Meeting Industrial Gear Oil Challenges with Additive Technology

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Agenda

- Trends and challenges of industrial gear oil market
- How have the evolving OEM requirements driven industrial gear oil performances ?
- Next generation additive technology to address the challenges




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Industrial Gear Oil Market Drivers & Trends

Manufacturing migration

OEM influence & specs driven by field challenges

Shift in base oils (growing use of Group II / III)

Growth in energy demand

Health, Safety and Environment

KEY MARKET DRIVERS

Reliability
Strong focus on seal compatibility

Efficiency

Durability
Extended equipment life and ODI

Increased productivity
Increased power density

Total cost of ownership

Specialized fluid requirements

KEY MARKET TRENDS

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What Will Drive Gear Technology and Lubrication?

Applications

- Growing wind turbine
- Growing food & beverage
- Growing robotics

- Noise, Vibration, Harshness
- OSHA regulation

- Power density
- Efficiency
- Upttime operation

Industry 4.0

- **Smart Factory**
  - Competition gear drive vs magnetic drive

- **Automation / Robotic**
  - Growth of precision gears and gear motors

- **Digitalization**
  - Gearbox Monitoring
  - Reliability and lifetime of equipment and lubricants

Materials

- **Plastic gears**

- **Coatings: DLC, WCC**
  - 30% less friction

- **Powder Metal Gears**
  - High strength
  - Long wear resistance

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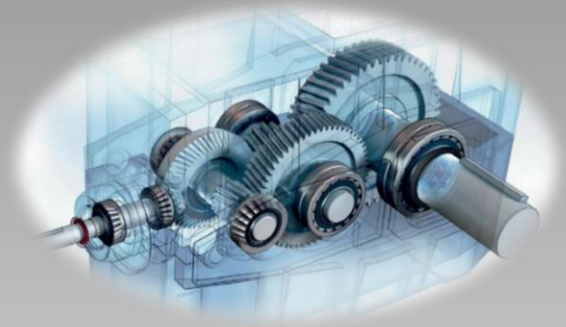
Industrial Gearbox Trends and Lubricants Challenges

Global/OEM Industry Trends

- Gear oil is a component of gearbox
- Challenging operating conditions (Increasing power density and Higher operating temperature)
- Smaller sump sizes
- Improved micropitting performance
- Clean gear concept
- Extended oil drain interval
- Reduced energy consumption



Challenges to Gear Oils

- Superior bearing/gear protection
- Corrosion protection
- Oxidation and thermal Stability
- Contamination control
- Excellent seal & paint compatibility
- Filterability / performance retention
- Improved foam and air release
- Improved friction
- Low temperature fluidity

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Wide Applications and Challenges – Not All Industrial Gear Oils Are the Same

Others -- Wind turbine, Food, Wood, Paper, Conveyor 15%

Source: Technavio Insights

	Gear Motor	Roller Mill	Industrial Robot	Wind Turbine
				
Gearbox	Small standard	Large standard	RV / Harmonic reducer	Planetary
Speed	High	Low	High Bi-direction	Variable speed
Load	Constant	High torque	Shock, High torque	Shock, High torque
Sump size	10 ～ 200 L	～ 5000 L	20 ~ 60 L	400 ～ 600 L
ODI	0.6 ~ 2 years	1～2 years	2 ～ 3 years	5～10 years
Lubricants	**Mineral** Oxidation Stability	**Mineral / Synthetic** AW / EP	**Synthetic** AW / EP, Friction	**Synthetic** Balanced AW / EP

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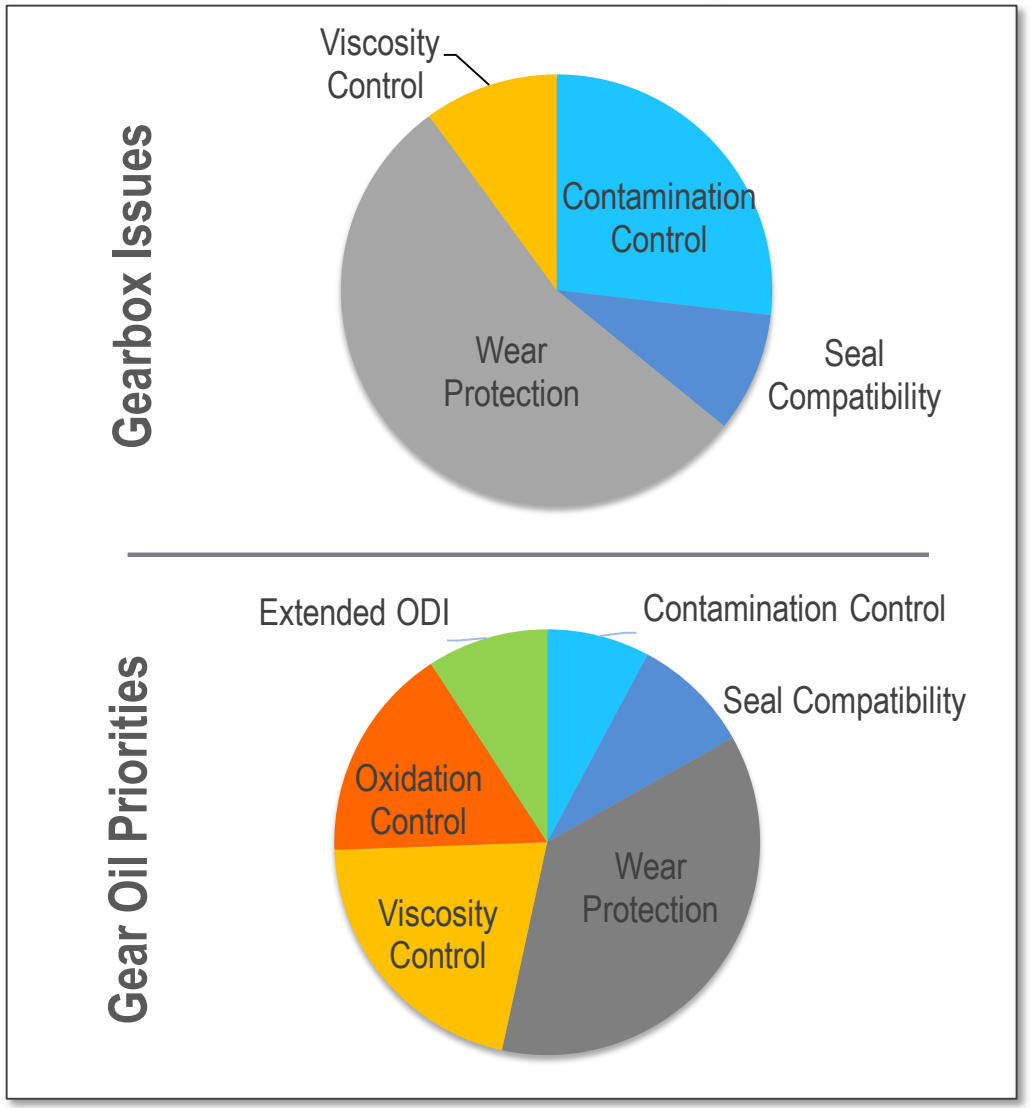
End-user Insight – Afton's Proprietary Research

Qualifications

- Maintenance personnel and engineers using industrial gear oils in industrial enclosed gearboxes
- Work full time maintaining heavy industrial machinery and accountable for fixing problems
- Deeply involved in lubricants and lubricant roles

End-user Interviews		
Industry	**USA & Canada**	**China**
Mining & Quarry	4	3
Steel & Metals	3	3
Cement & Aggregates	3	3
Pulp & Paper	3	3
Petrochemicals	5	3
Sugar Processing	-	3
TOTAL	**18**	**18**



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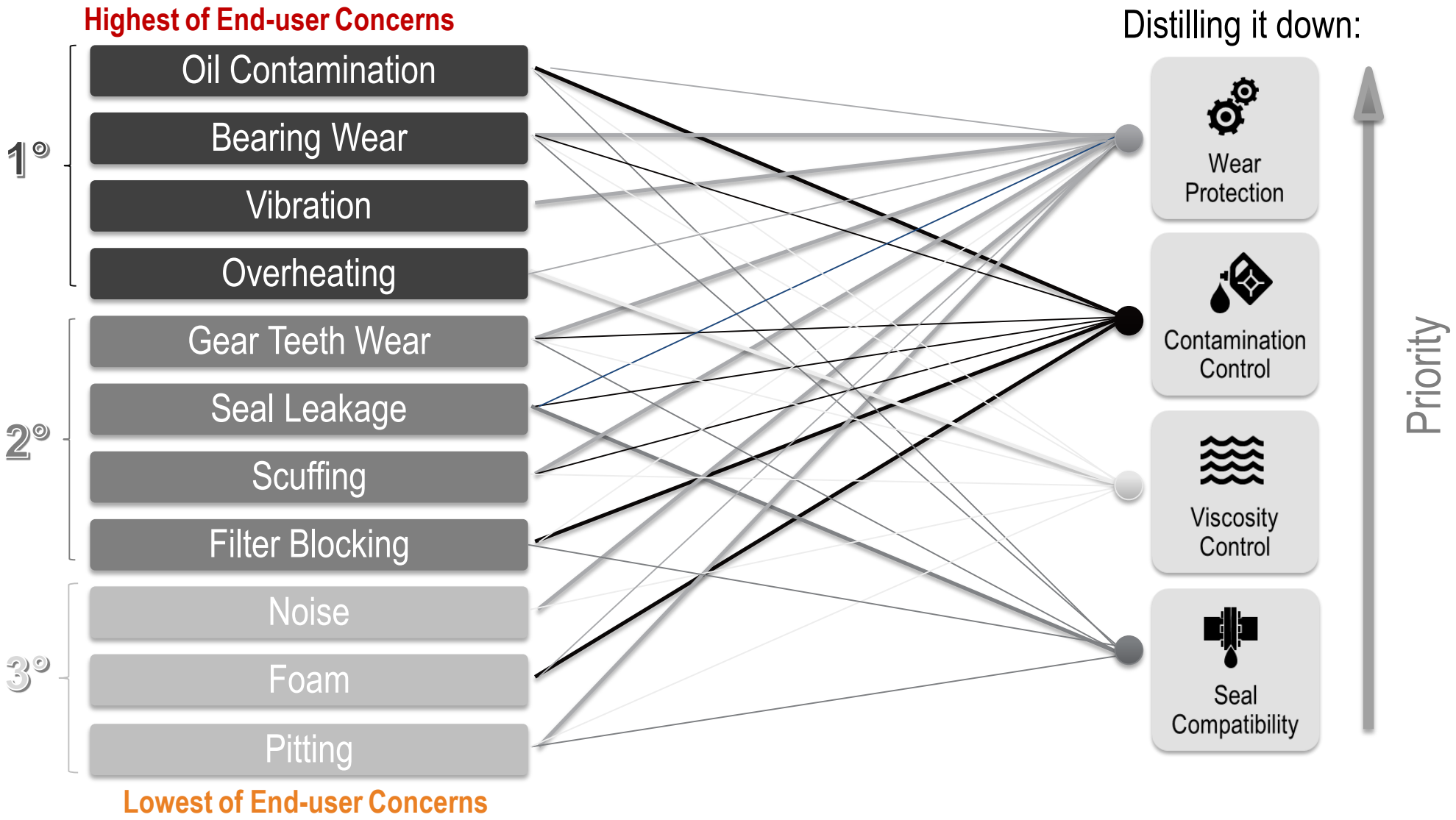
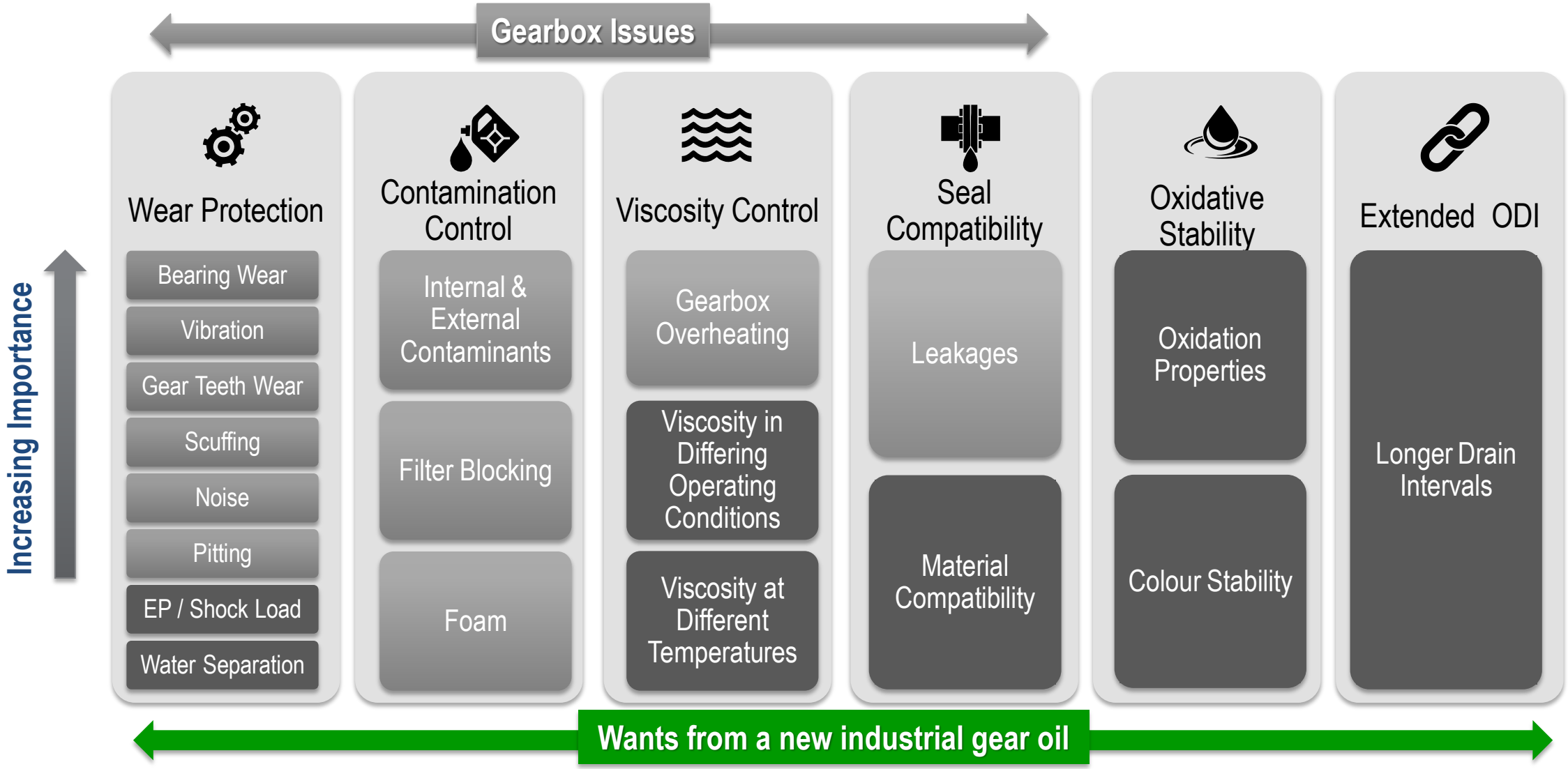
Insight – End-user Gearbox Issues



End-user Gearbox Issues and Wants from an Industrial Gear Oil



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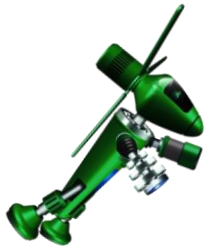
Industrial Gear Market Segmentation

Global IGO Demand: 935 KMT in 2018, growing to 988 KMT in 2027 (Kline)

Increasing temperature, Torque, Reliability and fluid ODI



Synthetic

Wind Turbine

Foam retention
WEC prevention

- **WT OEM:** Vestas, GE, SGRE, Goldwind
- **Gear OEM:** Winergy, ZF, NGC, Moventas
- **Bearing:** FAG, SKF, Miba
- **Standard:** IEC 61400, GB 33540.3 AGMA/AWEA 6006--A03

Synthetic
Mineral

Synthetic
Improved efficiency

Premium

Micropitting protection & filterability
Dynamic seal, sealant & paints compatibility

- Flender Rev. 16
- SEW
- ZF Industry
- Sumitomo (HIT)
- Eickhoff

- ISO 12925-1 L-CKSMP
- ISO 12925-1 L-CKD
- GB 5903 L-CKD

Mineral

Additional attributes such as Clean Gear

Mainstream

Bearing wear protection, extended EP protection,
Robust Corrosion, Static seal compatibility

- DIN 51517-3
- GB 5903 L-CKC
- ISO 12925-1 L-CKC
- AGMA 9005 F16 AS
- AIST 224

Entry

Basic Performance, Non-EP Circulating Gear

- GB 5903 L-CKB
- ISO 12925-1 L-CKB
- DIN 51517-1

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Key Fluid Performance Drivers – OEMs Depend on Own Specs & Approvals

Various bearing & gear tests by OEMs

Increased compatibility with non-metallic components (seals, sealant, filters & clutches)

FLENDER

Flender Rev.16 published October 2017

- FZG (A/8.3/90)
- FAG FE8 Bearing
- FVA Micropitting
- Flender foam
- Static/Dynamic seal compat
- Inner/Outer paints compat
- Sealant compatibility
- Flender Filterability

Pay attention to Energy Efficiency and Long Life / Extended Drain Interval.

High focus on dynamic seal compatibility

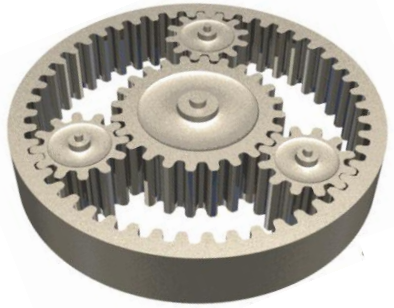
"40% seal failures come from oil compatibility issues"

ZF Industry

ZFN-W-17-145 Rev.3 released in Oct. 2019

Typical "Flender" performance

- FAG FE-8 Step 1 to 4
- DGMK 377-01 wear
- ASTM D2893 Oxidation at 121°C
- Various paint compatibilities
- Many additional liquid sealing compatibilities
- Wet brakes compatibility
- SKF roller and EmCor



SEW

Spec no. 07 004 03 13 released April 2016

SEW launched their own Genuine Gear Oil

- DIN 51517-3 is minimum requirement
- High focus on internal dynamic seal compatibility under most severe dynamic conditions
- FVA Micropitting

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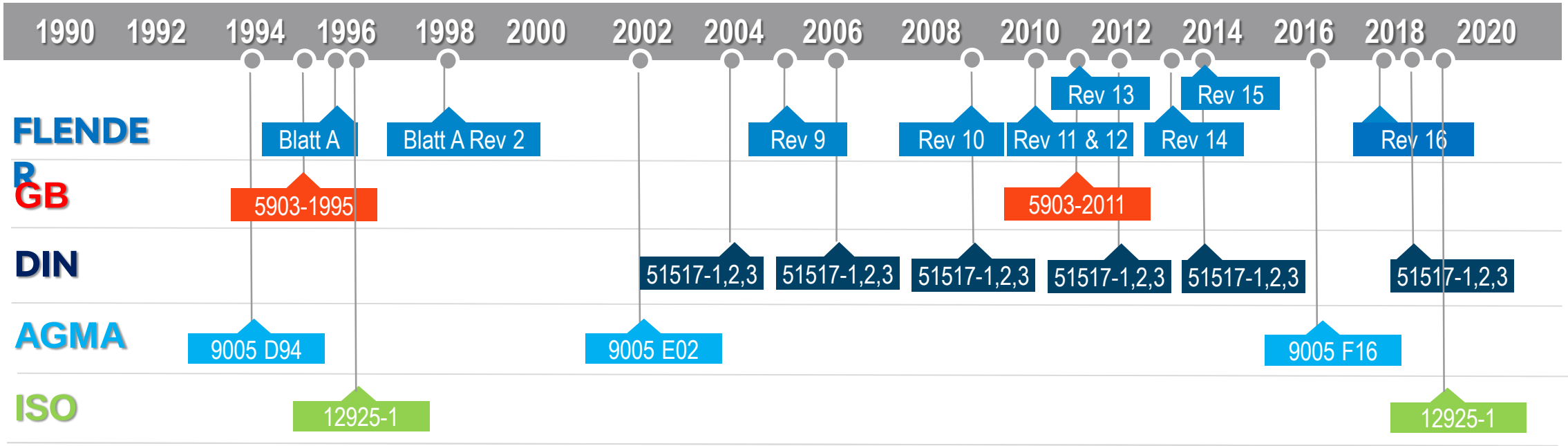
Gear Oil Standards – The Pace of Change is Quickening



Industry standards continues to grow in frequency focusing on key oil performance improvement

- Bearing wear and micropitting
- Static seal compatibility
- Environmentally friendly

Key OEMs focus own specification development on

- Dynamic seal compatibility
- Coating compatibility
- Filterability

Flender, SEW and **ZF Industrial** set the quality bar

Wind turbine gearbox OEMs (**ZF Wind, Winergy and NGC**) focus own specification development on

- Bearing wear (WEC prevention)
- Multi-metals compatibility
- Foam retention after filtration
- SKF EmCor salt corrosion

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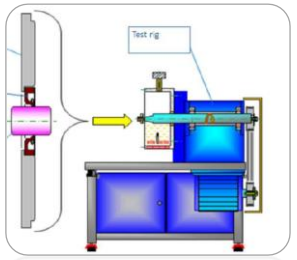
Gear Oil Specs – Key Performance Requirements

SPEC NAME	AIST 224	AGMA 9005 F16 Antiscuff Oil	DIN 51517-3 CLP	FLENDER Rev.16	SEW	ZF Industry
Rust Prevention	✓ (A & B)	✓ (A)	✓ (A)	✓ (A)	✓ (A)	✓ (A)
Copper Corrosion	✓	✓	✓	✓	✓	✓
Demulsibility	✓ ASTM D2711	✓ ASTM D2711	✓	✓	✓	✓
Oxidation Stability	✓ (121°C)	✓ (121°C)	✓ (95°C)	✓ (95°C)	✓ (95°C)	✓ (121°C)
Foam		✓ ASTM D892	✓ Flender	✓Flender	✓ Flender	✓ Flender
Four Ball Wear & EP	✓				✓ (Optional)	
Timken	✓					
FZG A/8.3/90	✓	✓	✓	✓	✓+ A/16.6/90	✓
FAG FE8 Bearing Wear		✓	✓	✓	✓+SRV (Option)	✓
FAG Stage 1-4						✓
FVA Micropitting				✓	✓	✓
Seal Compatibility			Static	Static & Dynamic	Static & SEW Dynamic	Static & Dynamic
Paint Compatibility				✓		✓
FZG slow speed wear					✓ (Optional)	✓
Wet brake compatibility						✓
SKF Roller / EmCor						✓





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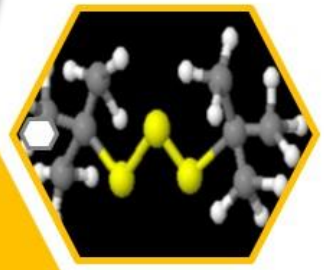
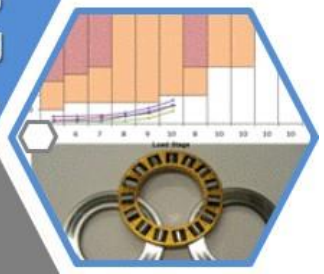
Next Generation IGO Additive Technology to Address the Challenges

Next Generation IGO Additive



EP agent system optimization

FM technology for FAG FE8 / micropitting excellence

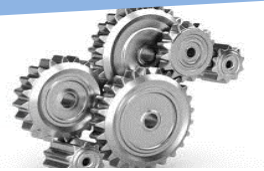


Robust dynamic seal compatibility chemistry technology

Multi-metals and parts compatibility chemistry design

To meet the challenges

- SEW approval
- ZF Industrial approval
- FLENDER approval
- DIN 51517 Part 3
- ISO 12925-1 L-CKD
- GB 5903-2011 L-CKD



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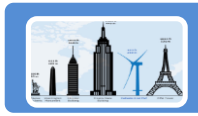
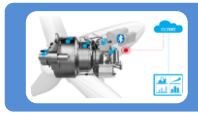
Wind Turbine Trends and Key Specifications for Gear Oils

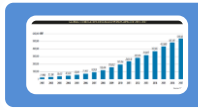

Wind turbine size growth


Evolution of digitalization


Fast growing offshore installation


OEMs get into aftermarket


Increased torque density


Increasing ODI up to 10 years

Wind Turbine OEMs

- Vestas
- GE
- Siemens & Gamesa
- Goldwind

WT Gearbox OEMs

- Winergy
- NGC
- ZF Wind
- Moventas
- Eickoff
- Flender

Bearing OEMs

- Miba
- SKF
- FAG
- NSK

Industry

- GB 33540.3
- ANSI.AWEA. AGMA 6006-A03
- ISO/IEC 61400
- DIN 51517-3
- ISO 12925-1 CKSMP

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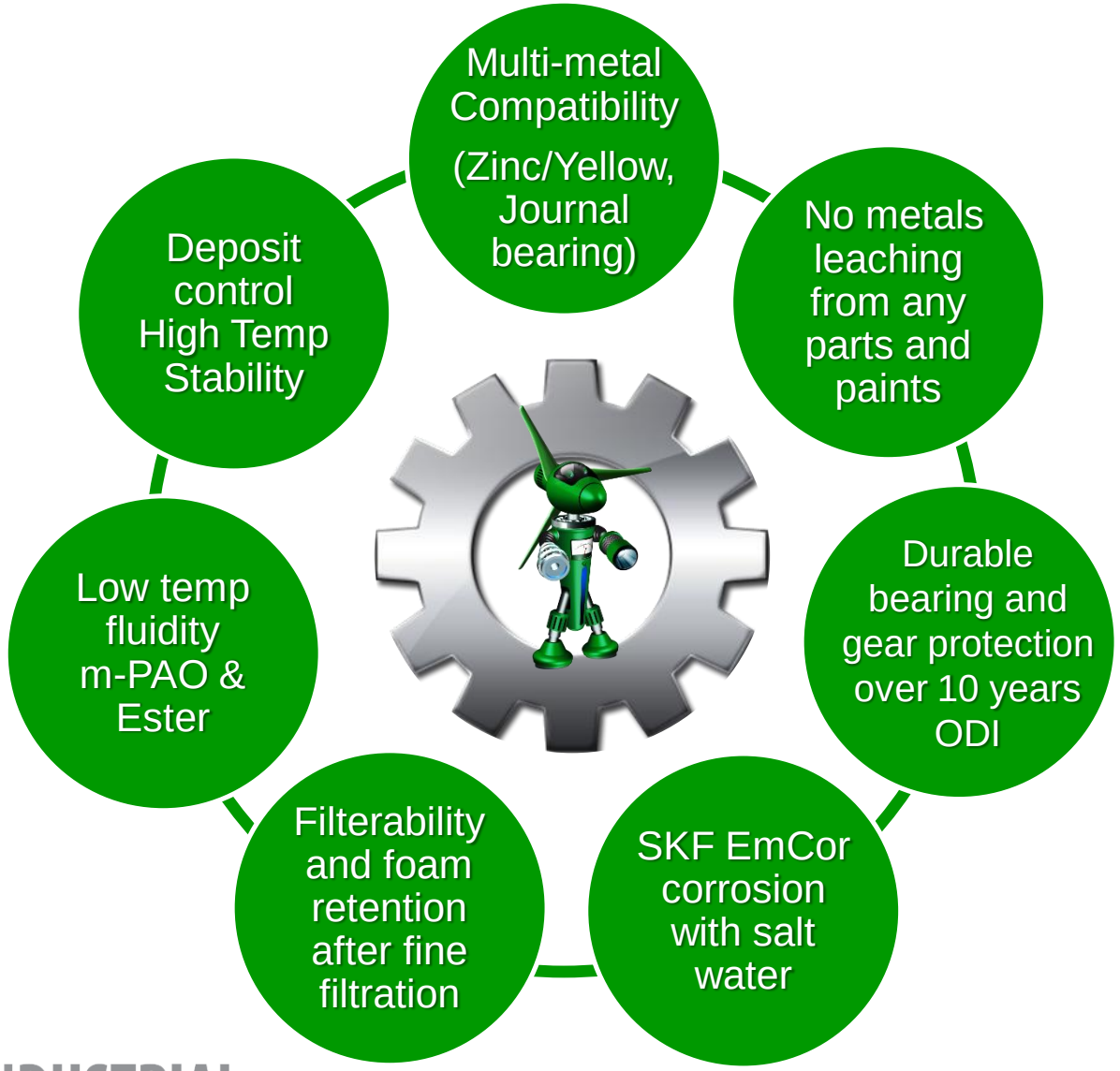
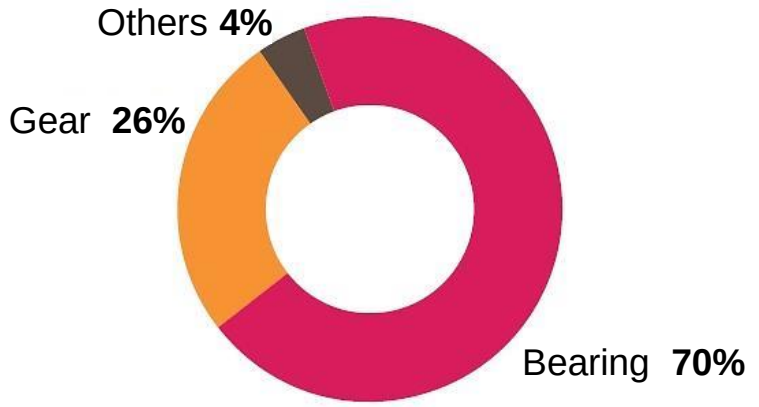
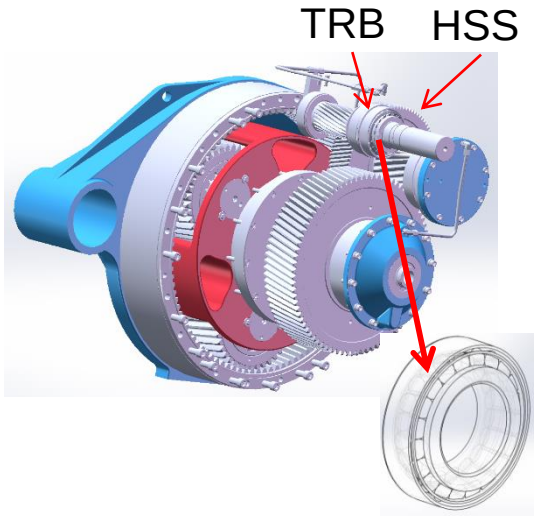
Next Generation Wind Turbine Gear Oil Additive Technology

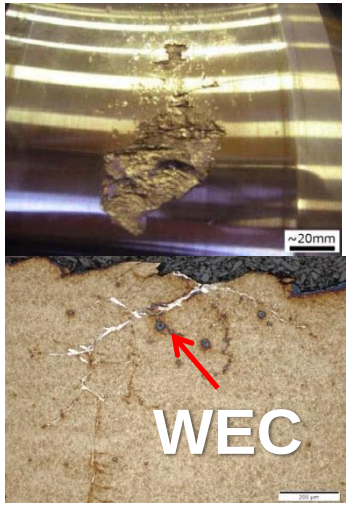


Wind Turbine Gearbox Failure



Source: WEU Onshore Asset Optimization & Reliability Benchmarking Report 2015





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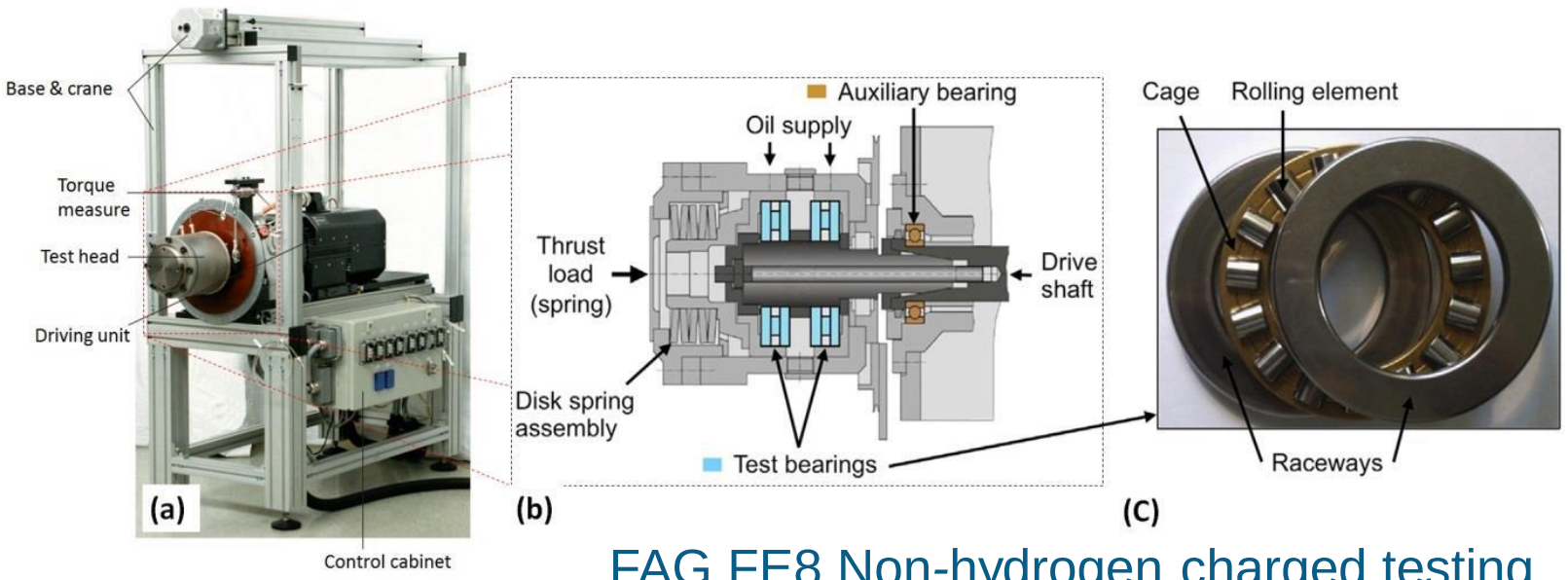
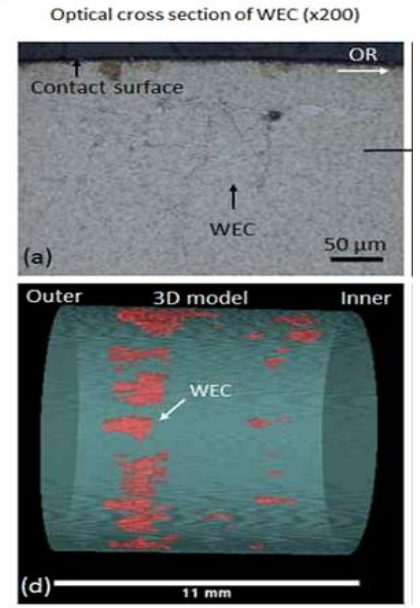
How the Gear Oil Helps Prevent WEC – Afton's Research

Based on available information, the lubricant needs to:

- Lower thin film friction (TFF) to reduce surface and subsurface stress.
- Control friction as load increases to reduce surface stress during transients.
- Form a tribofilm that is rich in Phosphorus (P) to absorb the surface stress.
- Maintain tribofilm composition as the load and sliding increase.





FAG FE8 Non-hydrogen charged testing

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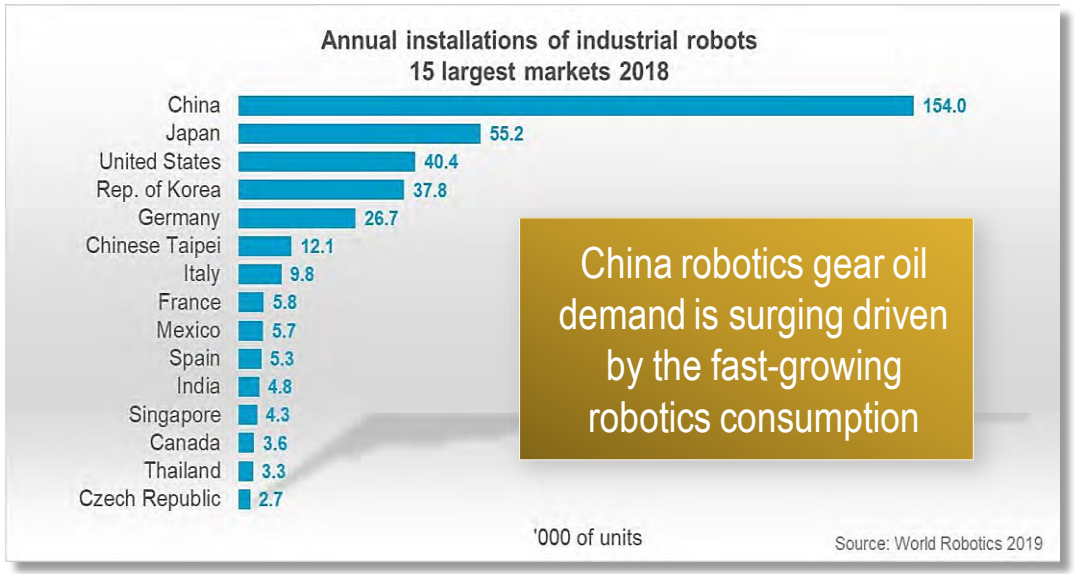
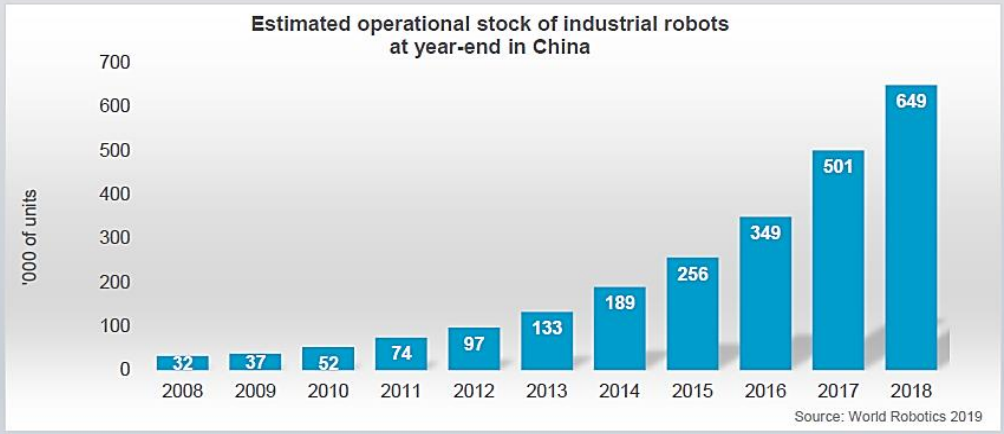
Industrial Robot Gear Lubrication – Market Needs a Standard



China robotics gear oil demand is surging driven by the fast-growing robotics consumption

Operational Stock in China: Increased by 30%



Industrial Robot OEMs	Gear Reducer OEMs
• ABB • KUKA • FANUC • YASKAWA	• Nabtesco • Sumitomo • Harmonic Drive

Industrial Robot Reducer Operating Conditions

- High friction
- Long time fatigue
- High shock load
- High operating temperature
- Long ODI
- Low temperature start
- Foam stability
- Leakage prevention

Lubricant Performance Requirements

- Anti-wear / Low friction
- Micro-pitting
- Extreme pressure
- Thermal stability
- Oxidative stability
- Low temperature performance
- Antifoam over time
- Elastomer compatibility

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