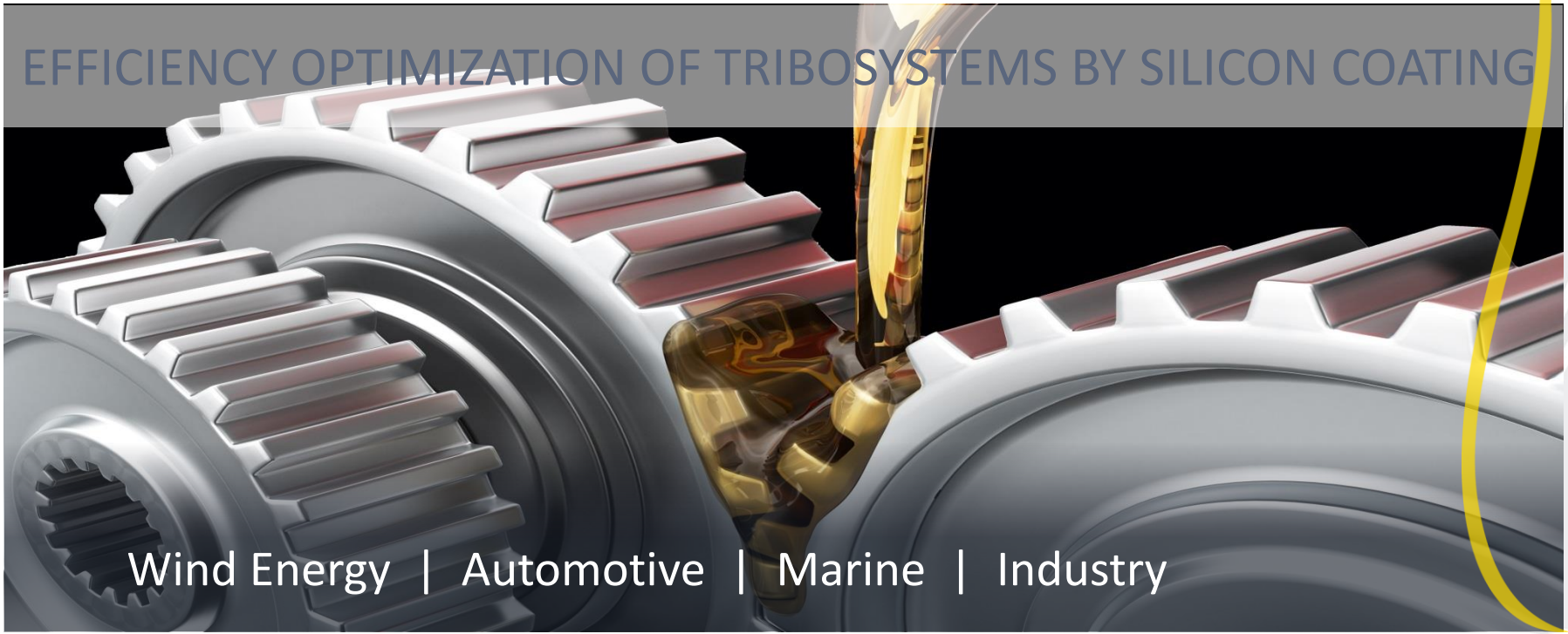
EFFICIENCY OPTIMIZATION OF TRIBOSYSTEMS BY SILICON COATING



Content

- Company and Products
- Technology
- Scientific tests
  - 2-disc
  - Sealing durability
  - Pin on disc
- Examples of applications (dyno test)
- Conclusion
- Next steps

REWITEC®

COMPANY AND PRODUCTS

- Establishment in 2003
- Developer, manufacturer and distributor of nano and micro particle based surface refinement products for the protection and the repair of tribologic systems
- Patents Europe, China, US application
- World wide sales network, office in Chicago
- Founder and Managing Partner: Stefan Bill

Target Markets

WIND ENERGY
- ONSHORE
- OFFSHORE

INDUSTRY
- STEEL
- CEMENT
- MINING
- OIL, GAS

SHIPPING
- MARINE
- INLAND
- YACHTS
- SUBMARINE

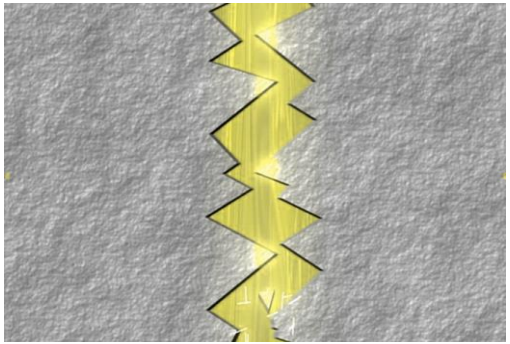
AUTOMOTIVE
- CONSUMER
- OEM
- MOTORCYCLES
- RACING
- OLDTIMER

The coating process

Step 1

Chemical-physical process

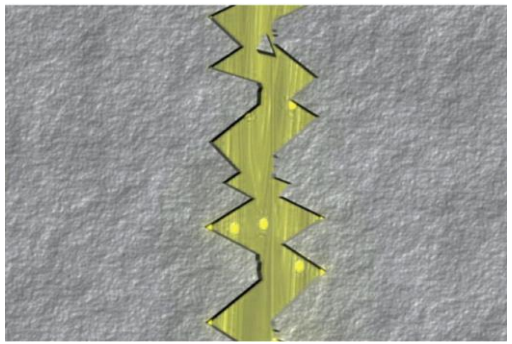
The product uses the lubricant as carrier to the mixed friction zones



Step 2

Chemical reaction

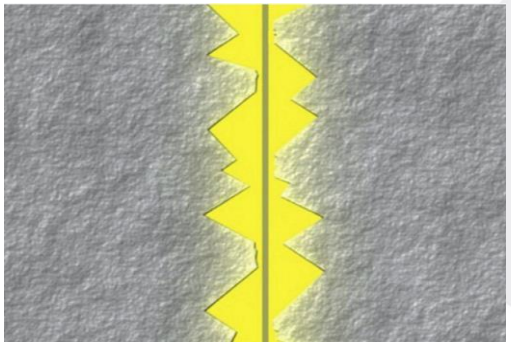
The coating particles ceramize the metal surfaces in mixed friction zones



Step 3

New metal-ceramic surface

Original material properties will be improved in terms of friction, temperature and wear significantly



REWITEC® IN ACTION

SCIENTIFIC TESTS

Scientific tests

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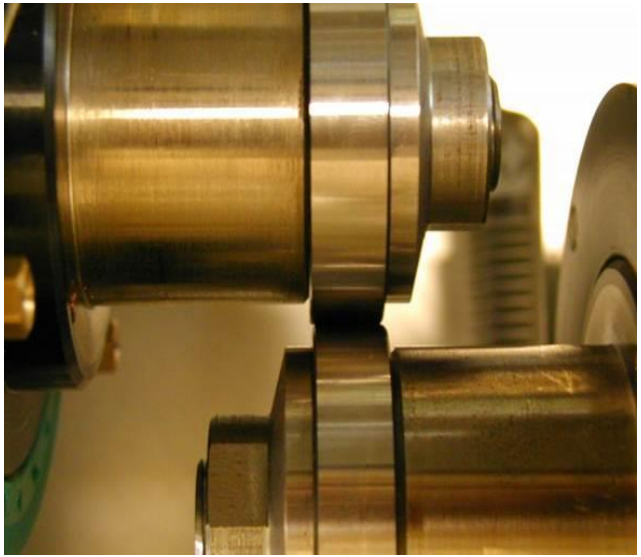
on the basis of a decision by the German Bundestag

KOMPETENZZENTRUM tribologie MANNHEIM

Competence Center of Tribology
Mannheim-Germany



2-Disc Assembly Rolling Wear Tests

Stress value: 1 GPa (normal force 2150 N)
Rotating speed: 424 rpm / 339 rpm, slip 20 %
Test-duration: 39,3 h
Temperature: oil inlet temperature 60 °C

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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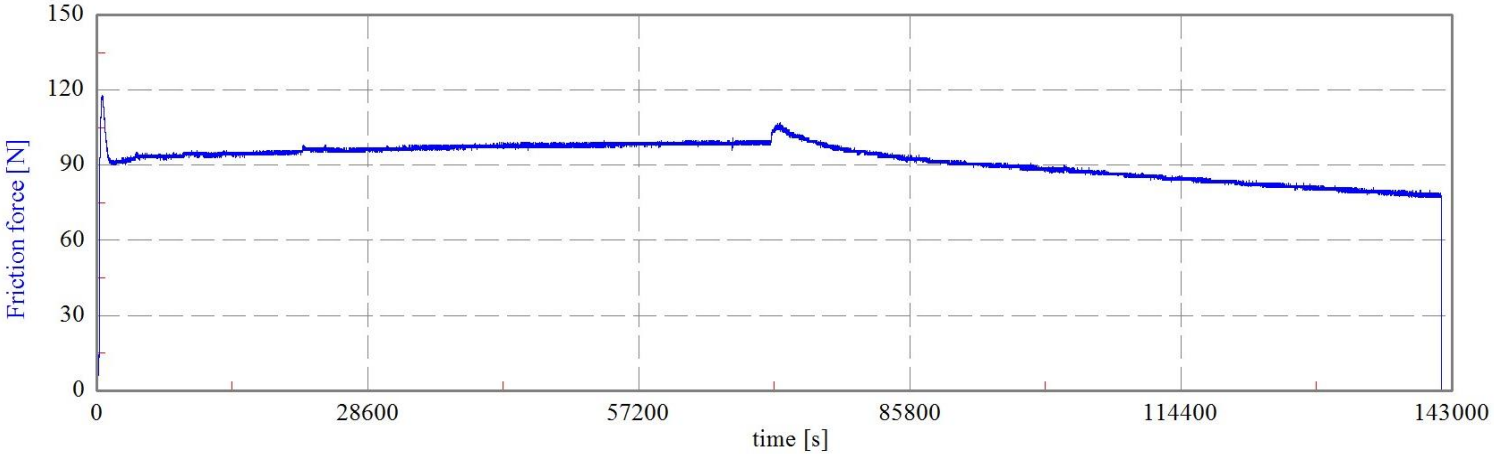
KOMPETENZZENTRUM tribologie MANNHEIM



REWITEC_1_27-06-2014 | 4.7.2014

Castrol Optigear X320 with REWITEC® added after 19 hours 39 minutes

$R_{z,\ before}$ = 2,389 µm
$R_{a,\ before}$ = 0,360 µm

$R_{z,\ after}$ = 1,129 µm (-53 %)
$R_{a,\ after}$ = 0,180 µm (-50 %)

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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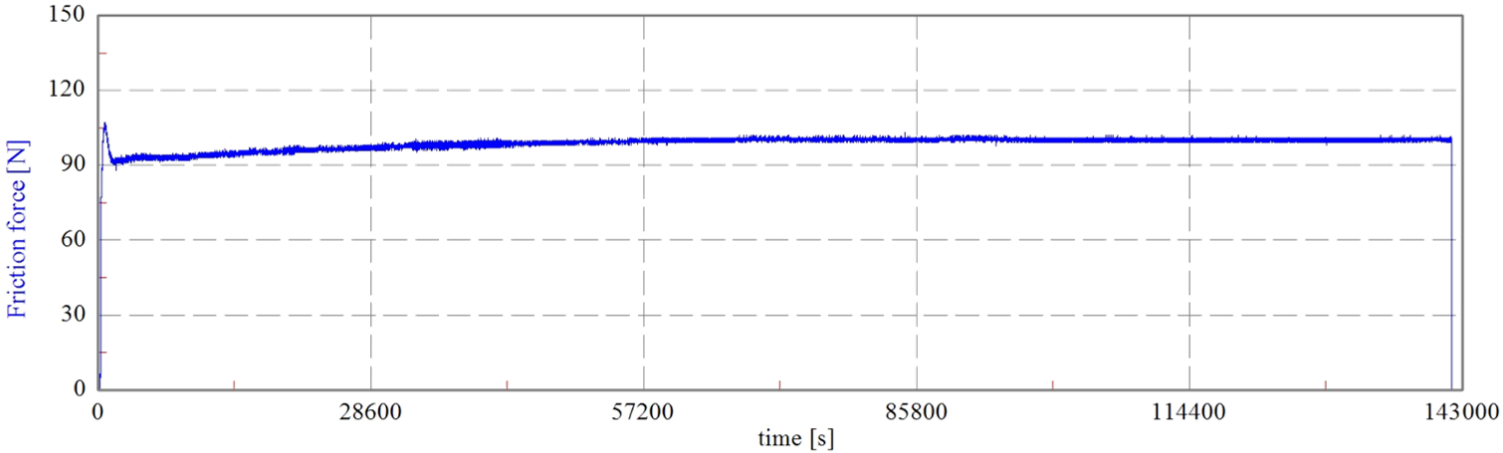

REWITEC_2_02-07-2014 | 4.7.2014

Castrol Optigear X320 without REWITEC®

$R_{z,\ before}$ = 2,389 µm
$R_{a,\ before}$ = 0,360 µm

$R_{z,\ after}$ = 1,663 µm (-30 %)
$R_{a,\ after}$ = 0,285 µm (-21 %)

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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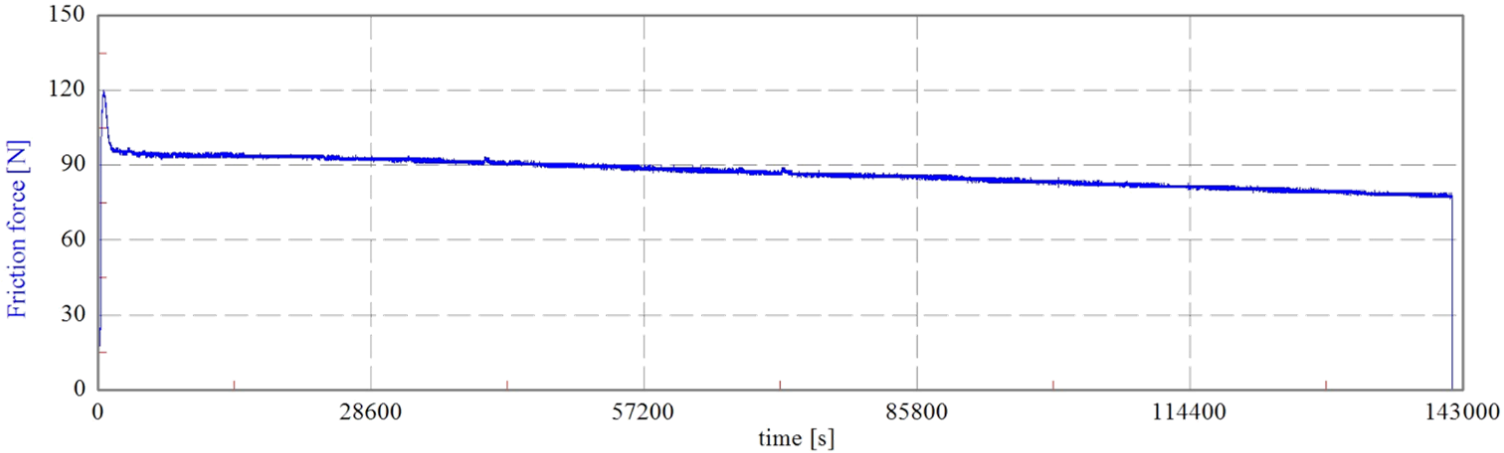

REWITEC_3_04-07-2014 | 4.7.2014

Castrol Optigear X320 with REWITEC®

$R_{z,\ before}$ = 2,389 µm
$R_{a,\ before}$ = 0,360 µm

$R_{z,\ after}$ = 1,024 µm (-57 %)
$R_{a,\ after}$ = 0,151 µm (-58 %)

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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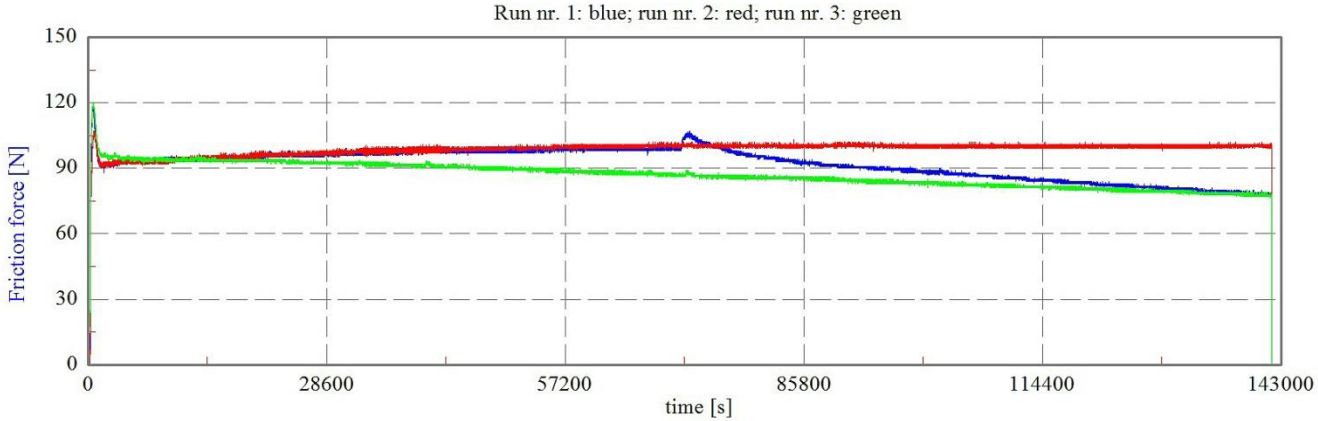

- Red graph without REWITEC®
- Blue graph with REWITEC® added after 20 hours
- Green graph with REWITEC® added at the beginning
- Reduction of the surface roughness (R_a) due to wear up to 58 %
- Reduction of the friction force up to 22 %

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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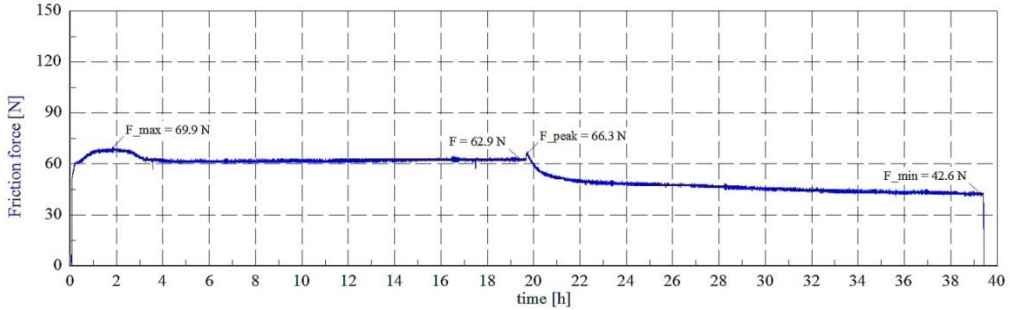
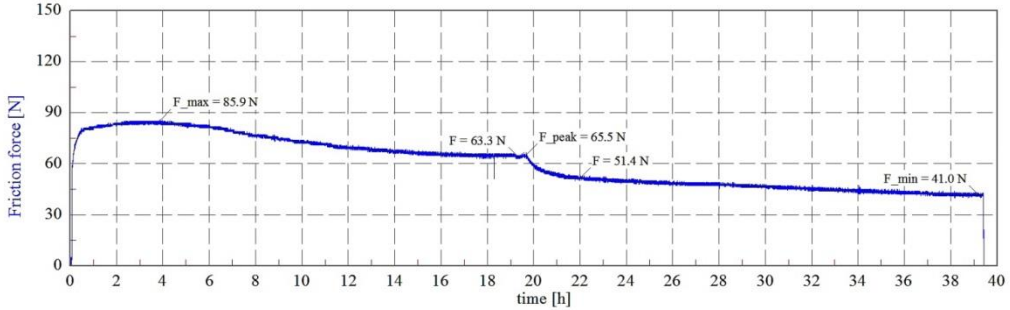


Castrol Optigear Synthetic X320



Mobilgear SHC XMP 320

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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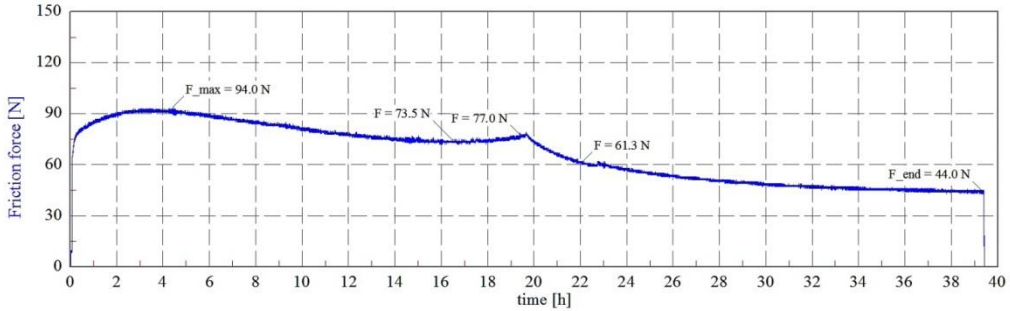
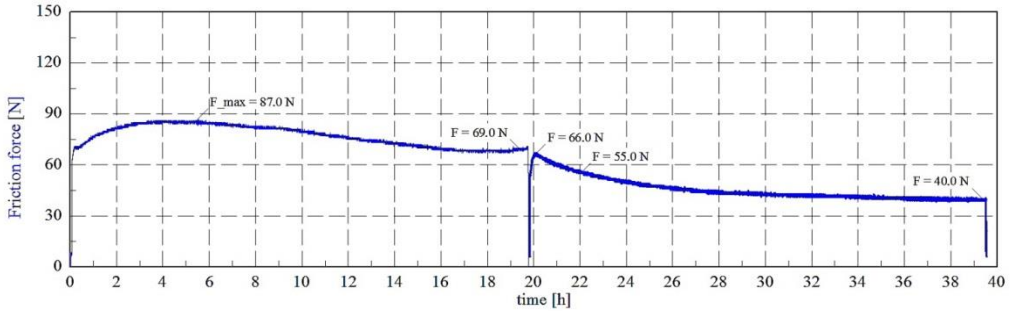


Klübersynth GEM 4-320N



Fuchs Unisyn CLP 320

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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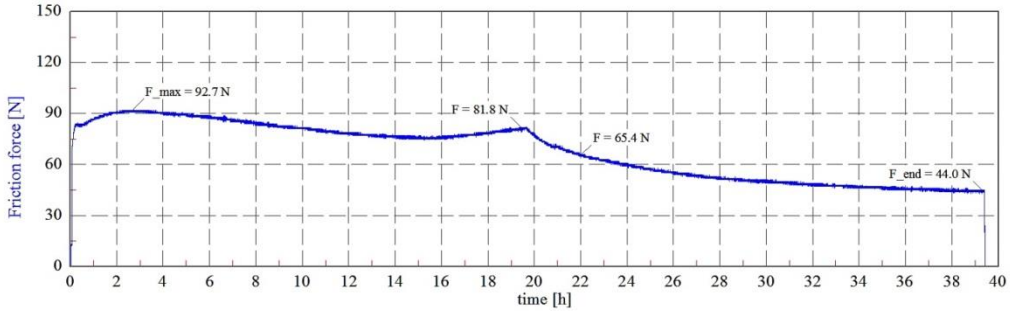
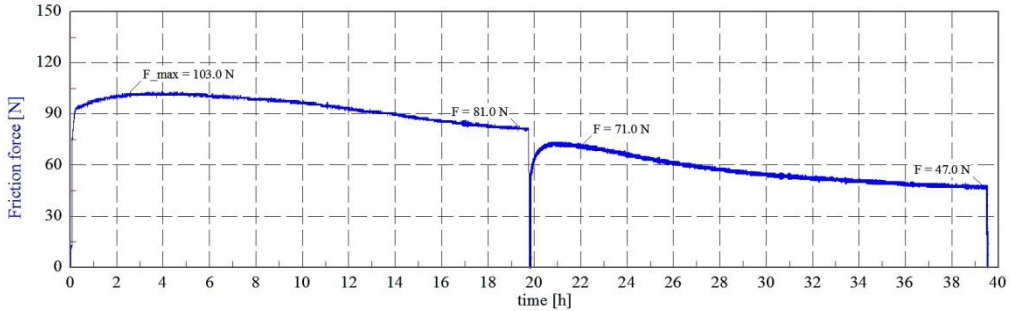


Amsoil PTN 320



Shell Omala S4 GX 320

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils

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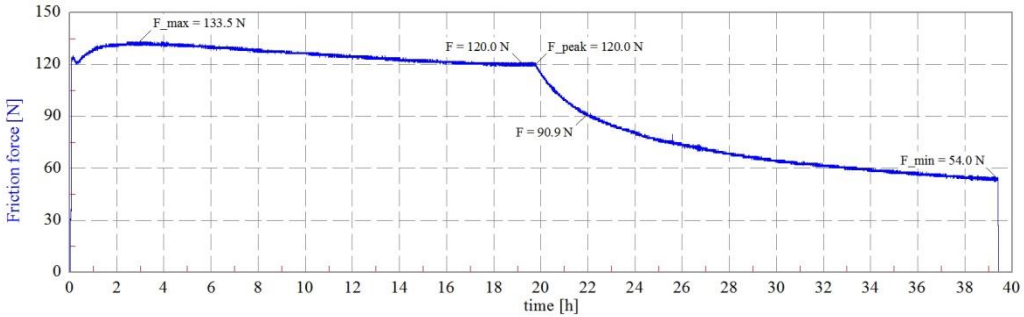

Klüberbio EG 2-150

Scientific tests
2-Disc assembly rolling wear test – grease test

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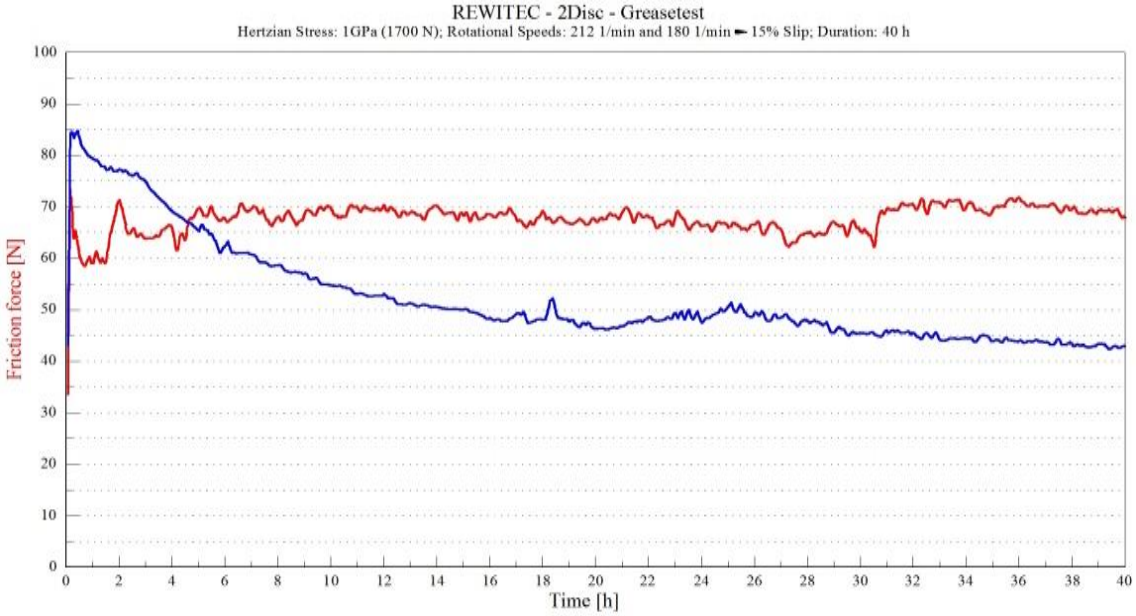

FAG Arcanol Multitop grease

Hertzian Stress:	1700 N
Rotational Speed:	212 min^{-1} and 180 min^{-1}
Slip:	15 %
Duration:	40 h

Scientific tests
2-Disc assembly rolling wear test – wind turbine oils – Overview

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	Oil grade	Castrol Optigear Synthetic X320	Mobilgear SHC XMP 320	Klübersynth GEM 4-320N	Klüberbio EG 2-150	Fuchs Unisyn CLP 320	Amsoil PTN 320	Shell Omala S4 GX 320
Measured data	R_a, before [µm]	0,22 µm	0,22 µm	0,22 µm	0,22 µm	0,22 µm	0,22 µm	0,22 µm
	R_a, after [µm]	0,129 µm	0,123 µm	0.100 µm	0.133 µm	0.109 µm	0.180 µm	0.165 µm
	R_a, Reduction [%]	**41 %**	**44 %**	**54 %**	**40 %**	**50 %**	**18 %**	**25 %**
	R_z, before [µm]	2,00 µm	2,00 µm	2,00 µm	2,00 µm	2,00 µm	2,00 µm	2,00 µm
	R_z, after [µm]	1,52 µm	1,18 µm	0.91 µm	1,04 µm	1.02 µm	1.51 µm	1.42 µm
	R_z, Reduction [%]	**24 %**	**41 %**	**55 %**	**48 %**	**49 %**	**25 %**	**29 %**
	Friction Force, before	62.9 N	63,3 N	73.5 N	120,0 N	69 N	81.8 N	81 N
	Friction Force, after	42.6 N	41,0 N	44,0 N	54,0 N	44,0 N	44,0 N	47,0 N
	Reduction Friction Force	**33 %**	**35 %**	**40 %**	**55 %**	**36 %**	**46 %**	**42 %**

Scientific tests
2-Disc assembly rolling wear test – steel vs. phosphated discs

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2-Disc Assembly Rolling Wear Tests with VW first fill manual gearbox oils

Stress value: 1 GPa (normal force 2150 N)
Rotating speed: 424 rpm / 339 rpm, slip 20 %
Test-duration: 39,3 h
Temperature: oil inlet temperature 60 °C

Scientific tests
2-Disc assembly rolling wear test – steel vs. phosphated discs

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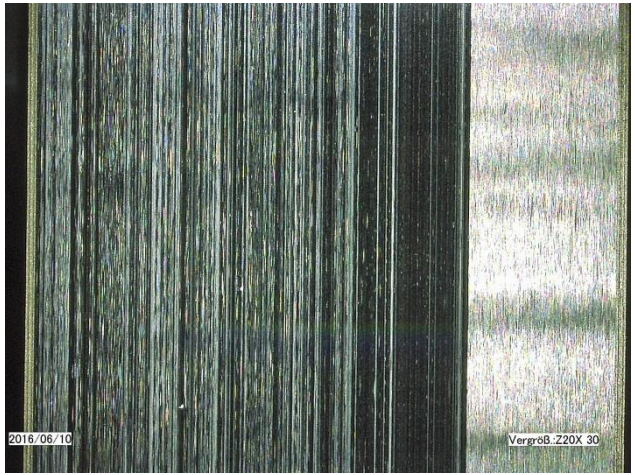
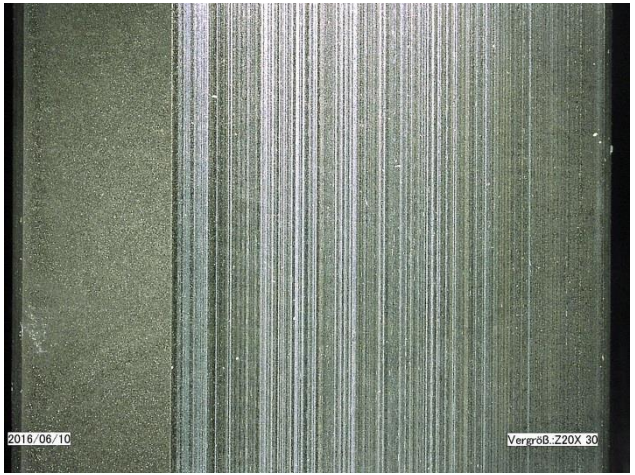
- Left: Standard steel disc
- Right: Phosphated disc

Scientific tests
2-Disc assembly rolling wear test – steel vs. phosphated discs





- Left picture: Standard steel disc without REWITEC®
- Right picture: Phosphate disc without REWITEC®

Scientific tests
2-Disc assembly rolling wear test – steel vs. phosphated discs

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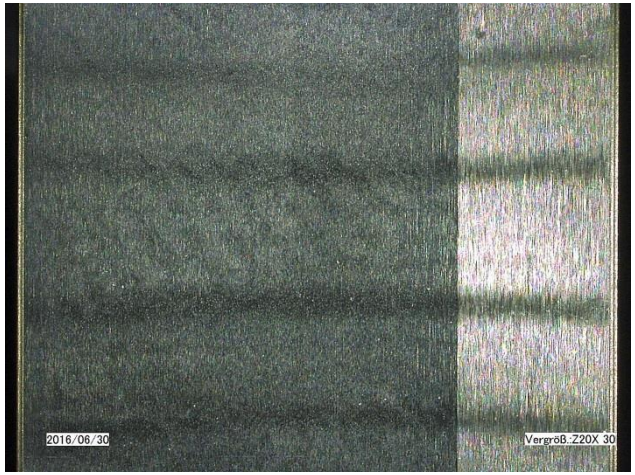

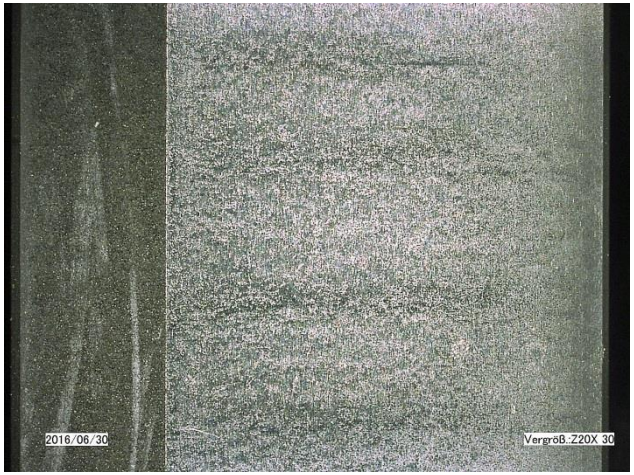

- Left picture: Standard steel disc with REWITEC®
- Right picture: Phosphated disc with REWITEC®
- Difference of the surface roughness up to 77 %

Scientific tests
2-Disc assembly rolling wear test – steel vs. phosphated discs

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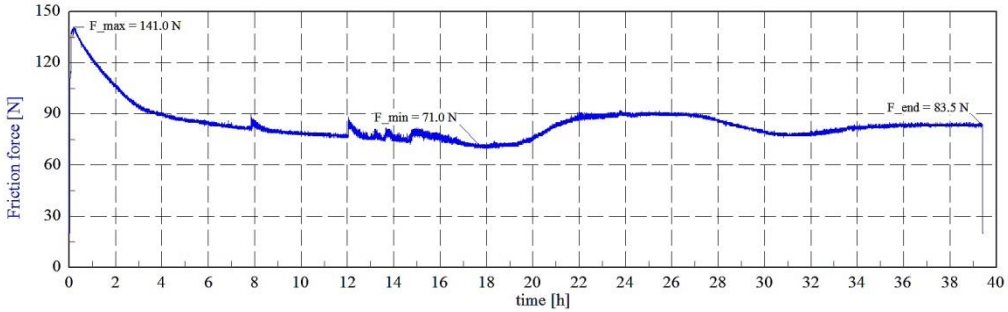
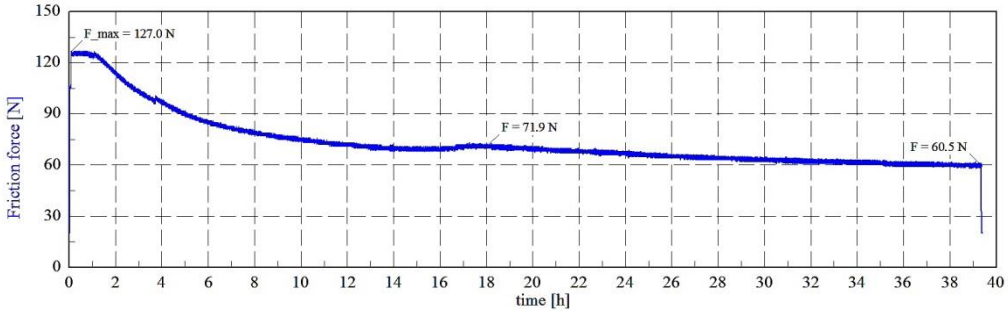


without REWITEC®



with REWITEC®

- Reduction of the wear up to 9 %
- Reduction of the friction force up to 28 %

Scientific tests
2-Disc assembly rolling wear test – steel vs. phosphated discs

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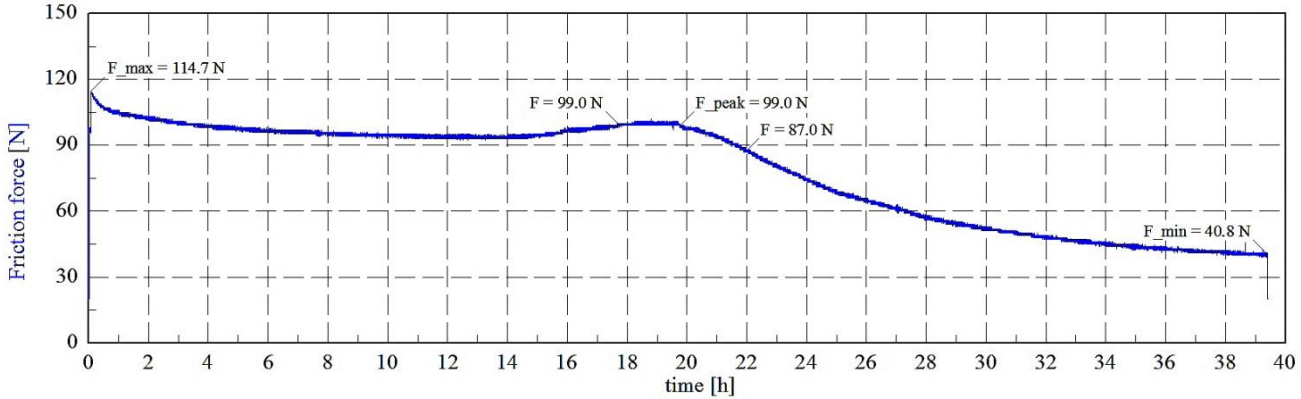

VW G 052 527 A2 with REWITEC® added after 19 hours 39 minutes

- Graph with REWITEC® steel-steel discs
- Reduction of the friction force compared to phosphated discs:
  - 51 % without REWITEC®
  - 33 % with REWITEC®

Scientific tests
2-Disc assembly rolling wear test – Engine oil

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Test parameters:

Test specimens	Test discs from previously damaged camshaft
Camshaft manufacturer	German engine manufacturer
Test period	40 h
Lubricant	Engine Oil SAE 10W-40 of the engine manufacturer

Scientific tests
2-Disc assembly rolling wear test – Engine oil

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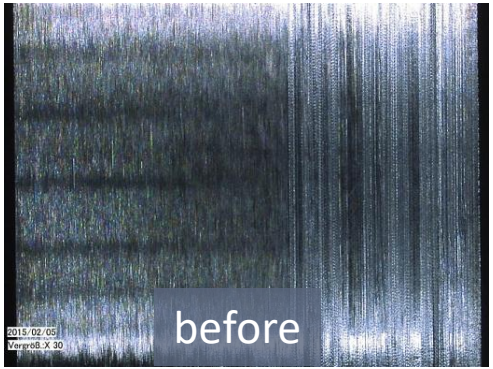
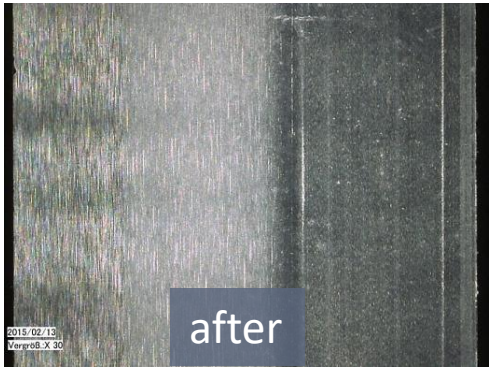


Camshaft disc before testing with REWITEC® :

- **Heavy grooves in the right section before the test-run**



Camshaft disc after testing with REWITEC® :

- **Grinding pattern completely disappeared**
- **Grooves significantly reduced**
- **Significant reduction of friction**

Scientific tests
2-Disc assembly rolling wear test – Engine oil

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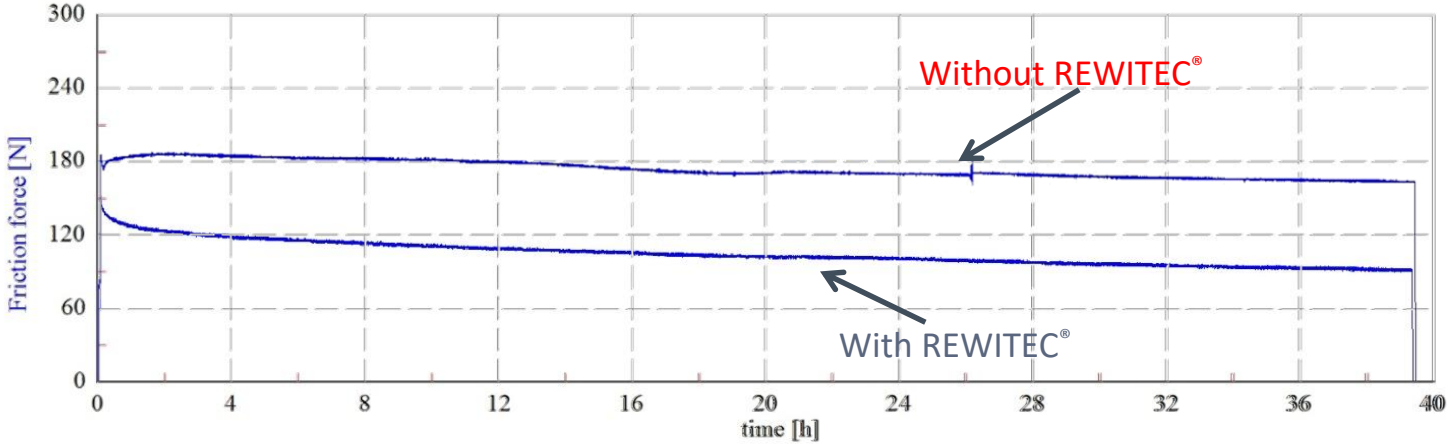

- Upper graph without REWITEC®
- Lower graph with REWITEC®
- Reduction of the friction force up to 45 %
- Reduction of the surface roughness up to 73 %*)

*) 50% less surface roughness can lead to a 20-fold life expectancy– thesis of Dr.-Ing. Michael Gleß.

Scientific tests
Sealing Durability of Radial Shaft Seals

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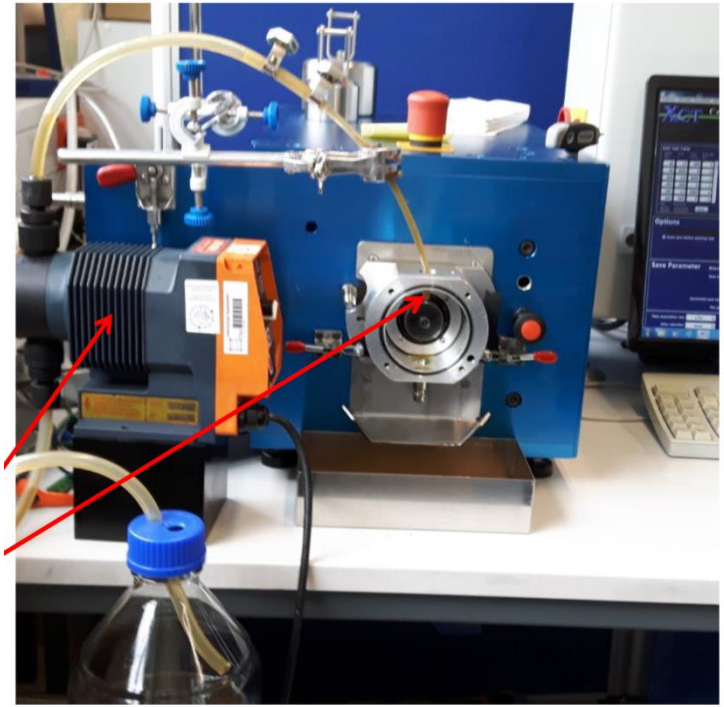

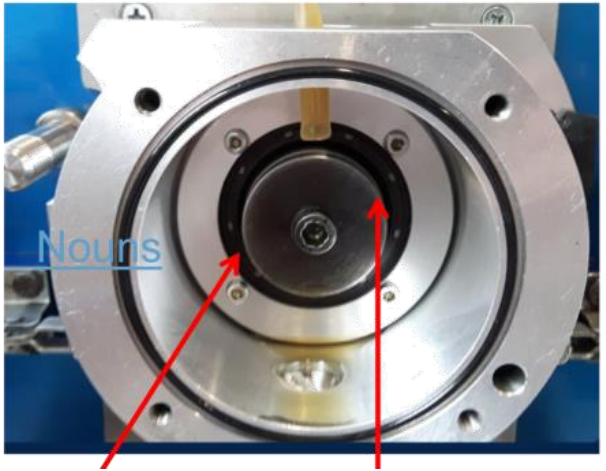

Scientific tests
Sealing Durability of Radial Shaft Seals

Supported by:

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Test 1: Engine oil (10W-40) without REWITEC®

Test 2: Engine oil (10W-40) with REWITEC®

None of the test pairings showed significant signs of abrasion

Scientific tests
Sealind Durability of Radial Shaft Seals

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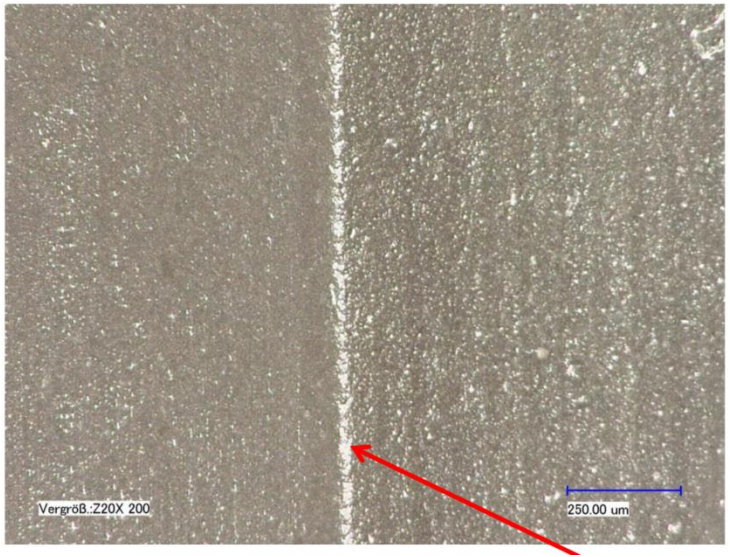
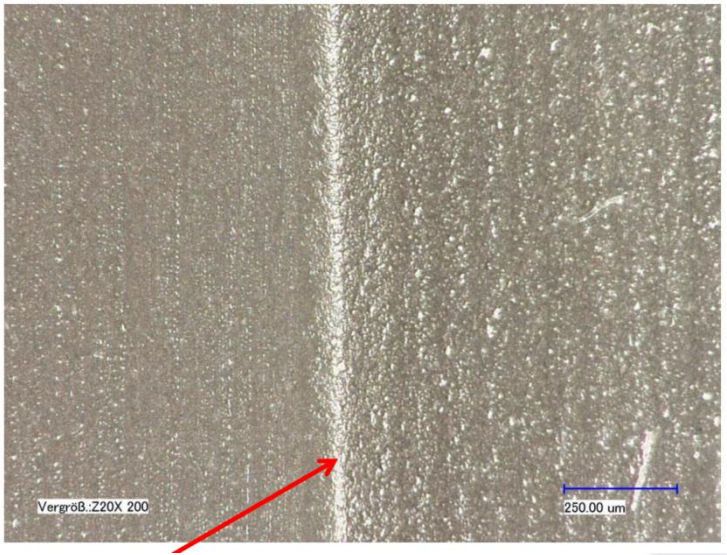
Test 1: Engine oil (10W-40) without REWITEC®



Test 2: Engine oil (10W-40) with REWITEC®



None of the test pairings showed significant signs of abrasion

Scientific tests
Pin-on-disc test

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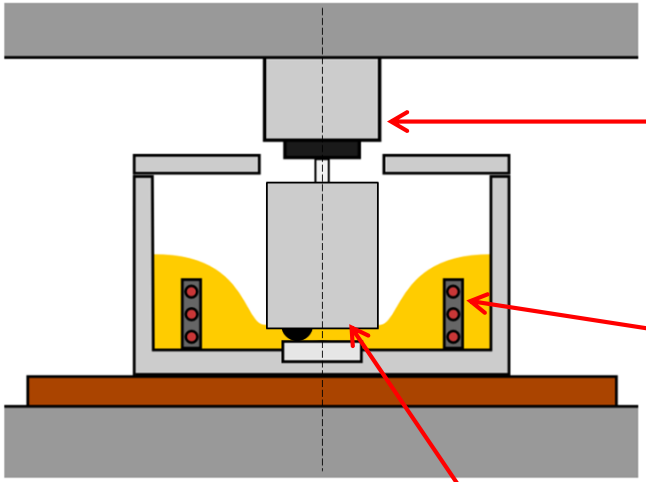
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

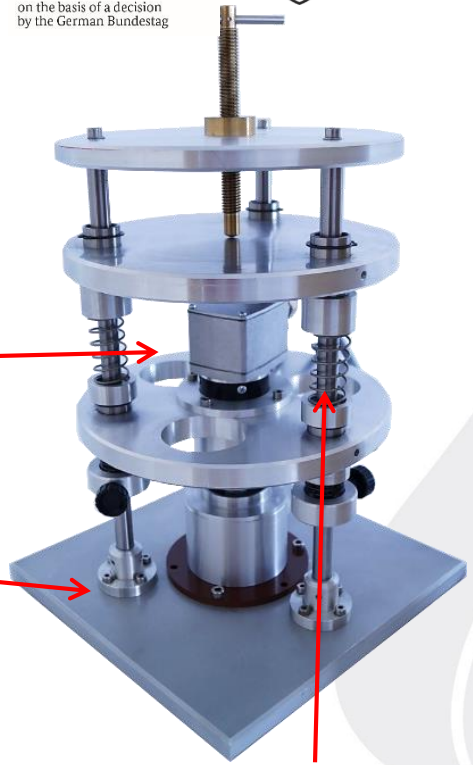
Micro Tribometer



Electrical motor

Heatable oilsump

Tribological contact (bearing ball on a plan steel plate)



Spring system to adjust normal force

Scientific tests
Pin-on-disc test

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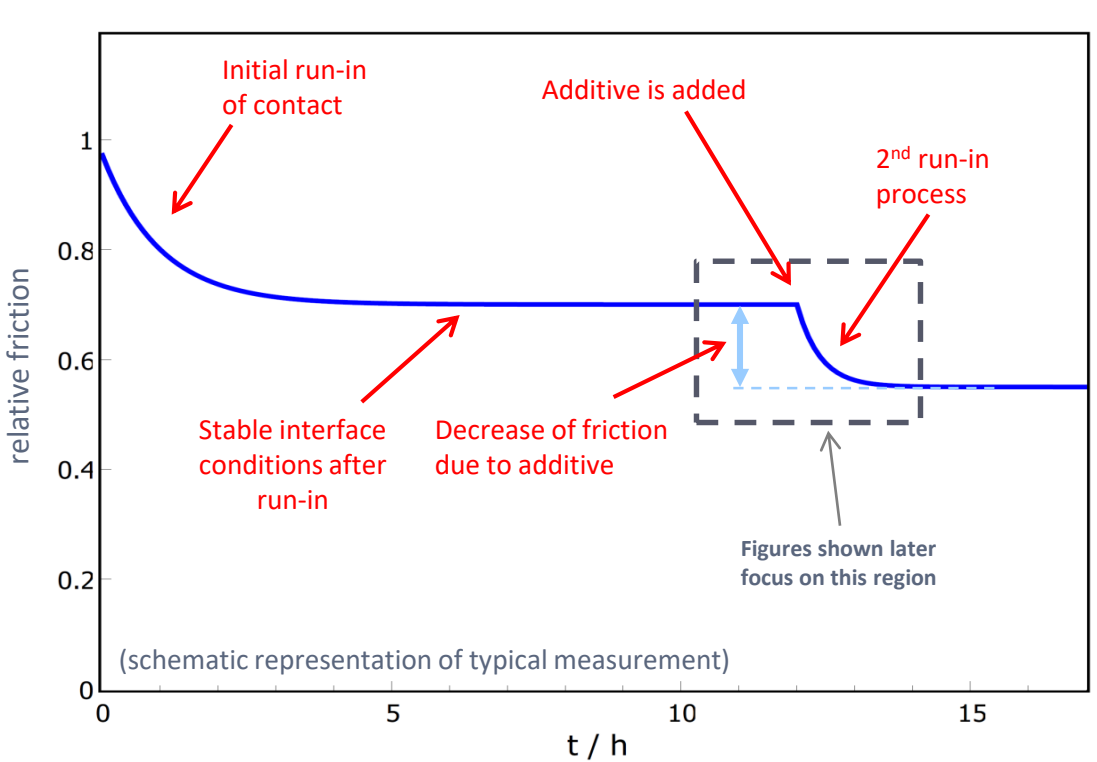

Measurement procedure:

I. Run-in of the contact until stable interface conditions are established

II. Additive is added

III. "2nd Run-in": improved tribo-contact is developed due to additive effects

IV. New stable interface conditions are established

V. Difference of friction levels before and after additiv addition:
Reduction of friction due to additive

Scientific tests
Pin-on-disc test – Exxon Marine Oils

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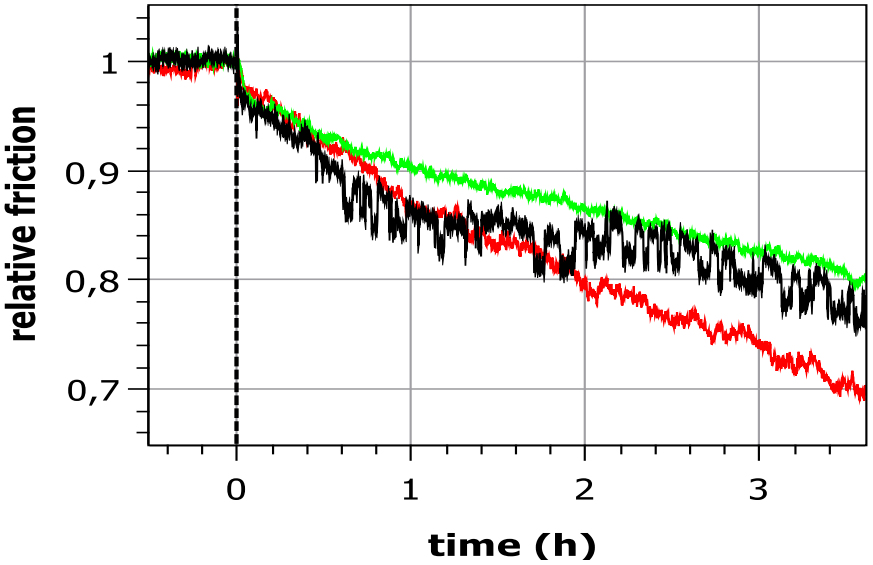


Oil Mobilgard 412 for A/E
Oil Mobilgard 300C for M/E Circ.
Oil Mobilgard 5100 L.O. Cyl.

Parameter:
70° C; 7 N; 2,500 min^{-1}

Scientific tests
Pin-on-disc test – Honda Engine Oils

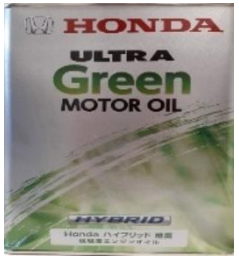
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Following very low viscosity oils were tested with REWITEC®:

- Motor oil Honda Ultra Next:
  - 0W-8

- Motor oil Honda Ultra Green:
  - 0W-25



Scientific tests
Pin-on-disc test – Honda Engine Oils

Supported by:
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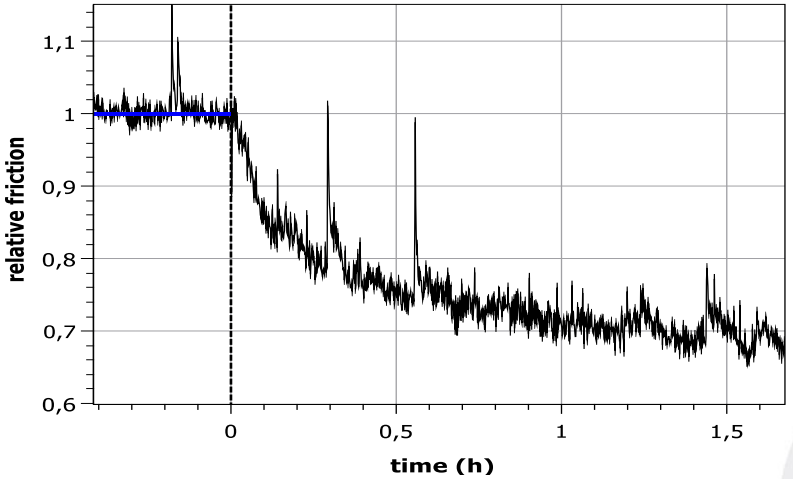
Honda Ultra Next motor oil
Room temperature; load 5 N; 4000 min^{-1}



Friction reduction 30 % after 1 hour

Scientific tests
Pin-on-disc test – Honda Engine Oils

Supported by:
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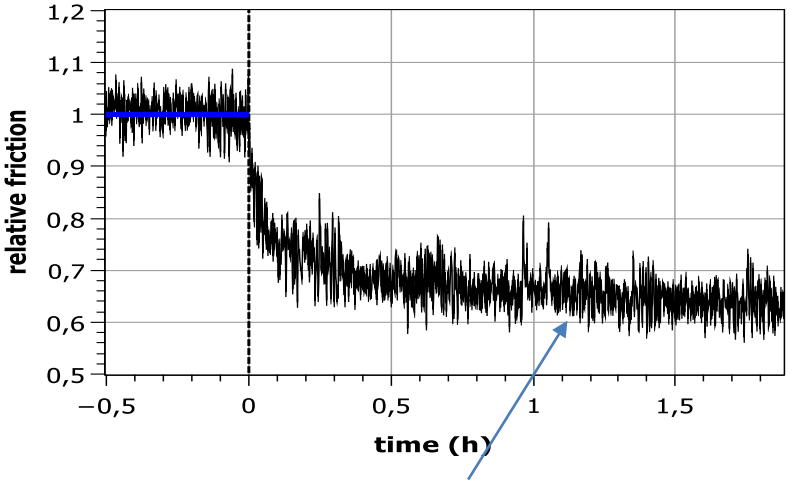
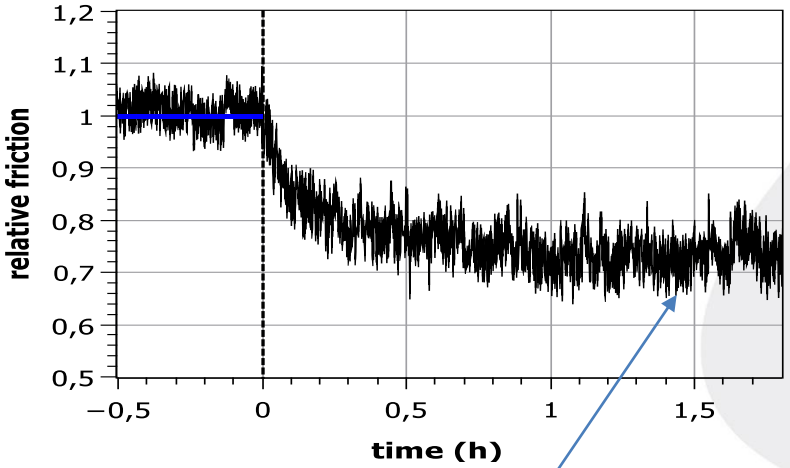
Honda Ultra Green engineoil
Room temperature; load 5 N;
4000 min^{-1}



friction reduction 35 % after 1 hour

Honda Ultra Green engine oil
70°C; load 5 N; 4000 min^{-1}



friction reduction 27 % after 1 hour

Examples of application:

Coating and analysis of a generator on a ship

Task:

- Fuel saving

Result:

In long-term testing with certificated measurement instruments, the following was noted:

- Significant fuel savings in the tested diesel generator „Daihatsu 6 DK28“
  → up to 14.000,- US$ per year

Examples of application:

Coating and analysis of a diesel generator

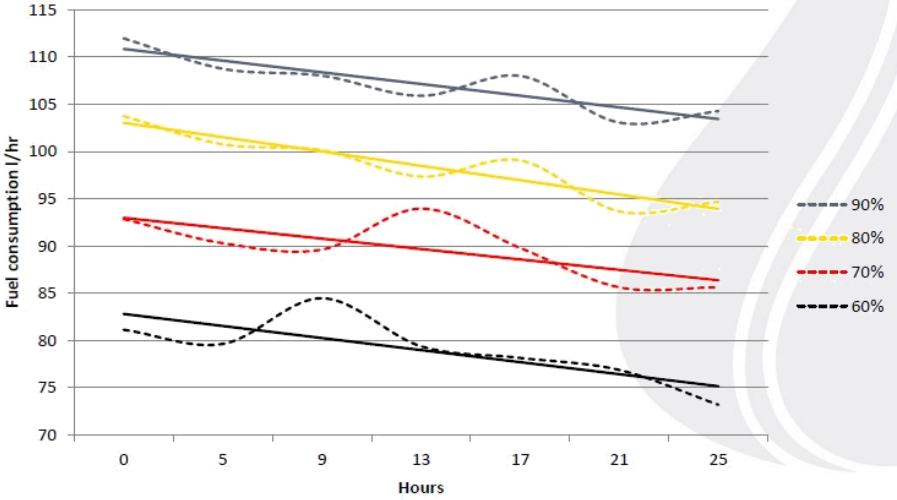
Task:

- Fuel saving

Result:

In long-term testing with certificated measurement instruments, the following was noted:

- Up to 9 % fuel savings in the tested diesel generator



Examples of application:

Nissan GT-R R32 engine treatment by M. Krumm

Test dynamometer:
Dynapack Chassis Dynamometers Evolution 3000

Baseline: 281 BHP / 348 Nm

Treatment with REWITEC® PowerShot® L (29.01.2016)
Improvement after 2 h: **+16 BHP / 15 Nm**

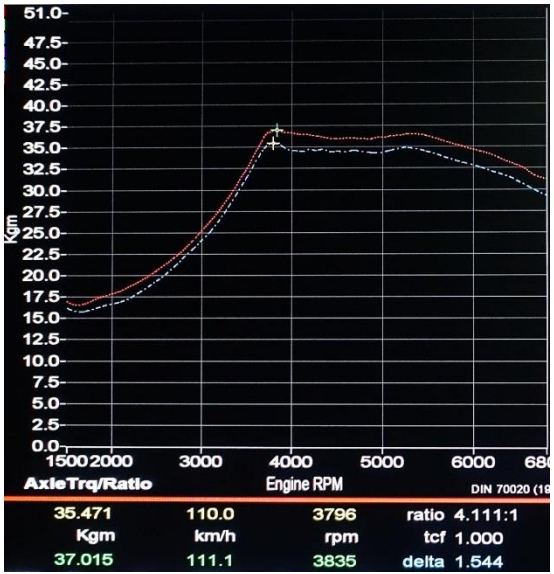
Additional transmission treatment with REWITEC® G5 (30.01.2016)

Complete end-result-improvement after 6 weeks: **+28 BHP**

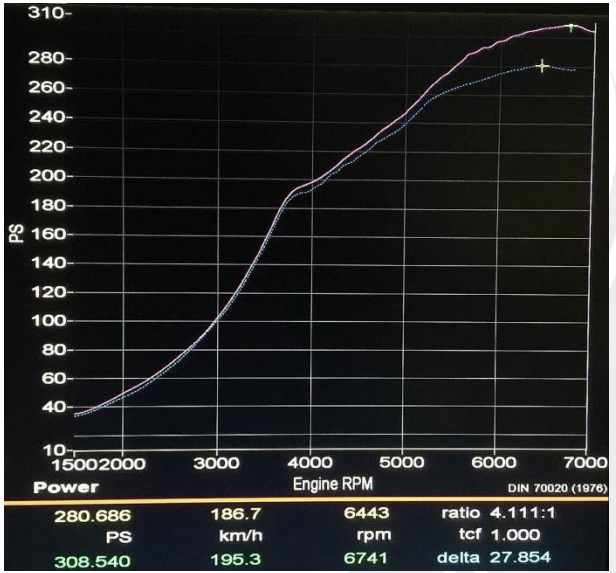
Examples of application:

Nissan GT-R R32 engine treatment by M. Krumm

29.01.2016



29.01.2016

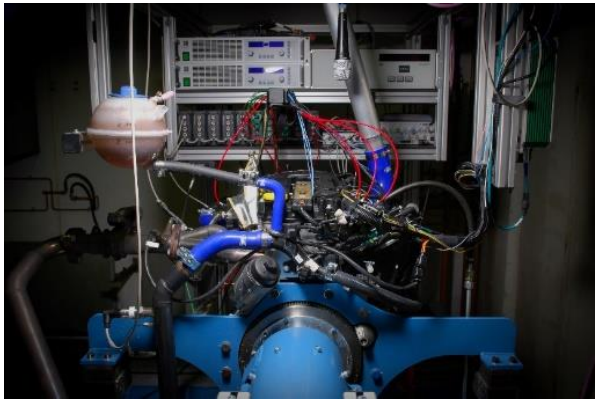


17.03.2016

Conclusion

- Up to 55% less friction and 54% less surface roughness (Ra) in 2-disc tests with gear lubricants
- Up to 35% less friction in Pin-on-disc tests with engine lubricants
- Very thin tribo layer with a high ratio of Si and Al in SNMS analyses (Secondary Neutral Mass Spectrometry)

Next Steps



- Detailed engine tests:
  - Bench tests at Ruhruniversität Bochum
  - Fuel efficiency, emissions

- FIB Micro sections for more detailed tribo layer analyses
- Further product formulation optimization for engine applications

Many thanks

FOR YOUR ATTENTION

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