Gefördert durch
Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

Lab-scale testing and performance screening of gear oils (GPS)

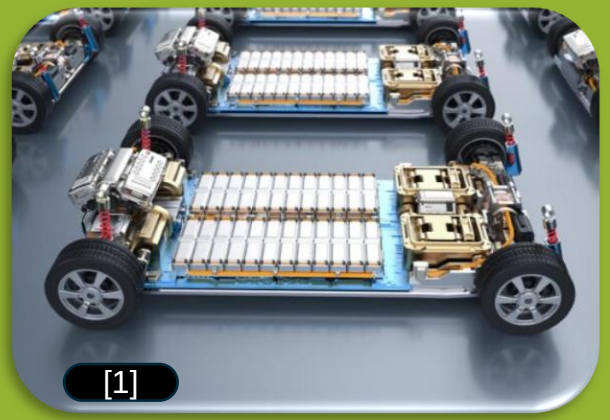
N. Kind, P. Beau, J. Pouillard
German Aerospace Center (DLR) – Institute of Test and Simulation for Gas Turbines
Beau Engineering Services

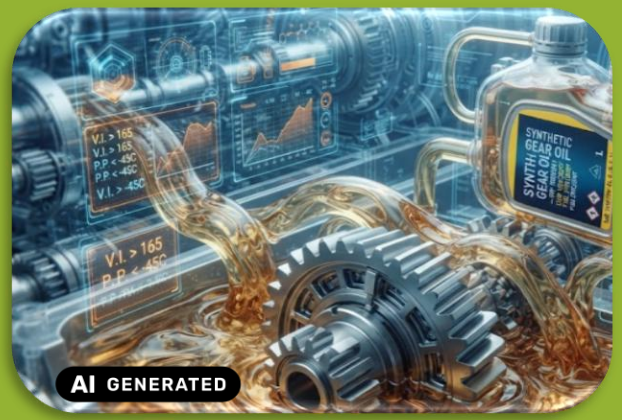
8th World Tribology Congress, WTC 2026
Rio de Janeiro, 21.09.2026

Motivation: Battery electric vehicle transmission gears

Environment & Mechanical loads

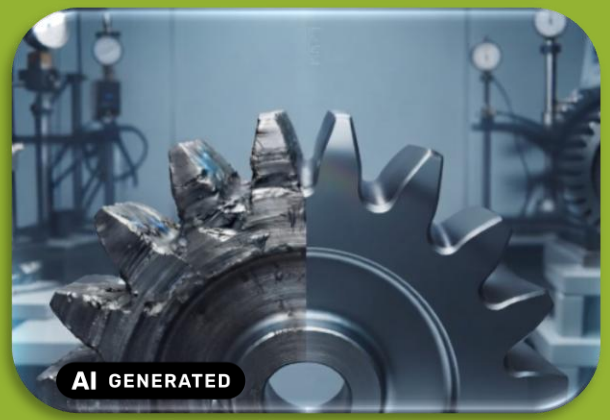
- high rotational speeds and sliding velocities in gear flanks
- instant torque, elevating transient contact pressures on gear flanks





Surface Engineering

- Specialized coatings against severe adhesive wear and scuffing



Lubricant Optimization

- low dynamic viscosity fluids increase overall powertrain efficiency
- Tailored dielectric properties to prevent electrical discharges in bearings and gear meshes

GPS Framework:
Screening method to evaluate commercial and R&D lubricants, e.g. for electric drivetrain applications.

Goal: Fast, cost-efficient identification of top-performing candidate oils for e-mobility applications

Kind; 2026, DLR Institute of Test and Simulation for Gas Turbines

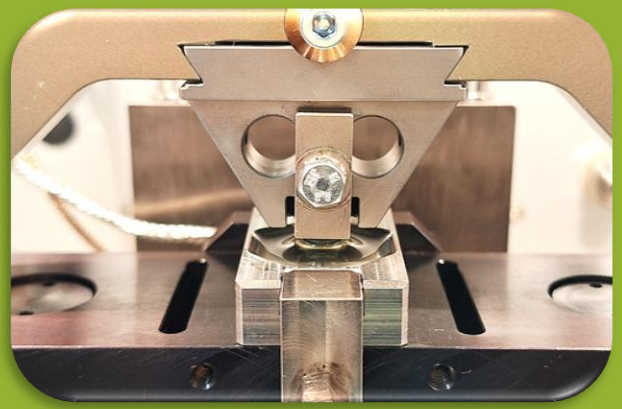
[1] Toyota and Tesla: Exploring viscosity's role in engine and drivetrain efficiency - F&L Asia

State-of-the-art



FZG Test Methods

- component level, e.g:
  - Standard test A/8.3/90 (ISO 14635-1)
  - EP step test A10/16.6R/90 (ISO 14635-2)
- widely used test rig to assess scuffing resistance and load carrying capacity in high EP oils
- critical test for a variety of fluids, including in automotive applications
- drawbacks: high cost, expert set-up, challenges with low viscosity oils (RR2021)



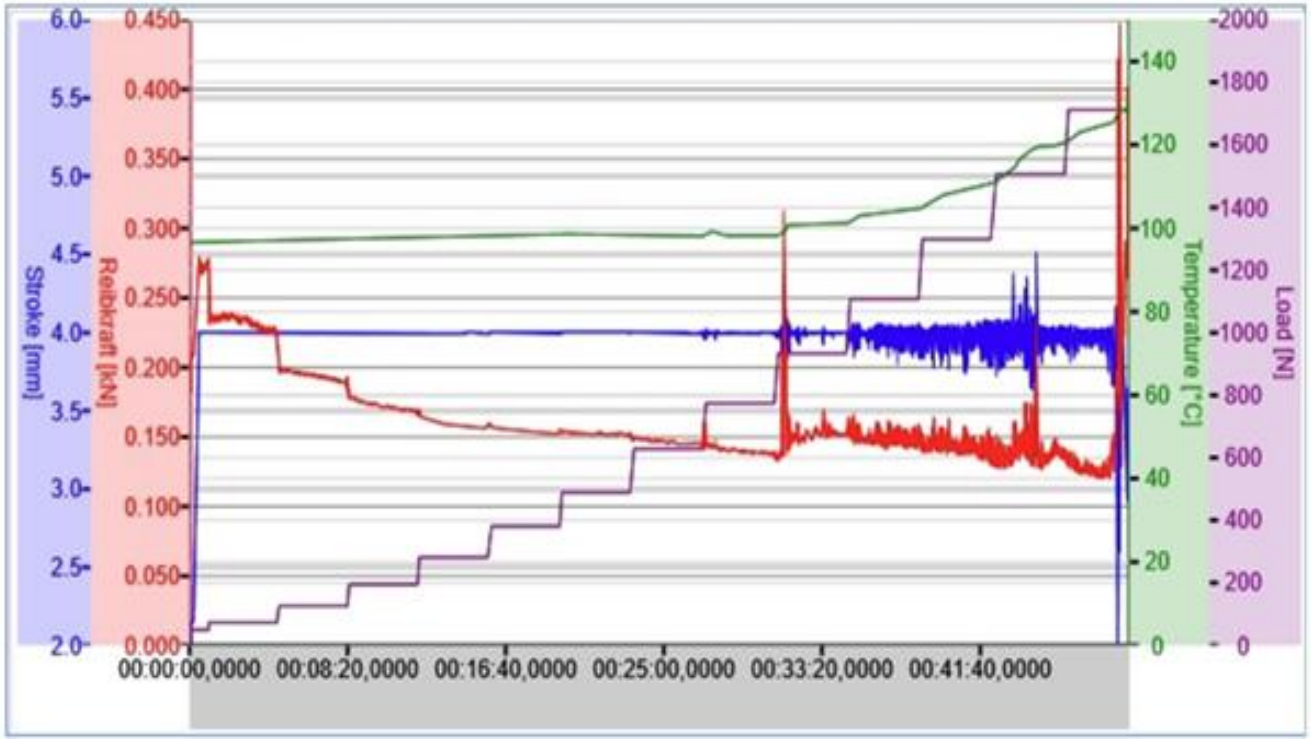
Lab-scale Test Methods

- coupon level, e.g:
  - EP step test DIN 51834-7 E (ASTM D8316)
- cost-efficient
- limitation: lack of criterion for interruption of the scuffing test
- **Different ways to tackle limitation:**
  - **Galary (2014)**
  - **Massocchi et al (2022)**
  - **Patzer, Beau (2024) [3]**

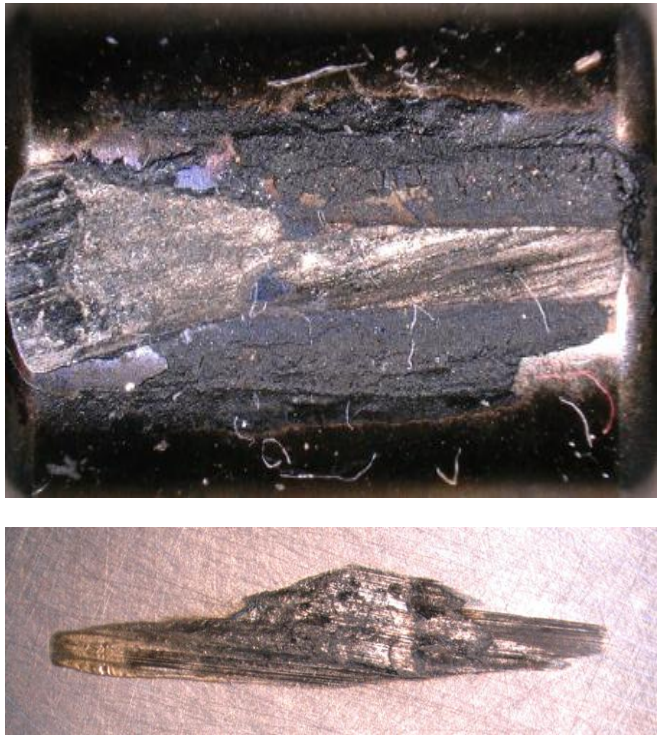
[2] Zahnradverspannungsprüfstand, FZG-Prüfstand - Tribologie Mannheim
[3] Patzer, Beau (2024): Functional Screening Methods for Performance Assessment of transmission components

State-of-the-art

DIN E 51834-7 : no sensitive cutoff criteria

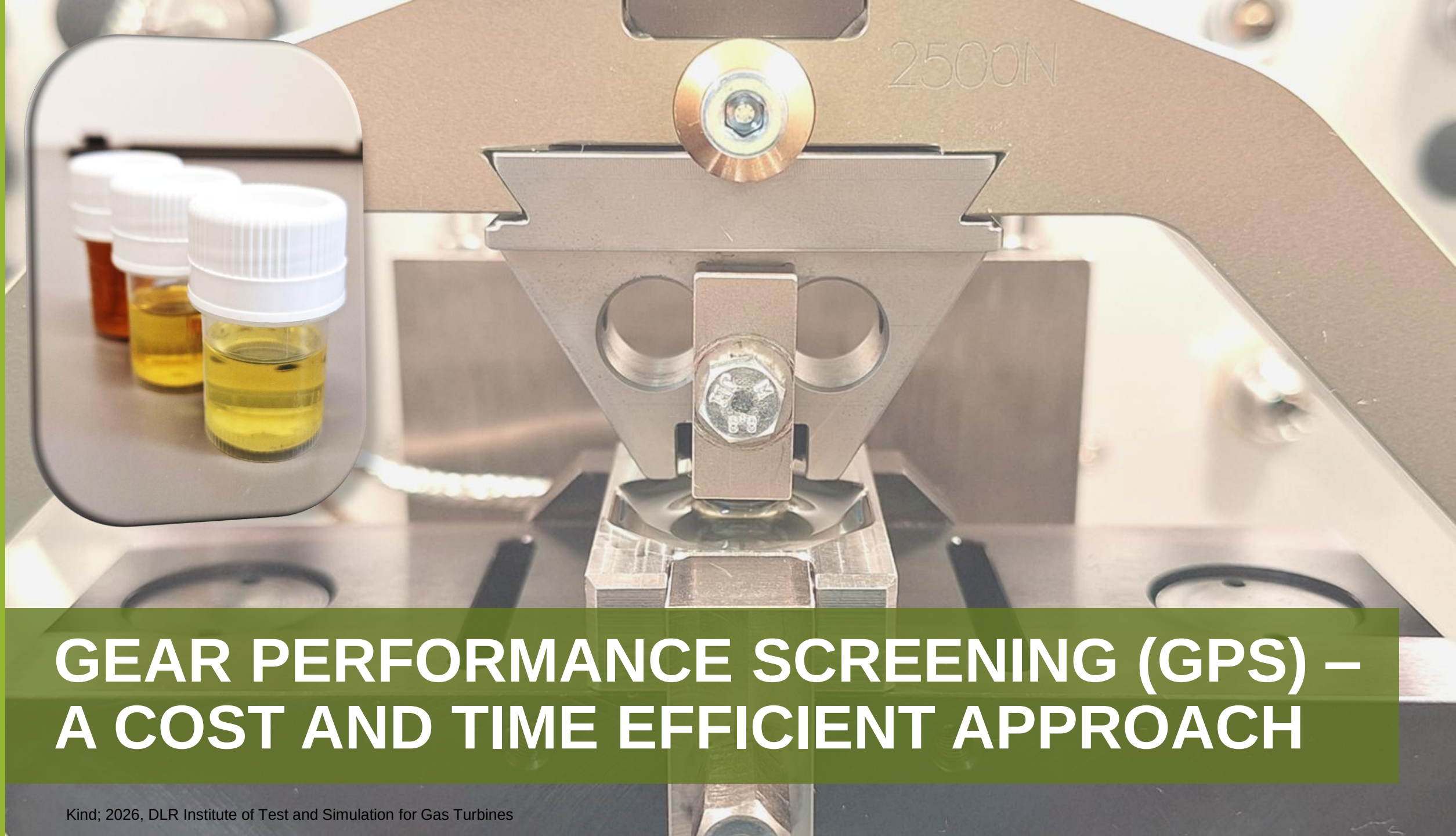


Plots from tribotestings:
CoF (red), stroke (blue), temperature (green), load steps (purple)



Specimen inspection after testing:
severe adhesive wear on disk and cylinder

[2] Zahnradverspannungsprüfstand, FZG-Prüfstand - Tribologie Mannheim



GEAR PERFORMANCE SCREENING (GPS) – A COST AND TIME EFFICIENT APPROACH

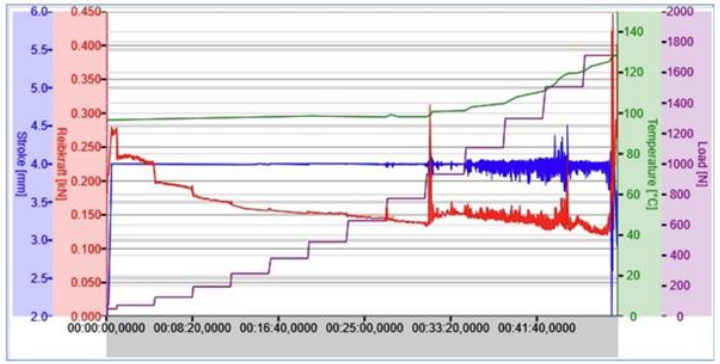
Test procedure and Methodology

Comparison to DIN E 51834-7

- Sensitive cutoff criteria of GPS test procedure enables

Test parameter	DIN E 51834-7	GPS method
Contact configuration	Cylinder-on-disk (10° inclination)	Ball-on-disk
Lubrication	0.3 ml („one drop“)	0.95 ml in oil bath
Temperature	98 °C	60 °C
Normal force F_N	Increments acc. to FZG loads A/8.3/90, ISO 14635-1, 50 N - 2202 N	Increments of 50 N, 50 N - 2000 N
Frequency f	50 Hz	30 Hz (moderate) 60 Hz (harsh)
Stroke s	4 mm	2 mm
Cutoff criteria	**None; manual postprocessing of CoF graphs required**	**s < 95 % (30 Hz), s < 99 % (60 Hz); CoF > 0.3**

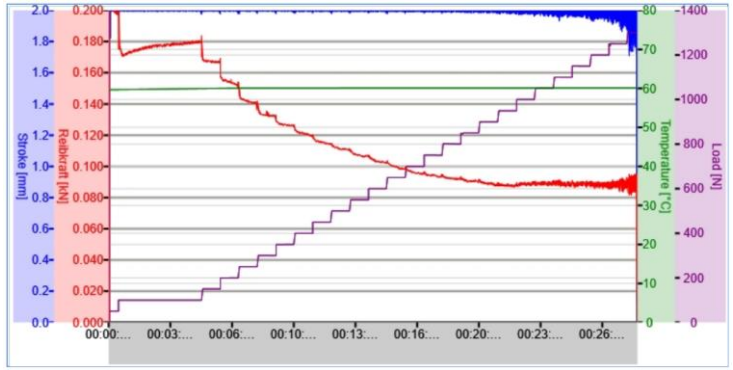
DIN E 51834-7: no sensitive cutoff criteria

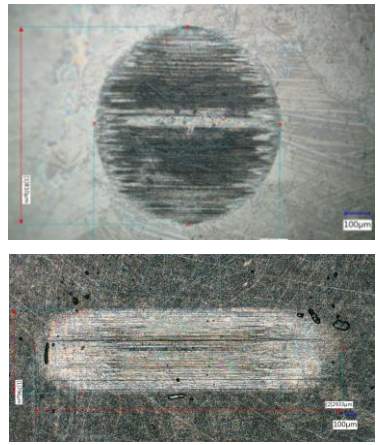




severe adhesive wear on disk and cylinder

GPS: sensitive cutoff criteria





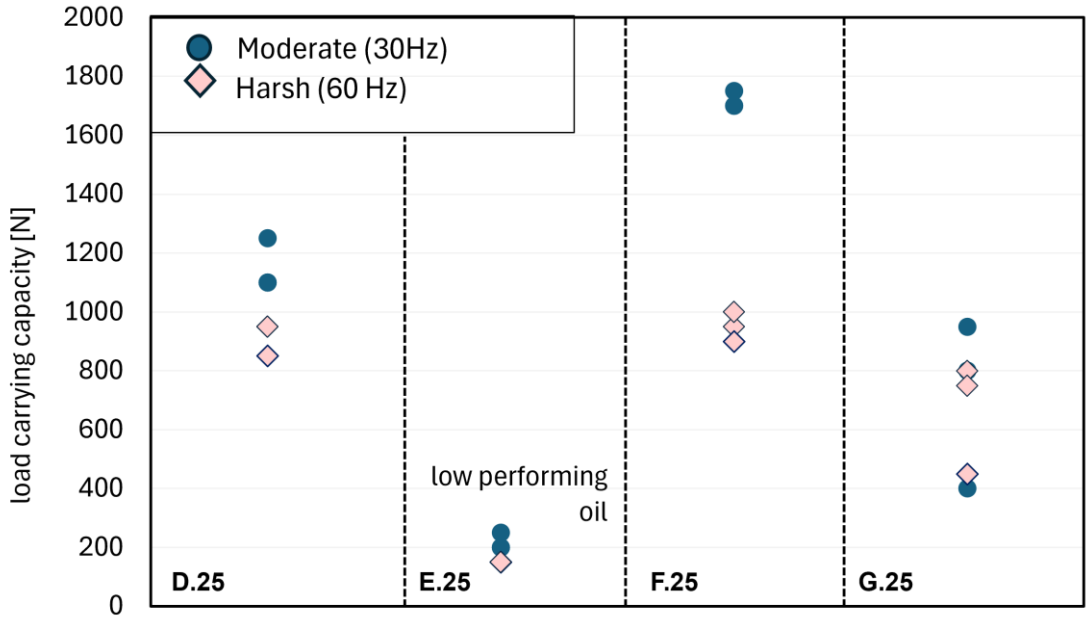
onset of adhesive wear on ball, abrasion on disk

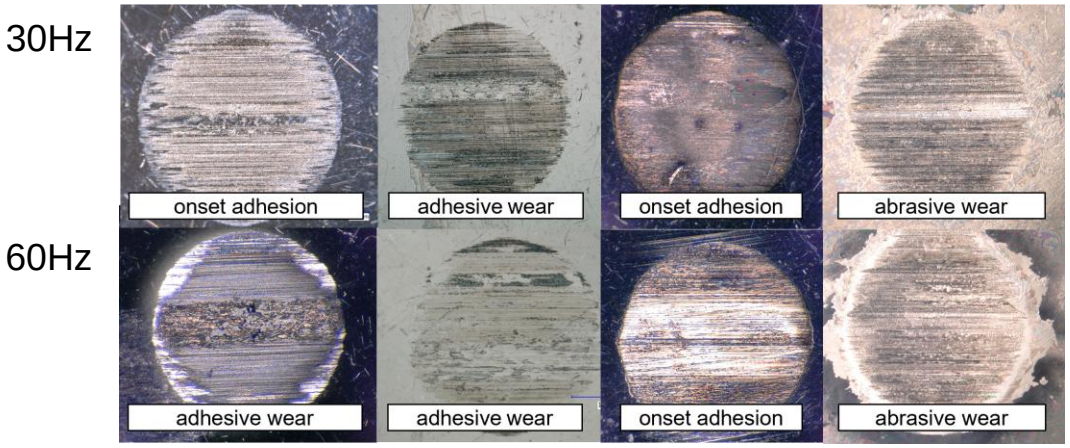
GPS Benchmark Results

Scuffing / EP behavior

- Four oils of different viscosity grades and field of application were tested

Code	D.25	E.25	F.25	G.25
Type	gearbox	gearbox	hydraulic	hydraulic
$\mu_{kin,40°C}$ [mm²/s]	14,5	50,9	46,0	23,0
SAE grade	-	75W	75W	75W
ISO grade	15	46	46	22





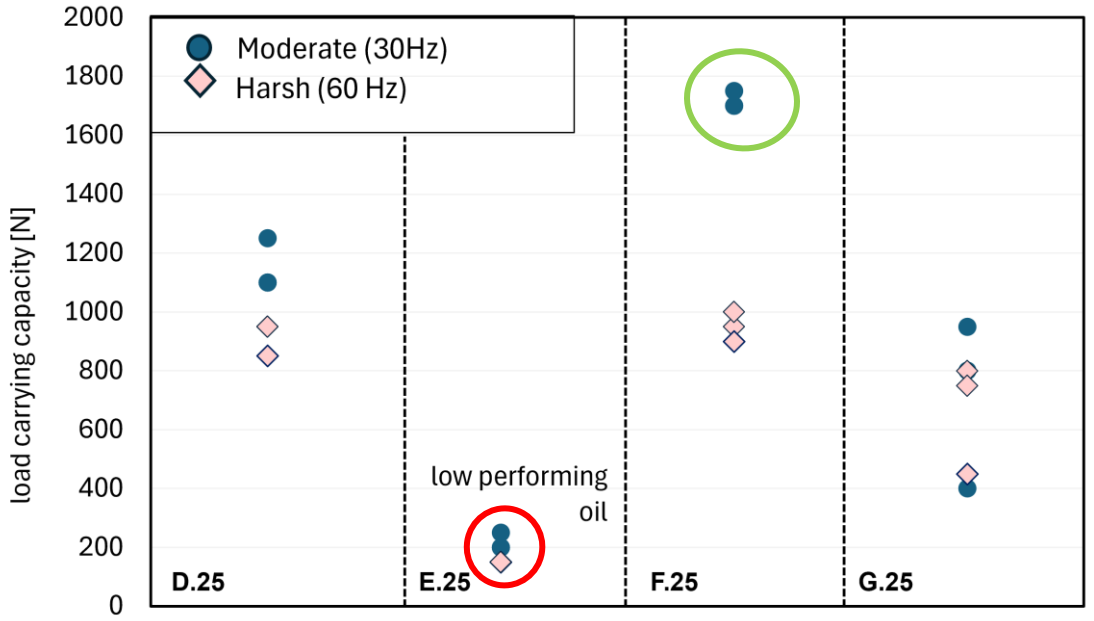
- Both test variants (30 Hz, 60 Hz) identify the low-performing oil E.25 with load carrying capacity < 400N
- Capability to detect scuffing confirmed by microscopy
- Moderate test conditions (30Hz) lead to least adhesive wear and increased sensitivity to detect adhesion
- Low load carrying capacity correlates to severe drop in CoF with every load step

GPS Benchmark Results

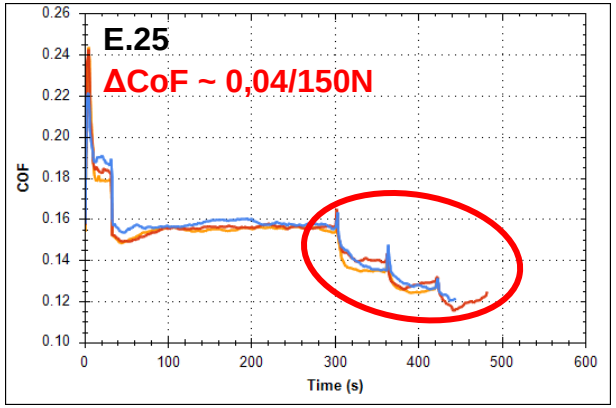
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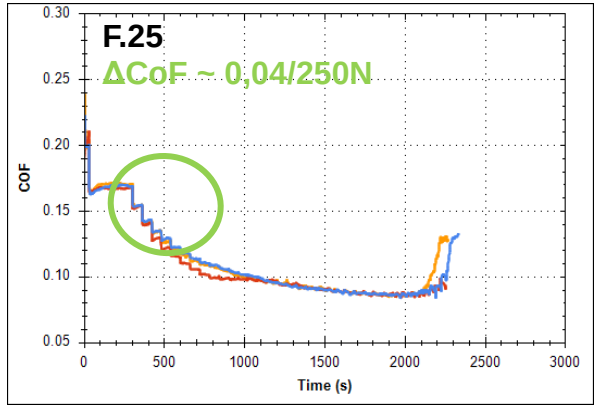
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Rating	✚	▭	✚	◯



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GPS Benchmark Results

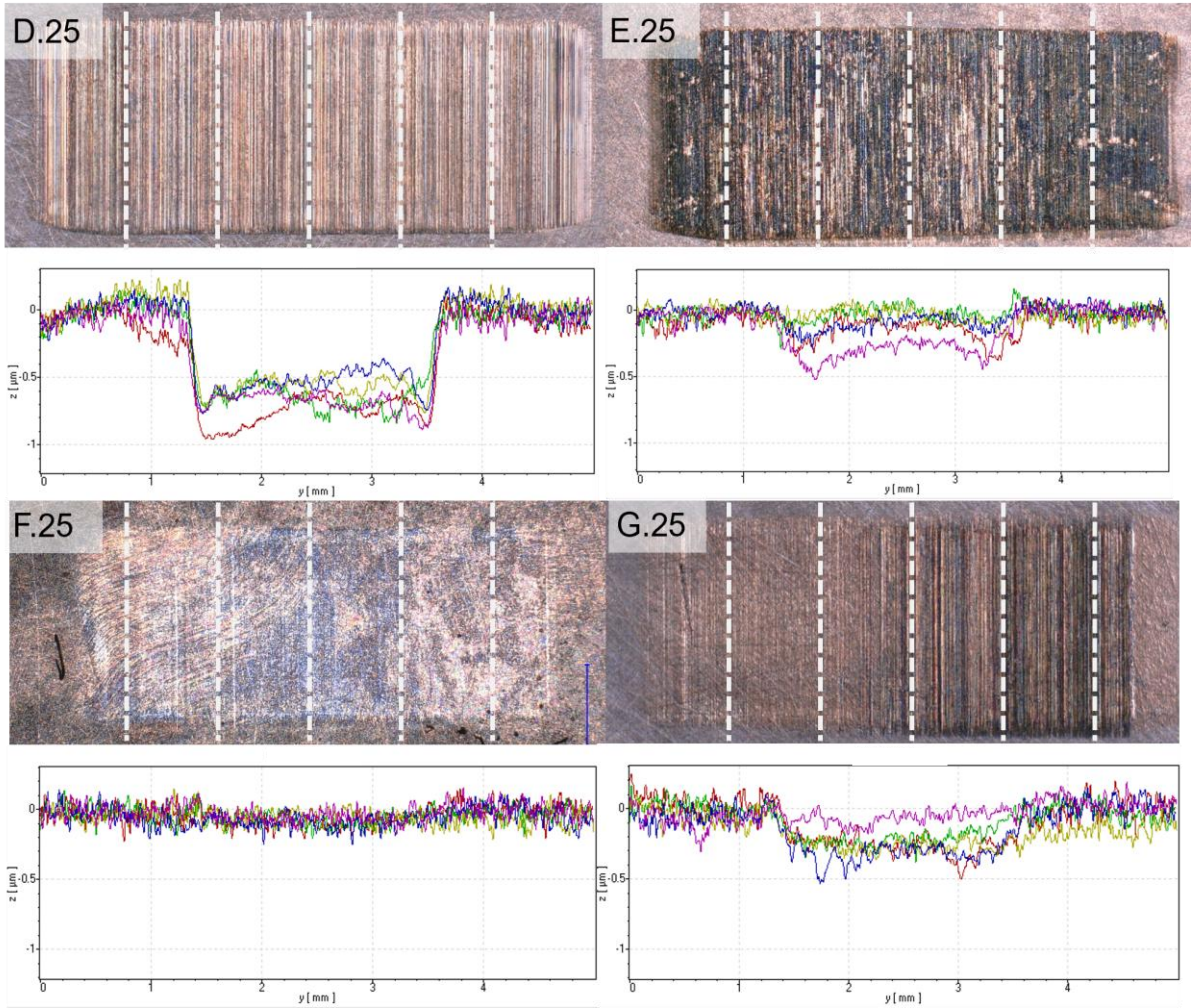
Wear resistance (AW)

- In addition to scuffing resistance by GPS, wear resistance was assessed at reduced contact pressure

Test parameter	wear resistance
Contact configuration	**cylinder-on-disk (90°)**
Lubrication	0.95 ml in oil bath
Temperature	60 °C
Normal force F_N	250 N (15“) 500 N (45“) 1000 N (60“)
Stroke s	2 mm
Frequency f	30 Hz (moderate)

- Wear volume was measured by white light interferometry, MicroView+ (Polytec)
- Oil F.25 exhibits the highest resistance to wear, associated with negligeable wear depth and wear volume.





GPS Benchmark Results

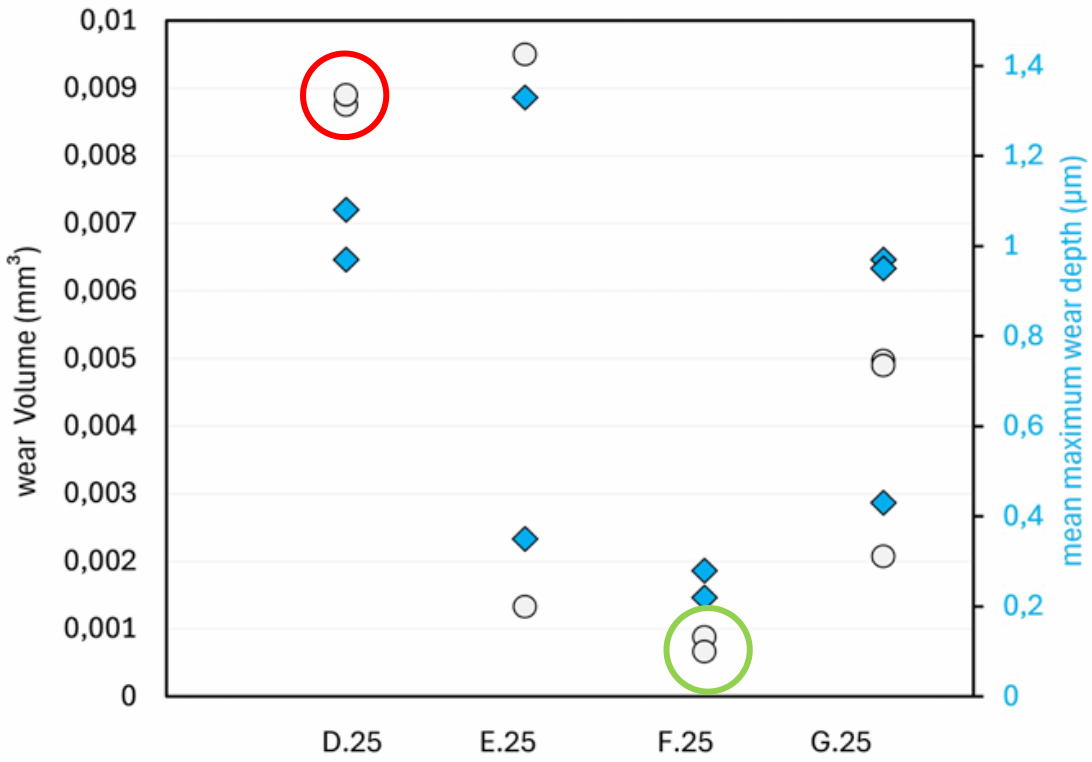
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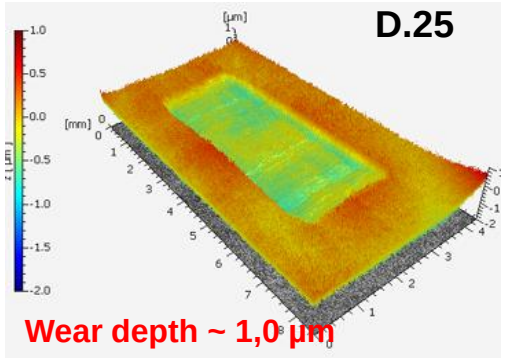
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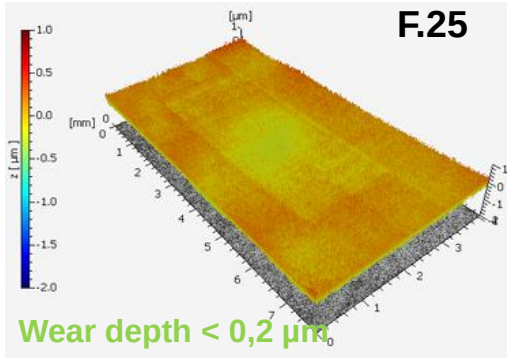
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- Oil F.25 exhibits the highest resistance to wear, associated with negligeable wear depth and wear volume.

Code	D.25	E.25	F.25	G.25
Rating	▭	○	✚	○







Discussion

Rating and comparison to DIN E 51834-7

- The GPS method clearly identifies oils of low scuffing resistance (E.25).
- Additional tests at reduced contact pressure identify oils of superior wear resistance (F.25)
- Oil F.25 performs best in terms of scuffing and wear resistance

Code	D.25	E.25	F.25	G.25
GPS scuffing	✚	▬	✚	◯
GPS wear	▬	◯	✚	◯

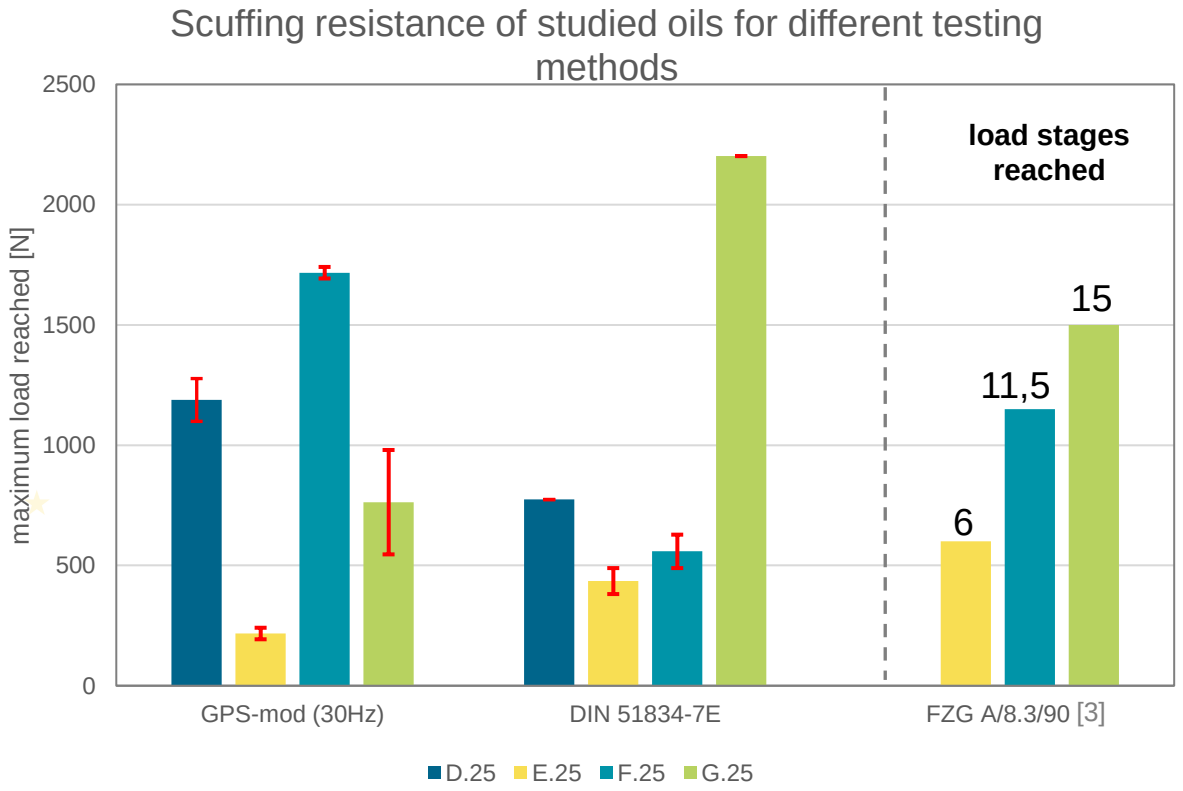
Discussion

Rating and comparison to DIN E 51834-7

- The GPS method clearly identifies oils of low scuffing resistance (E.25).
- Additional tests at reduced contact pressure identify oils of superior wear resistance (F.25)
- Oil F.25 performs best in terms of scuffing and wear resistance

Code	D.25	E.25	F.25	G.25
GPS scuffing	✚	▬	✚	◯
GPS wear	▬	◯	✚	◯
DIN 51834-7E	◯	◯	◯	✚
FZG A/8.3/90	n/a	▬	◯	✚

Observation: The rating depends on the test method used (GPS, DIN 5134-7E, FZG A/8.3/90) !



[3] Patzer, Beau (2024): Functional Screening Methods for Performance Assessment of transmission components

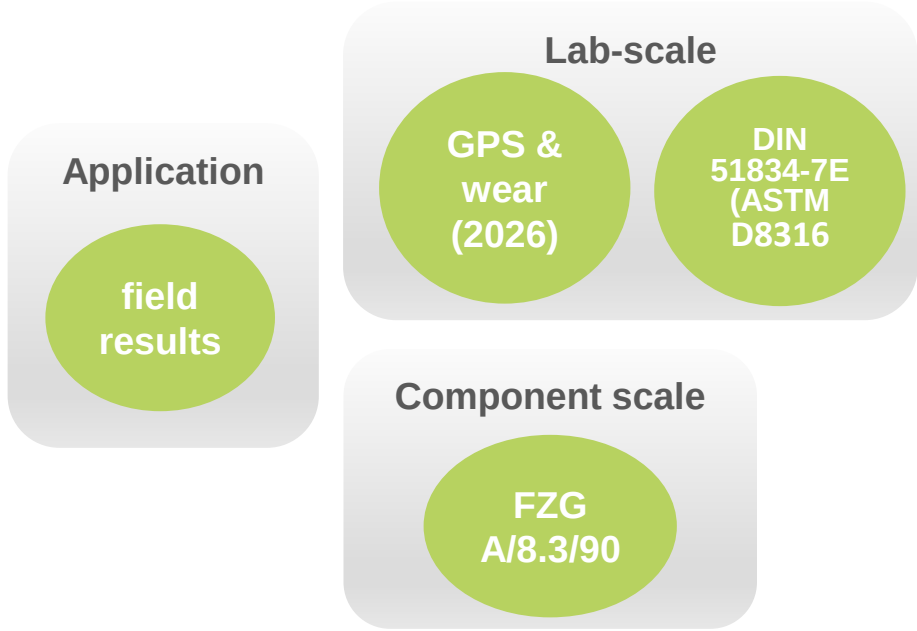
Conclusions & Outlook

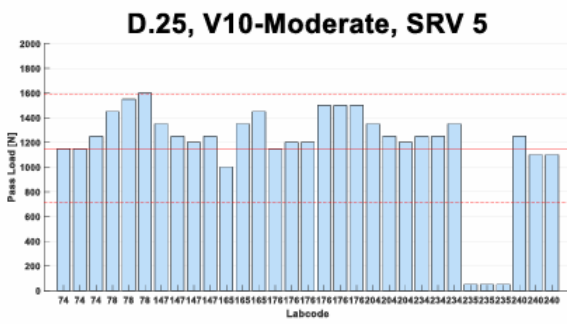
Conclusions

- GPS prescreening is sensitive to the onset of adhesive failure → quick identification of low performing oils
- Additional wear tests at reduced pressure yield information on wear resistance of oils
- The GPS method complements other standards, e.g DIN 51834-7E and A/8.3/90

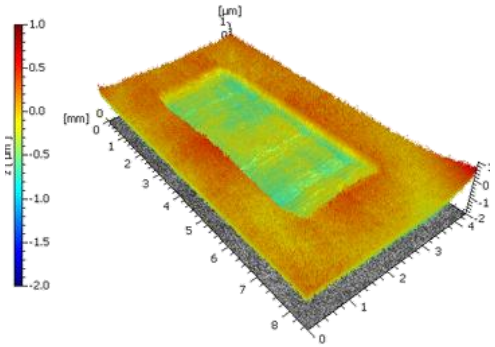
Outlook

- more contributors to address the same topic
- focus on performance of low viscosity oils and dielectric fluids
- standardization „3D wear measurement“ in scope of *DIN NA 062-09-109*





Contribution of institutes and labs in Round Robin Tests 2025 (GPS) [4]



Standardization of 3D wear measurement within *DIN NA 062-09-109*

[4] Optimol Instruments (2026); Report on statistical evaluation of round robin test 2.2025 and 3.2025

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09/24 09:30-10:50
EXPO CENTER SECOND FLOOR - OCEANIA IV

Johannes Walz

High-temperature fretting wear behaviour of established Tribaloys and a newly developed high-entropy alloy of reduced Cobalt content

Gefördert durch
Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie

THANK YOU FOR YOUR ATTENTION