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# New High Viscosity Basestock for Gear Applications

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# Historical development of gears

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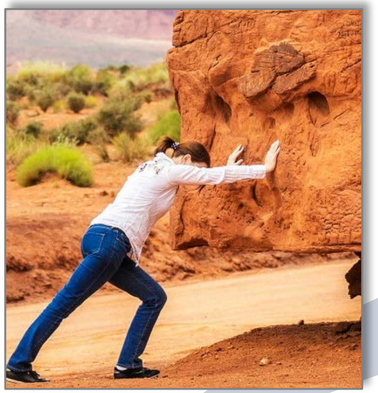

**Before wheels:**
Sliding

**~ 3000 BC:**
Invention of wheels

**~2000 BC:**
Invention of spoke wheels

**~400 BC:**
Wheels in technical applications

**Today:**
High performance gear applications

➔ Today's gears need lubrication in order to increase efficiency and equipment lifetime

# Today’s gear lubricant performance criteria

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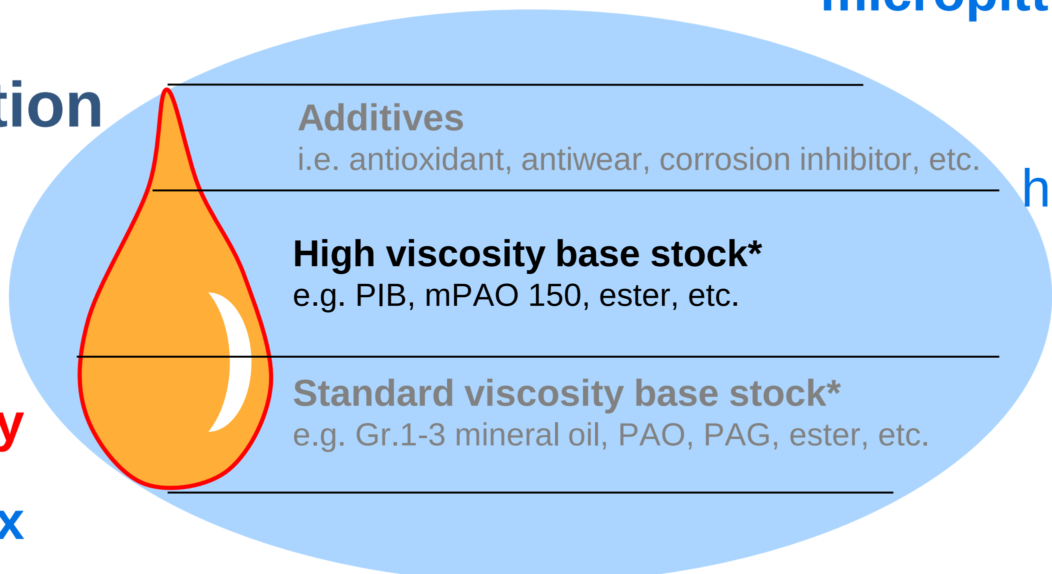
**energy efficiency**

toxicity

**micropitting resistance**

temperature resistance

**wear protection**




high load capacity

costs

renewability

**lubricity**

**compatibility**

shear stability

**viscosity index**

biodegradability

**longer drain intervals**

**fuel economy**

→ Today, increasing performance criteria and sustainibility drive lubricant developments

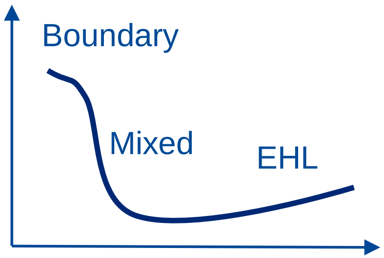
* traditionally PAGs are synthesized to desired viscosity

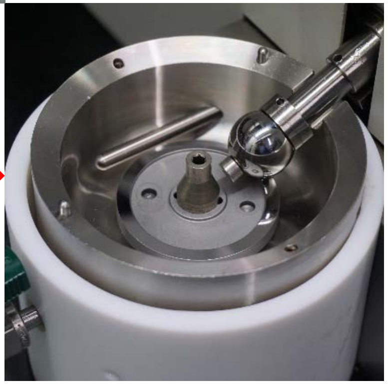
# How to screen efficiency



## Mini Traction Machine (MTM)

- Ball on disc with variable speeds of each
- 2 test methods established for MTM:
  - Traction curve
    → variable Slide-Roll-Ratio (SRR)
  - Stribeck curve
    → variable speed (constant SRR)



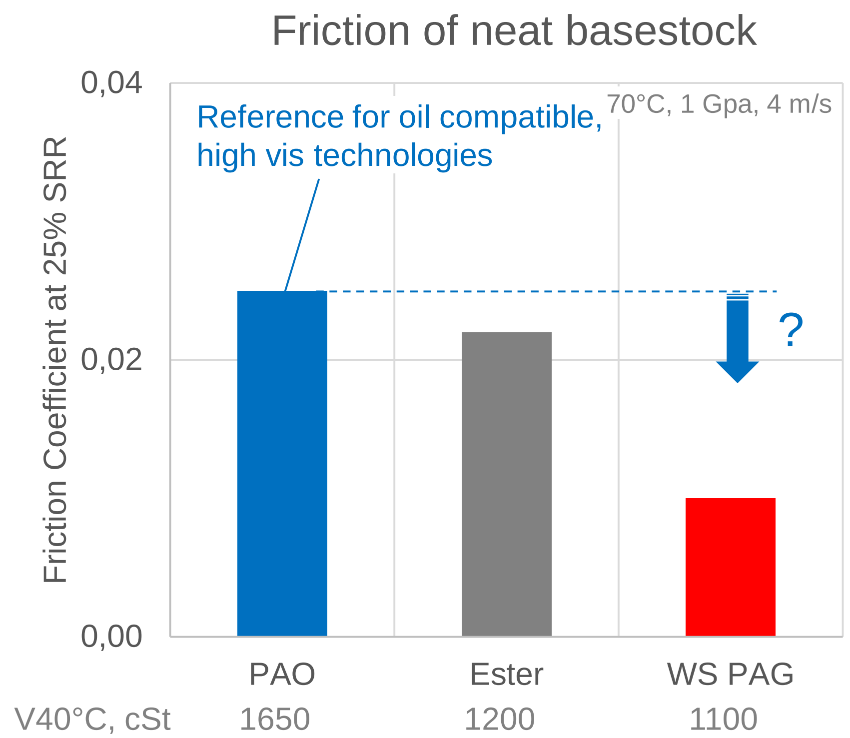
→ A quick way to measure friction in all kind of friction regimes

# Current high viscosity technologies





- Traditionally, main performance parameters for the use of **high viscosity basestock** have been
  - Thickening efficiency
  - Shear stability
  - Handling
  - …
- Increasing costs for energy, equipment and labor force make wear and frictional properties more important
- Water soluble PAGs
  - deliver best in class friction
  - however, have limited compatibility with almost all other basestocks




→ Is there a way to improve friction coefficient while still being compatible with mineral oil / PAO?

# Development of new Energy Efficient Basestock (EEB)

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Friction reduction leading to energy savings for end-customer

Compatible with mineral oil and PAO

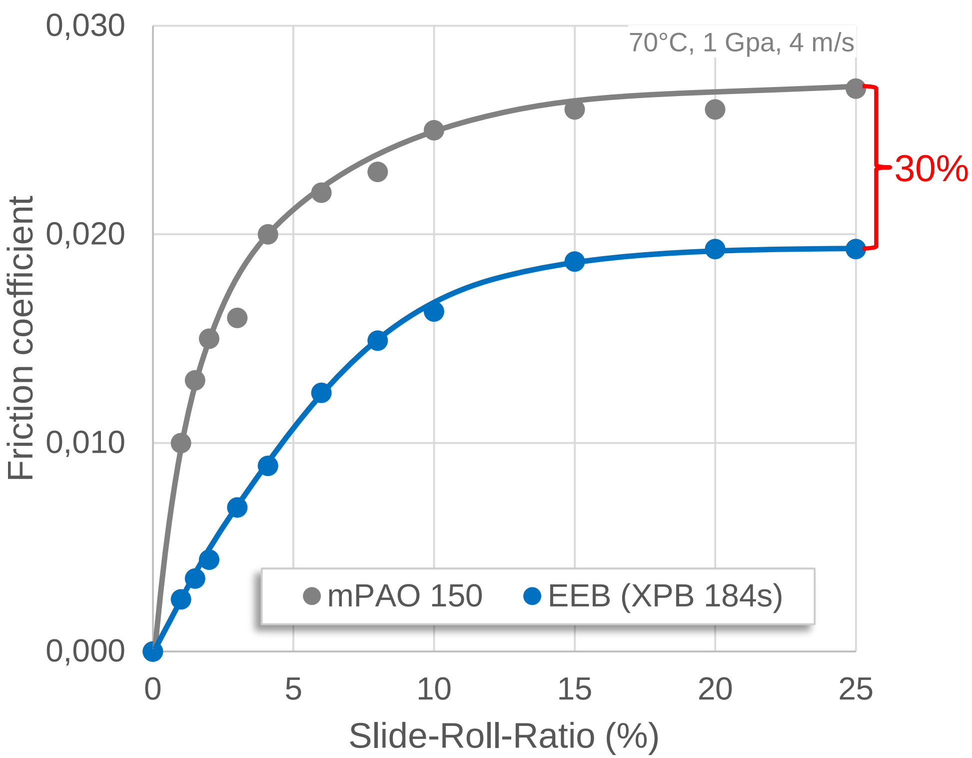
New high viscosity base stock approach using hybrid chemical structure

| | EEB (XPB 184s) |
|---|---|
| **Viscosity at**<br>**40°C (mm²/s)**<br>**100°C (mm²/s)** | <br>1000<br>120 |
| **Viscosity index** | 222 |
| **Density (g/cm³)** | 0.93 (15°C) |
| **Pour point (°C)** | -39 (ISO) |
| **Cloud point (°C)** | < -66 |
| **Flash point coc (°C)** | 220 |
| **Aniline point (°C)** | 60 |

➔ Better friction coefficient than competitive oil soluble technologies

# MTM friction coefficient





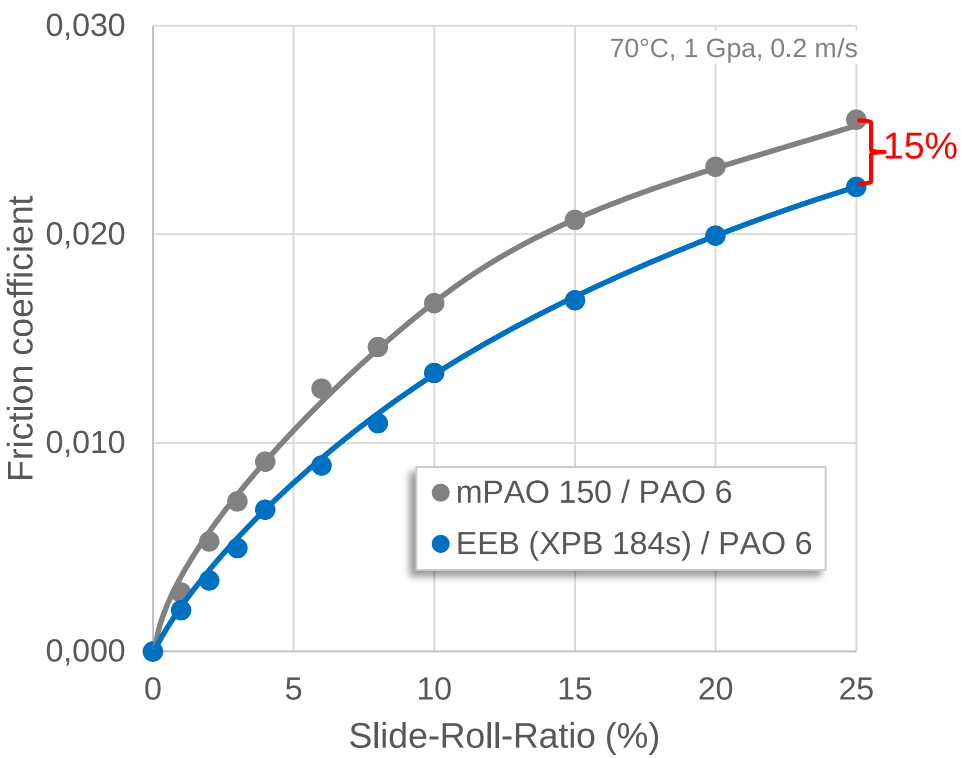

- The new EEB shows better friction performance than benchmark, however…
- Viscosities differ for the neat basestocks at measured temperature
→ dilute with low vis PAO to reach same viscosity at test temperature

| | mPAO 150 | EEB (XPB 184s) |
|---|---|---|
| $V_{40°C}$, cSt | 1650 | 1000 |
| $V_{70°C}$, cSt | 420 | 300 |

→ Is the better friction a pure viscosity effect?

# MTM friction coefficient (binary mixture)






- Blended both high vis basestocks with PAO6
- Viscosities differ only marginally at test temperature
- Viscosity at 40°C is almost “off-spec” for a ISO VG 320 grade
  → What’s the difference for same ISO VG? (see slide 12)

| | mPAO 150 / PAO 6 | EEB (XPB 184s) / PAO 6 |
|---|---|---|
| $V_{40°C}$, cSt | 316 | 290 |
| $V_{70°C}$, cSt | 96 | 94 |

→ But what happens if one uses Gr. III instead?

# MTM friction coefficient (binary mixture)

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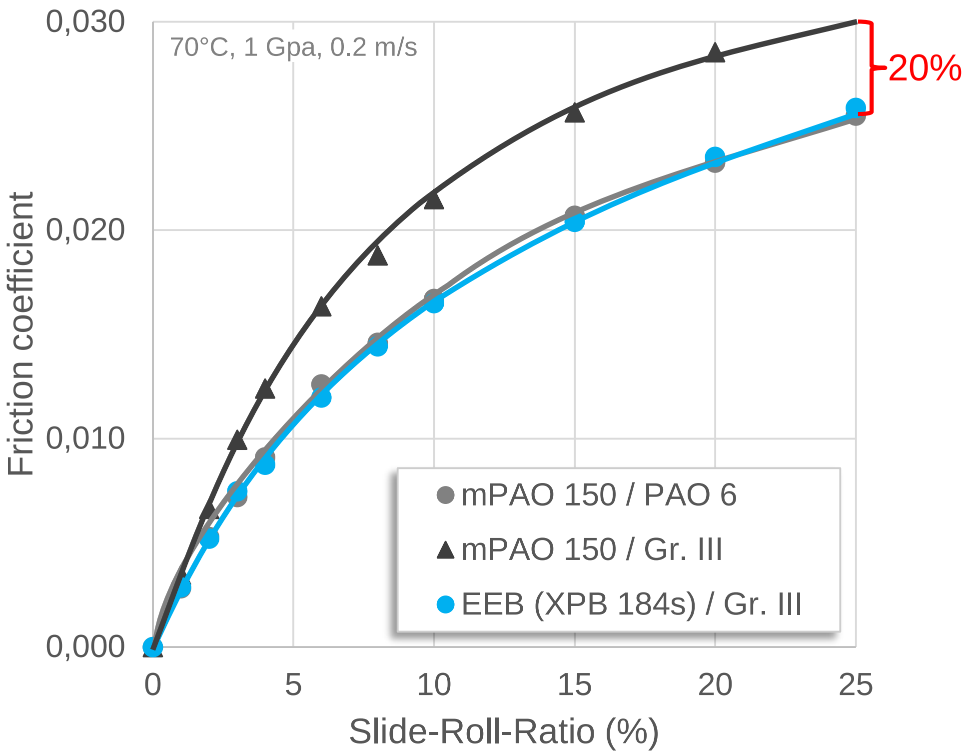



- Frictional properties of a viscosity neutral binary blend based on EEB with Gr. III are better than binary blend based on mPAO 150 and Gr. III
- Frictional properties of a viscosity neutral binary blend based on EEB with Gr. III are in the range of binary blend based on mPAO 150 and PAO 6

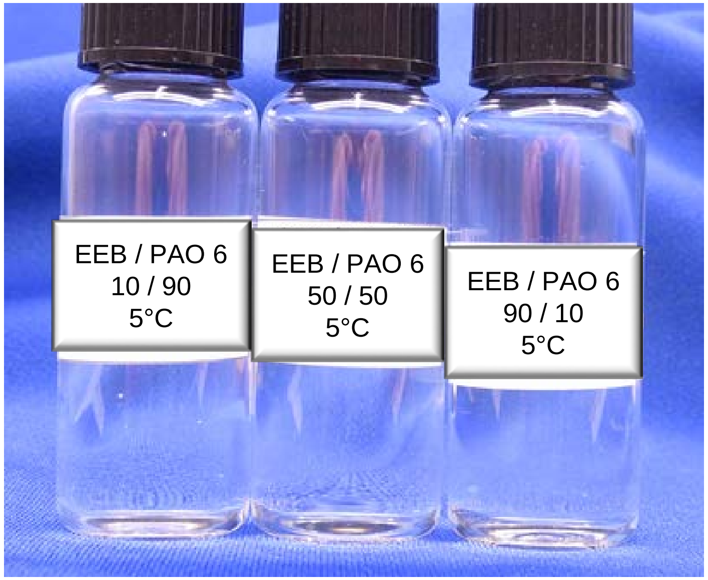
| | mPAO 150 / PAO 6 | mPAO 150 / Gr. III | EEB (XPB 184s) / Gr.III |
|---|---|---|---|
| $V_{40°C}$, cSt | 316 | 314 | 300 |
| $V_{70°C}$, cSt | 96 | 93 | 94 |
| VI | 181 | 173 | 193 |

➔ EEB can improve frictional properties of base oils from different API categories

# Solubility with other basestocks



| API Group | | (Test oil / EEB) | EEB (XPB184s) |
|---|---|---|---|
| I, II, III | Mineral Oil* | 10/90 | ✓ |
| | | 50/50 | ✓ |
| | | 90/10 | ✓ |
| IV | PAO 6 | 10/90 | ✓ |
| | | 50/50 | ✓ |
| | | 90/10 | ✓ |
| IV | PAO 40 | 10/90 | ✓ |
| | | 50/50 | ✓ |
| | | 90/10 | ✓ |
| V | Nynas T22 | 10/90 | ✓ |
| | | 50/50 | ✓ |
| | | 90/10 | ✓ |




Test conditions:
Ratios: 10/90, 50/50, 90/10
Temperatures: 5°C, RT, 60°C
Duration: >4 weeks

➔ EEB is fully soluble in Gr. I-V base oils

* Several mineral oils tested in each API category

# MTM friction coefficient (fully formulated)

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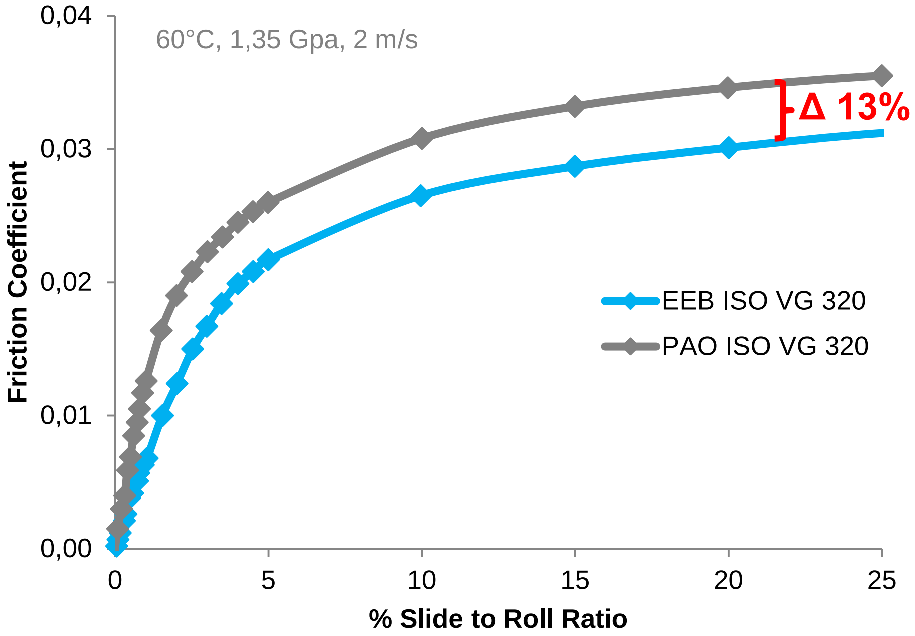
- PAO based product is a commercial fully formulated ISO VG 320 gear oil
- EEB based experimental formulation done with low vis PAO 6 to meet viscosity grade
- In elasto-hydrodynamic lubrication, EEB based formulation shows a friction benefit of approx. 13% over PAO based formulation




➔ EEB based formulation reduces friction in fully formulated lube

# MTM friction coefficient (fully formulated)

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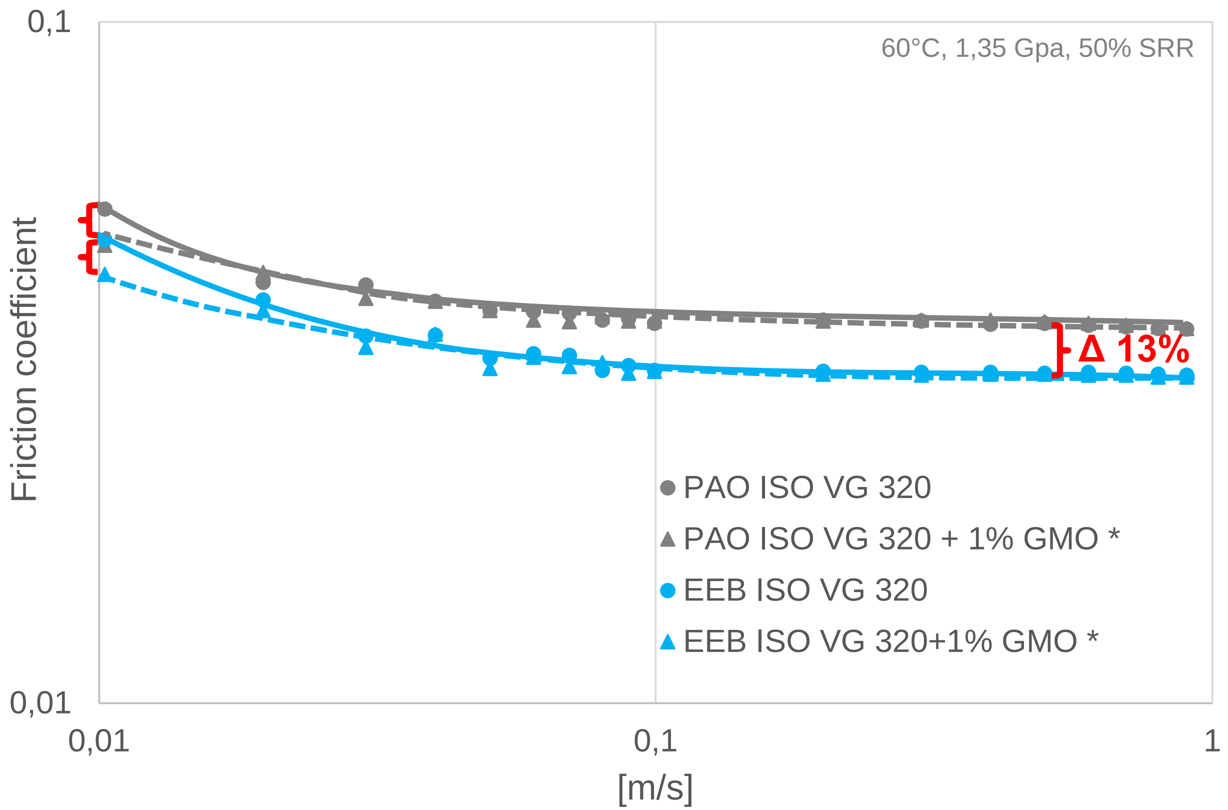
- EEB based formulation reduces friction in all friction regimes
- Friction modifier response is equivalent for both, PAO and EEB based formulation
- Friction modifier can only improve the friction properties in boundary lubrication




➔ EEB reduces the friction coefficient in all friction regimes

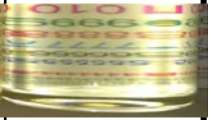
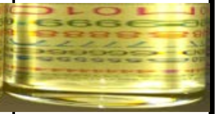
* glycerol mono-oleate

# Oil Compatibility (fully formulated)





- Compatibility of fully formulated lubricants (ISO VG 320) has been tested
- Variables:
  - different thickeners
  - different additive packages
  - different ratios
- No incompatibilities observed (haziness, phase separation, …)

| EEB : gear oil | 90:10 | 50:50 | 10:90 |
|---|---|---|---|
| Industrial Gear Oil VG320 (based on high vis PAO) |  |  |  |
| Industrial Gear Oil VG320 (based on PIB) |  |  |  |

➔ EEB based gear oil is compatible with other non polar gear oils

# Other Performance data (fully formulated)

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| | Method | EEB based formulation | DIN Limit |
|---|---|---|---|
| Kv40, cSt | ASTM D445 | 337 | 288-352 |
| Kv100, cSt | ASTM D445 | 46 | - |
| Viscosity Index | ASTM D2270 | **197** | 90 min |
| Pour Point, °C | ASTM D97 | **-48** | -9 max |
| Copper corrosion, 100 °C, 3 hrs | ASTM D130 | 1b | 2 max |
| Rust, fresh water, 24 hrs | ASTM D665A | PASS | PASS |
| Rust, synthetic sea water, 24 hrs | ASTM D665B | PASS | - |
| Demulsibility at 82 °C, separation time, min | ASTM D1401 | 45/33/2 (20) | 30 max |
| Foam Seq I, ml, after stop and after 10 min | ASTM D892 | **0/0** | 100/0 |
| Foam Seq II, ml, after stop and after 10 min | ASTM D892 | **0/0** | 100/0 |
| Foam Seq III, ml, after stop and after 10 min | ASTM D892 | **0/0** | 100/0 |
| US Steel-200 oxidation, 312 hrs at 95 °C | Kv100 Viscosity increase, % | 1.45 | 6 max |
| | Precipitation number, ml | <0.05 | - |
| FZG Scuffing (A/8,3/90), FLS | | **>14** | >12 |
| KRL shear test, 100 hr | Kv100 % viscosity loss | **0.60%** | - |

➔ EEB based ISO VG 320 gear lubricant is expected to meet DIN51517 part 3 CLP *

* More testing is ongoing

# Summary

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**Performance**

- EEB delivers exceptional frictional performance and oil compatibility
- EEB performance confirmed also in finished lubricant formulations

**Chemistry**

- EEB is a new **high viscosity** basestock approach
- Unique performance achieved through new to the world hybrid structure
- Other viscosity grades under development

**Thanks for the support**

- Karolin Geyer
- Frank Rittig
- Philip Ma
- Gene Zehler…and many more

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