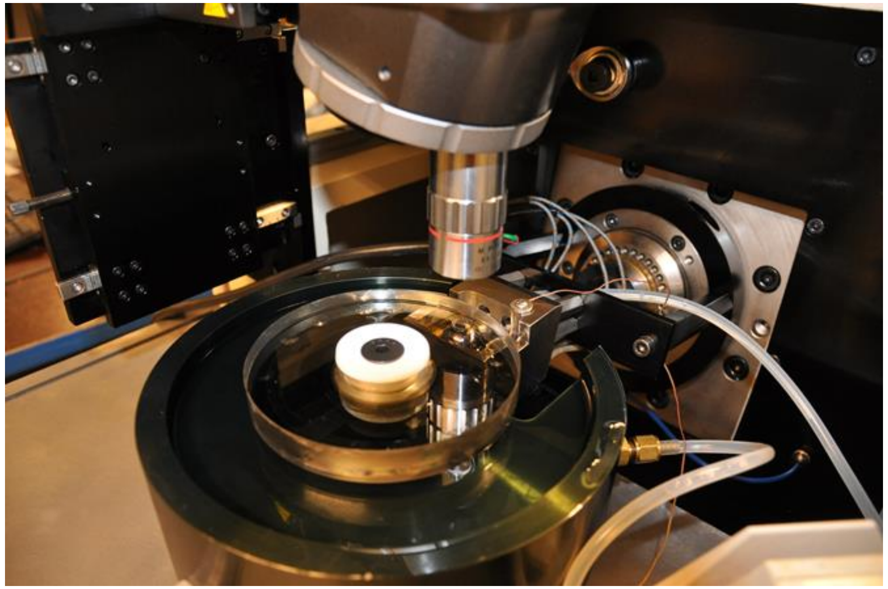


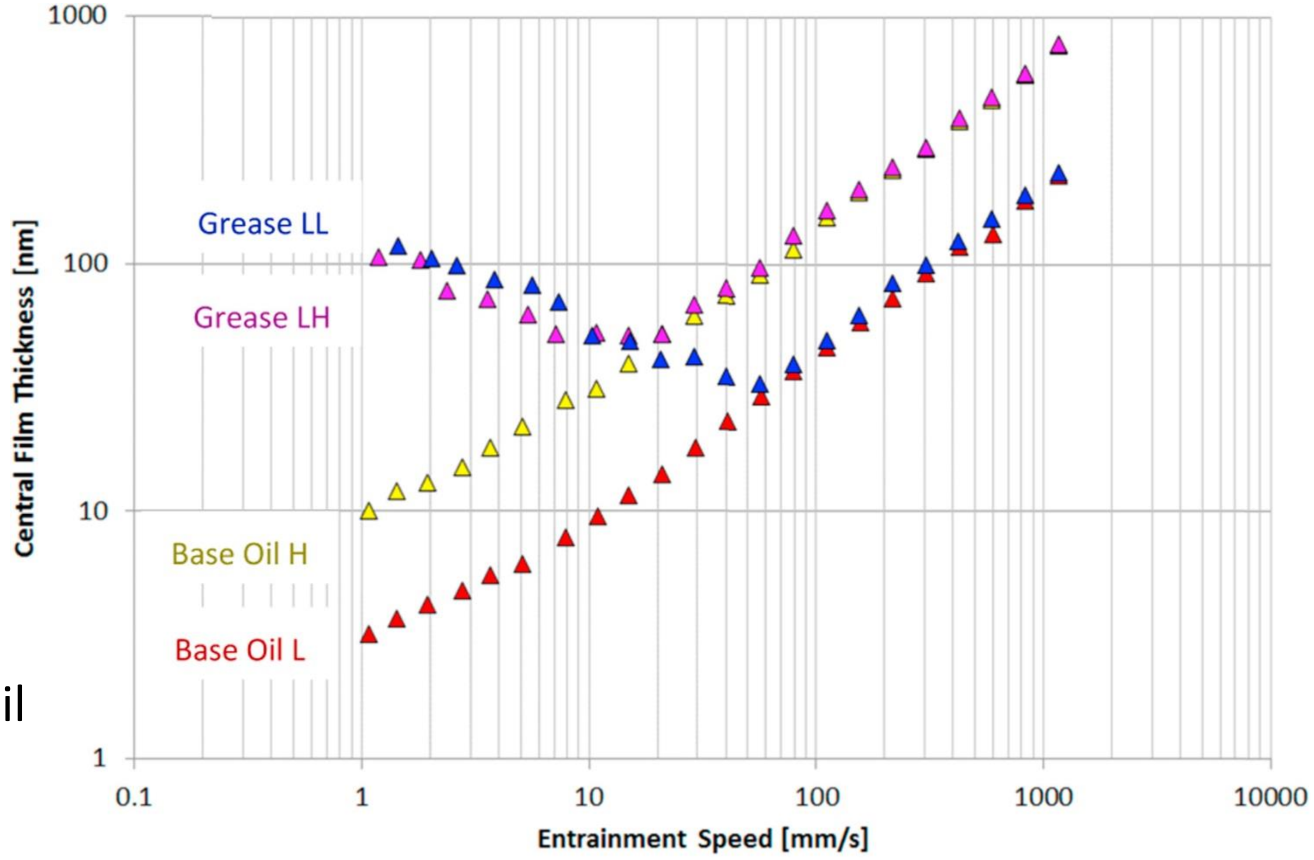
WHAT DO WE KNOW?

Lubricating grease – Concept

- **90% of rolling bearings are grease lubricated**
- **Used for curve rail lubrication**
- **Represent only 9% of the lubricants market share**
  - 1 out of 9 papers published on lubrication are about grease (2019).
- **Knowledge on grease are scarse in comparison to oil lubrication.**
- **Knowledge developped by grease developpers and bearing manufacturer are not published.**

Film thickness measurements: Ball on disc device + optical interferometry

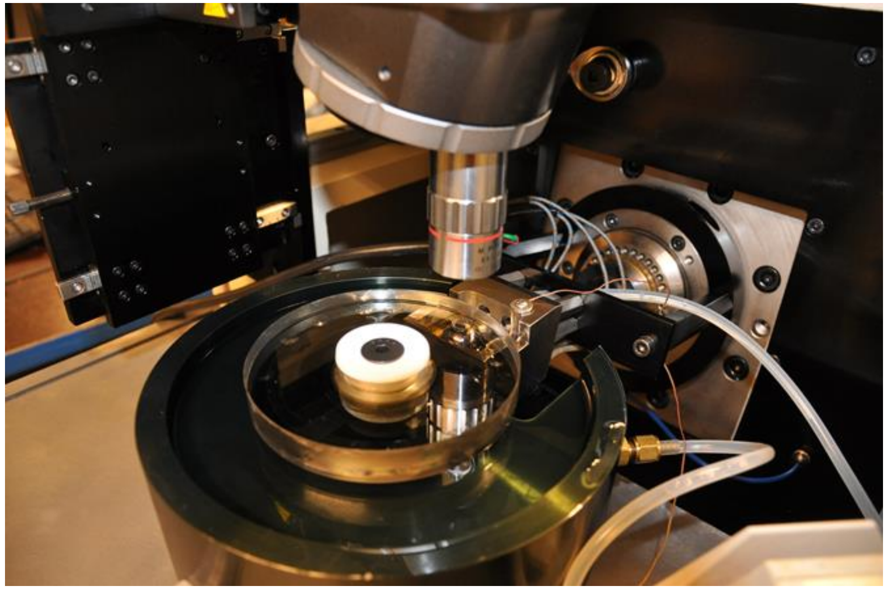


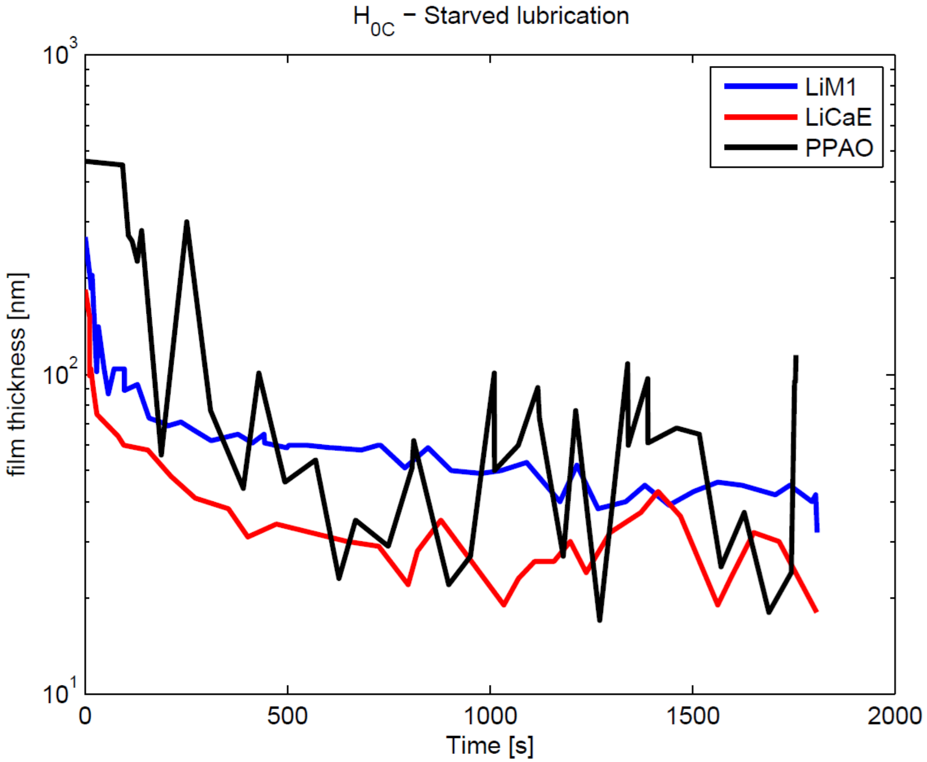


- High speed: h_{oc}Grease ≈ h_{oc}Bleed-oil > h_{oc}Base oil
- Low speed: h_{oc} Grease ≠ h_{oc} Bleed-oil
- h_{oc} & U_{hmin} at low speeds → thickener

WHAT DO WE KNOW?

Film thickness measurements: Ball on disc device + optical interferometry

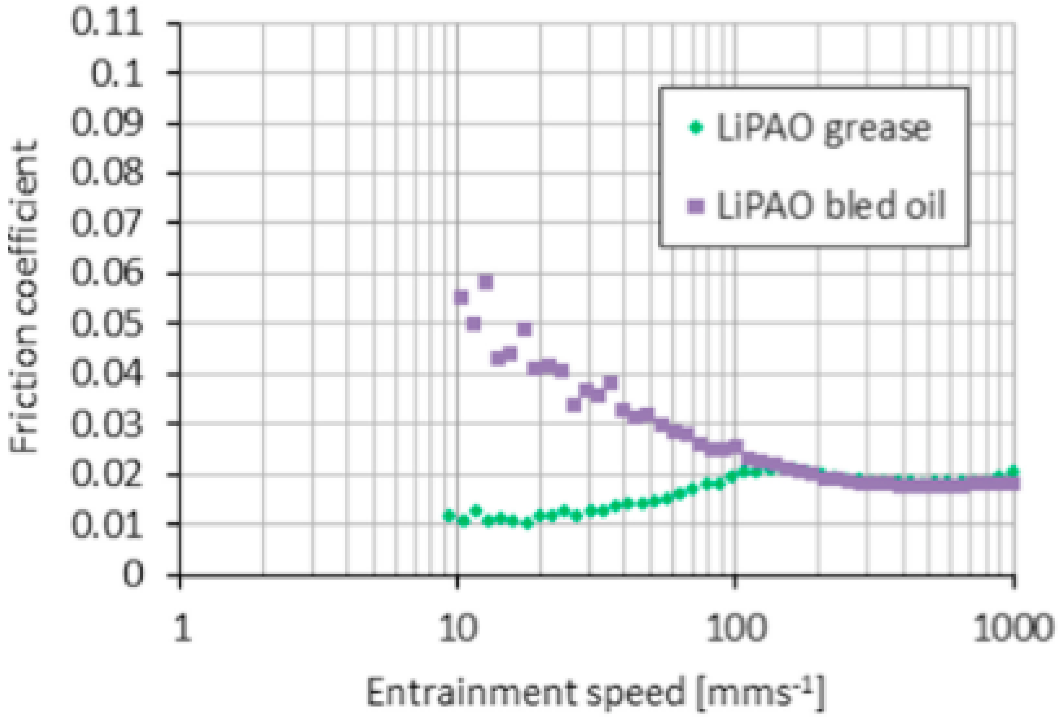




- Lowest values of film thickness curves → limited amount of bleed-oil
- Film thickness is locally and momentarily increased → thickener
- PP > Ca > Li

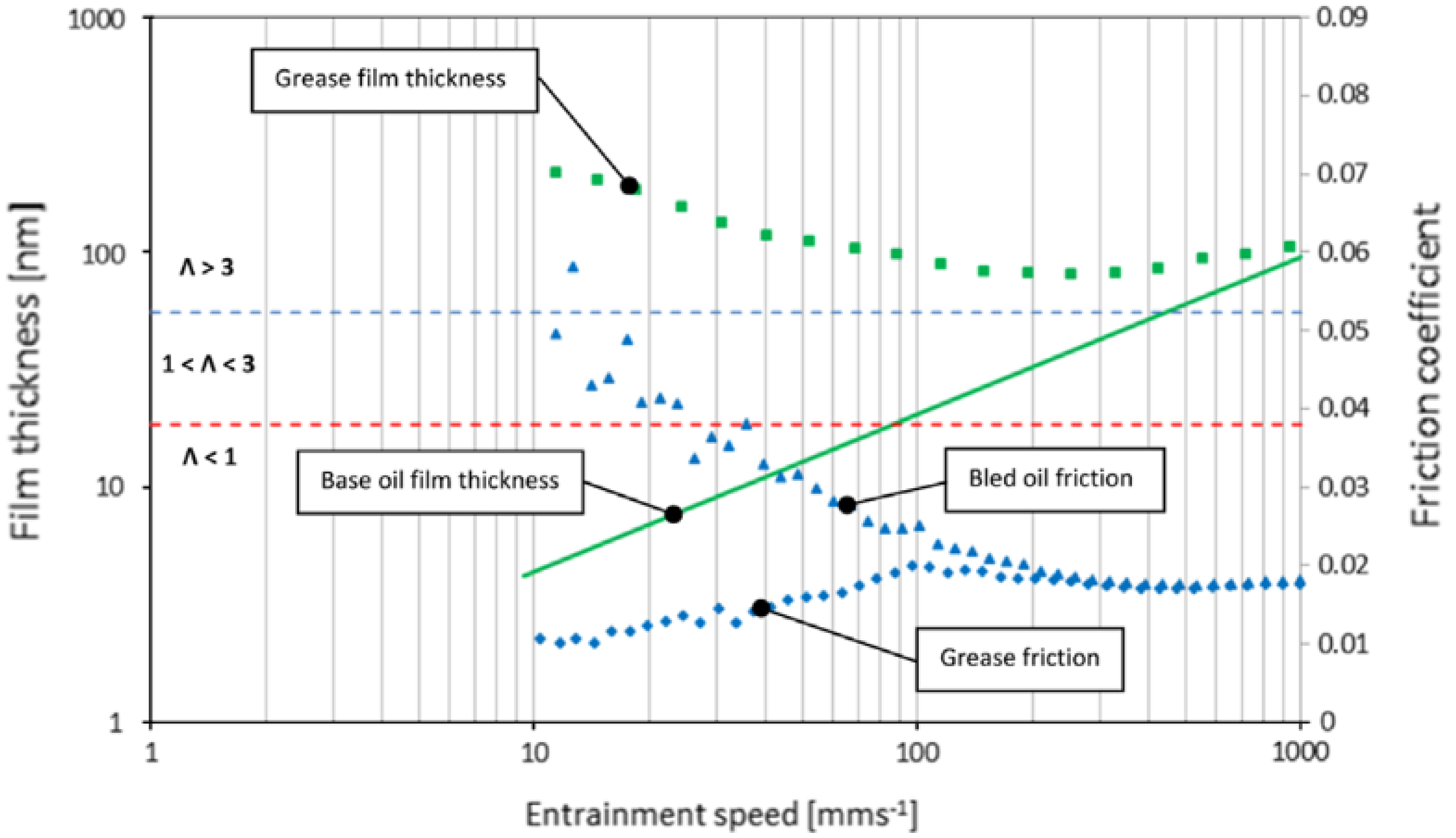
WHAT DO WE KNOW?

Traction coefficient measurements using a Ball on disc device



- High speed: COF Grease ≈ **COF** Bleed-oil
- Low speed: COF Grease ≠ COF Bleed-oil
- COF & U_{hmin} at low speeds → thickener

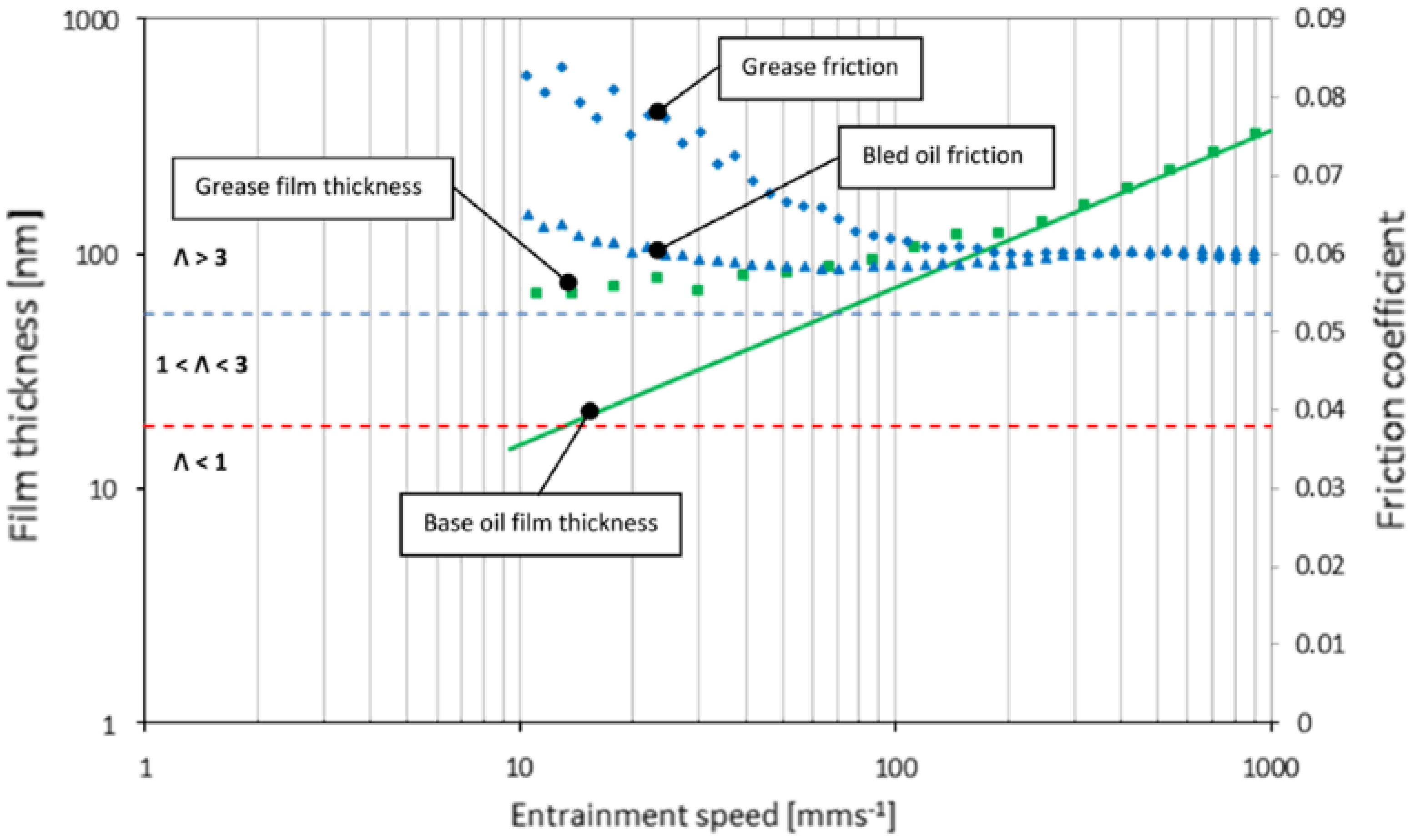
Film thickness and friction for different greases



- High speed:
  - COF Grease ≈ COF Bleed-oil
  - h Grease ≈ h Bleed-oil
- Low speed:
  - COF Grease < > COF Bleed-oil
  - h Grease > h Bleed-oil

WHAT DO WE KNOW?

Film thickness and friction for different greases



- High speed:
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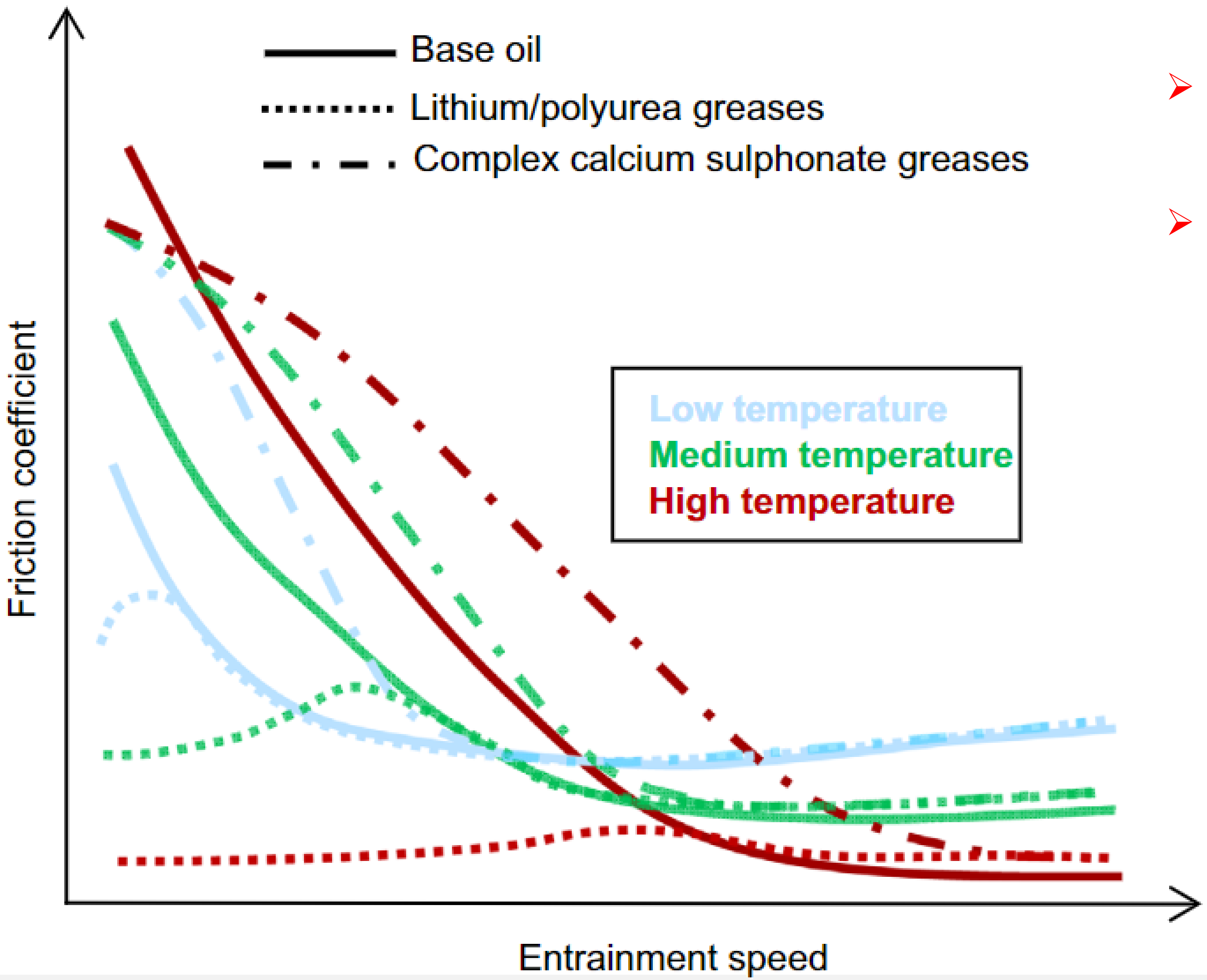
  - h Grease > h Bleed-oil

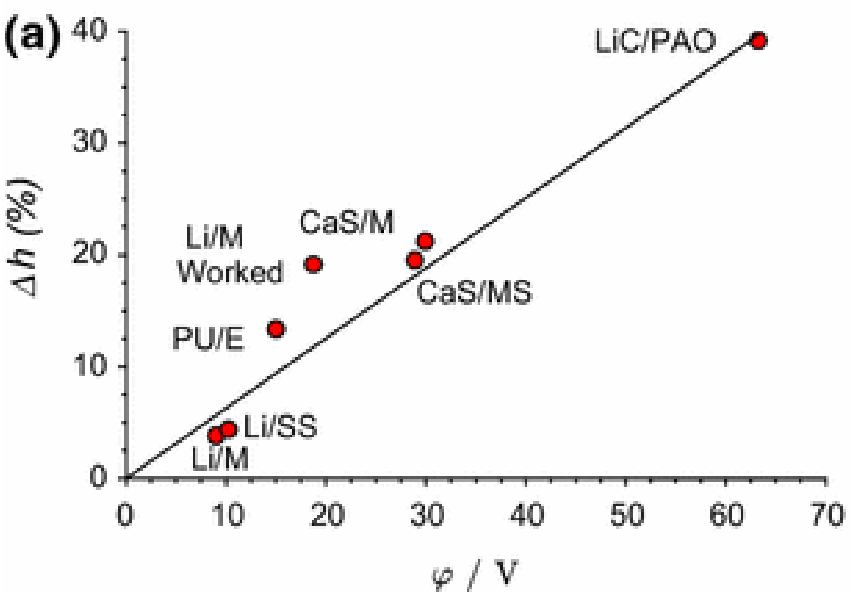
WHAT DO WE KNOW?



- **Calcium grease follow stribeck curve**
- **Lithium and Polyurea grease do not – friction reduces at low entrainment speed**

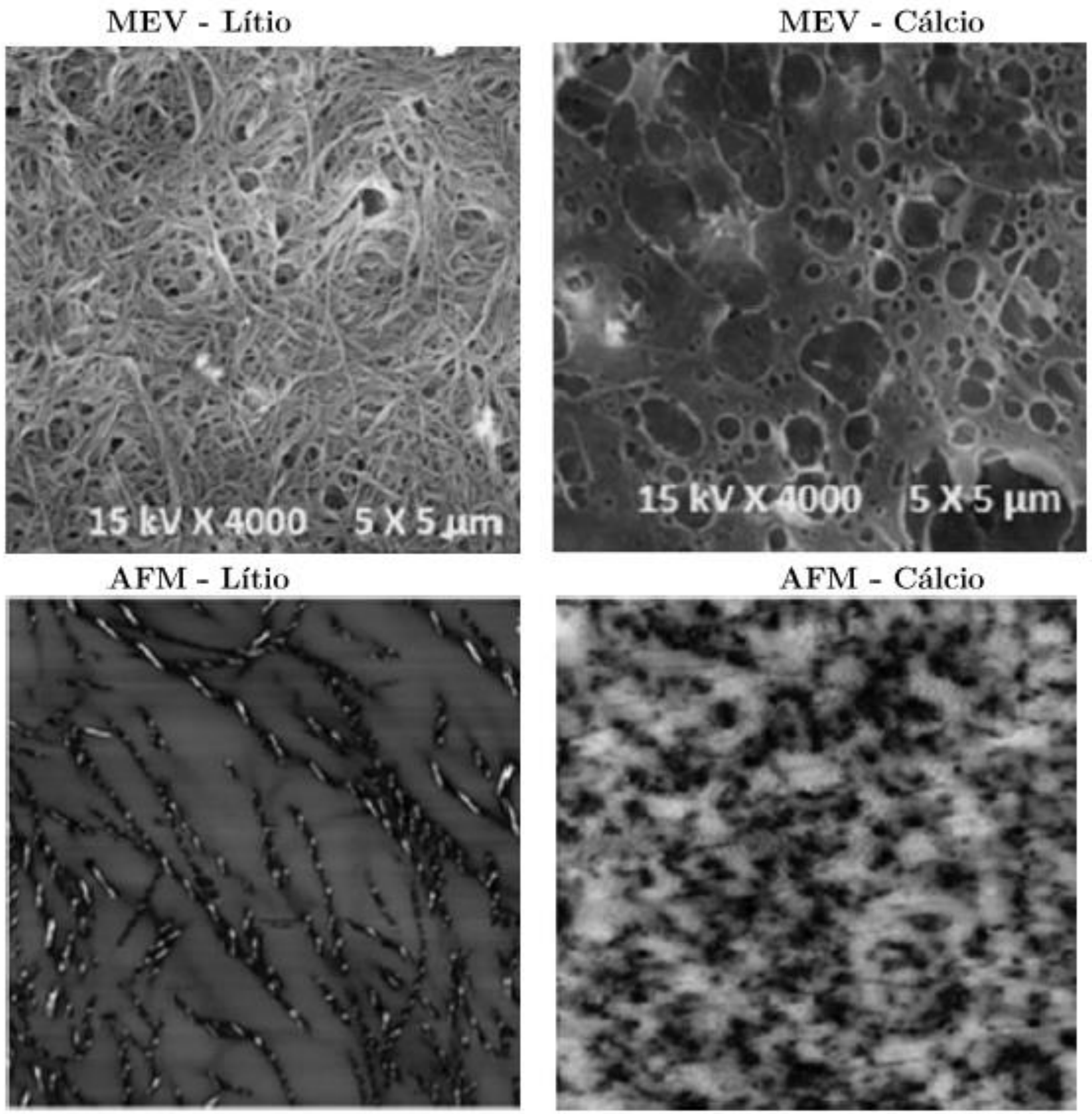
Why and what is the impact on wear?

WHAT DO WE KNOW?



	Graxa de lítio	Graxa de cálcio
Morfologia	Fibras torcidas	Partículas esféricas
Comprimento médio (L)	≈2± 0.40 µm	-
Diâmetro médio (D)	≈0.1 ± 0.02 µm	≈0.26 ± 0.05 µm
Volume médio (V)	≈0.0157 µm3	≈0.009 µm3

Size and quantity of thickener!!!



Fonte – (CYRIAC et al, 2016)

WHAT DO WE KNOW?

Summary

- High speed: Grease can be modelled as oil
  - We don't know why
- Low speed: Thickener crosses the contact and changes film thickness and friction
  - We don't know why
- Film thickness is improved by PP > Ca ≈ Pu > Li OR size and quantity?
  - We don't know
- What is the impact of the formulation on wear, fatigue???
  - Not established in the literature
- What is the impact of the additives on tribological performance???
  - Not established in the literature

2. RAIL CURVES

Commercial options available

CLARETECH ECOCURVE HEAVY HAUL
Environmentally friendly All Season curved rail protection on Heavy Haul and Class 1 railways.
NLGI 1.5

ELM TempFlex® 35 to 160 w/MoS2 Rail Curve Grease
Biodegradable Rail Curve Lubricant

ELM
Environmental Lubricants Manufacturing, Inc

MOLYGRAPH | engineered lubricants

Nome Anterior: Shell Alvania HDX, Shell Retinax HDX
Shell Gadus *S2 V220AD 2*
Graxa de alta performance com aditivos sólidos para múltiplas aplicações

WHITMORE
TECHNICAL DATA SHEET
RAILMASTER® LFG
HIGH PERFORMANCE RAIL GREASE WITH GRAPHITE

KLÜBER LUBRICATION

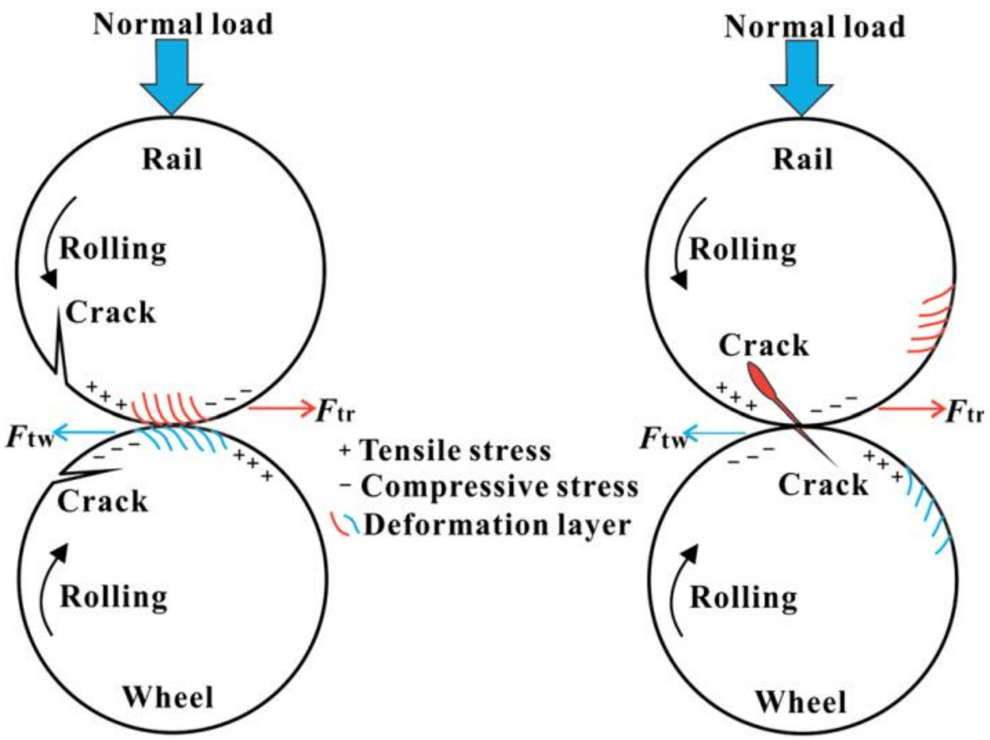
Product Data Sheet
Effective Date 01.01.2015 Version 1.0
PETRONAS
High Performance Grease

Petronas Grease LiCa GEP 2.5
Extreme Pressure Industrial grease fortified with friction reduction additives
Heavy Loads | Water Resistant | Corrosion Protection

Klüberrail LEA 62-2000
Readily biodegradable wheel flange lubricant for rail vehicles

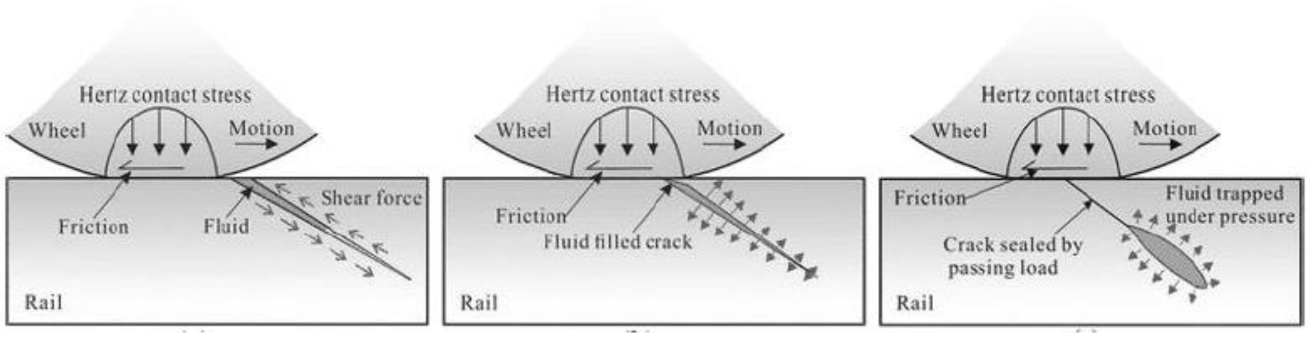
BECHEM Ecorail 5501
Biodegradable rail lubricant

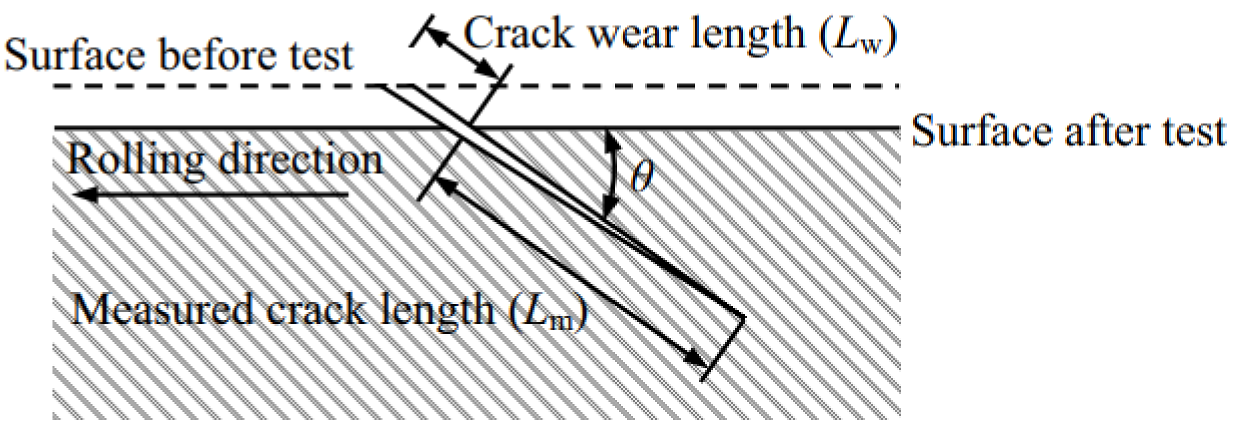
Twin disc tests



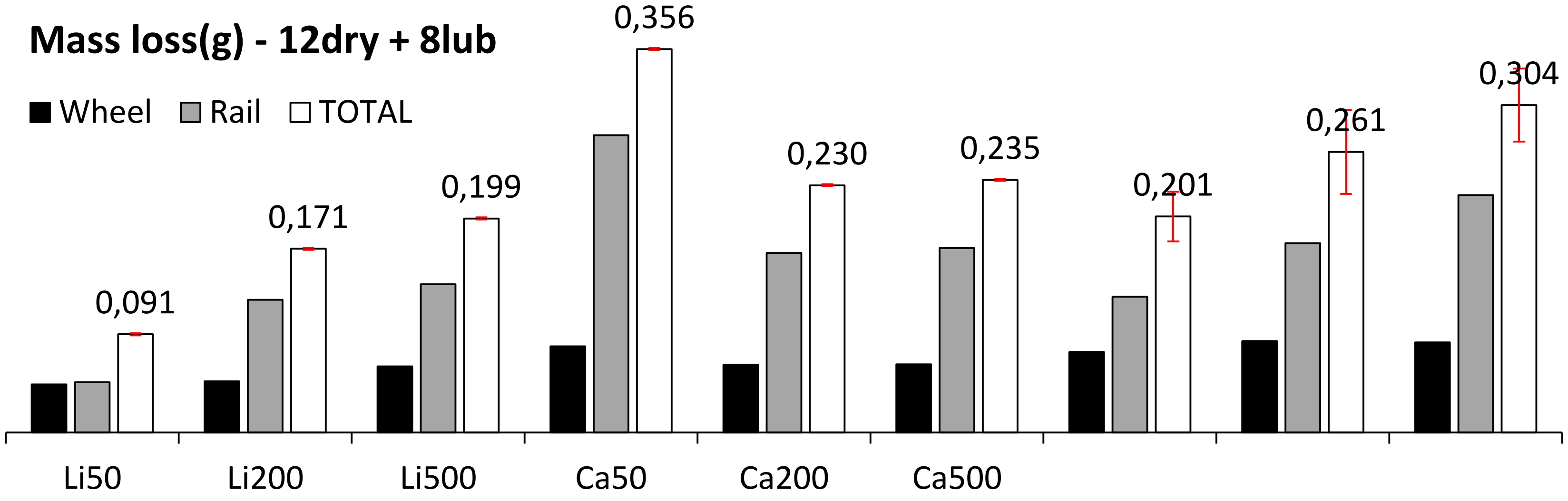
dry

lubricated





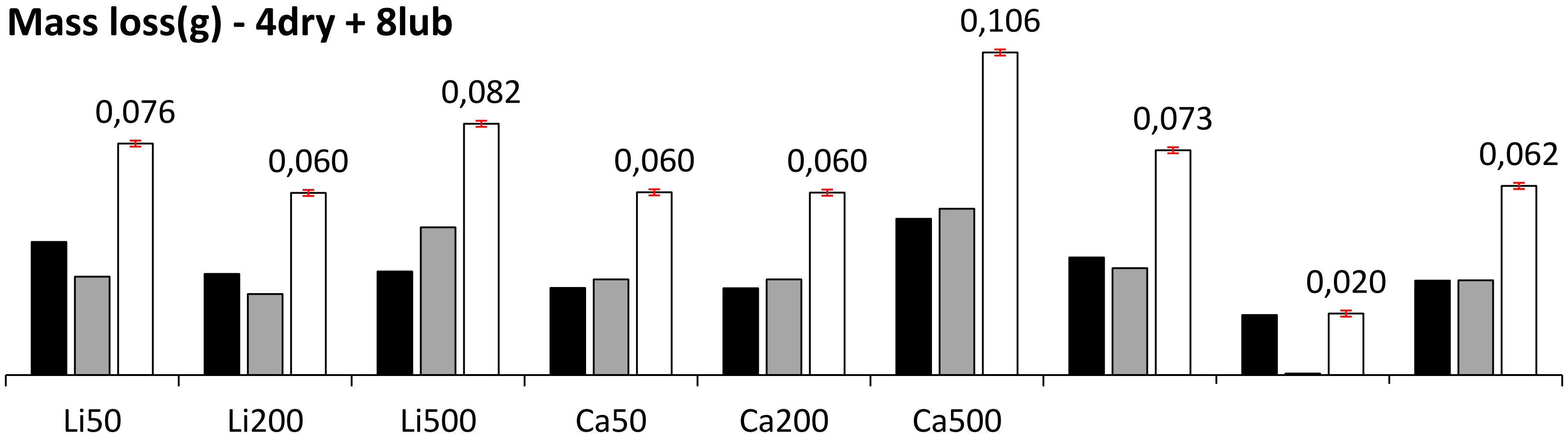
2. RAIL GREASES



$K_{wheel} < K_{rail}$

Wear mode: crack propagation

Lubrication → crack propagation



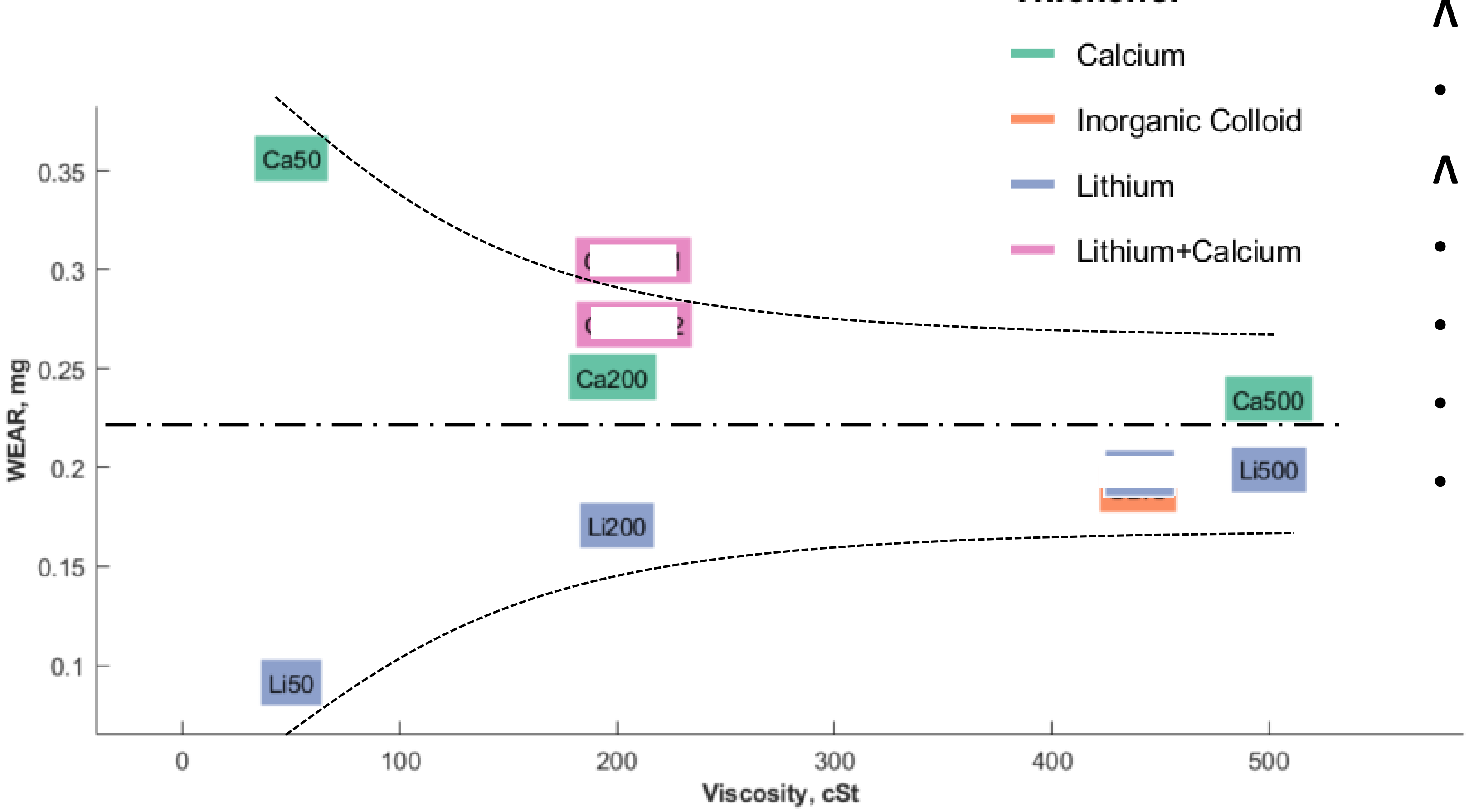
$K_{wheel} < K_{rail}$

Wear mode: rolling/sliding wear

Lubrication → wear resistance

2. RAIL GREASES

Mass loss(g) - 12dry + 8lub



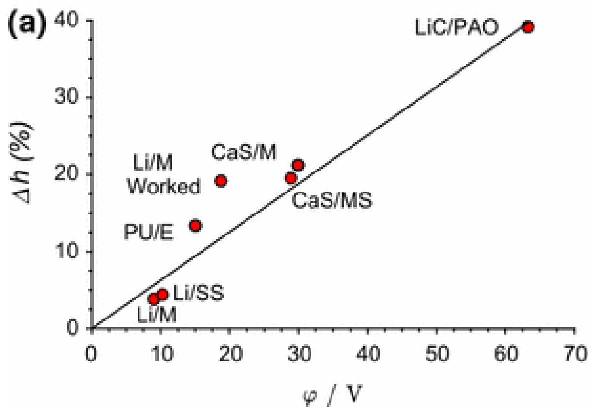
Λ ~ 0,6 Λ ~ 1,5 Λ ~ 3,0

Λ > 3,0

- formulation is not relevant

Λ < 3,0

- Calcium thickener increases wear
- Lithium thickener reduces wear
- Additive package also impacts wear
- Consistency also impact wear



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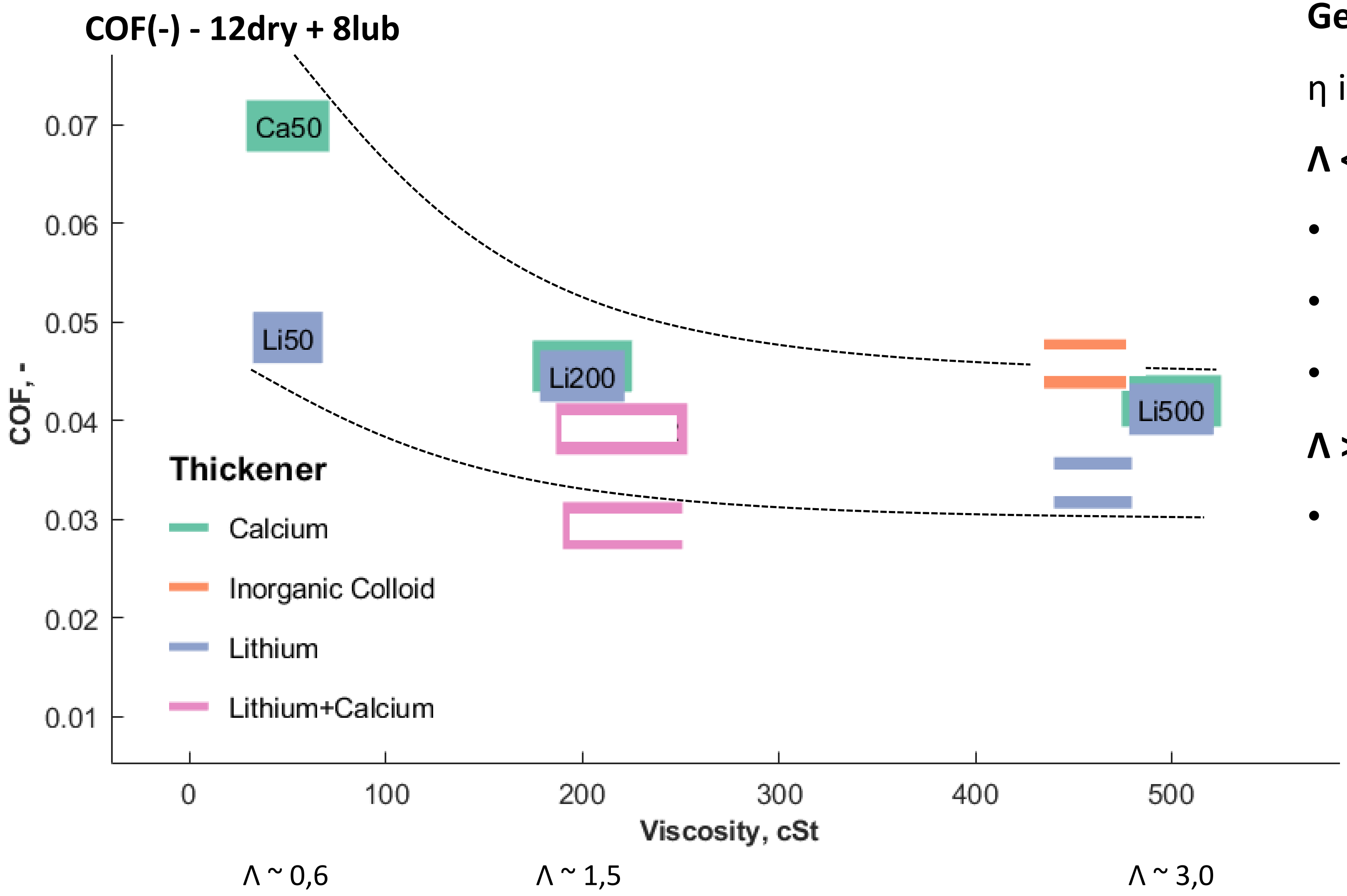


General trend

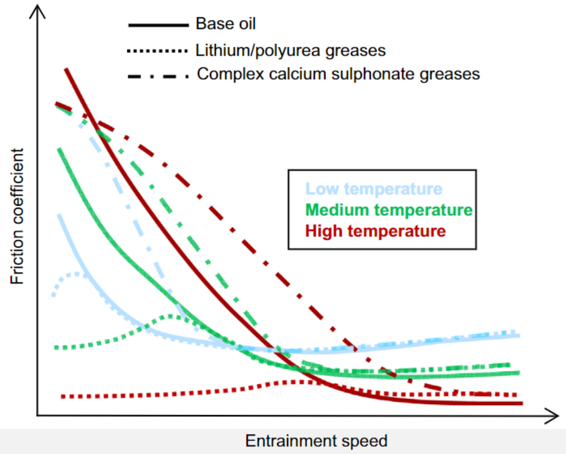
η increases → μ decreases

Λ < 3,0

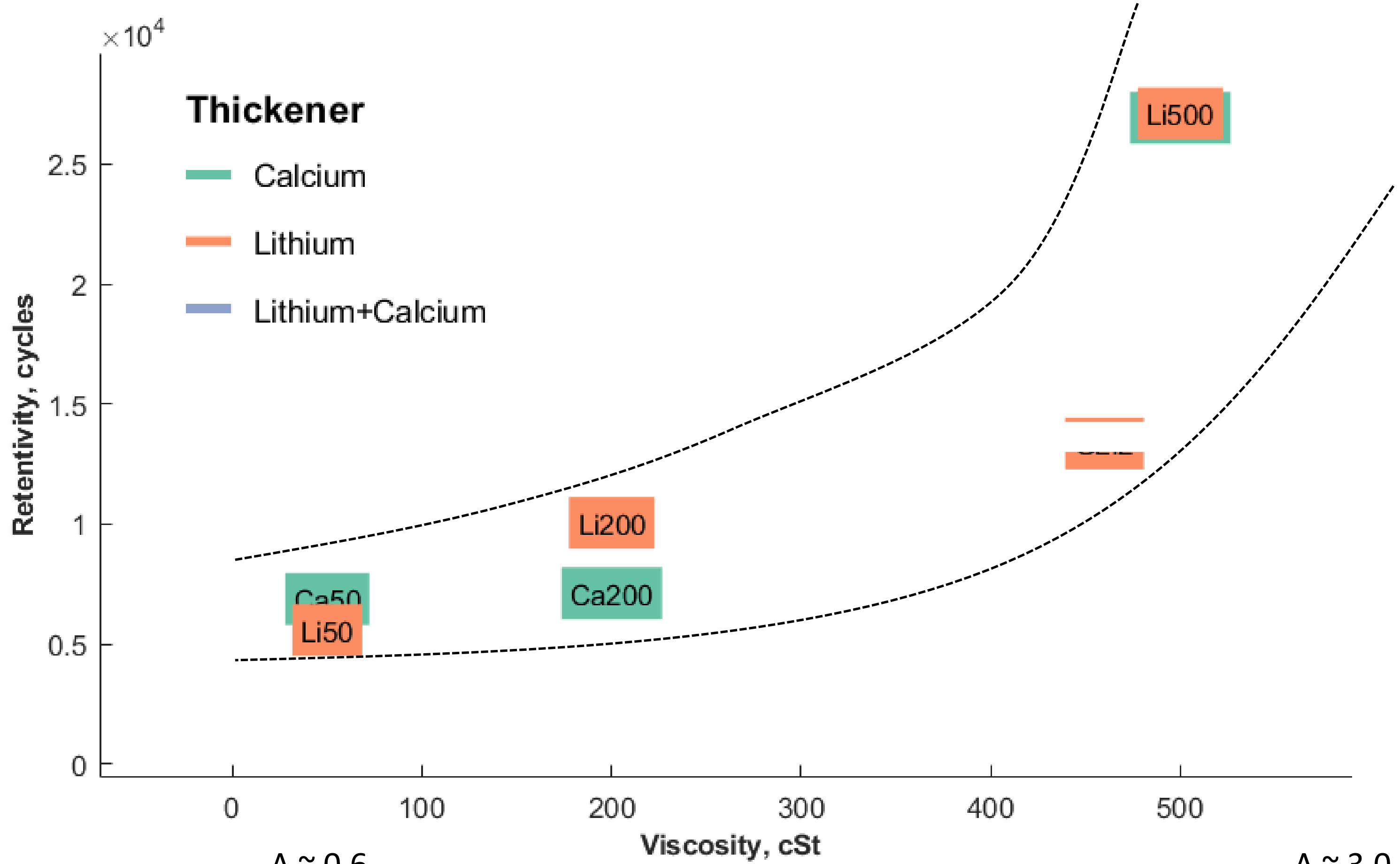
- Calcium increases friction
- Additive package may affects friction
- Consistency may affects friction

Λ > 3,0

- Thickener is not relevant



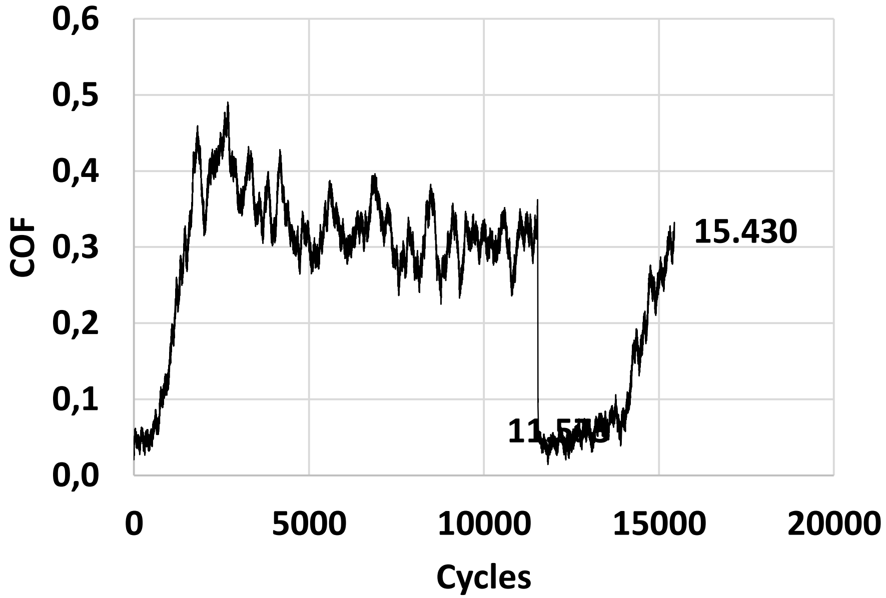
Retentivity (cycles) - 4dry + lub



Λ ~ 0,6 Λ ~ 1,5 Λ ~ 3,0

General trend

η increases → Rt increases



2. RAIL GREASES

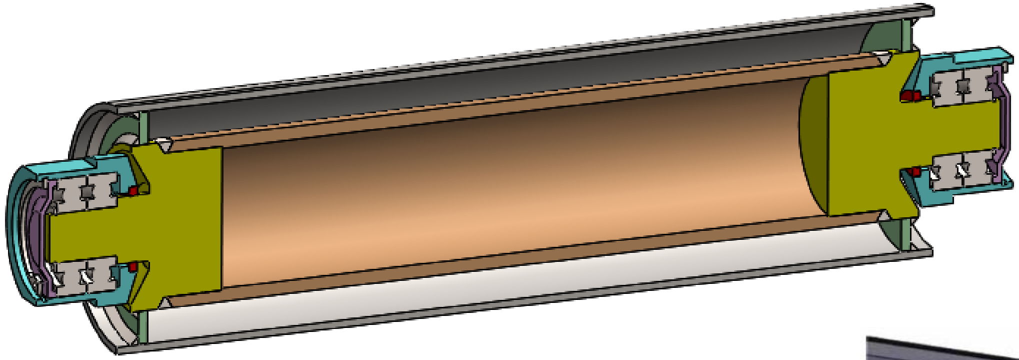
Summary

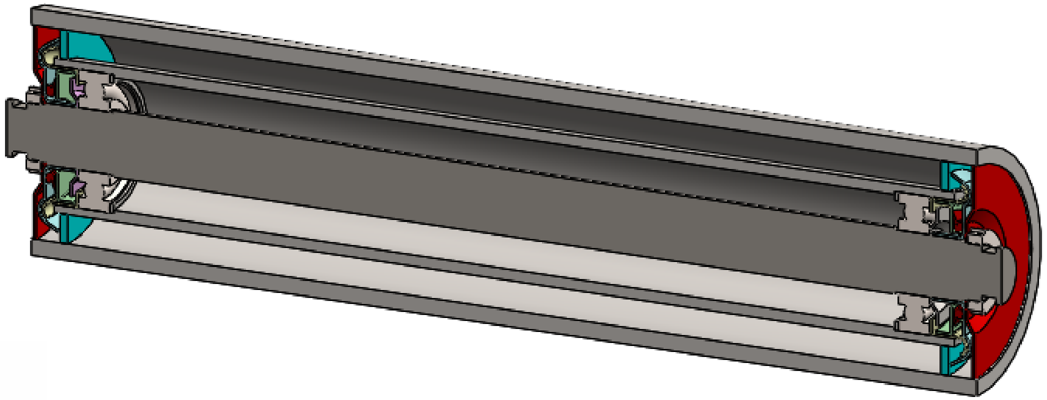
- $\Lambda > 3,0$
  - Base oil defined tribological response
  - High viscosity increases retentivity
- $\Lambda < 3,0$
  - Calcium thickener
    - high wear (new result in the literature)
    - high friction (agrees with literature)
  - Lithium thickener
    - Low wear (new result in the literature)
    - Low friction (agrees with literature)
  - One tested formulation presents better results than the commercial options available at lower costs

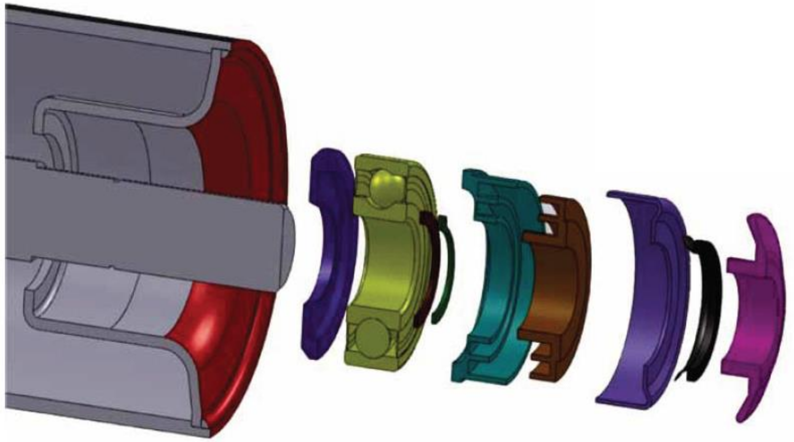
3. IDLER`S ROLLING BEARINGS

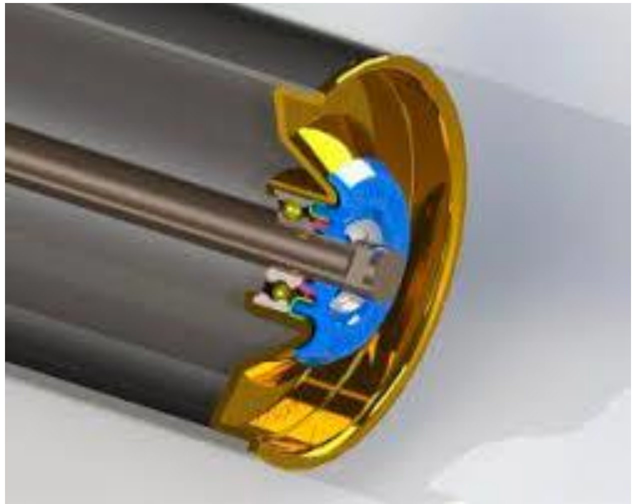
- grease selection -

Idler design

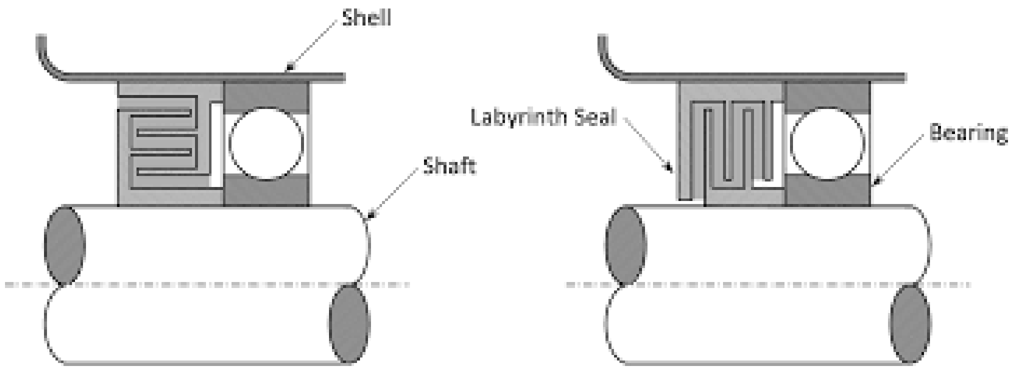


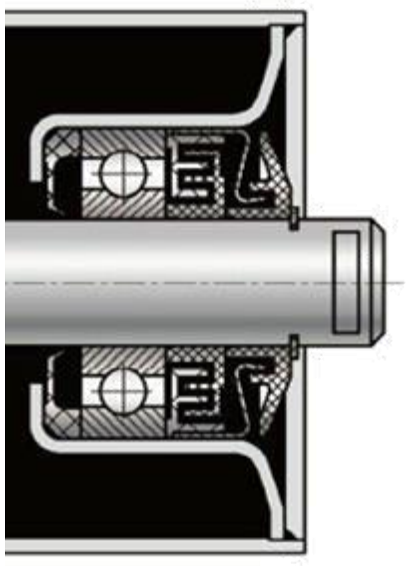


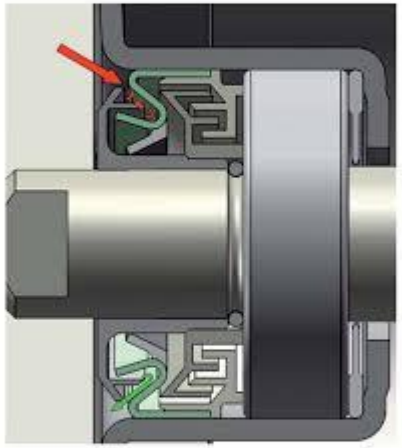




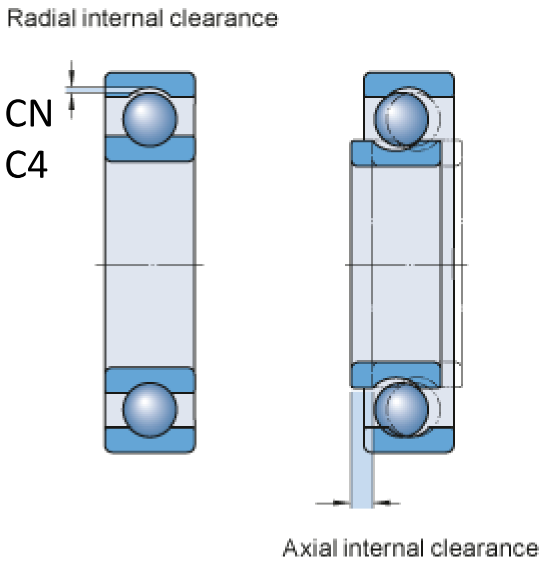
Sealing solution







Rolling bearing type



Lubricating grease

Viscosity from 50 cSt to 500 cSt

Thickener type: Lithium, Polyurea, Calcium, etc

Base oil: Mineral and Sythetic

3. ROLLING BEARING

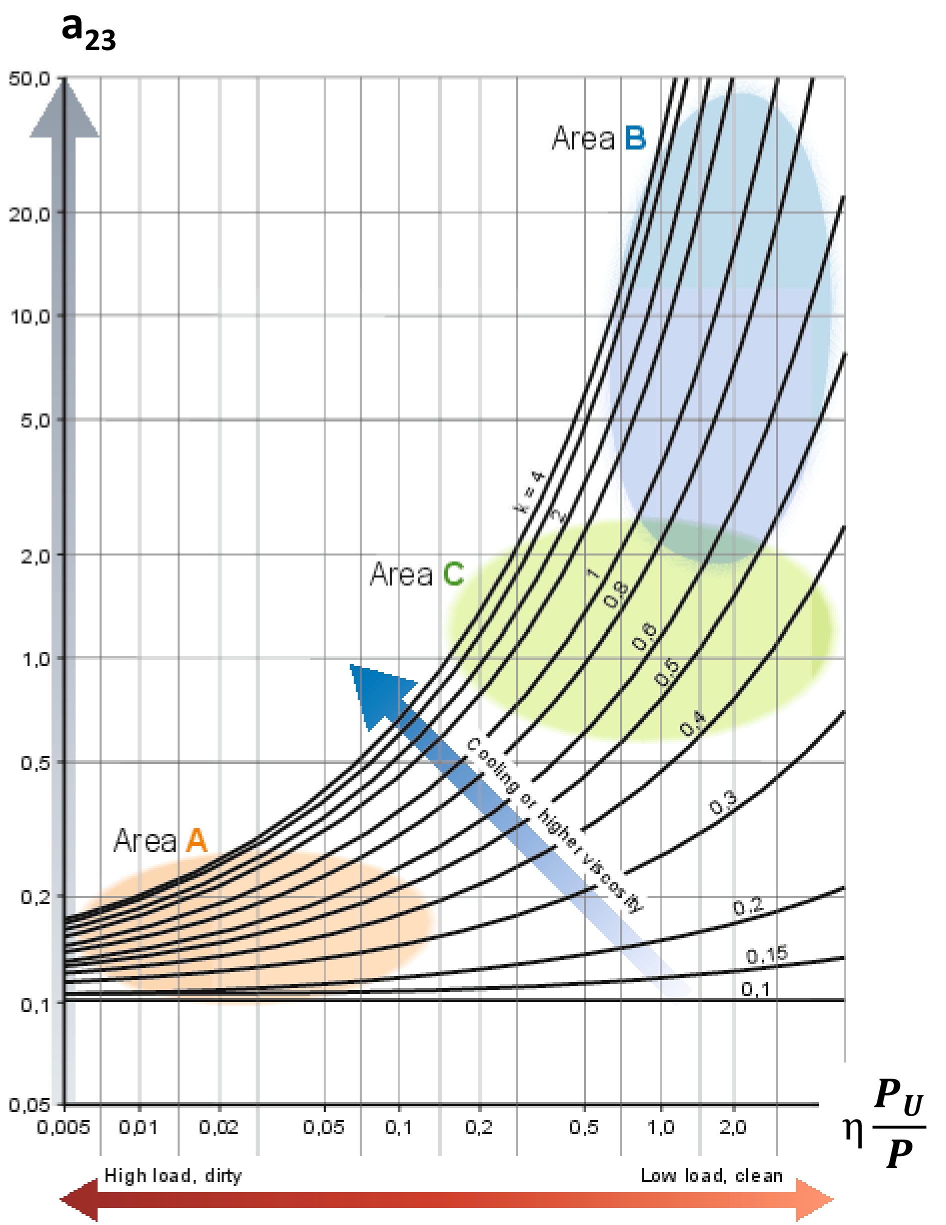
$$L_{mh} = \left(a_1 \times a_{23} \times \left({}^{C}/_{P}\right)^3\right) \quad [h]$$

a_1: adjustment factor for reliability;
a_{23}: life modification factor depends on operational condition, contamination and lube viscosity;

a_1

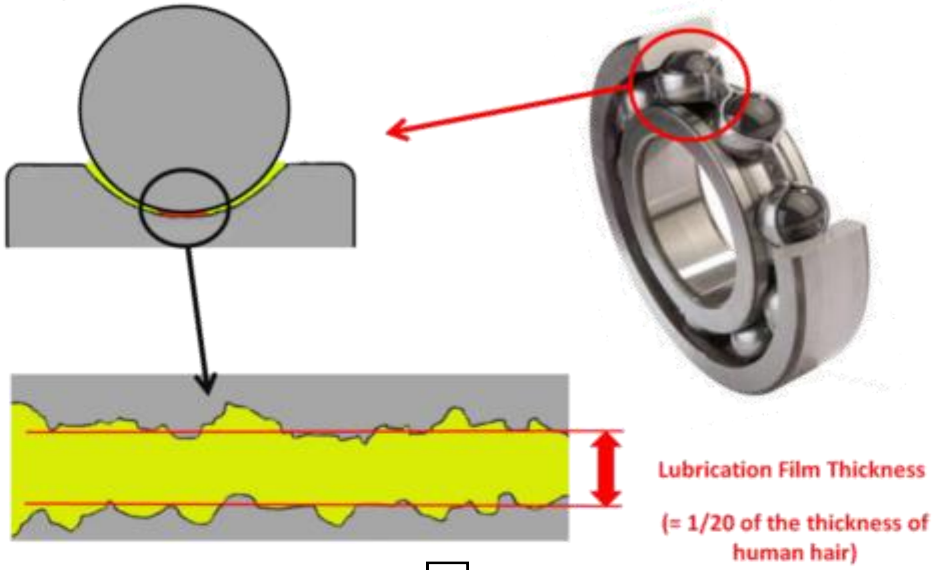
Reliability %	L_{na}	a_1
90	L_{10a}	1
95	L_{5a}	0,62
96	L_{4a}	0,53
97	L_{3a}	0,44
98	L_{2a}	0,33
99	L_{1a}	0,21

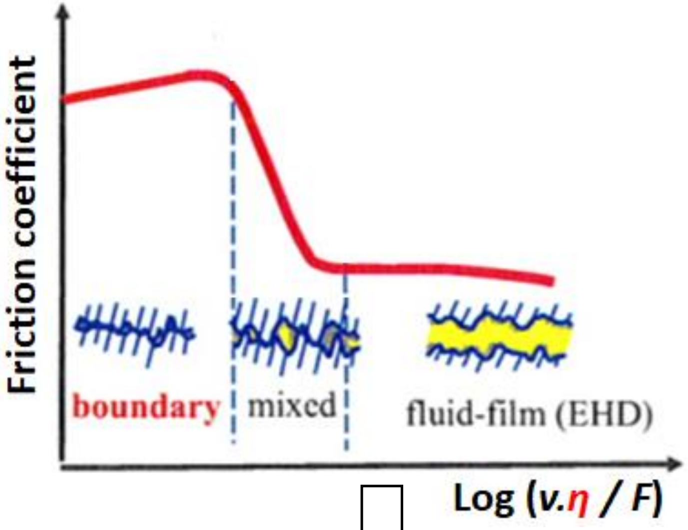
k: viscosity ratio
C: Dynamic bearing capacity
η: contamination factor
Pu: fatigue limit load
P: bearing equivalent load

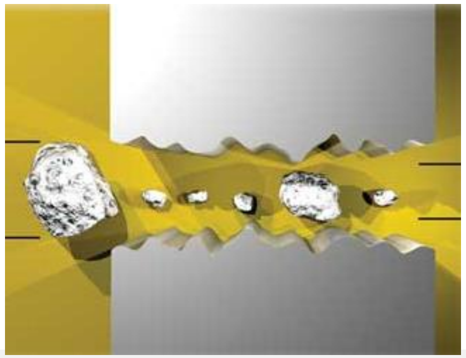


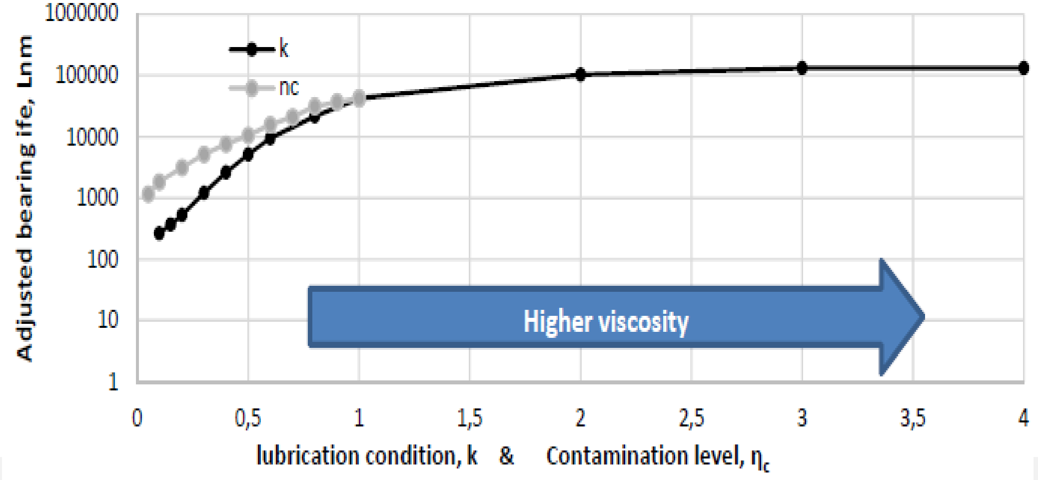
3. ROLLING BEARING

Viscosity & Contamination



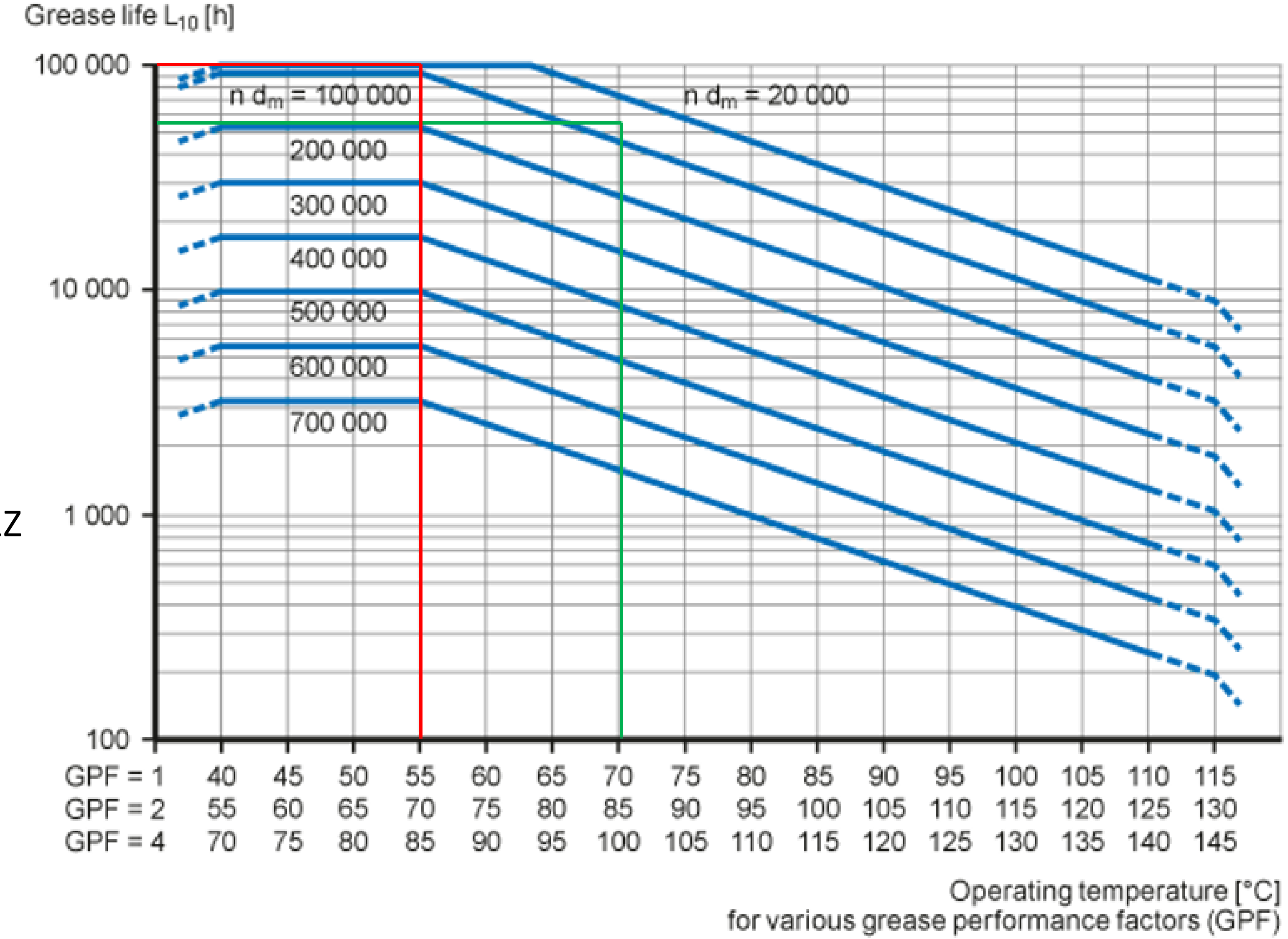






Grease performance factor (GPF)

- Polyurea + ester oil grease (GPF=4)
- Polyurea + mineral oil grease (GPF=2)
- Lithium + mineral oil grease (GPF=1)



Example:

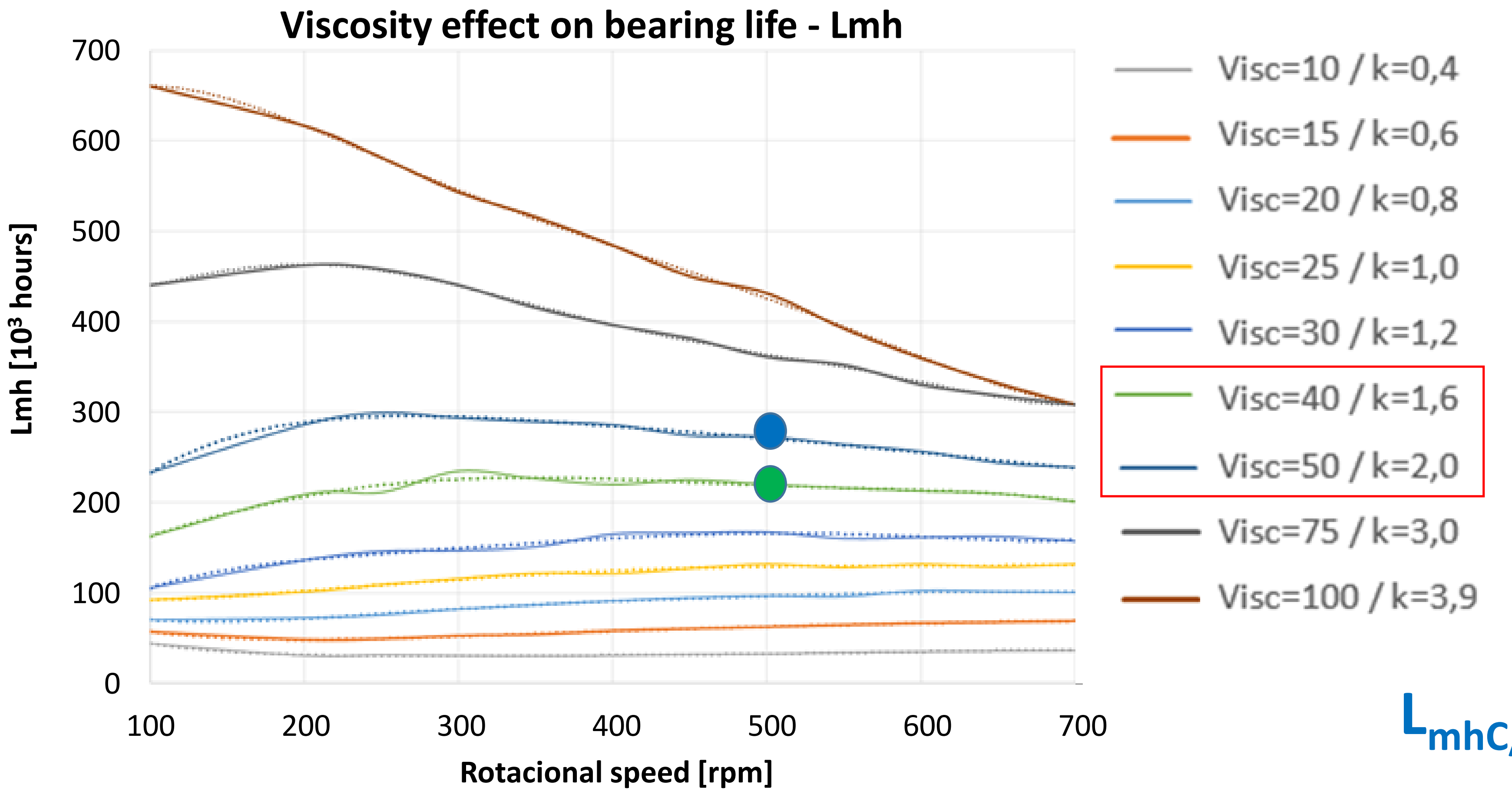
Rolling bearing 6309-2Z

Speed: 500 rpm

Temperature: 70°C

GPF2 70% > GPF1

$$L_{mh} = (a_1 \times a_{23} \times L_{10h}) \quad [h]$$



Rolling bearing 6309-2Z

Speed: 500 rpm

Temperature: 60°C

Load: 4000 N

Grease A/B: ≈ 220 kh

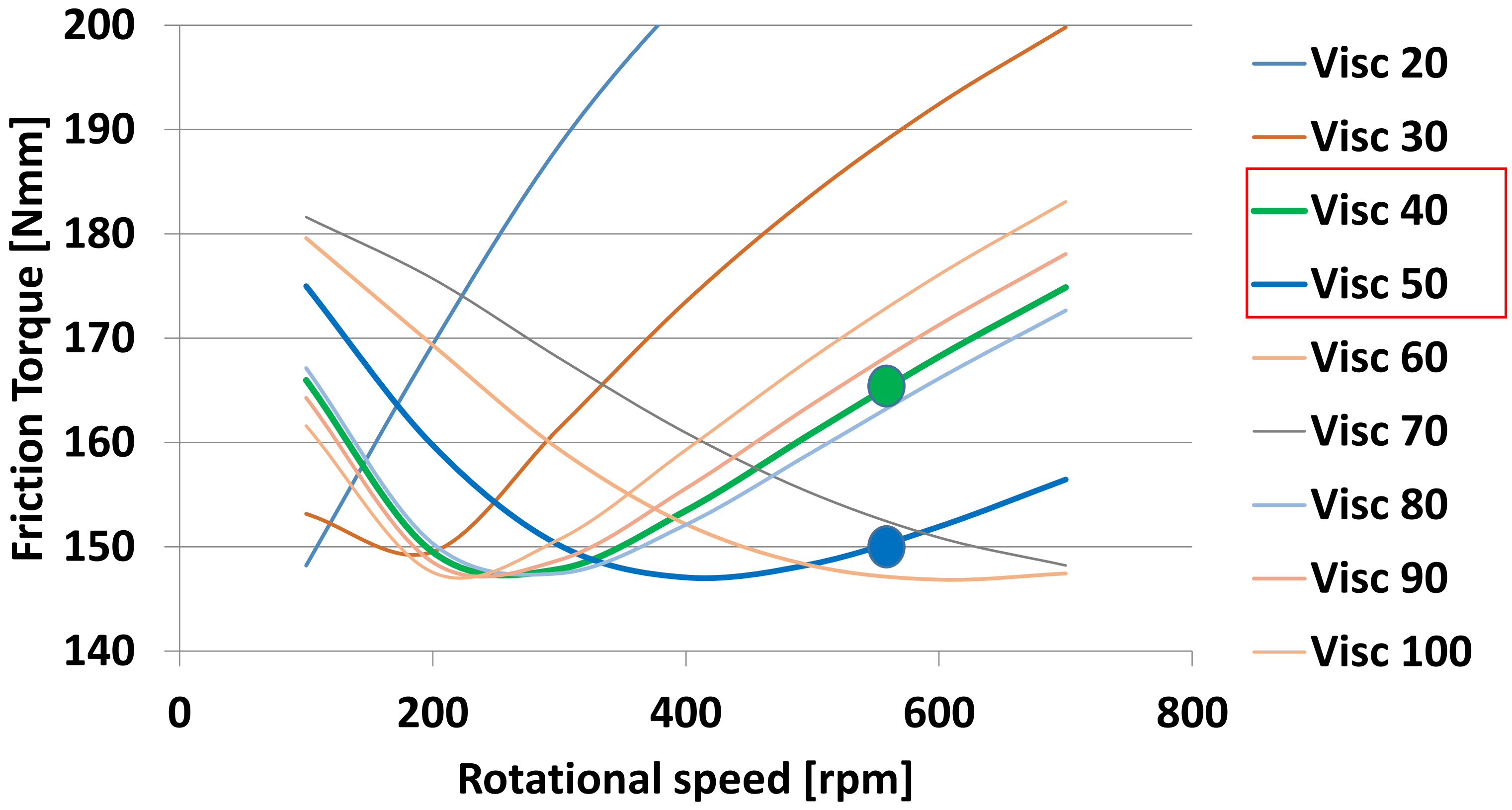
Grease C/D: ≈ 280 kh

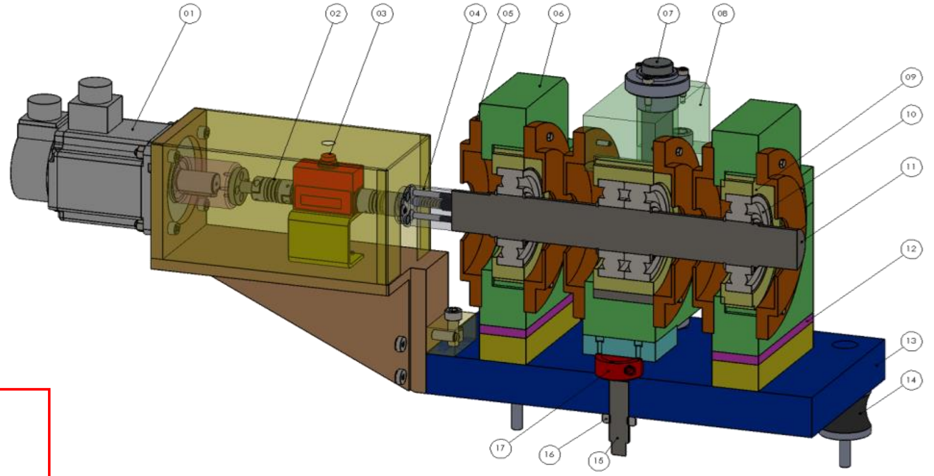
$L_{mhC/D}$ is 15 % > $L_{mhA/B}$

Viscosity parameter OK, but could be higher

Viscosity effect on friction torque loss

$$M_{total} = \varphi_{ish} \cdot \varphi_{rs} \cdot M_{rr} + M_{sl} + M_{drag} + M_{seal}$$





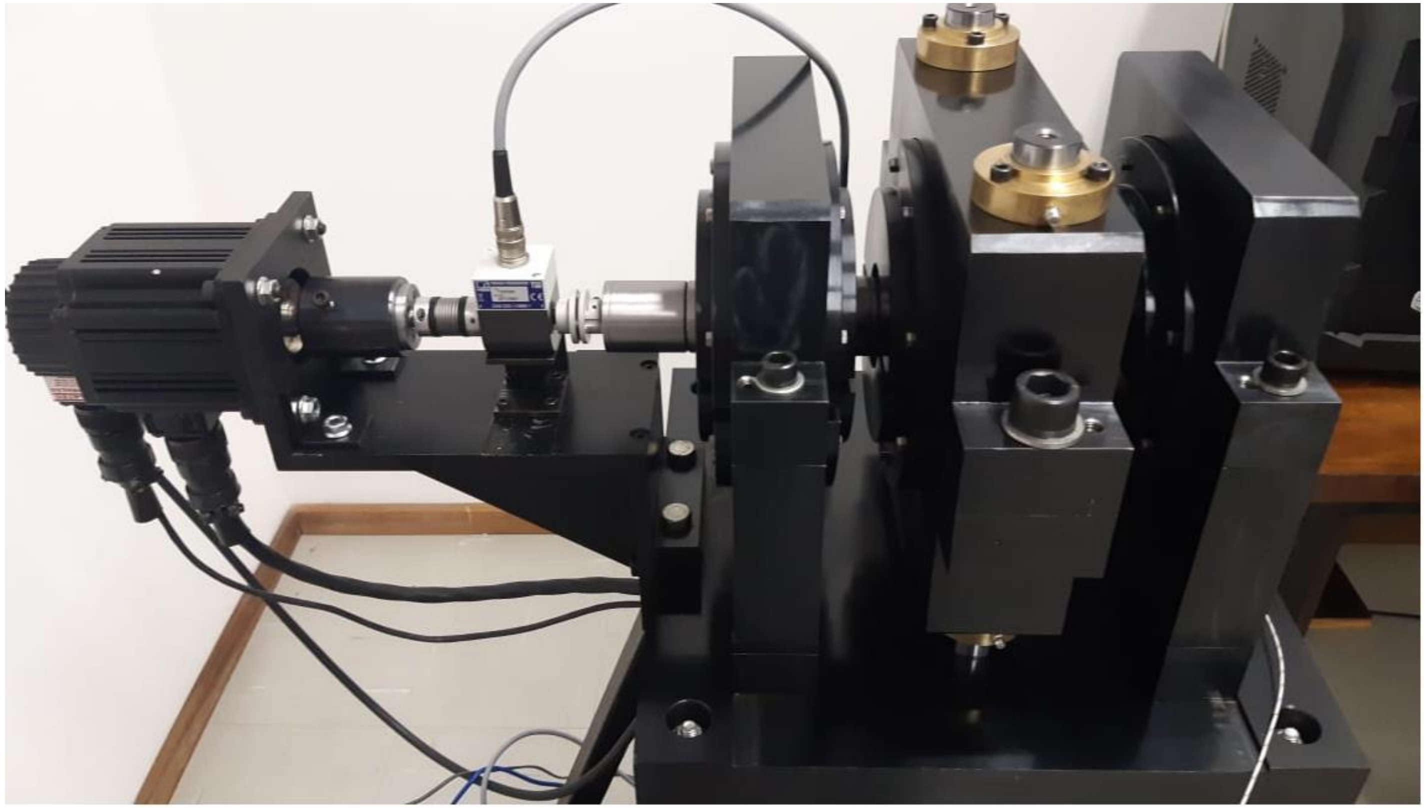
Rolling bearing 6309-2Z
Speed: 500 rpm
Temperature: 60°C
Load: 4000 N

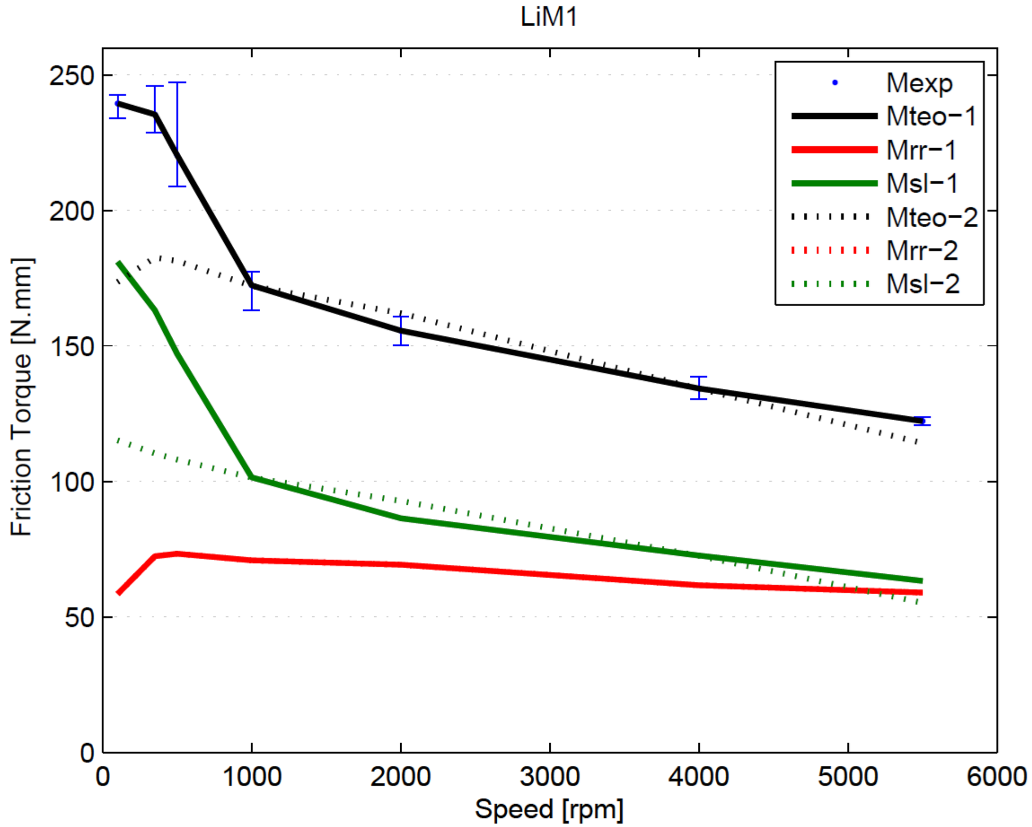
Grease A/B: ≈ 165 Nmm

Grease C/D: ≈ 150 Nmm

$L_{mhC/D}$ is 10 % < $L_{mhA/B}$

Rolling bearing power loss rig





Summary

- For the analyzed conveyor belt, operational viscosity should be increased from 40 cSt to 60 cSt.
- Such modification increases theoretical bearing life in ≈ 20% and efficiency in ≈ 15%
- Polyurea greases present longer life than lithium grease under usual idlers operating conditions
- Bearing power loss can be measured and the current models can be upgraded to include the effect of additives and thickener

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