KLÜBER LUBRICATION

your global specialist

Avoiding Component Failures

Increasing field reliability

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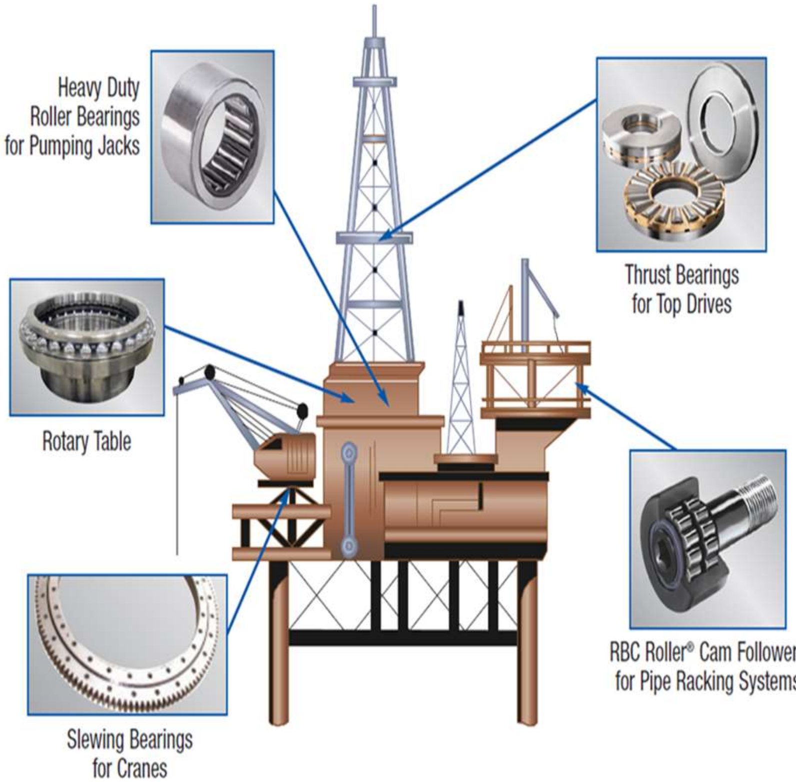
Agenda

- A few words about Kluber Lubrication
- Lubrication Fundamentals
  - Tribology
  - Oils and Greases
- Lubricant Selection for Bearings and Gears
- Bearing Failure Modes and Prevention
- Gears Failure Modes and Prevention
- Chains Failure Modes and Prevention
- Best Practices
  - Lube Storage and Shelf Life
  - Grease Gun Use and Fill Quantity
- Q and A



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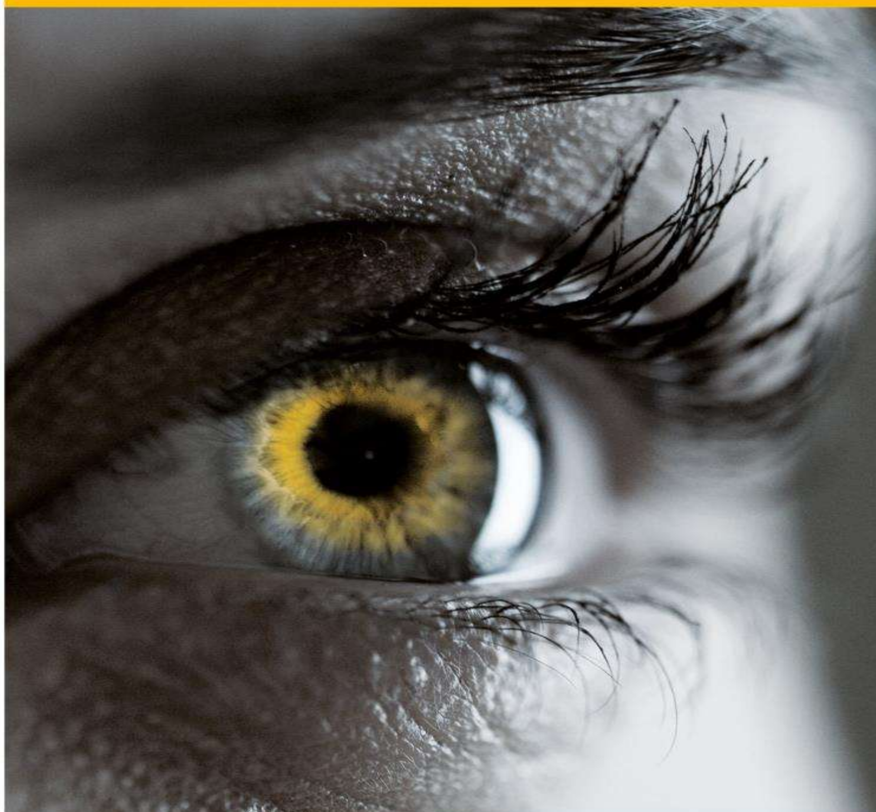
Pioneer in speciality lubricants since 1929



Founded by Theodor Klüber
A part of the Freudenberg group since 1966

Our Vision
To be the company of preference

To provide superior quality and customer value

To develop innovative solutions which save energy and resources

Appreciated for our values

Pioneers of passion

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More than 170 employees in research and development

Development centers and production in 6 continents

Unique test fields with more than 110 test benches

Customized test equipment

Extensive analytics

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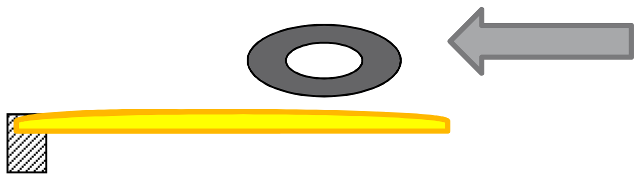
What is Tribology and the Function of a Lubricant?

Tribology – study of friction, wear and lubrication. It is the science of interacting surfaces.



Function of a lubricant:

- **The basic function of the lubricant is to reduce friction by separating the interacting surfaces.**
- **Viscosity of the oil will determine whether there is sufficient film.**
- **Additives can improve wear protection when the lubricating film is insufficient.**

Friction Conditions

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Boundary Friction

The surfaces of the friction components are in **intense contact** and covered with a **thin lubricant film**. **Wear** is excessively high.

Mixed Friction

The surfaces of the friction components have **some contact and** are **not separated completely**. **Wear** occurs usually within acceptable limits.

Fluid Friction

The surfaces of the friction components are **completely separated** by a lubricating film.

Viscosity

What is Viscosity?

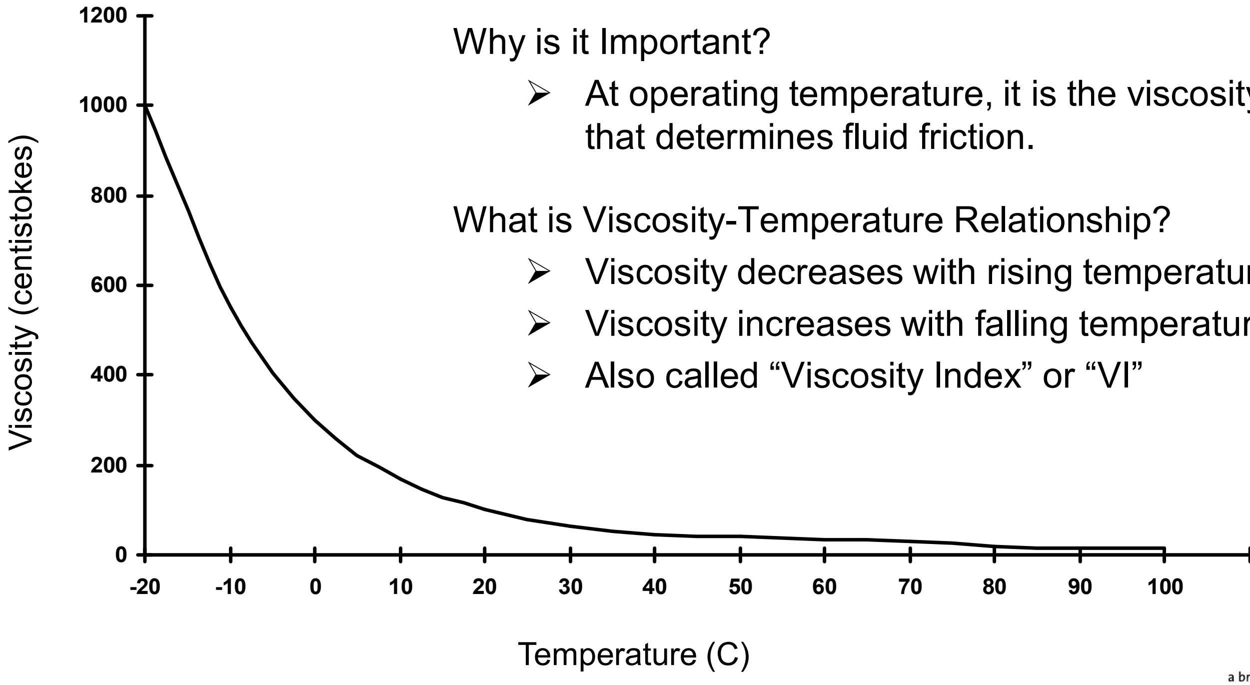
- It is the resistance of a fluid to flow.

Why is it Important?

- At operating temperature, it is the viscosity that determines fluid friction.

What is Viscosity-Temperature Relationship?

- Viscosity decreases with rising temperature
- Viscosity increases with falling temperature
- Also called "Viscosity Index" or "VI"



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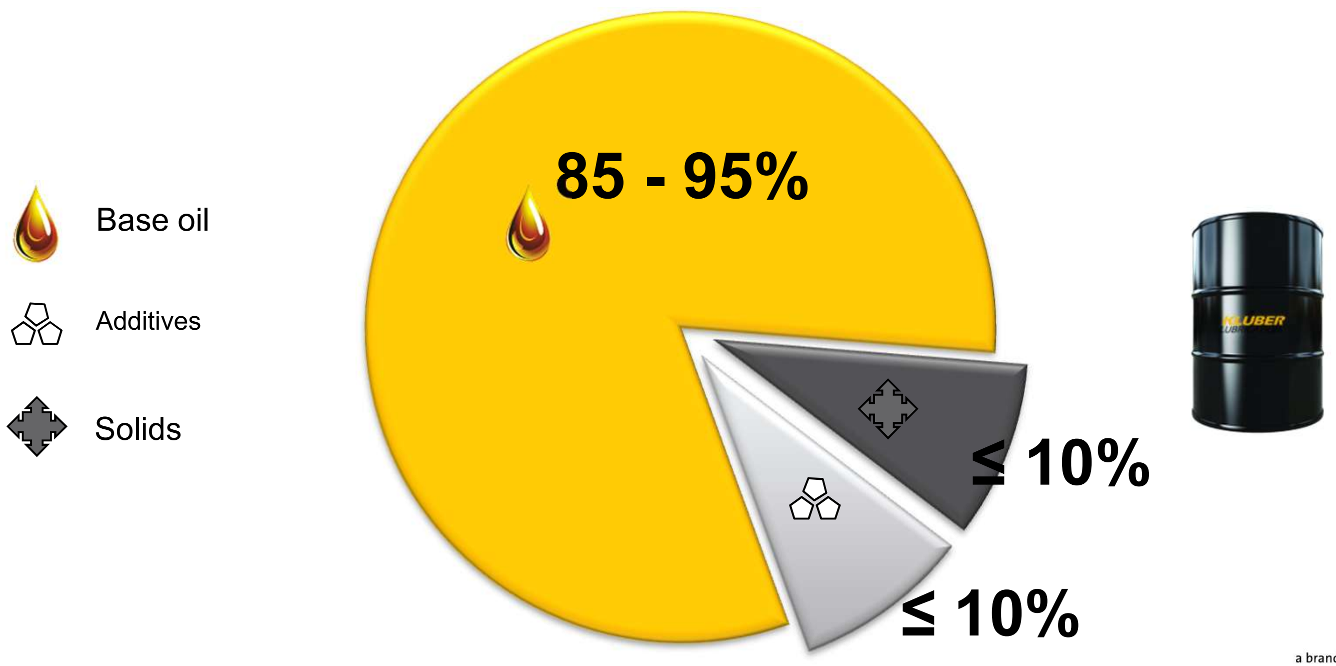
Lubricating Oils

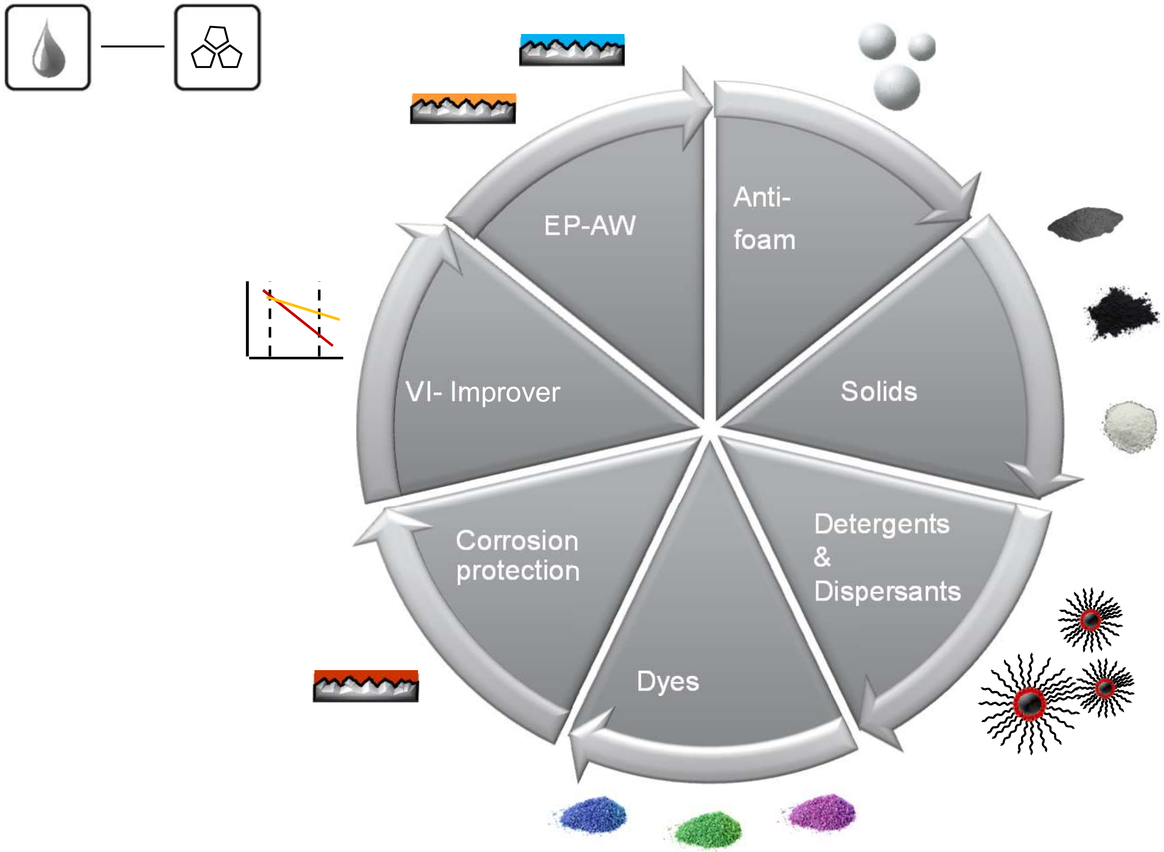
- Hydraulic Oil
- Machine Oil
- Gear Oil
- Chain Oil
- Motor Oil
- Compressor Oil
- Bearing Oil
- etc.

Lubricating Oils

Composition



Additives


EP-AW
Anti-
foam
Solids
Detergents
&
Dispersants
Dyes
Corrosion
protection
VI- Improver

Lubricating Oils

Synthetic oil vs. mineral oil

Advantages

- Longer lubricant life
- Longer relubrication intervals
- Reduced oil consumption
- Improved viscosity-temperature behavior
- Consistent behavior

Be aware of…

- Compatibility with elastomers
- Do-it-all oils
- Unrealistic temperature ranges

Temperature Ranges

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Mineral oil

➢Up to 100ºC (210ºF)

PAO

➢Up to 140ºC (280ºF)

PAG

➢Up to 160ºC (320ºF)

Ester

➢Up to 260ºC (500ºF)

PFPE

➢Up to 300ºC (572ºF)

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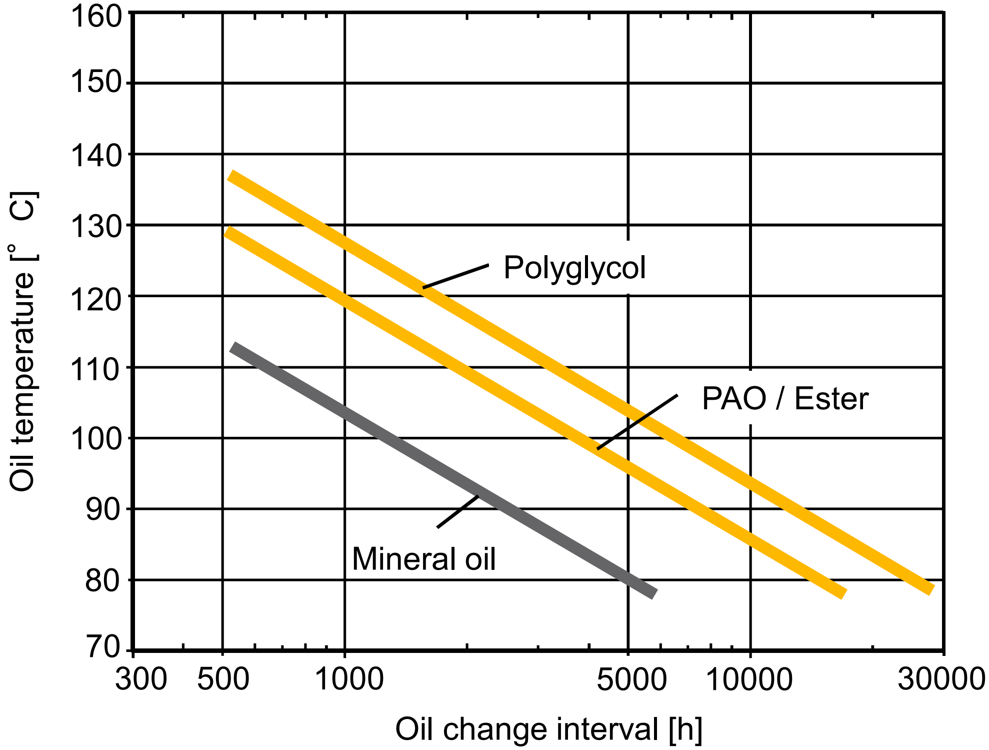
Achievable oil change intervals



15 K Rule

- For every 15ºC of temperature **increase**, the life of the oil is reduced by half
- For every 15ºC of temperature **decrease**, the life of the oil is doubled

Miscibility of base oils

	Mineral	PAO	Ester	PAG	Silicone	PFPE
Mineral	✓	✓	✓	✗	✗	✗
PAO	✓	✓	✓	✗	✗	✗
Ester	✓	✓	✓	?	?	✗
PAG	✗	✗	?	✓	✗	✗
Silicone	✗	✗	?	✗	✓	✗
PFPE	✗	✗	✗	✗	✗	✓

Influences on load-carrying capacity and efficiency

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Gear failure	Material	Construction / operating conditions	Lubricant
Tooth root breakage (tooth root strength)	X	X	-
Scuffing load-carrying capacity (scuffing load)	(X)	X	XX
Wear behaviour (wear limit)	(X)	X	XX
Pitting (flank strength)	X	X	X
Micropitting	X	X	X(X)
Efficiency	-	X	X
Overheating	-	X	X

XX strong influence X influence - no influence

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Lubricating grease

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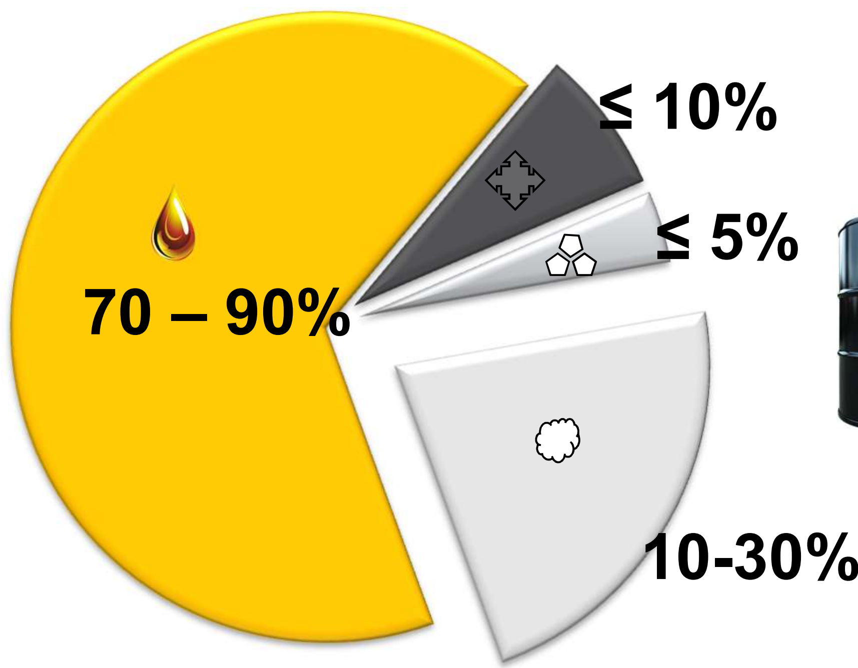
Composition

Base oil

Additives

Solids

Thickener



Grease Thickening Agents

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Metal Simple and Complex Soaps

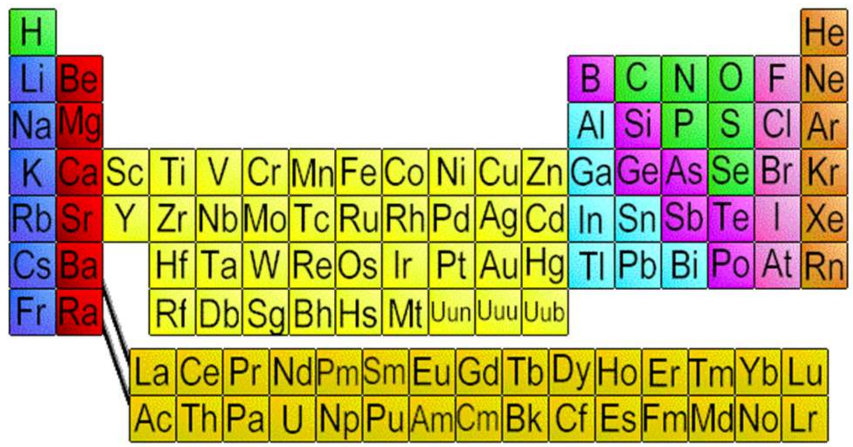
- Lithium
- Calcium
- Aluminum
- Sodium
- Barium

Gels

- Silica
- Bentonite

Others

- Polyurea
- PTFE



Grease Stiffness Classification

NLGI-Classes (DIN 51 818)

NLGI *National Lubricating Grease Institute*

NLGI- Class	Worked penetration in 0.10 mm		Application
000	445 to 475	fluid greases	Small gearboxes Central lubrication systems
00	400 to 430		
0	355 to 385		
1	310 to 340	soft greases	Bearings
2	265 to 295		
3	220 to 250		
4	175 to 205		
5	130 to160	hard greases	Seals, taps, and valves
6	85 to 115		

Lubricating grease

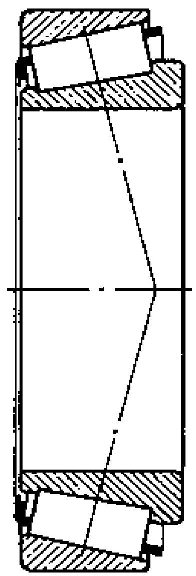
Thickener

Miscibility

	Soaps				Complex Soaps					Non-Soaps		
	AL	Ca	Li	Na	AL C	Ba C	Ca C	Li C	Na C	Bentonite	Polyurea	PTFE
Al	✓	?	✓	?	✓	?	✓	✓	?	✓	✓	✓
Ca	?	✓	✓	✓	✓	✓	✓	?	✓	✓	✓	✓
Li	✓	✓	✓	✗	✓	✓	✓	✓	✗	?	?	✓
Na	?	✓	✗	✓	✓	✓	?	?	✓	✗	✓	✓
Al C	✓	✓	✓	✓	✓	✓	?	✓	?	✗	✗	✓
Ba C	?	✓	✓	✓	✓	✓	?	?	✓	✓	?	✓
Ca C	✓	✓	✓	?	?	?	✓	✓	✓	?	✗	✓
Li C	✓	?	✓	?	✓	?	✓	✓	?	✓	?	✓
Na C	?	✓	✗	✓	?	✓	✓	?	✓	✗	✓	✓
Bentonite	✓	✓	?	✗	?	✓		✓	✗	✓	✓	✓
Polyurea	✓	✓	?	✓	?	?	✓	?	✓	✓	✓	✓
PTFE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Grease Selection Criteria

- **Type of Motion**
  - Rolling or Oscillating
  - Combined Sliding and Rolling
- **Speed**
- **Temperature**
- **Load**
- **Operating Environment**



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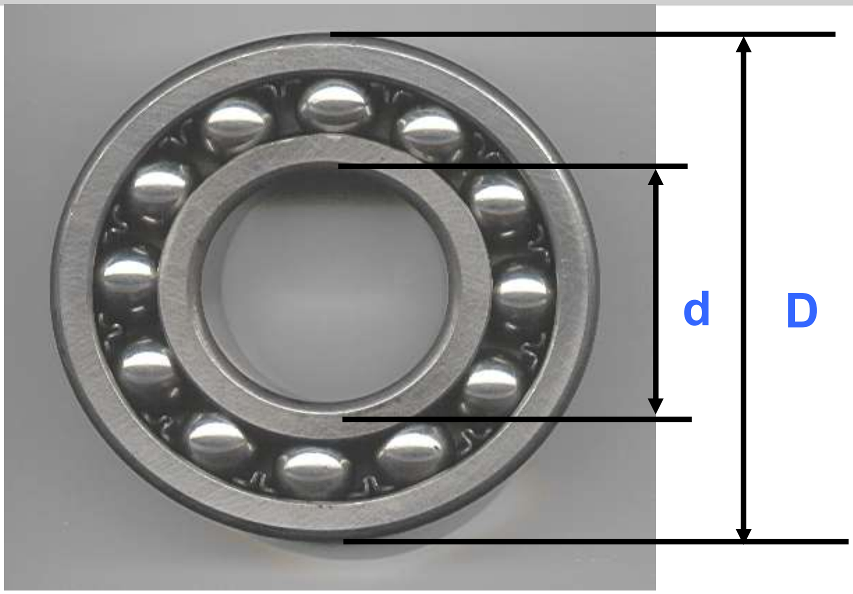
Speed Factor



d = Bearing inner diameter (mm)

D = Bearing outer diameter (mm)

n = Speed (rpm)

$$\frac{d + D}{2} \times n$$

= Speed factor (nDm)

< 50 000	low
100,000 – 500,000	medium
500,000 – 1,000,000	high
> 2,000,000	very high

Bearing Temperature

- Lubricant Selection is Dependent upon Bearing Temperature
- Bearing Temperature is influenced by the Lubricant Selection
- The Fifteen Degree Rule Applies
  - For Every 15ºC Change in Bearing Temperature, the Lubricant Life is Either Reduced by Half or Doubled

Industrial Gear Oil Functions

Prevention of gear damages

- Improvement of lubricant film formation
- Formation of reaction layers for surface protection
- Lower material fatigue

Efficiency improvement

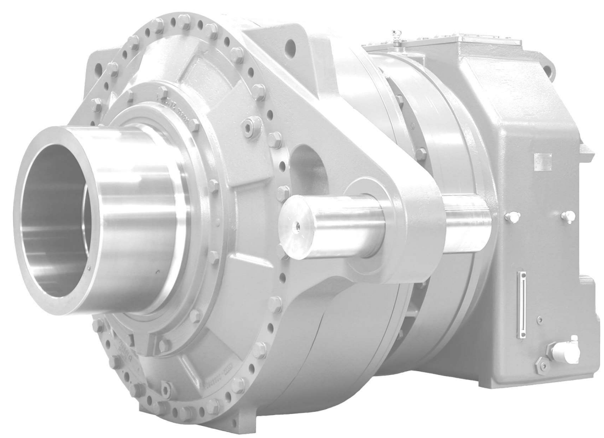
- Reduction of friction
- Especially for conditions of high sliding

Optimization of heat regulation in the gear box

- Higher operating temperatures
- Improved heat transfer

Clean gear box

- Dispersion of wear particles and oxidation products
- Low residue formation
- Good filterability



Properties of Gear Oils

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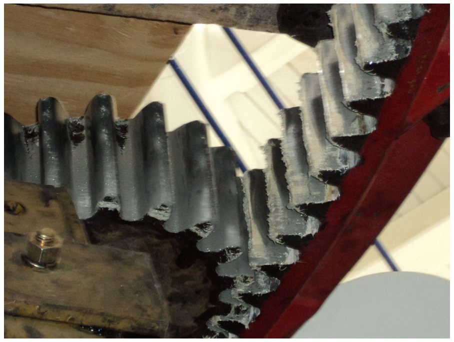
Properties	Mineral oil	Polyalphaolefin	Polyglycol
Viscosity-temperature behavior	OK	good	best
Ageing resistance	OK	good	best
Low-temperature characteristics	poor	best	good
Wear protection	OK	good	best
Friction coefficient	OK	good	best
Neutrality towards sealing materials and paints	best	best/OK	poor/good

Open Gears

Open Gear Lubricant Requirements:

- Adhesiveness
- Changing Temperatures
- Water, Chemicals, Dirt
- High Loading (additives/solids)



Gearbox Oil Change Concerns

Chemistry miscibility

- Mineral vs. PAO vs. PAG
- Be aware of reductions in performance or temperature viscosity relationship when mixing different chemistries

Contact Zone Compatibility

- Seals, Sight Glass, Paints, Metals

Gearbox Oil Change Procedure

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Steps

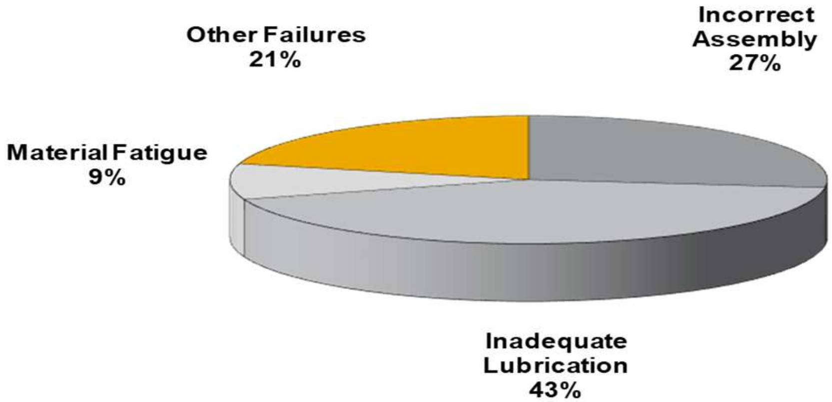
- Drain used gear oil completely while still warm
- Wipe sump with lint-free rag
- Fill with flushing oil (same product to be refilled later)
  - Removes wear particles, dissolves residue & dilutes remaining oil
- Drain flushing oil
  - This oil can be re-used for flushing other boxes but should not be used operationally
- Change filter, if applicable, and clean soiled gear components
- Insert and tighten drain plug
- Fill with fresh oil
- Run briefly, check oil levels, and take reference oil sample

Bearing Failure Modes and Prevention

https://www.maintworld.com/Applications/Use-Ultrasound-for-Low-Speed-Bearing-Monitoring

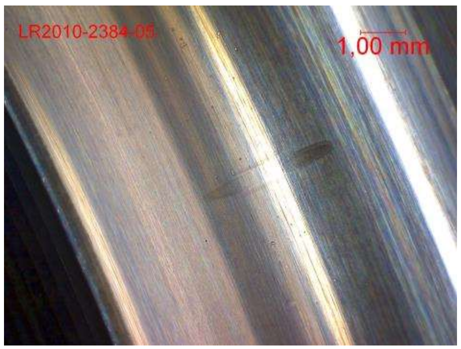
w.mobilegeneratorservice.com/trailer-bearing-repair.html

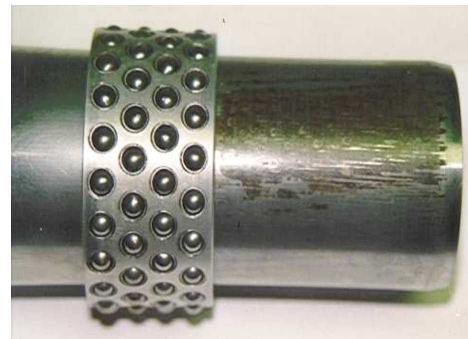
Rolling Bearing Failure Statistics

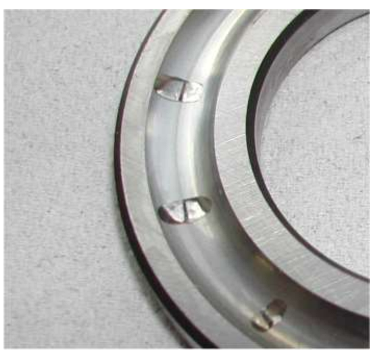


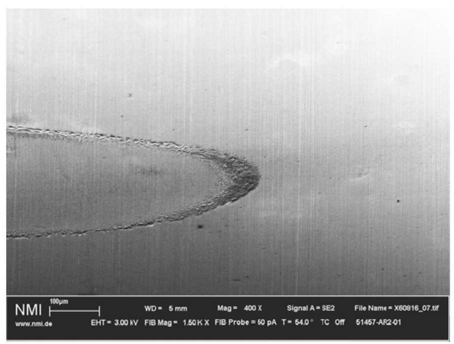
- Selection and use of the wrong lubricant !
- Mixing of different lubricants !
- Contamination of the lubricant !
- Lubricant loss from the bearing !
- Under lubrication or over lubrication !

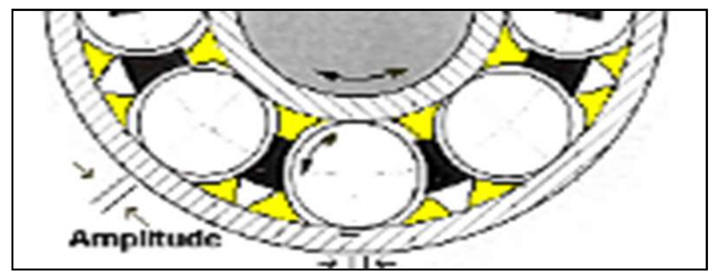
False Brinelling Effect





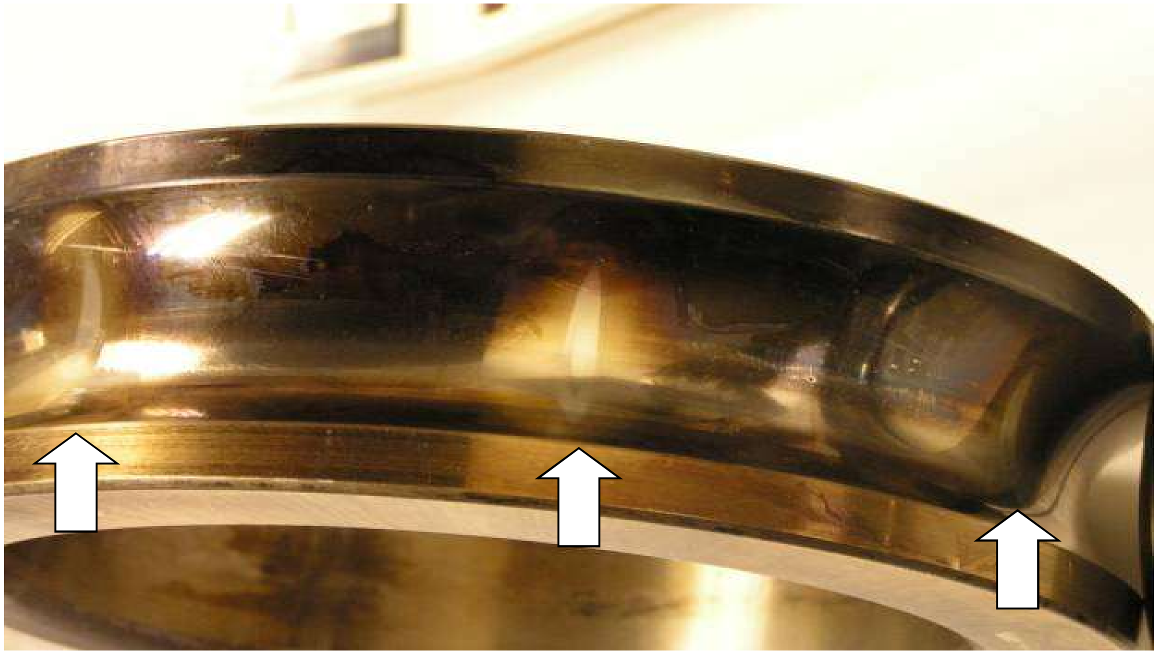






False brinelling damage occurs due to small oscillatory movements of the bearing inner ring and rolling elements during static “off load” conditions.

False Brinelling Effect



- Generator bearing
- SKF 6322 C3
- Non Drive End
- 1500 rpm
- Standard Polyurea Grease

Competitor product 1: wear limits were exceeded so test had to be stopped after 13.5 hours.

Competitor product 2: wear limits were exceeded so test had to be stopped after 39.6 hours.

Klüberplex BEM 41-141 attained maximum run-time of 50 hours.

How to prevent False Brinelling damage?

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- Prepare newly manufactured bearings with

  Lubricating fluids for rolling bearings subjected to frequent oscillation and/or rotating movements.

- Protect against False Brinelling failures with

  Lubricants with specially designed base oil to provide fluid film in oscillatory movements

  A proper additive package can provide boundary lubrication protection

  Improved corrosion protection

  Improved bearing wear protection

  Improved bearing operational reliability

  Lower Total Cost of Ownership

Corrosion Failure of Bearings

Lubricant: Mineral Lithium EP 2 grease

Mud agitator bearing

Failure cause :

Ingress of brine water into the bearing resulting in washout of the grease and severe corrosion.

EMCOR test bearing

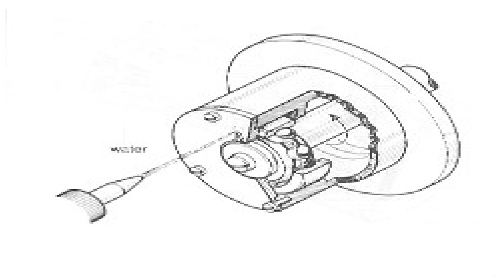
Failure cause :

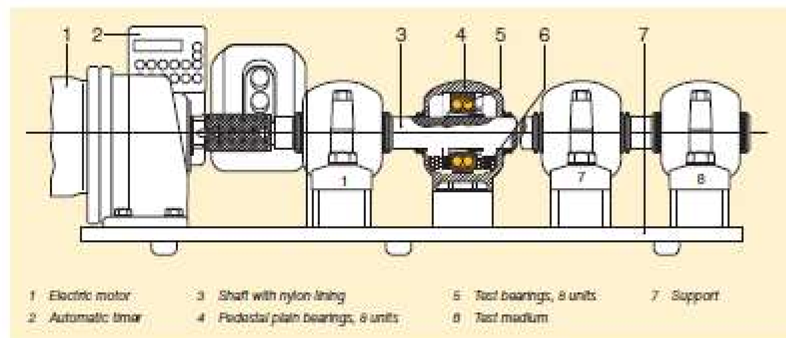
Corrosion spots developed at ball / raceway contact points when the test bearing was stationary.

Corrosion occurred due to water absorption into the grease thickener system.

Washout and Corrosion Failure Prevention

- Select greases with water resistant thickener types (ie. Barium, Calcium Complex)
- Select greases with high apparent dynamic viscosity for best sealing effect
- Select greases with high base oil viscosity (within recommended operating range)
- Select greases with high NLGI classification





EMCOR machine

Water Washout can be measured by spraying a rotating bearing with media and determining greases ability to stay in the bearing.

EMCOR test rig can also be used to measure a greases ability to provide corrosion protection with still water or sea water.

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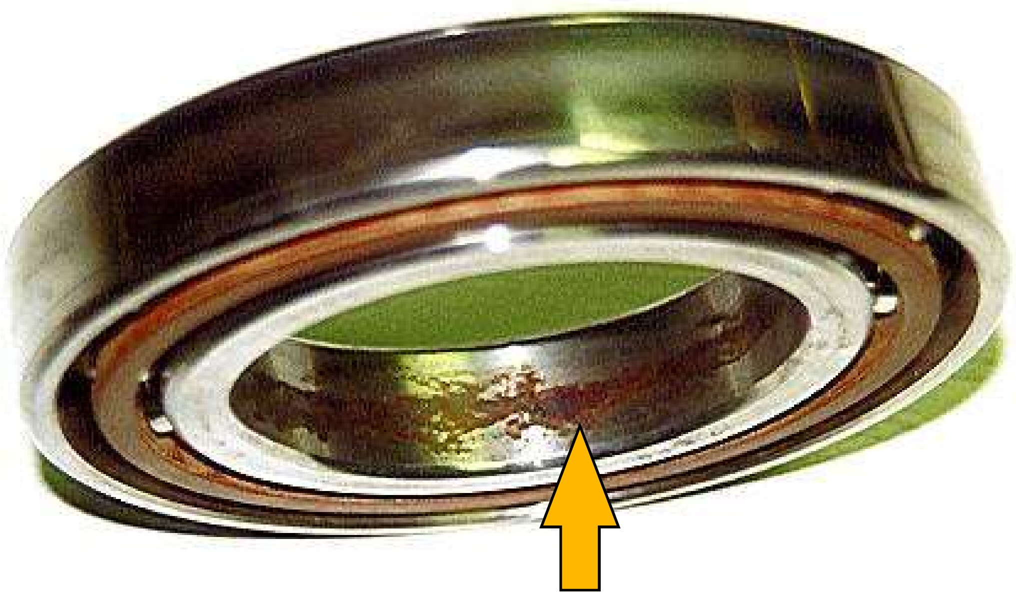
Fretting Failure of Bearings



Machine Tool Spindle Bearing

Failure cause(s) :

Fretting corrosion scars clearly visible between the bearing inner ring and spindle location from which the characteristic red - brown, fretted oxide, particles are released. Fretting corrosion occurs at interfaces due to :

- ➢ Bearing fits being too loose
- ➢ Vibration
- ➢ Micro oscillation
- ➢ Bearing creeping effect

Fretting Corrosion in Tapered Roller Bearing

Drive Coupling Safety Element Bearing

Failure cause(s) :

Drive coupling rotates with central support bearing remaining “stationary” though subject to micro oscillation. This motion induces lubricant loss, false brinelling and eventual fretting of bearing raceways due to the absence of a separating / lubricating film. Lubricating grease becomes heavily loaded with characteristic red-brown fretted oxides invoking excessive bearing wear and ineffective release of the Safety Element during emergency overload situation!

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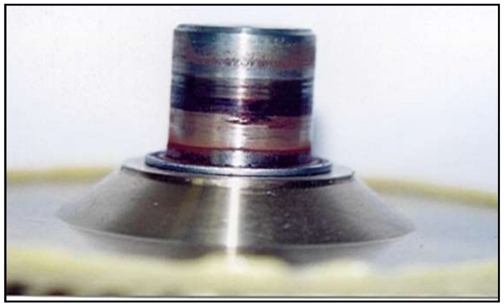
Prevention of Fretting Corrosion



Apply a thin layer of anti fretting paste to bearing and shaft interfaces to minimise or prevent the development of fretting corrosion.

- Reduces assembly and disassembly forces (eliminates assembly damage)
- Allows bearings to “slide” thus enabling thermal shaft movement (often utilizing solids)
- Prevents wear through reduction of fretting oxide debris
- Prevents seizure through reduction of fretting oxide debris
- Improves equipment reliability…… Reduces costs!

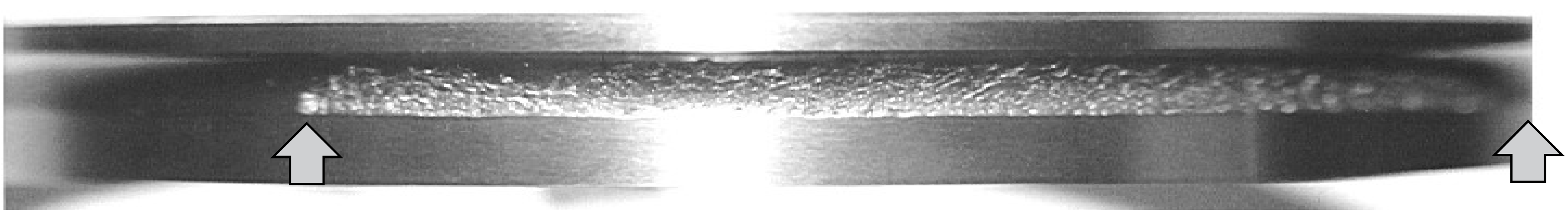
Raceway Fatigue in Angular Contact Ball Bearing

Formula 1 Front Wheel Bearing

Failure cause :

Fatigue of raceway after only 410 km operation.
Failure believed to result from :

- Extreme contact pressure
- Poor Wetting of Lubricant
- Insufficient EP/AW Additives



Raceway Fatigue
Deep Groove Ball Bearing

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Pulley Drive Clutch Bearing

Failure cause(s) :

- Fatigue failure of clutch bearing subject to outer ring rotation following its 40 year service life.
- Lubrication starvation of bearing inner ring raceway resulted in inevitable surface fatigue. Severe fatigue spalling craters are evident around the entire bearing inner ring with lesser damage visible on the corresponding outer ring raceway.

All bearings may eventually end this way !

Raceway Failure Solution

http://www.skysports.com/football/news/11664/11296214/what-would-premier-league-kits-look-like-on-formula-one-cars

- Choose product with appropriate NDM (speed rating) for application
- EP and AW package for applications with high pressure
- Appropriate base oil to handle temperatures and lifetime
- Reduce contamination by increasing lubrication intervals
- Especially in cases with outer ring rotation proper wetting is CRITICAL

Failure Mode - Electrical Erosion

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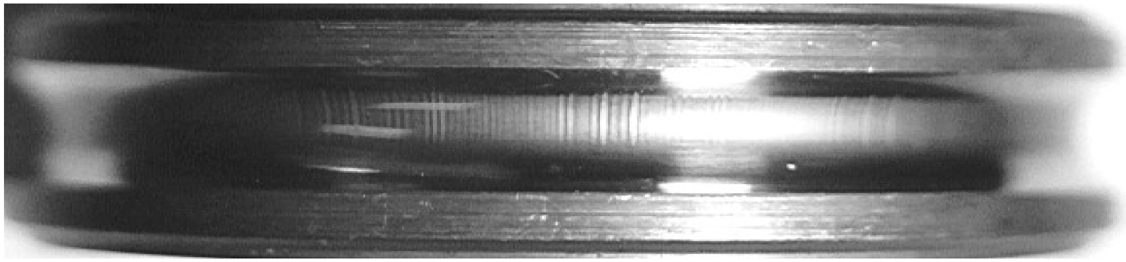

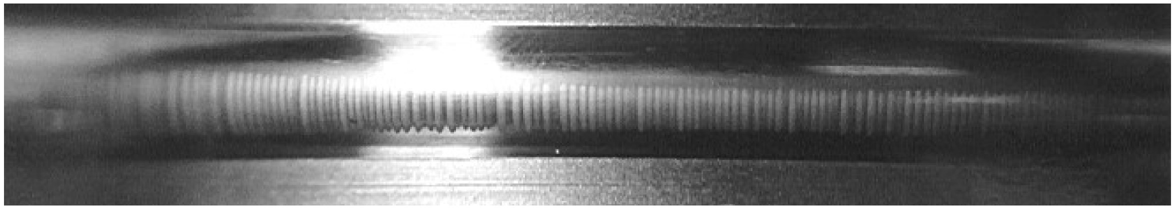

Failure cause :

- Electrical erosion in hertzian contact zones
- "Bar code" markings from electrical arcing damage.
- Damaged bearings become extremely noisy with increased vibration levels followed by rapid mechanical seizure or cage failure

Problem in industry

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Generator Fan - 11 months in operation

Generator Fan

- SKF 6324 C3
- Speed 1125 rpm
- Ambient temperature
- Dusty environment
- 315 KW motor

Electrical Erosion Prevention

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Lubricants which are designed to:

- Prevent of electrical erosion damage
- Dissipate of electrical energy
- Improve bearing operational reliability
- Improve wear protection
- Extend bearing life reducing overall costs

Uses..

- Electric motor bearings
- Inverter driven bearing applications
- Conveyor bearings
- Plastic processing bearing applications
- Areas where static electricity may develop

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High Temperature Lubricant Failure in Full Compliment Conveyor Bearing

Overhead Conveyor Bearing

Failure cause :

Thermally induced decomposition of lubricant following 1 months operation in a paint stoving installation at 250 ° C (482 F).

Lubricant decomposition led to bearing skidding following mechanical seizure of the rolling elements.

The “high temperature” hydrocarbon based conveyor lubricant was thereafter deemed unsuitable for the high temperature process conditions.

High Temperature Lubricant Failure in Full Compliment Conveyor Bearing

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Overhead Conveyor Bearing

Failure cause :

Lubricant decomposition, paint stoving installation at 230° C (446 F). Bearing seizure.

Choosing the right base oil for High Temperatures

- Possess a very high viscosity index
- Are chemically inert
- Are compatible with metals and plastics
- Are not flammable
- Resistant to oxidation

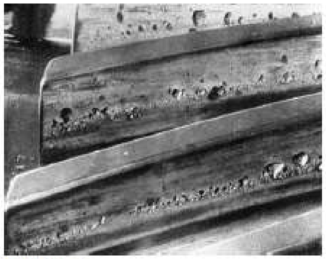
- Can operate from -90C to 300, basically unchanged
- Do not carbonize like esters and PAOs
- Do not migrate like silicones
- Have negligible evaporation loss

Gear Box Failure Modes and Prevention

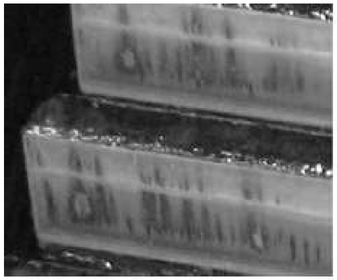

https://www.maintenance.org/topic/planetary-gearbox-failure-photos

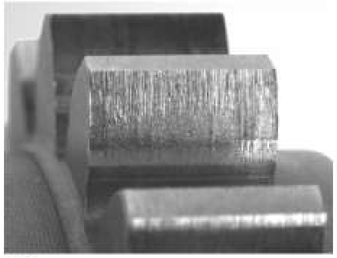
Top Drive Gear Box

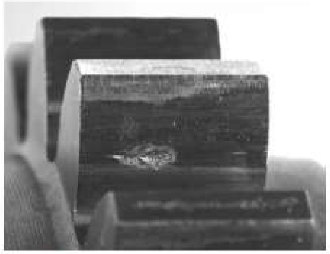
Failure Modes in Gear Boxes

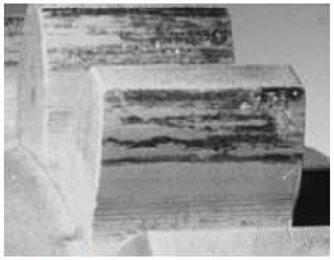

Pitting


Scuffing


Scuffing


Wear


Pitting

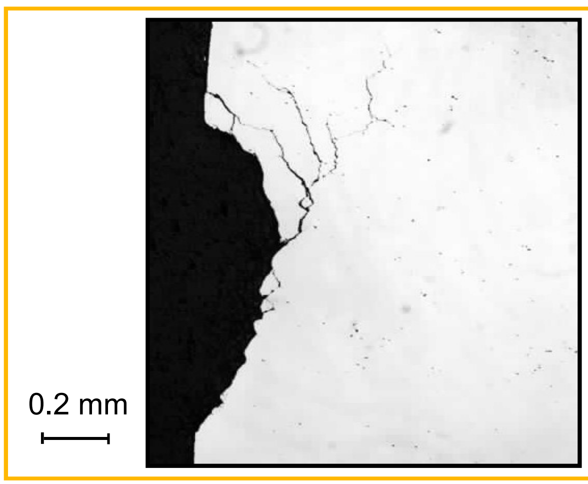

Micropitting

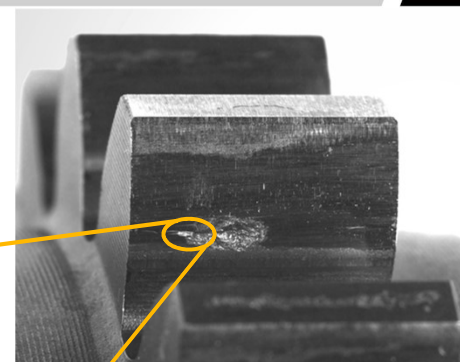
Industrial gear

Pitting failure

Pitting failure
Definition

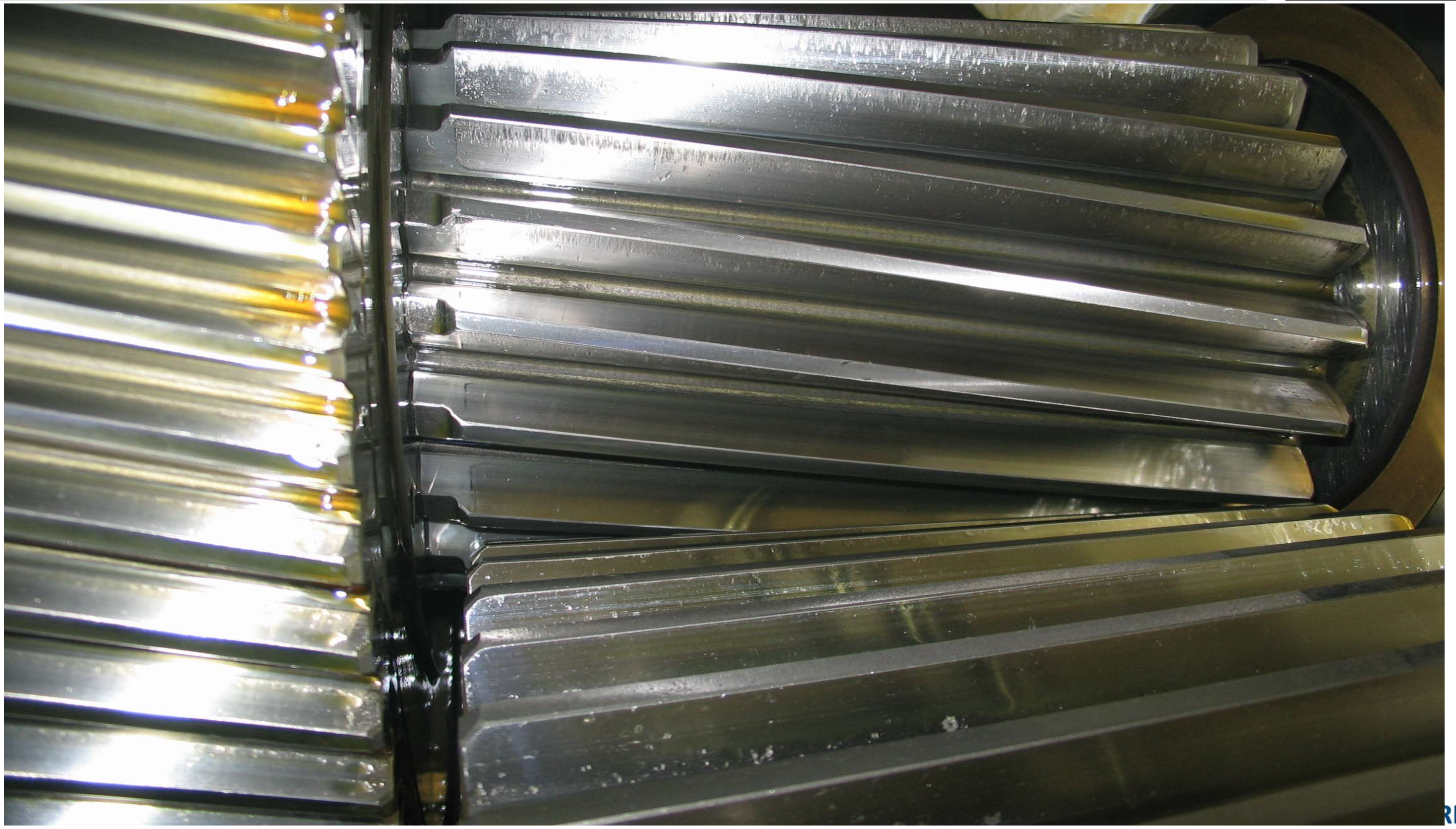
- Fatigue failure
- Mostly in the area of negative specific sliding
- Shell-shaped material loss out of the surface of tooth flanks (Pitting)
- Different pitting shapes





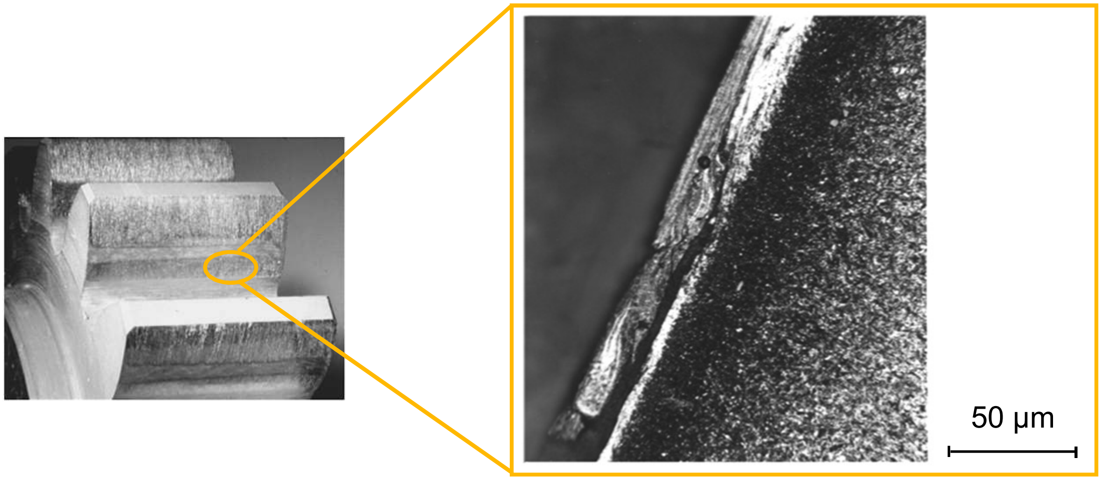
- Consequential failures possible

Industrial gear
Scuffing failure



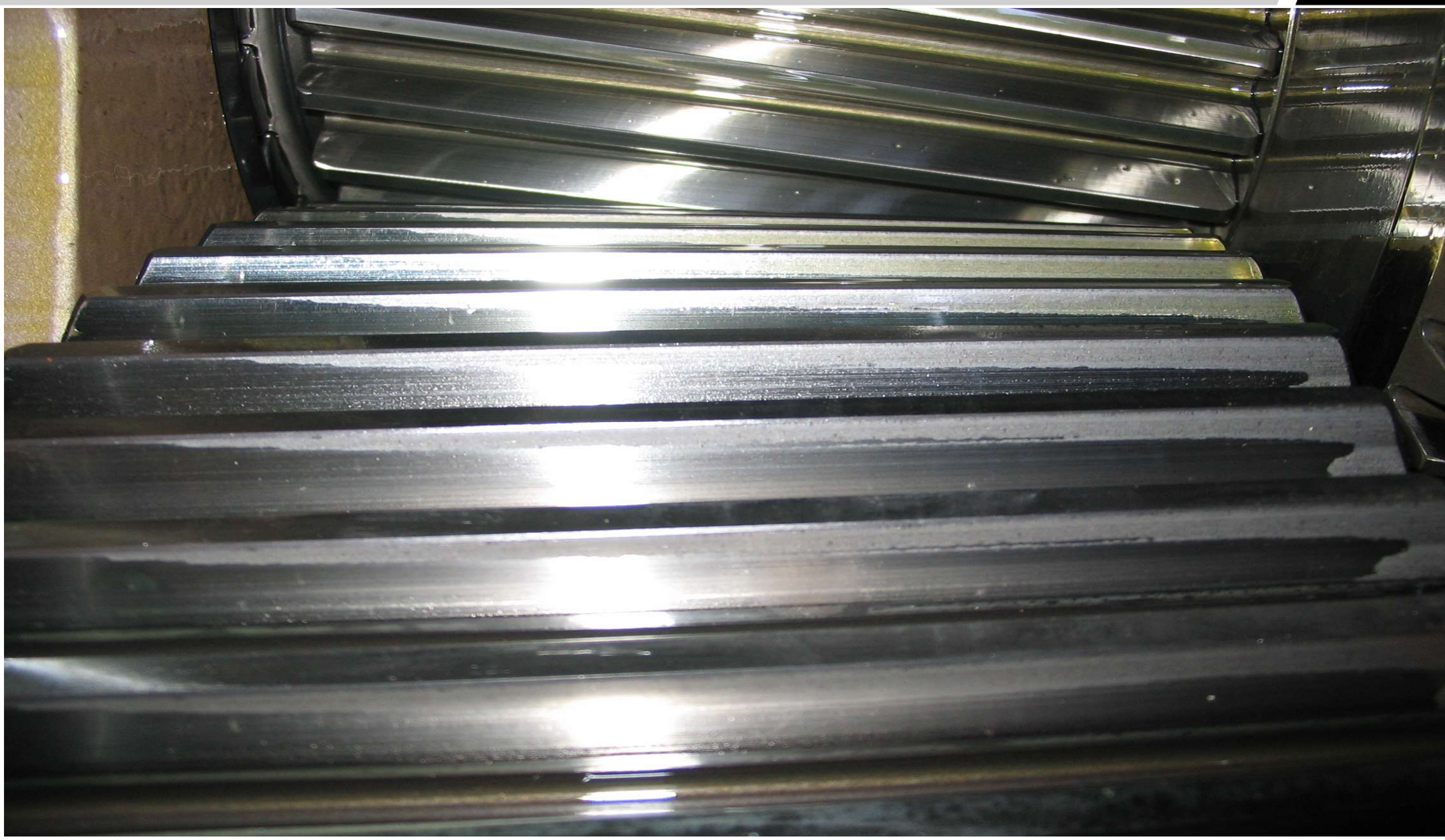
Scuffing failure
Definition

- Scuffing occurs at failure of the surface protection
- Too high surface temperatures in the tooth contact
- Local welding of the tooth flanks of pinion and wheel, torn apart immediately due to the rotation



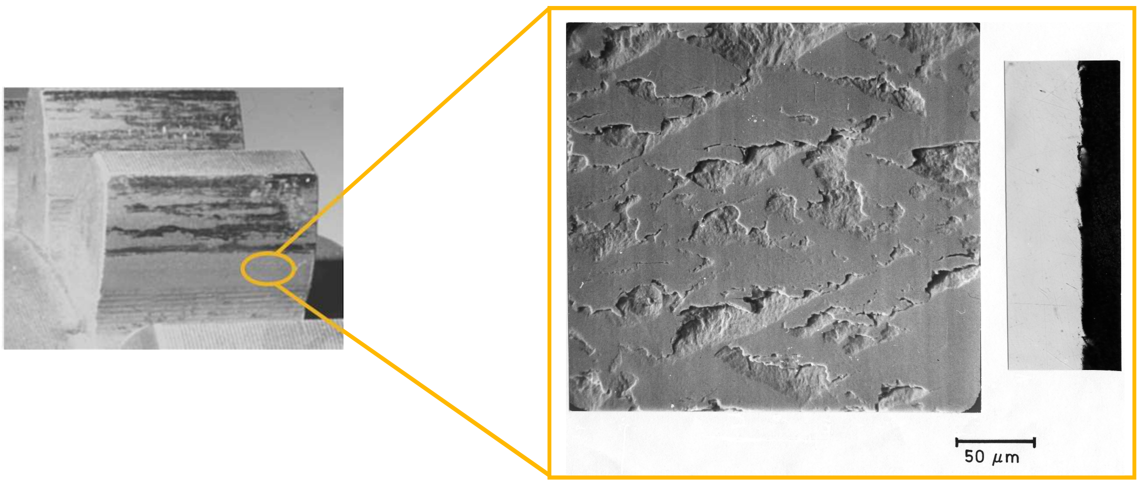
- Irreversible surface damage
- Consequential failures possible

Industrial gear
Micropitting failure



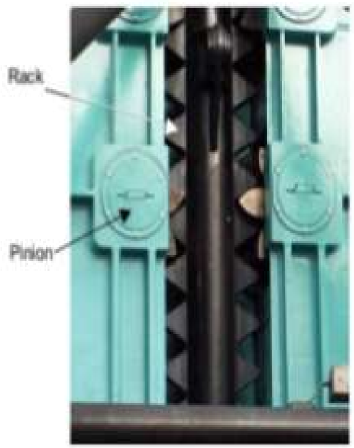
Micropitting failure
Definition

- Fatigue failure
- Particularly on the tooth flanks of case hardened gears
- Finest cracks and pores on the surface of tooth flanks (Micro pittings)
- Greyish coloration

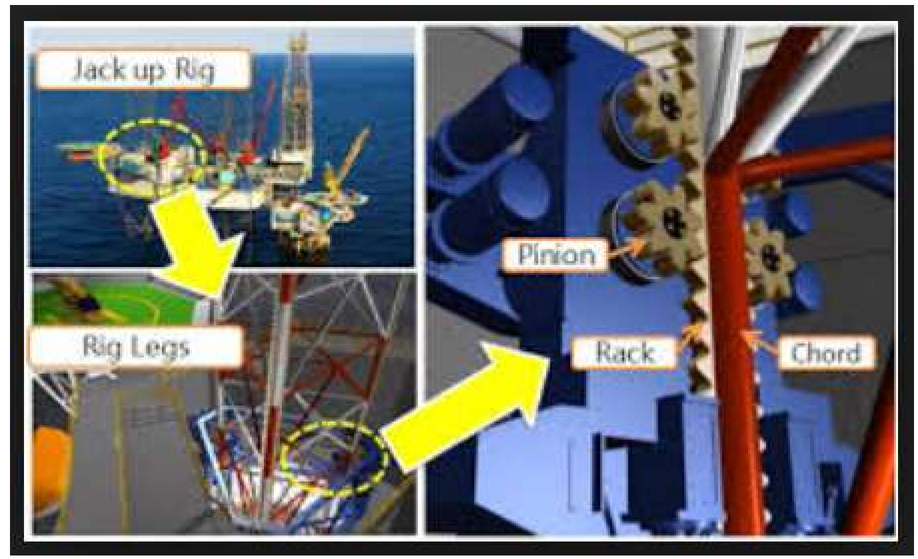


- Irreversible material loss and change of the profile form of the tooth flanks
- Consequential failures possible

Jack up leg gearbox



Demonstration of the pinion working mechanism



Jack up pinion wear

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Chain Failure Modes and Prevention

Lubrication of Chains

Chains are Typically Exposed to:

- Outdoor Weather Conditions
- Changing Temperatures
- Water and Chemicals
- Shock Loads
- Localized Loading on the Bushing

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Lubrication of Chains

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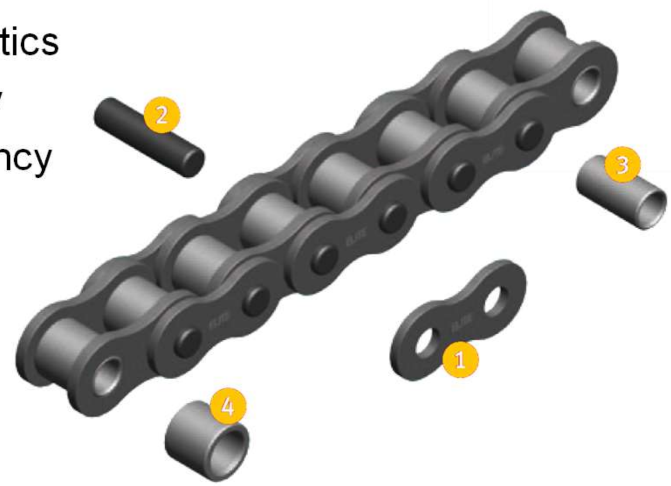
Requirements of Chain Lubricants:

- Good Adhesion
- Corrosion Protection
- Resistance to Media
- Good Spreading Characteristics
- High Load Carrying Capacity
- Low Carbon Forming Tendency



1. Chain plates
2. Pins
3. Bushes
4. Roller

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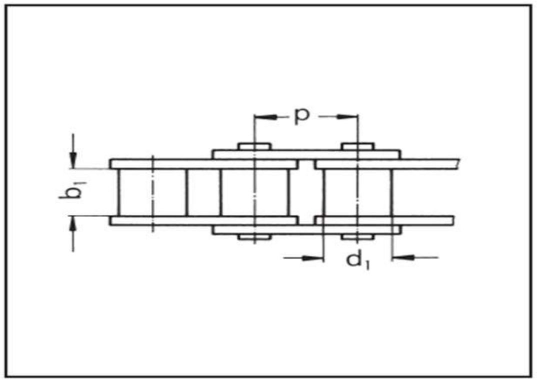
Improper Lubrication

Worn out pin

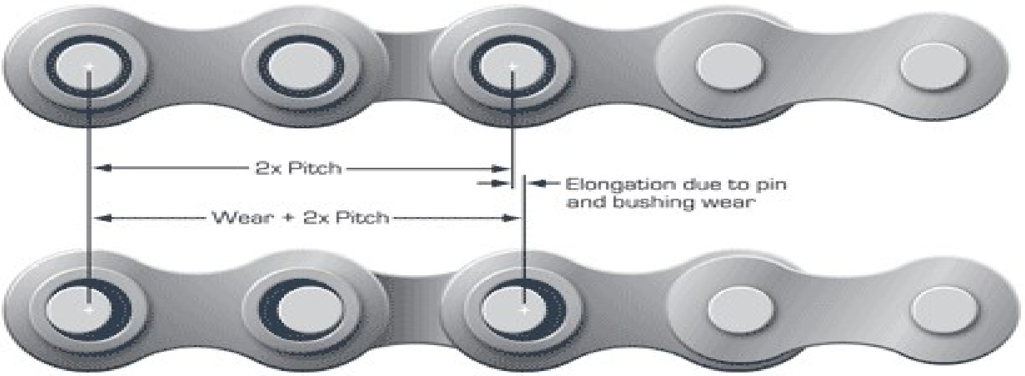
http://www.chainweargauge.com/roller-chain-inspection/worn-roller-chain-sprockets-replacement/17-leaf-chain-inspection

Remember Me?



The size of the chain is determined by the pitch p, the inner width b_1 and the diameters of the rollers or bushes d_1 respectively. Multiplying pitch p with the number of links X gives the length L of the chain.

$$L = p \cdot X \quad [mm]$$



Preventing premature chain elongation

Scope
Behaviour of chain lubricants under actual service conditions and influencing factors

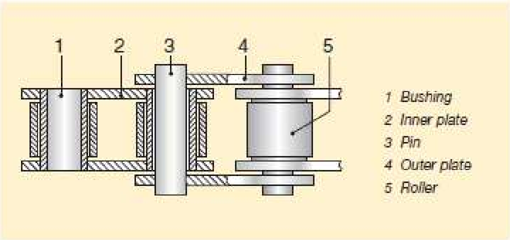
Standard
Klüber test conditions

Specimen
Roller chain 1/2"
DIN 8187 – 08 B – 1 x 82 E

Test conditions

Speed:	0.1 to 8 ms^{-1} standard: 1.6 / 2.4 / 4.8 ms^{-1}
Strand force:	200 N to 3500 N standard: 1500 N / 1000 N / 200 N 500 N / 800 N
Ambient temperature:	– 40 to 150 °C standard: room temperature
Duration of test:	up to 1000 h standard: 150 h

Procedure
- ❑ Apply lubricant on two test chains
- ❑ Mount the chains in the test rig
- ❑ Set the test parameters
- ❑ Record and document the service parameters and tribological data



Single roller chain DIN 8187

Result
A
Wear and friction values by continuously recording the
- ❑ Chain length
- ❑ Electric power consumption and change of the drive motor (friction)
- ❑ Drive torque (non-standard)
- ❑ Temperature of the circulating test chains
- ❑ Speed, load and strand force (load parameters)

B
- ❑ Running time until reaching the defined chain elongation, e.g. 0.1%

High viscous chain oil =

Provide emergency lubrication for chain operating at various speeds
- ➢ Penetrates chain to get into pin and bushing
- ➢ Highly viscous and adhesive products stays in necessary place
- ➢ Improved wear protection
- ➢ Extended chain life reducing overall costs

Uses..
- ➢ Draw works
- ➢ Motion Compensators
- ➢ Cat walks
- ➢ Etc.

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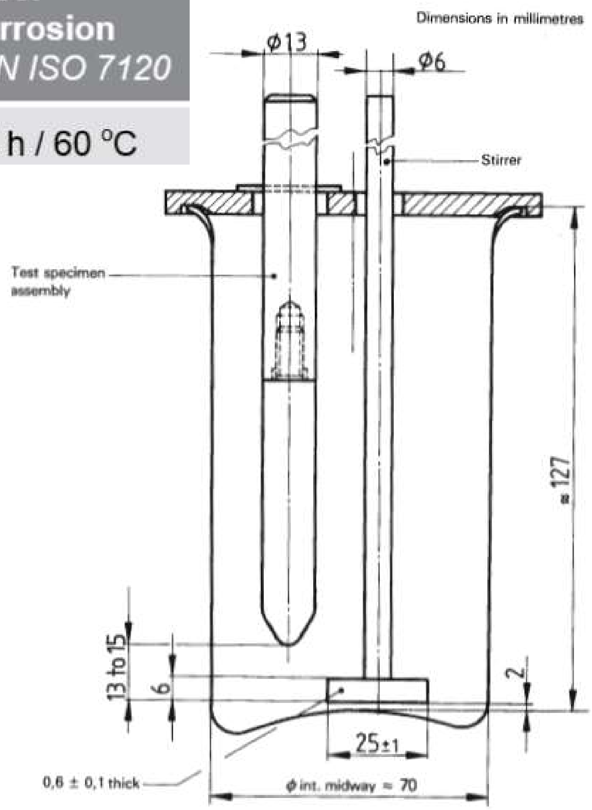
Prevention of chain corrosion

Steel corrosion
DIN ISO 7120

24 h / 60 °C



Specialty adhesive lubricants

=

- Adhesive to avoid chemical or water washout
- Anti Corrosion Package to resist oxidation
- Improved chain life reducing overall cost
- Improved wear protection
- Improve safety for all workers near the application

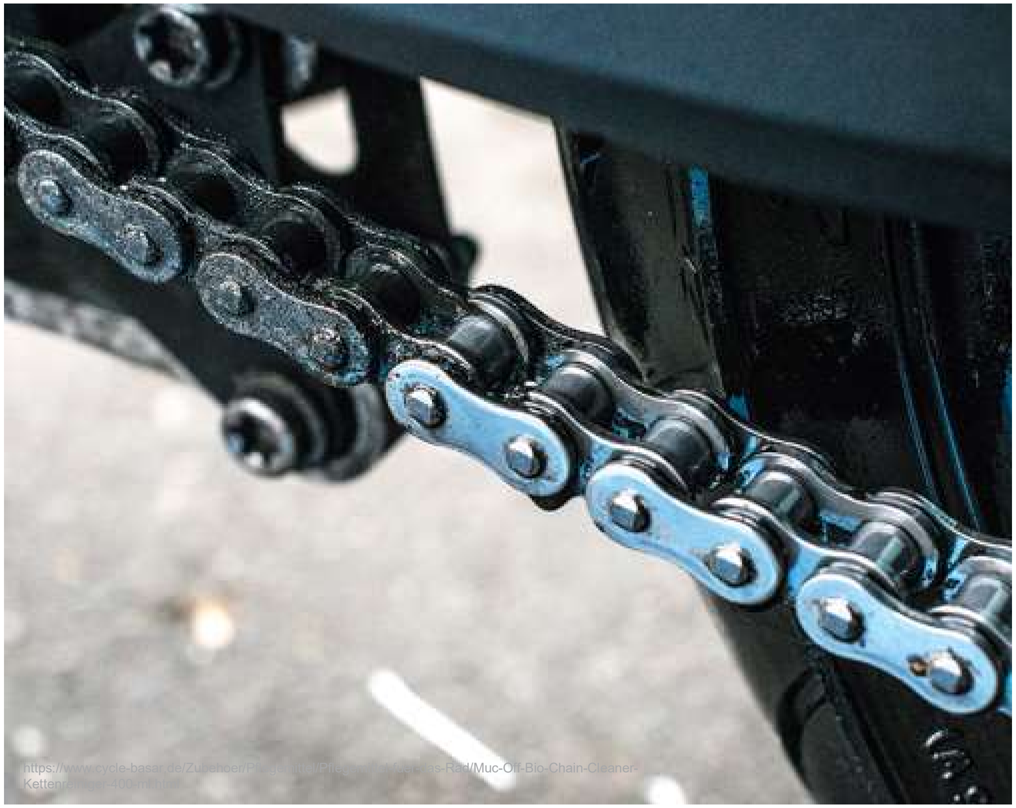
Uses..

- Chains exposed to chemicals
- Chains used outside

Chain Residue Formation Failures

http://www.chainweargauge.com/roller-chain-inspection/worn-roller-chain-sprockets-replacement/17-leaf-chain-inspection

Prevention of chain residue formation



Lubricating oils with cleaning effect

=

- ➢ High Temperature chains or chains in dirty environments
- ➢ Choose a product with solvent in the lubricant: Clean and Lubricate at the same time
- ➢ Not required to stop operation to clean chain
- ➢ Improved wear protection
- ➢ Improve safety by not requiring use of harsh chemicals to clean them, but also providing lubrication

Best Practices

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Lube Storage

- Minimizing risk
- Containers must be closed
- Properly labeled
- Cleanliness
- Awareness

Best Practices

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Shelf Life of Lubricants

- Specified from the date of manufacture
- Unopened container
- Stored indoors in a dry location
- Approximated
- NOT an expiration time (check it)

Best Practices

Grease gun storage

- Unpressurized
- Clean, cool, dry area and in a horizontal position to help keep the oil from bleeding out of the grease
- Cover the coupler to keep free from dirt and contaminates
- Calibrate grease guns regularly to ensure proper delivery amounts

Best Practices

Grease Gun Preparation Procedure

- Calibrate the delivery volume
- Label grease gun to ensure that the correct product is used consistently
- Use a vent plug to help flush old grease and reduce the risk of too much pressure on seals
- Avoid contamination while loading the grease gun
  - If using a cartridge, avoid metal slivers from the metal lid
- Match the label on the gun to the label at the lube point

Best Practices

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Grease Gun Preparation Procedure

- Clean the dispensing nozzle and grease fitting before attaching the grease gun. Pump a small amount onto a rag.
- Lubricate the bearing SLOWLY while it is rotating (if possible)
- Clean the grease fitting after applying grease
- Use grease fitting caps to keep them clean

Best Practices

Establish a proper Bearing Fill Quantity

Under Lubrication

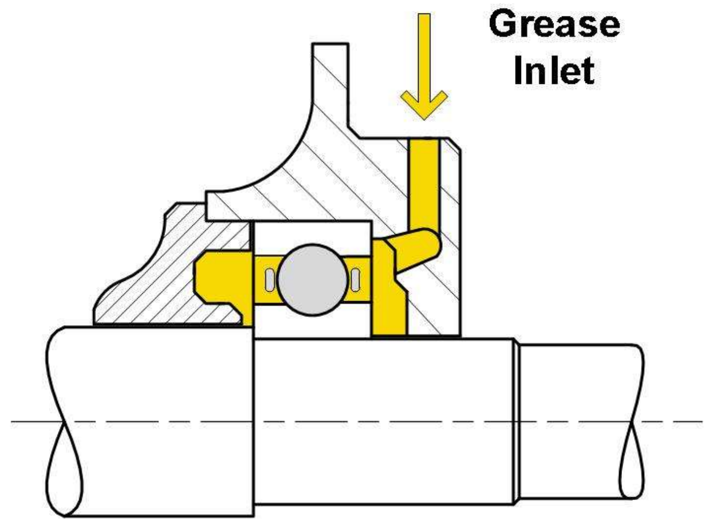
- Boundary Friction
- Lubricant Starvation
- Increased Wear

Over Lubrication

- Increased Fluid Friction
- Increased Heat
- Shorter Operational Life

Bearing Fill Quantity - Based On

- Bearing Type
- Speed
- Reservoir Volume
- Seals or Shields



Best Practices

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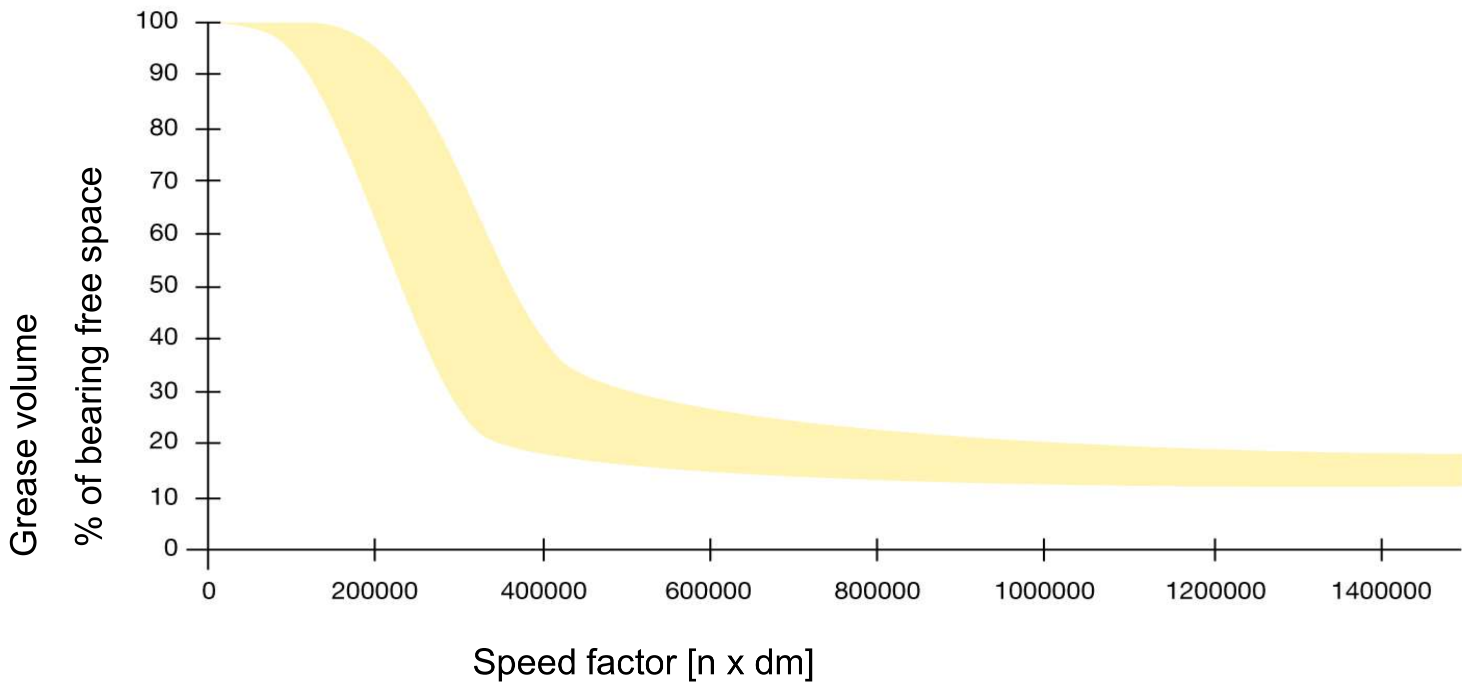
Initial Grease Fill



Best Practices

Grease Changeover Procedure

Initial Verifications:

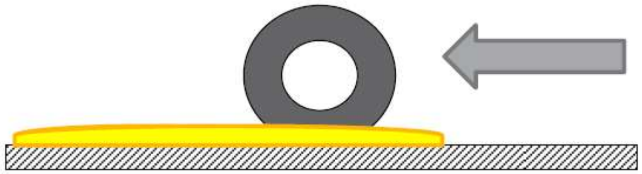
A. Check Grease Exit
B. Check Grease Compatibility
C. Check Bearing Function
D. Check Bearing Fill Quantity

Procedure:

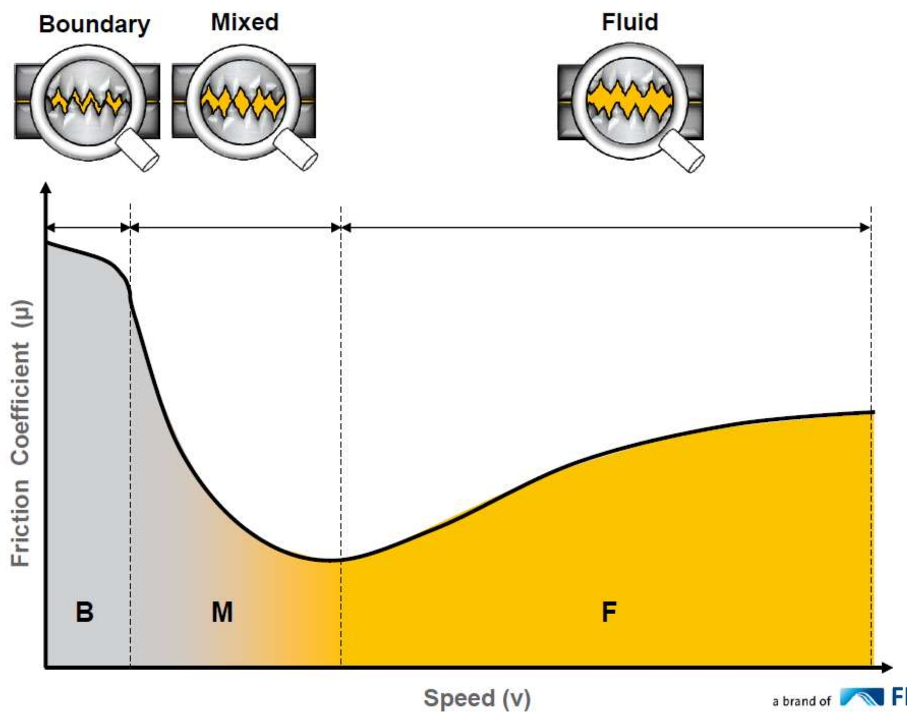
1. Pump in grease while bearing is running slowly
2. Let run for 1 to 2 hours
3. Repeat step one
4. Relubricate after one week
5. Resume normal relubrication schedule

Conclusion

Lubrication is important to your operation. Don't disregard it.



- The basic function of the lubricant is to reduce friction by separating the interacting surfaces
- Viscosity of the oil will determine whether there is sufficient film
- Additives can improve wear protection when the lubricating film is insufficient



Conclusion

Lubricant Selection

Review Industry/Application Literature

- OEM Recommendation (lube chart)
- Brochures

Collect all Bearing/Application Data

- Questionnaire (Bearing type, speed, temperature, etc)

Computer Based Analysis

- “EHD” viscosity calculation

your global specialist

Thank you for your attention

Jakub 'Kuba' Bednarz

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