Innovation in Motion

Advanced Coating Technologies for high engine efficiency and weight reduction

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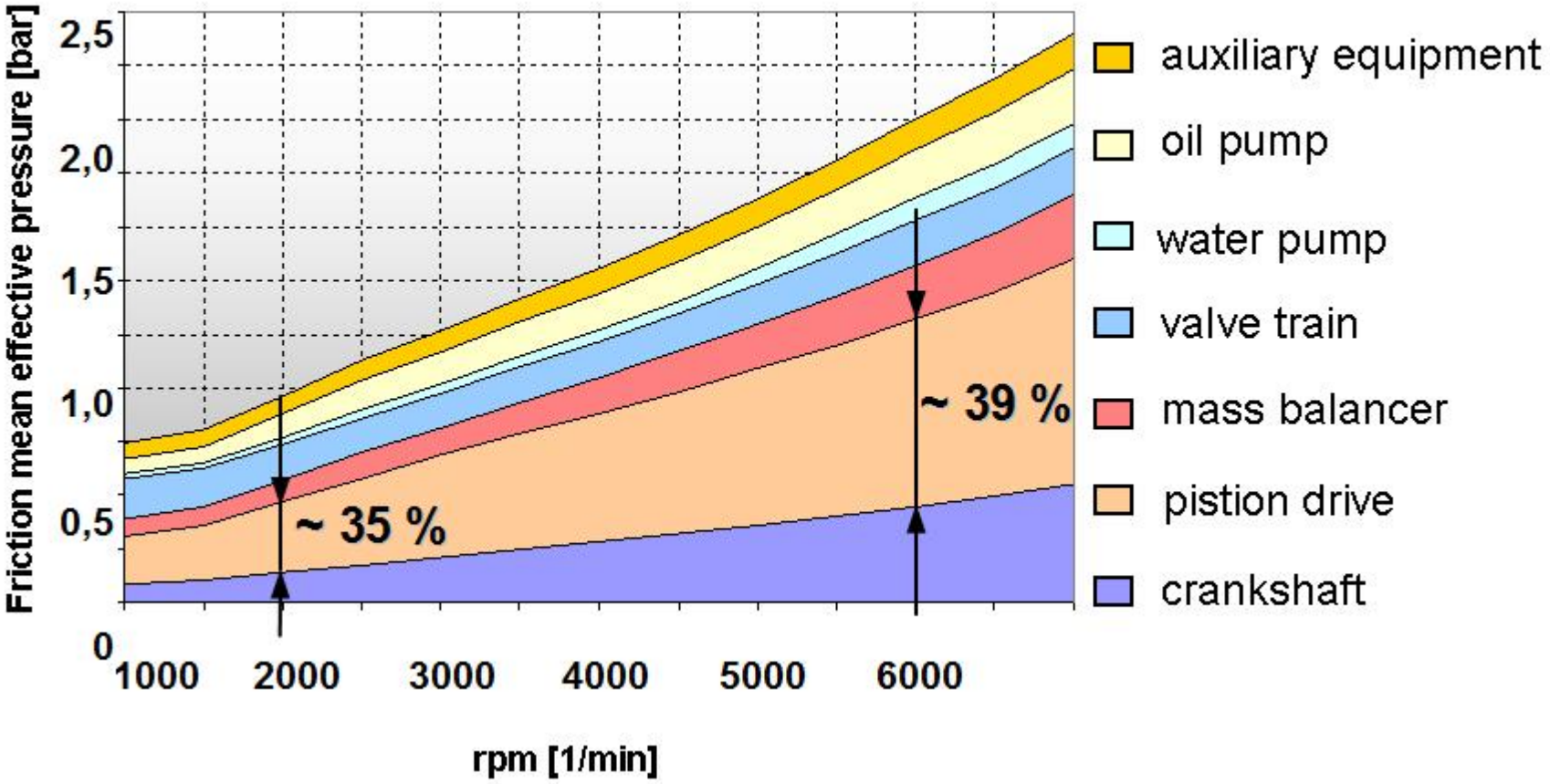
Agenda

- Motivation
- Coating solutions for engine efficiency and weight reduction
- Summary

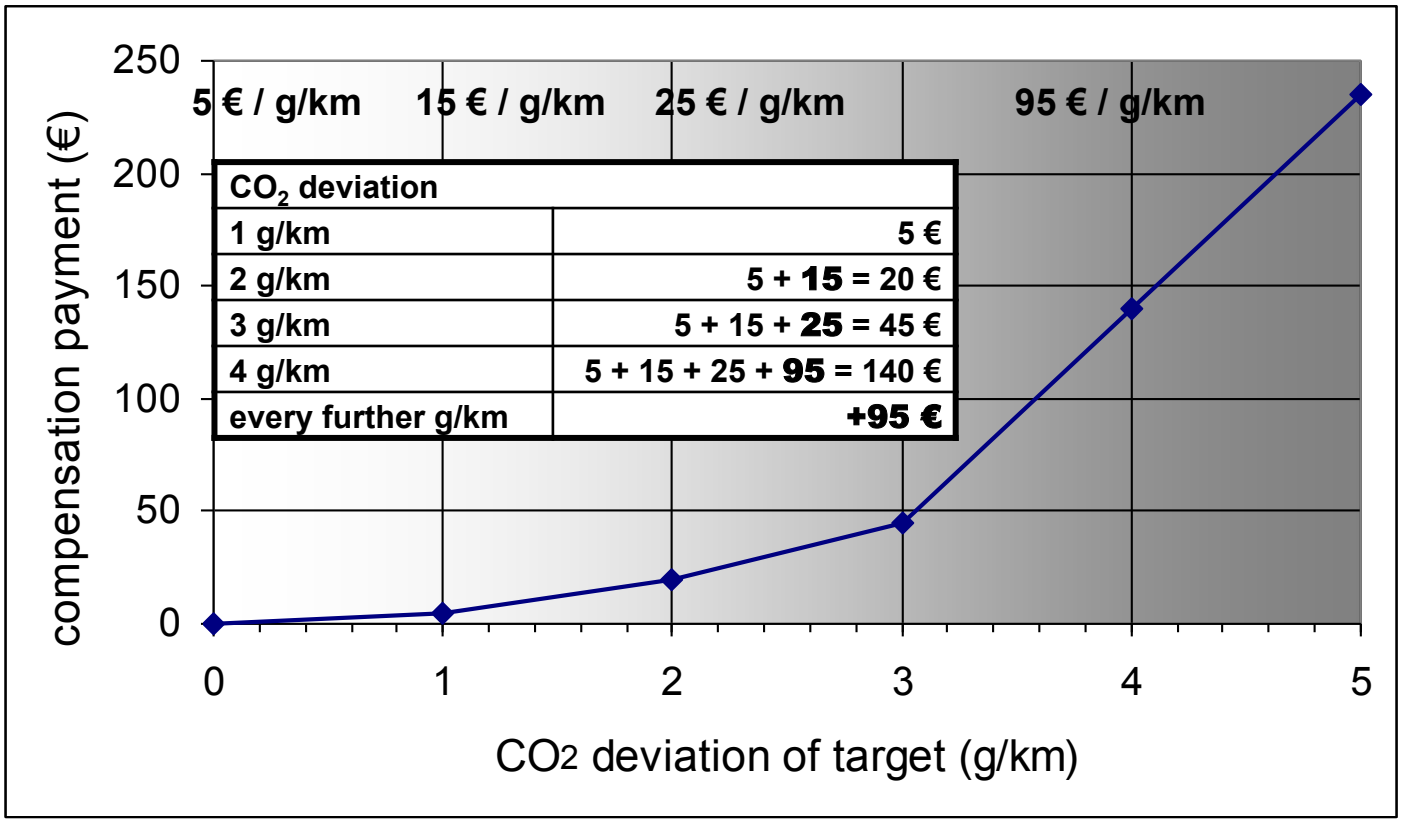
Motivation



Source: A.Merkle, M.Werner, Technical University of Munich, Institute of Combustion engines ©2008-2009

Motivation

EU 2012 CO_2 regulations for passenger cars
Compensation payment 2012 to 2018



Multiplied by registered new cars in EU27

(2010: ~13.4Mio.)

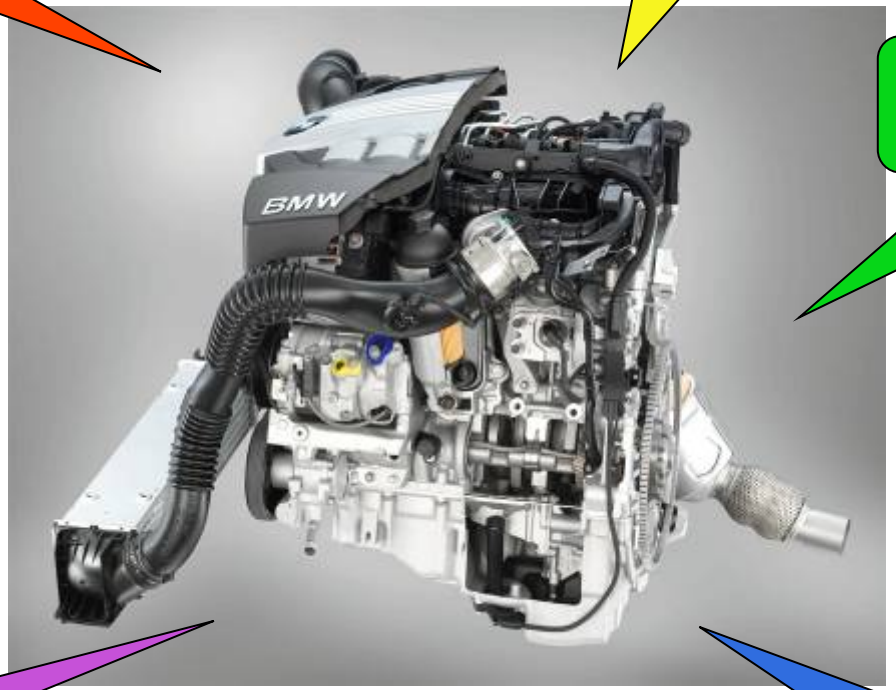
Compensation payment from 2019 on: 95€ / g/km

Source: www.bmu.de

Engine – Potential for Coatings

Weight reduction

Fuel consumption reduction



Reduction of CO_2, NO_x

Reduce construction space

Durability increase

Examples for coating solutions

- I) PVD- und PA-CVD coatings
- II) Polymer and sliding lacquer coatings
- III) Electroplated coatings

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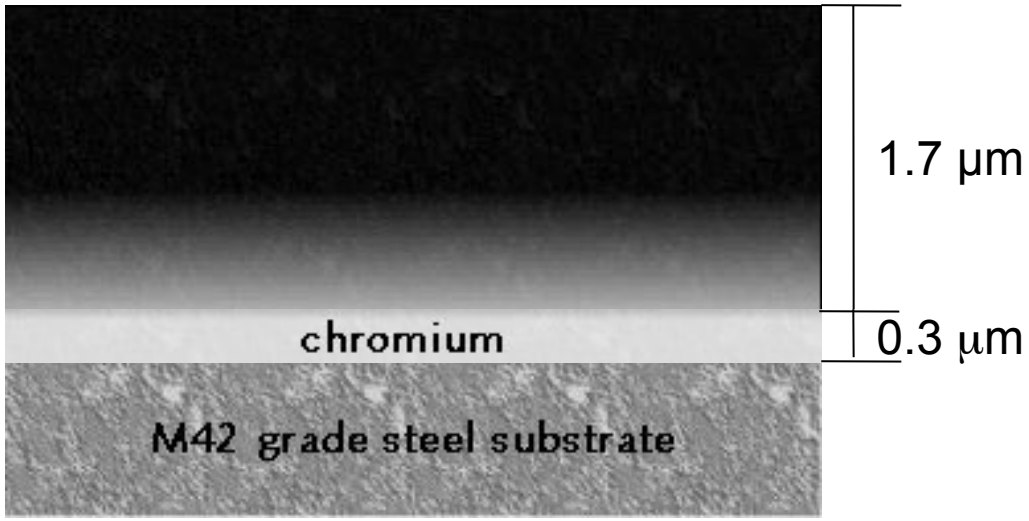
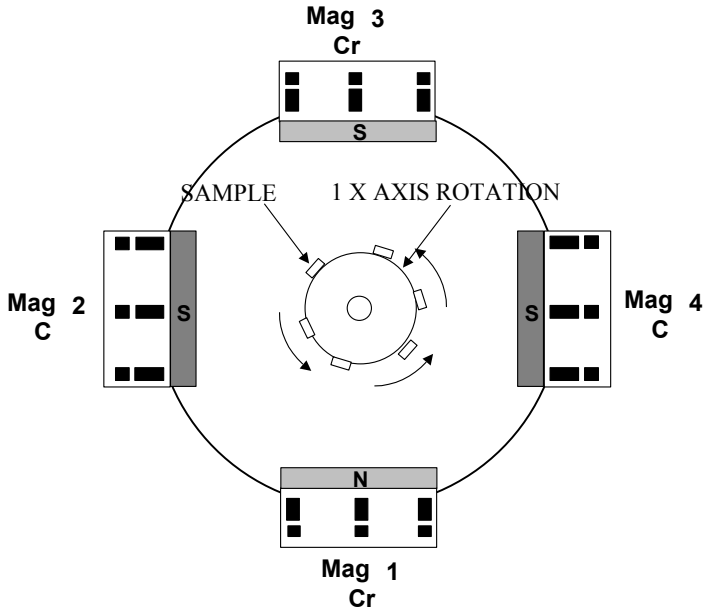
I) PVD coatings: Graphit-iC™ (1200-2000HV)

A three step process is used for the deposition of Graphit-iC™:

- ion cleaning
- deposition of a thin metallic chromium layer
- deposition of the a-C:Cr layer





Tribometer Wazau TRM 1000

- Normal force: 5 - 1000N
- rpm: 0 – 3000 rpm
- v_{max}=14m/s (@ Ø90mm)
- Oscillating 5 Hz (1° -360°)
- Temperature: RT – 250°C (air)
  RT – 150°C (oil)
- Substrate dimensions:Ø 5 - 90mm
- Configuration:
  Ball-on-Disc; Disc-on-Disc;
  Pin-on-Disc; Ring-on-Disc

100Cr6 Ball-on-Disc, 2GPa, 25°C

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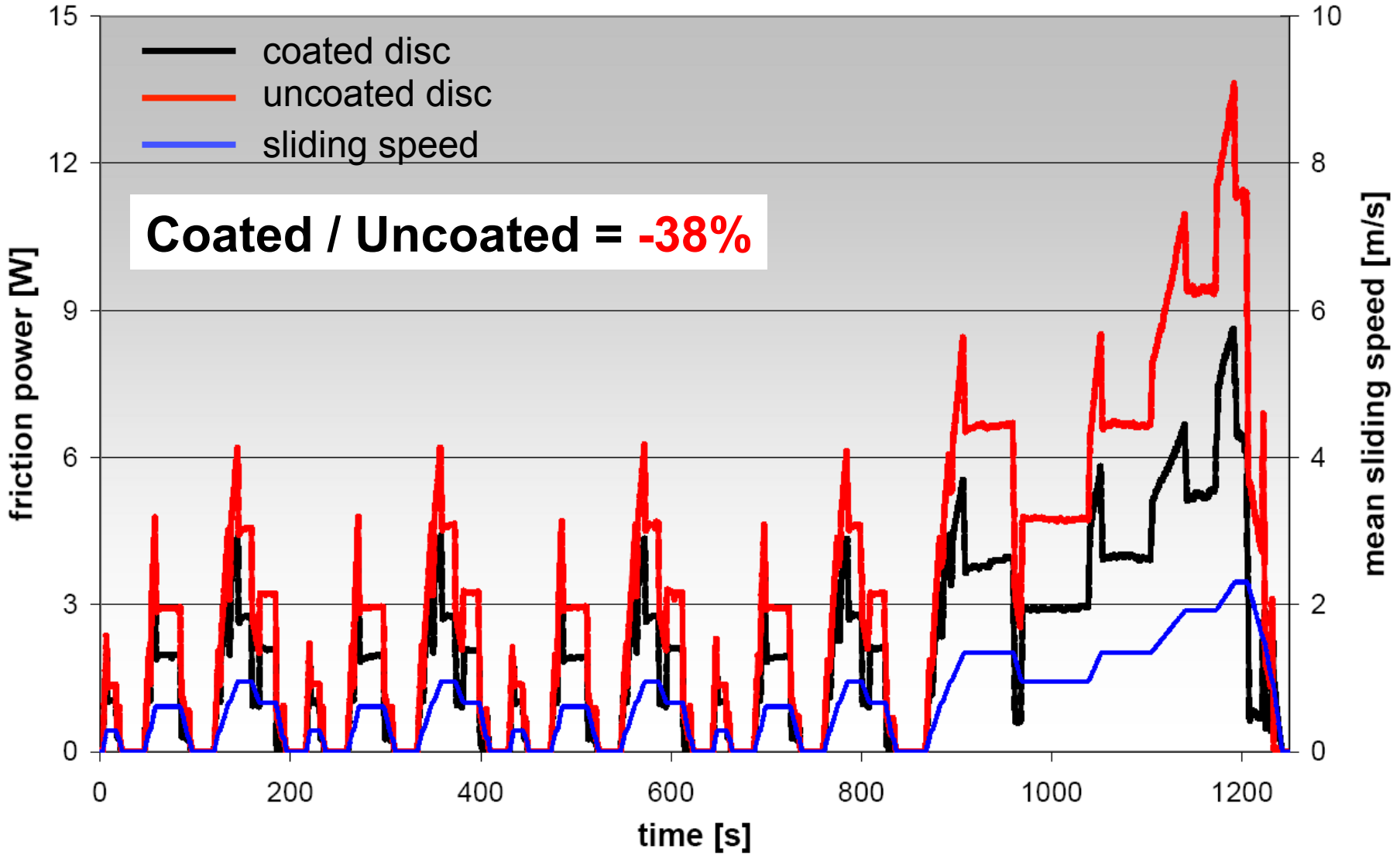
Graphit-iC™ Oil: Shell Helix Ultra (5W30)



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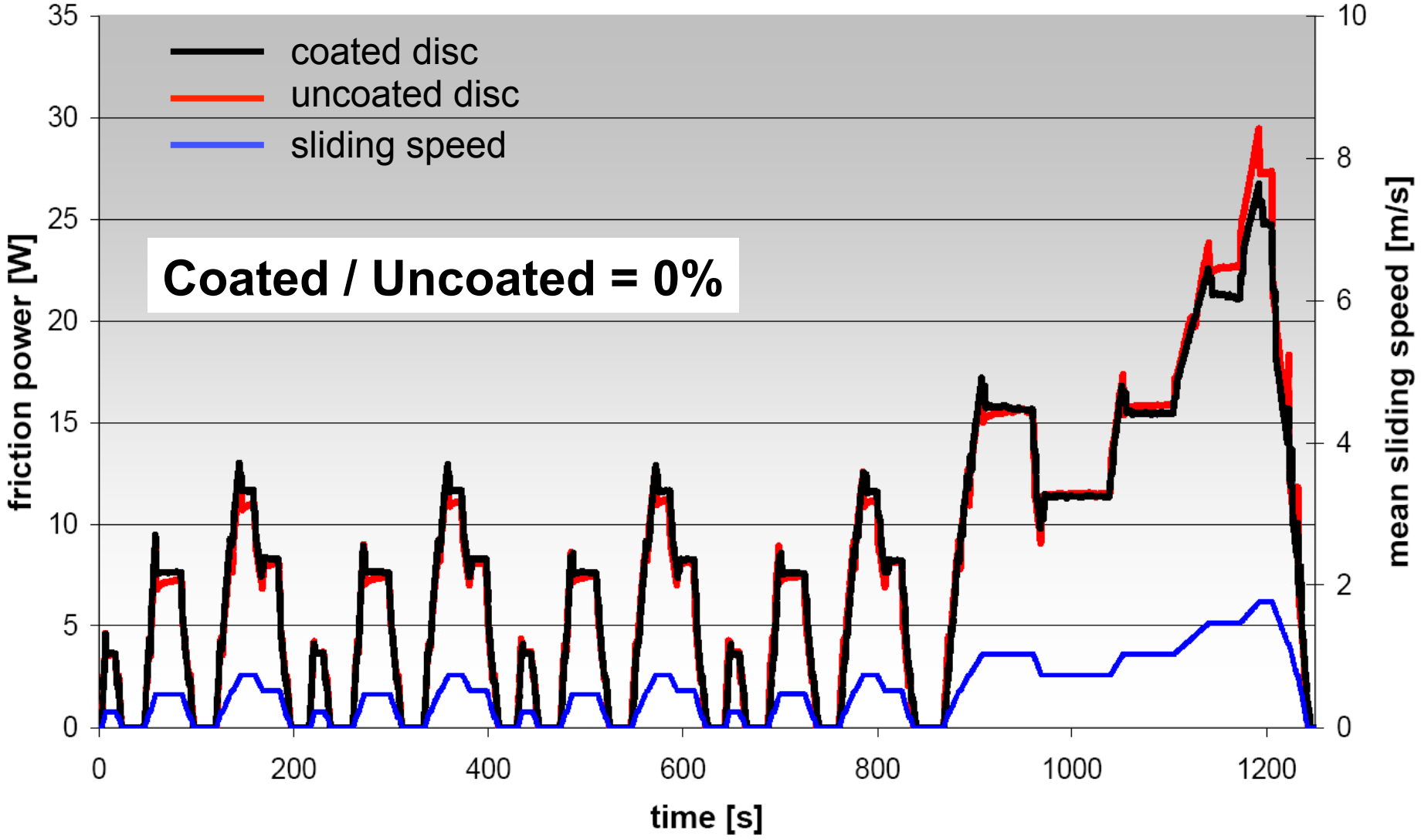
100Cr6 Ring-on-Disc, 2MPa, 25°C

Graphit-iC™ Oil: Shell Helix Ultra (5W30)



100Cr6 Ring-on-Disc, 2MPa, 90°C

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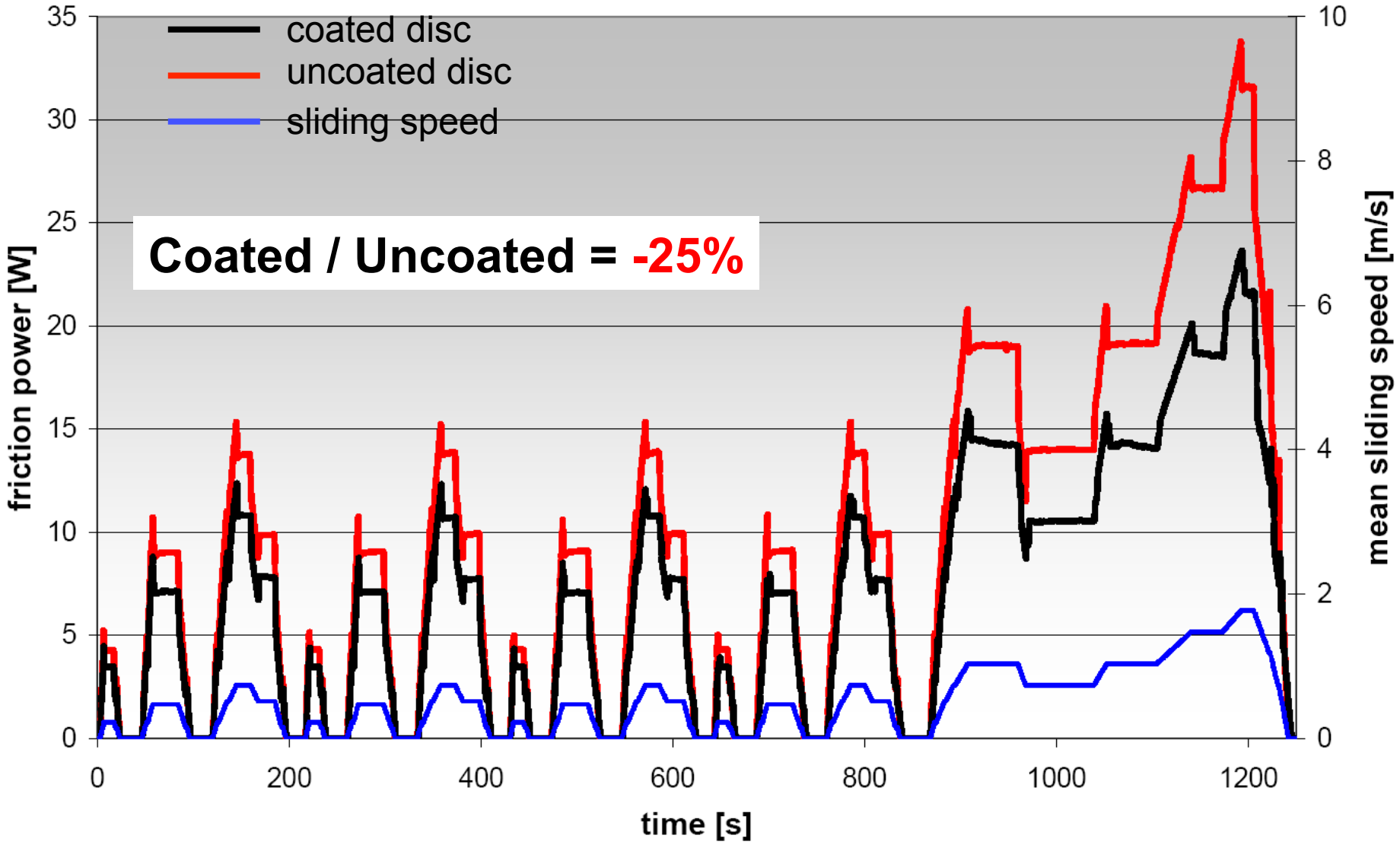
Graphit-iC™ Oil: Shell Helix Ultra (5W30)



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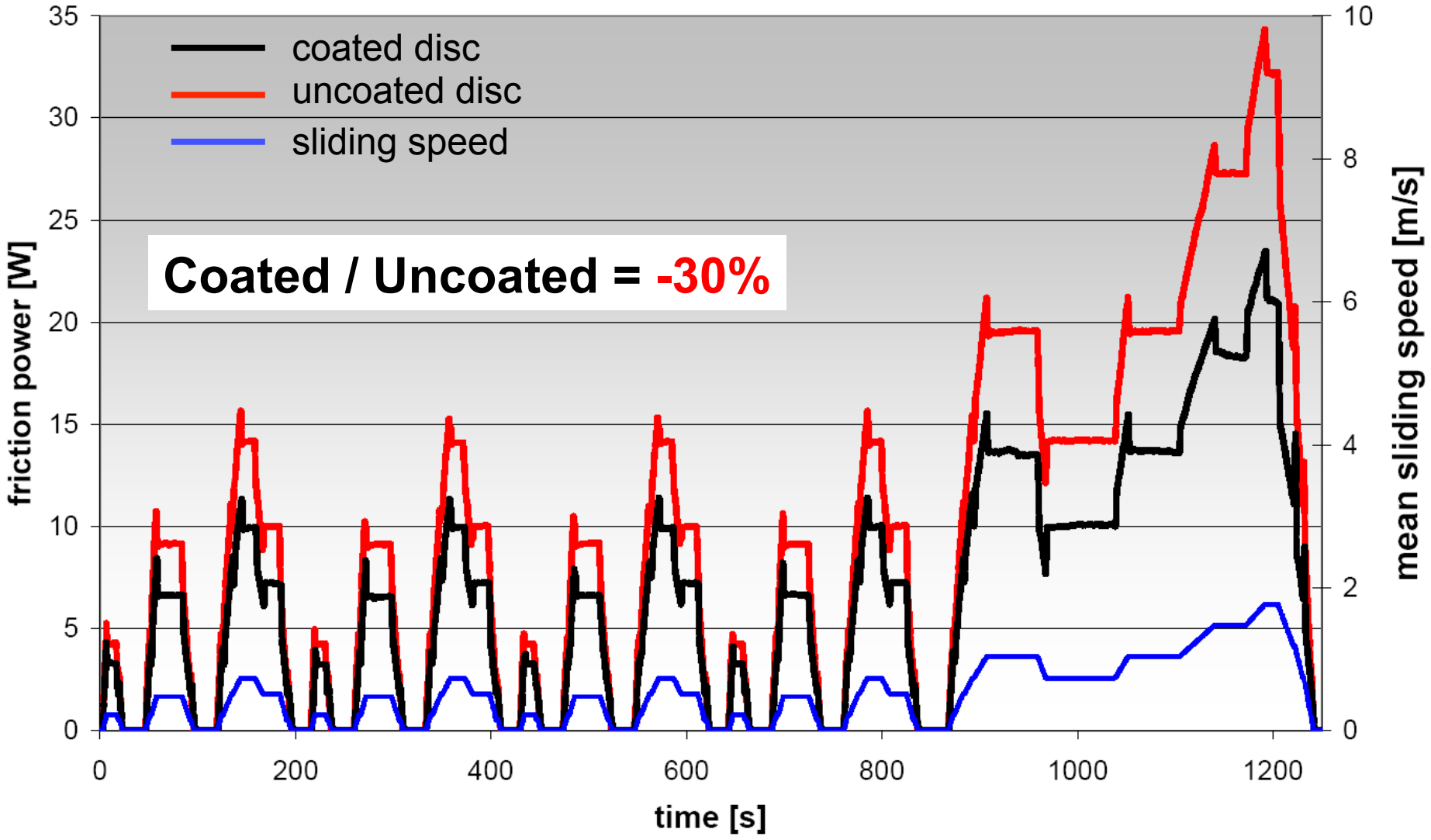
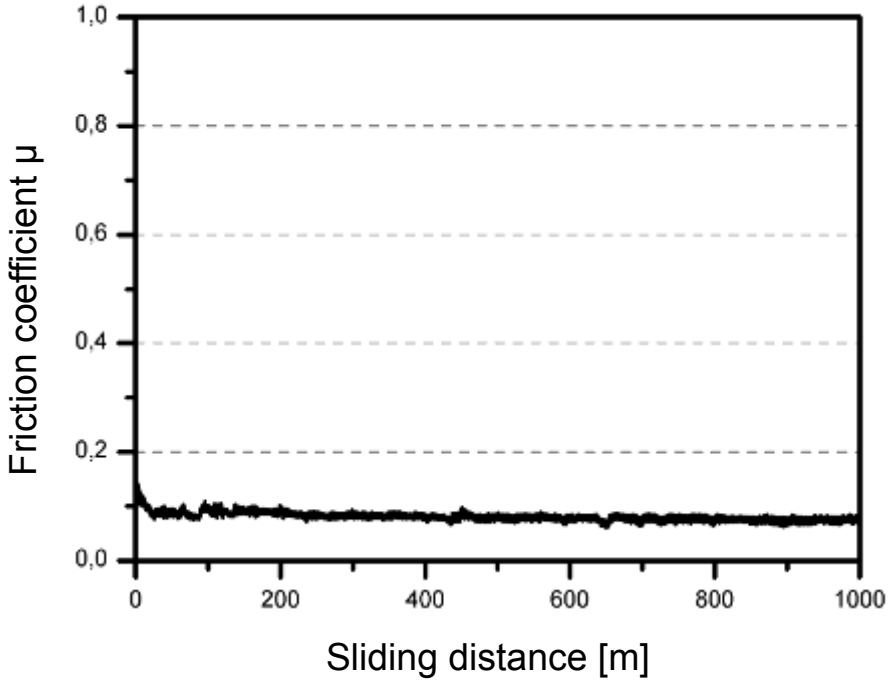
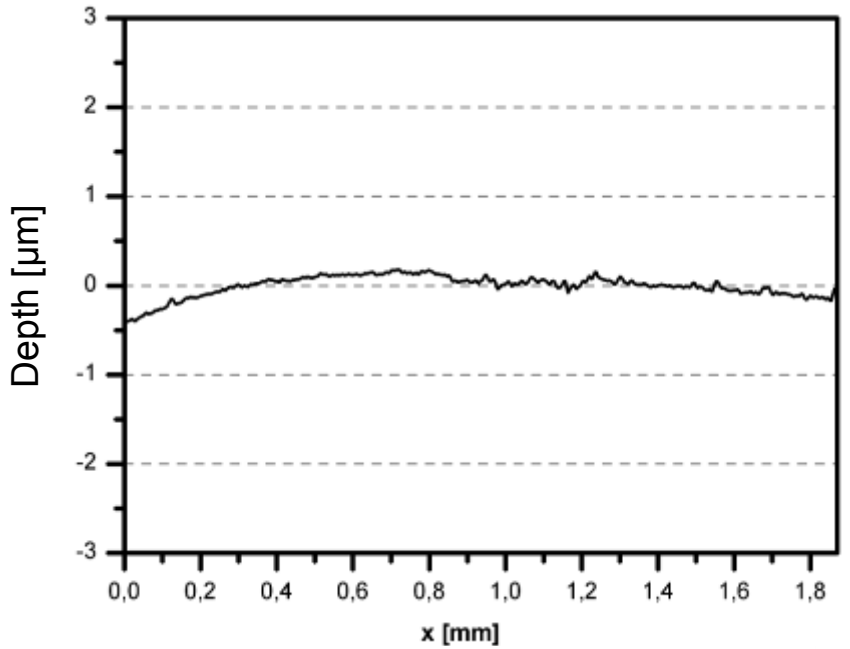
100Cr6 Ring-on-Disc, 2MPa, 120°C

Graphit-iC™ Oil: Shell Helix Ultra (5W30)



Graphit-iC™ (1200-2000HV)

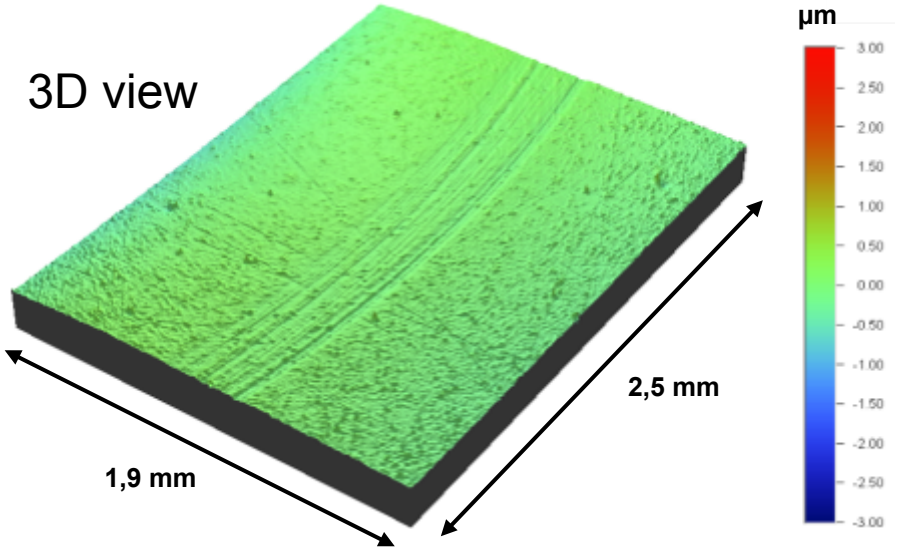




Ball-on-Disc Test:

- Applied Load: 10N
- Conditions: RT; dry
- Friction coefficient ~ 0,08
- Low specific wear (< $3 \cdot 10^{-17} m^3/mN$)

3D view



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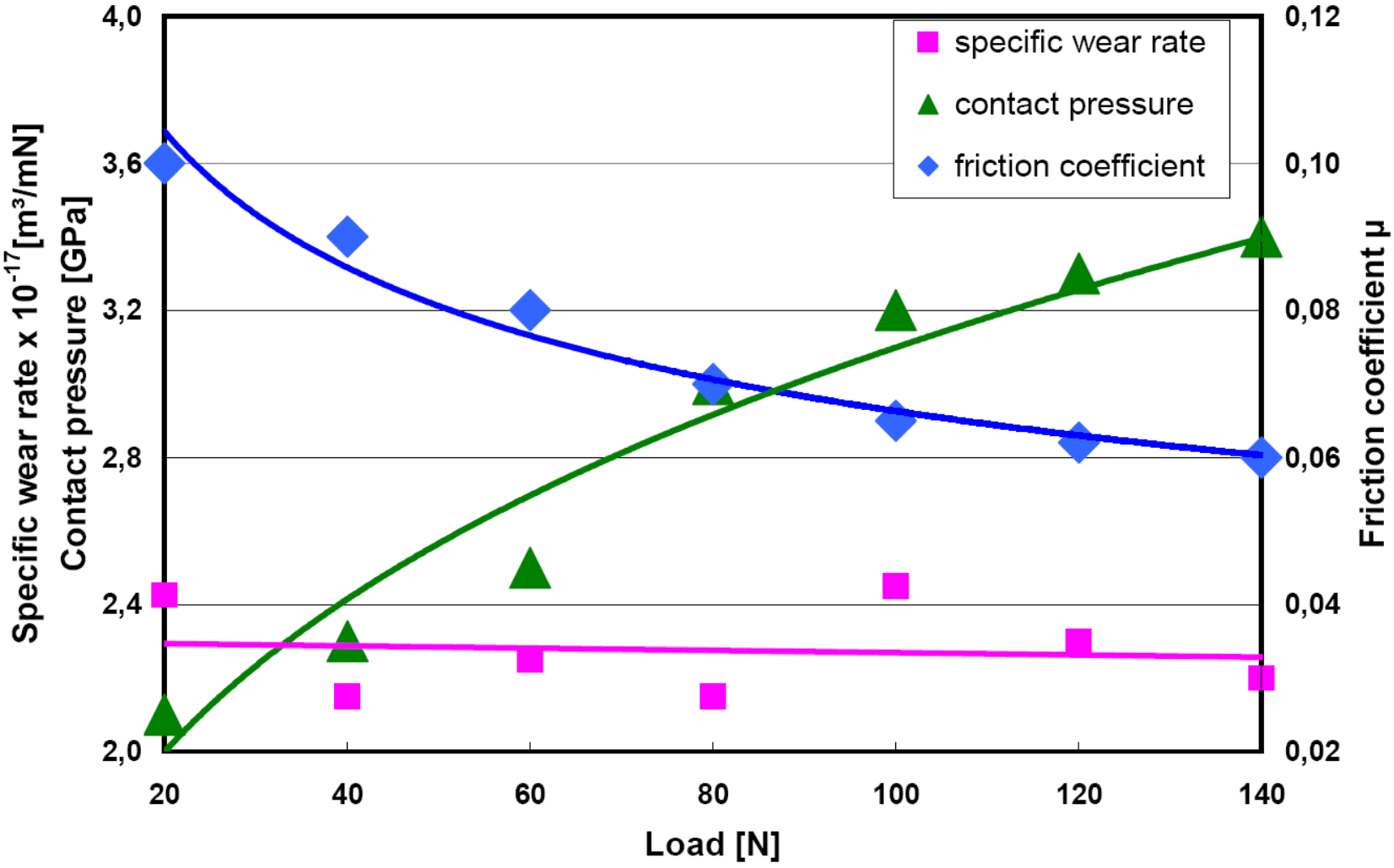
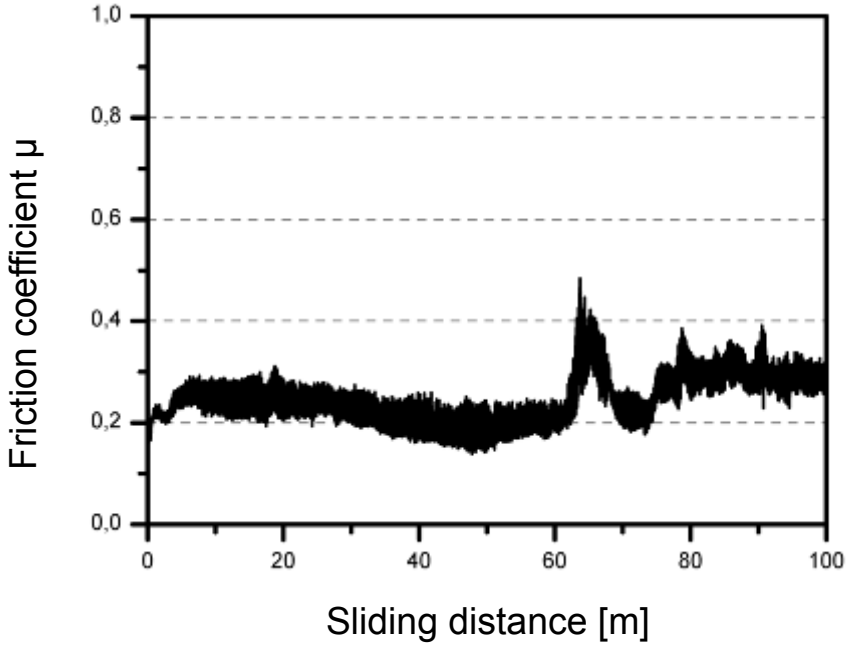
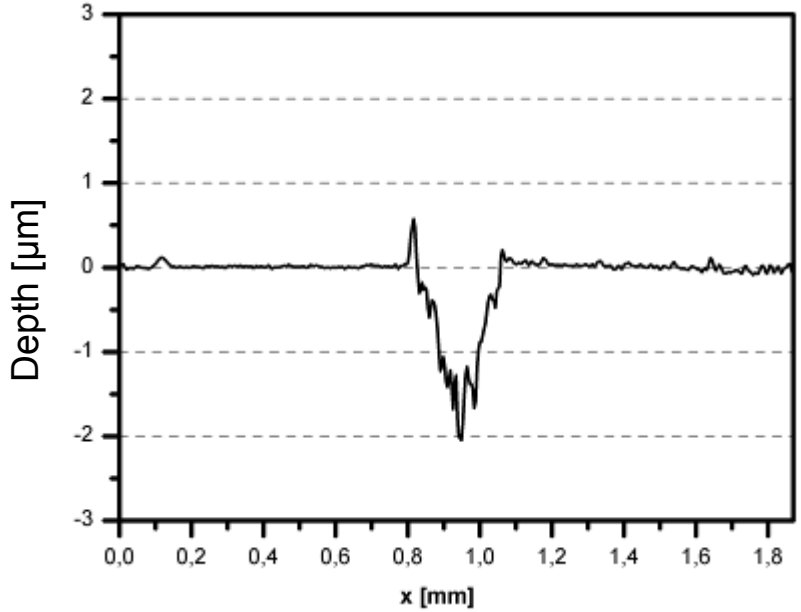
Graphit-iC™ (1200-2000HV)

Ball-on-disc; RT; dry



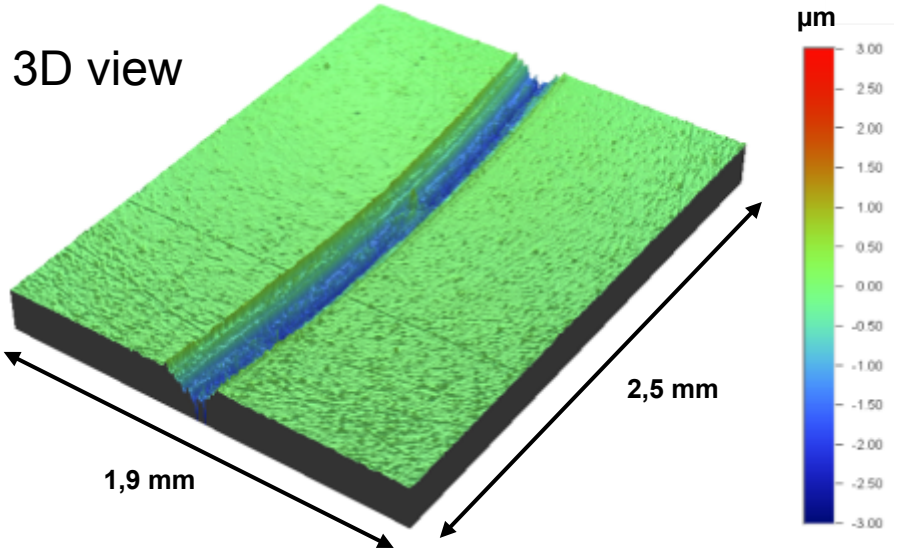
Graphit-iC™ (1200-2000HV)





Ball-on-Disc Test:

- Applied Load: 10N
- Conditions: 250°C; dry
- Friction coefficient ~ 0,2
- Coating failure



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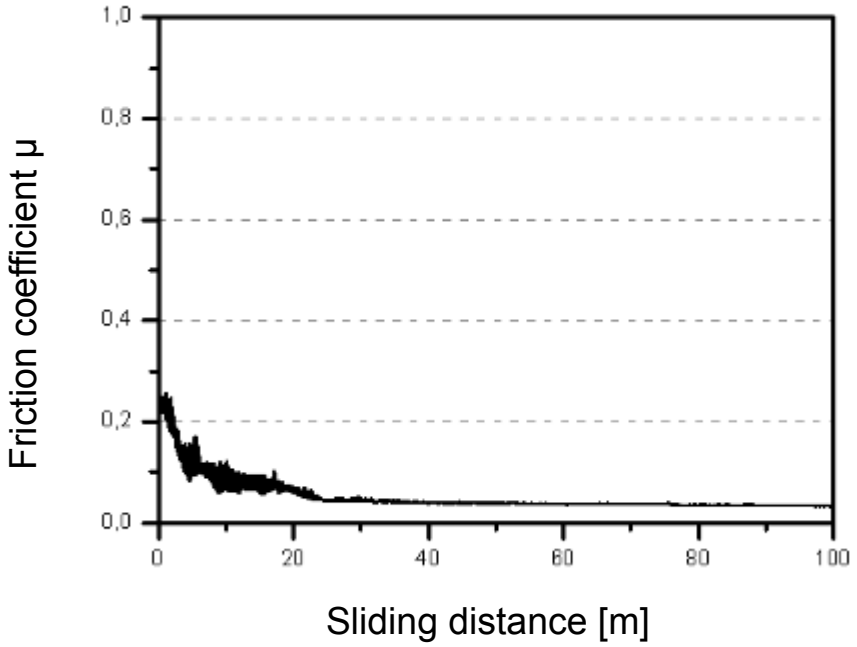
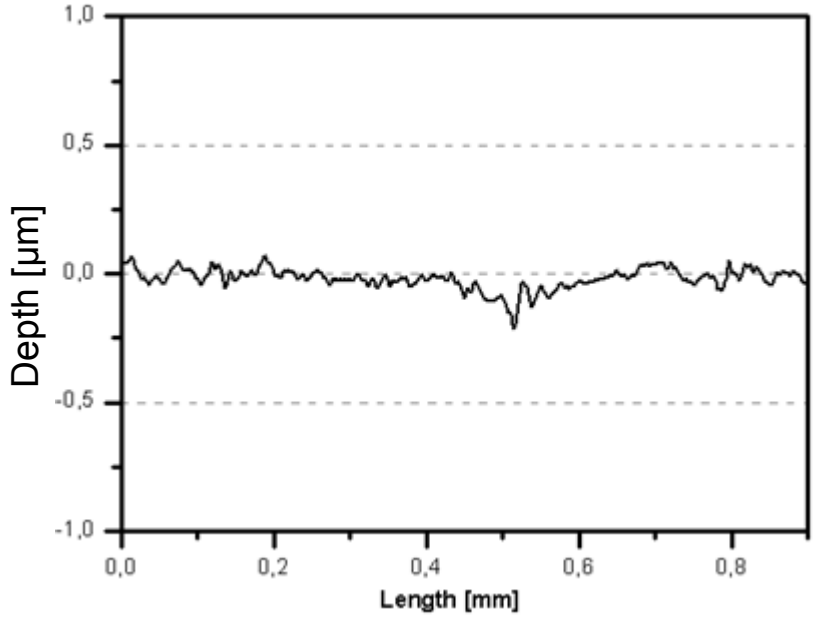
Graphit-iC™-HT (1600-2200HV)





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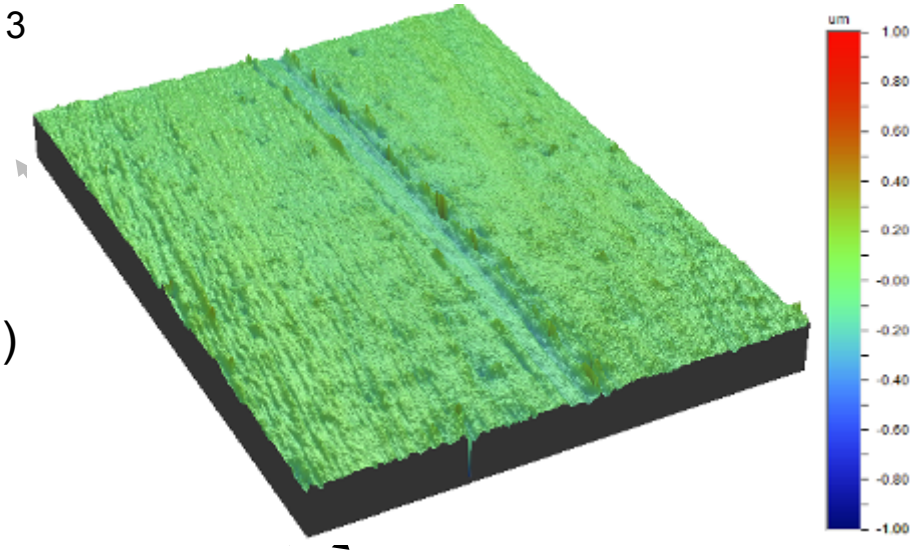
Ball-on-Disc Test:

- Applied Load: 10N
- Conditions: 325°C; dry
- Friction coefficient ~ 0,05
- Very low specific wear (< $3 \cdot 10^{-17} m^3/mN$)



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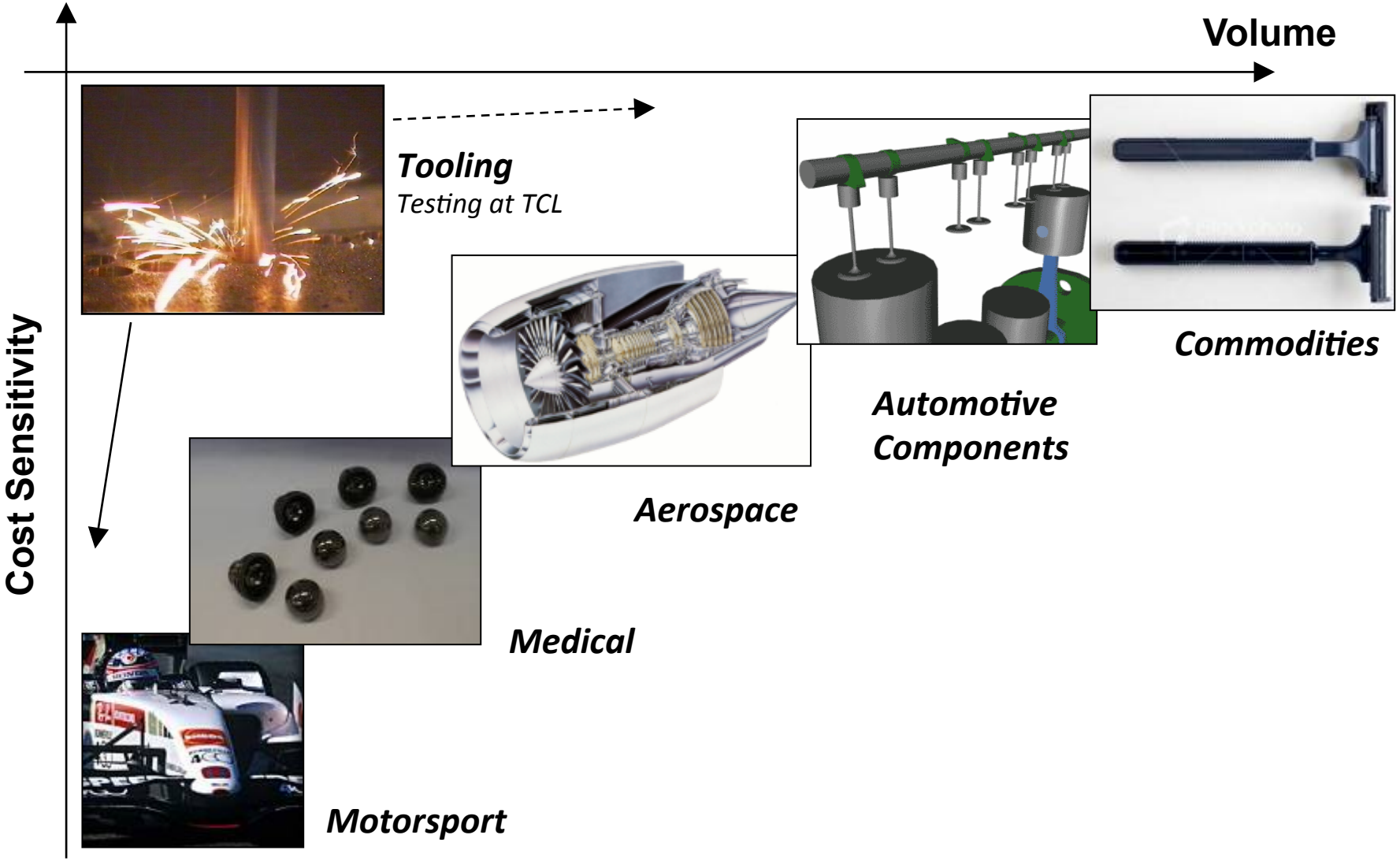
Graphit-iC™ potential applications



F1 Motorsport

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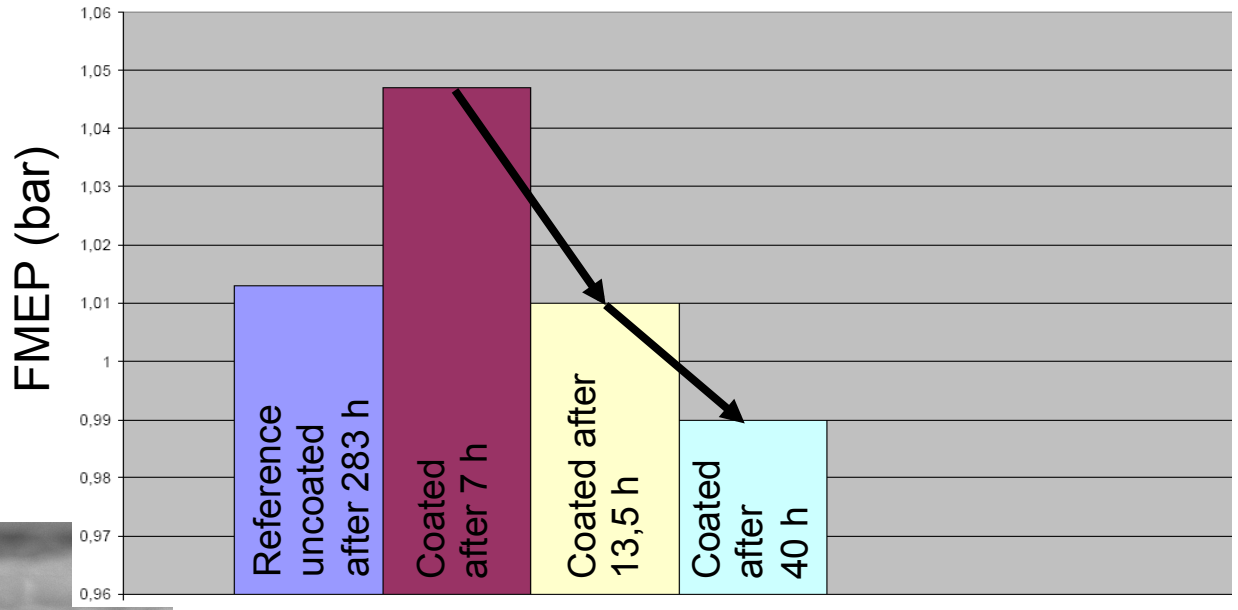
Source: http://news.bbc.co.uk/media/images

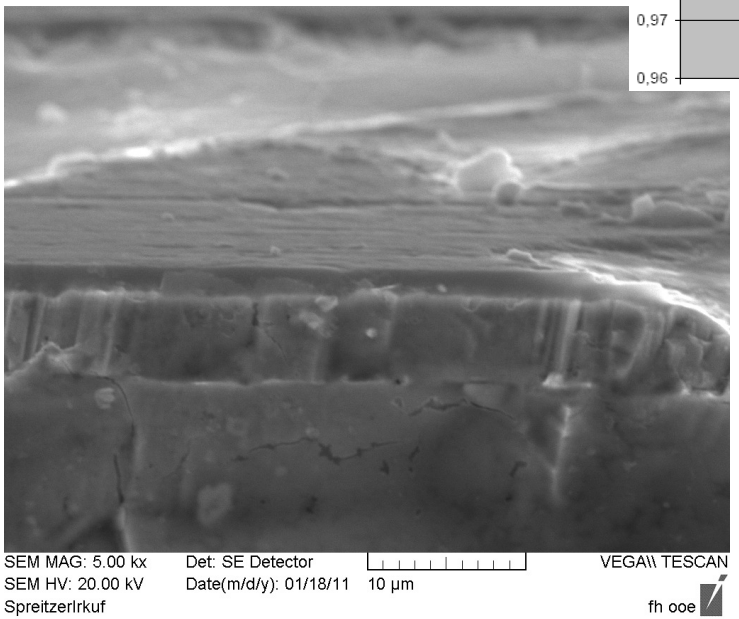
We are working directly with half of the current F1 teams

Coated Components Include…

Racks and pinions
Pistons
Rings
Gudgeon pins
Shell bearings
Valves
Followers
Ancillary components
KERS Parts
(Kinetic Energy
Recovery System)

Graphit-iC™ coated piston ring





at 3000 rev/min

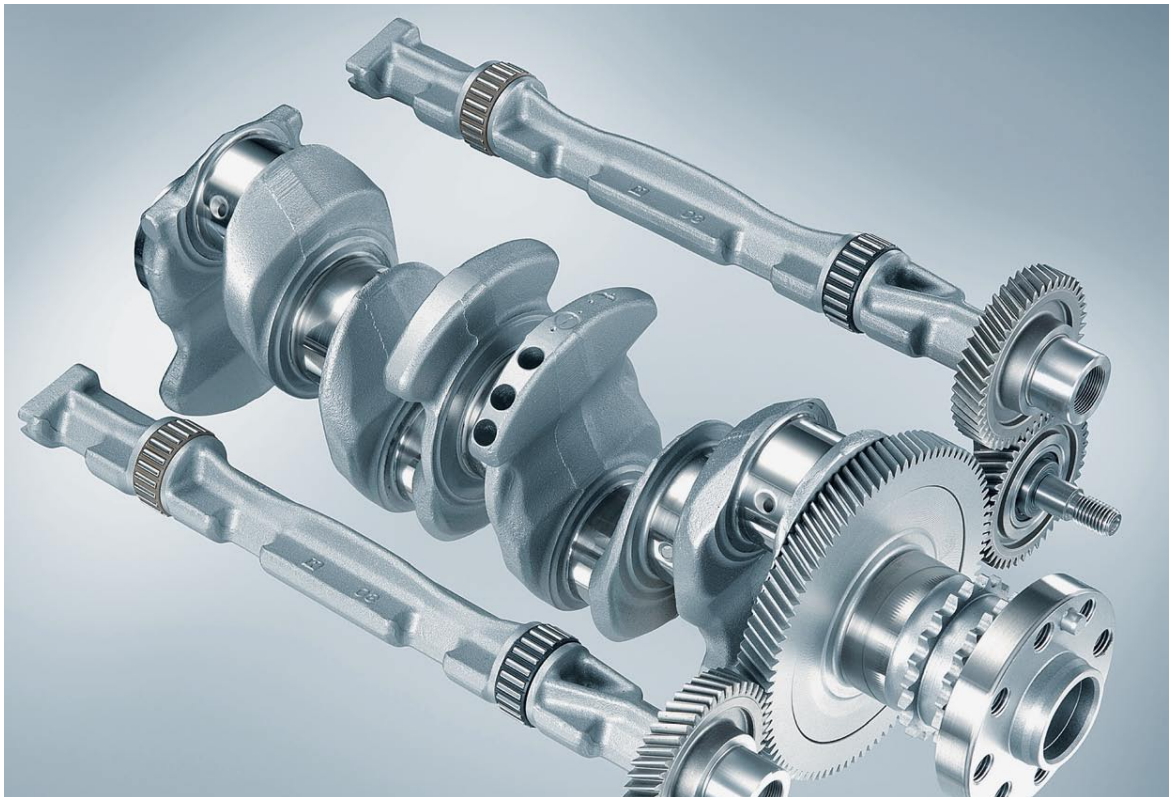
2-Cylinder Motorcycle Engine:

Internal Friction is reduced
with coated piston rings

IIa) Polymer coatings: Spacecoat®

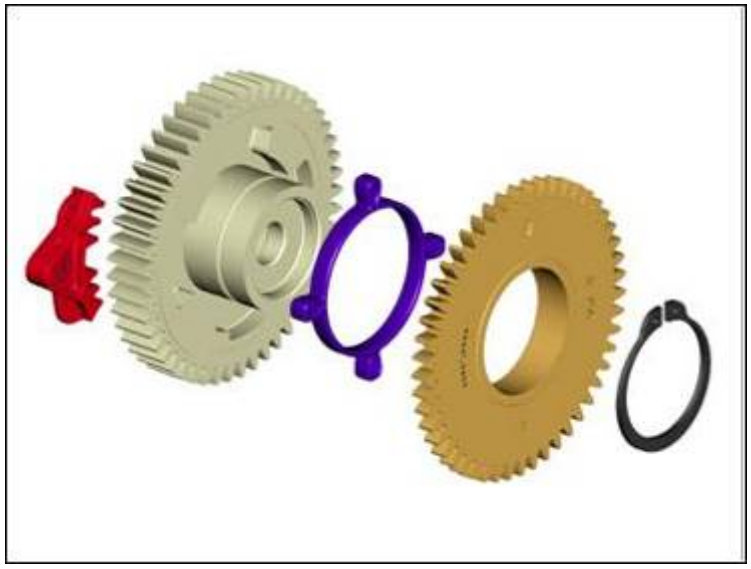
Mass Balancer Systems with Spacecoat® for NVH and friction reduction (Split gear solution)

Already in use: Audi, BMW, GM, VW, …



Comparison Split Gear vs. Spacecoat®

Miba Sintered Gear with Spacecoat® adjustment
versus serial solution of a split gear system



Weight of split gear system: 847g

Weight of coated gear system : 571 g

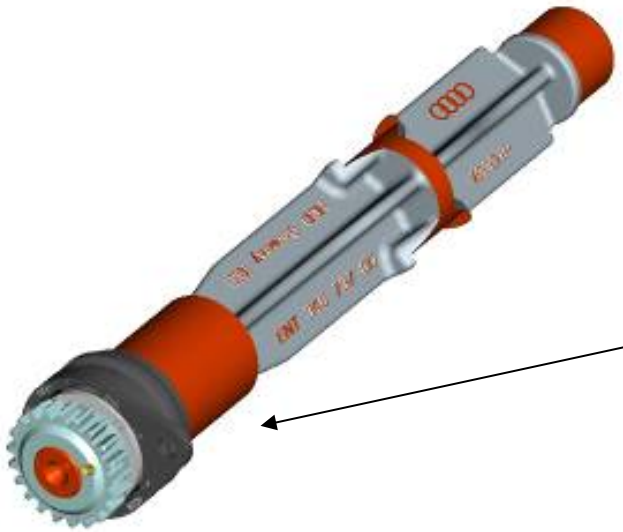
→ Weight reduction of 276 g (32%)

Comparison Split Gear vs. Spacecoat®

- Weight reduction potential 32%
- Friction reduction potential @2000 rpm 20%
- Noise reduction potential > 5 dB

IIb) Sliding lacquers: Synthec™Pro

Engine : EA 888 Audi 4 Cylinder Gasoline (World engine)
Integrated Mass Balancer System
Reason: Engine Start Stop



Rotational speed : max. 14000 U/min

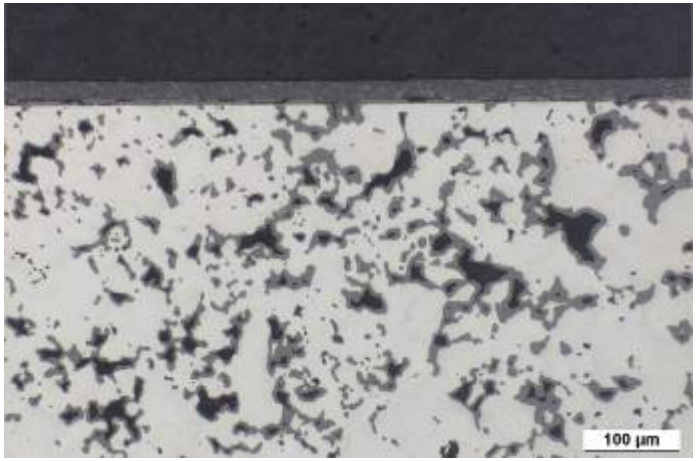
Max. Torque: max. 60 Nm

One Radial- and two integrated axial bearings on a net shape sintered part

IIb) Sliding lacquers: Synthec™Pro

Synthec™Pro on Bearing Block (EA 888) for friction and wear reduction:

Detail radial bearing surface
- 20 µm Synthec™Pro
- direct coating



Overview radial bearing surface:
- 20 µm Synthec™Pro
- direct coating of sinter part
- after endurance test almost no wear visible
- minimal smoothening of surface asperities

Polymer and sliding lacquer coating

A high performance sliding lacquer

SYNTHEC™

- Special additives enable optimized application variations, providing outstanding tribological functions

  - Wear resistance
  - Friction reduction
  - Emergency behavior (especially in mixed friction environment, e.g. for new Start/Stop Strategy)

III) Electroplated coatings: ENiP12

ENiP12 on Turbocharger compressor wheel (diesel engines)

Driving force: Euro-VI-standard – exhaust gas recirculation (EGR)

Increases soot production, can add abrasive contaminants, increases

Engine oil acidity → can reduce engine longevity

Solution: wear resistant coating

Compressor wheel

coated with 30µm ENiP

Weight and/or Friction reduction examples

- Main bearings
- Conrod bearings
- Idler gears
- Camshafts
- Crankshaft
- Mass Balancer Shafts
- Piston pins
- Piston rings
- Piston skirts
- Valves
- Replacement of liner
- Wear resistance coatings on lightweight parts like Al Alloy

Summary

- Reducing CO_2 emission is one of the top priorities for the automotive industry
- The costs for CO_2 emission rise tremendously for OEM's (and customers!)
- Additional measures in reducing CO_2 emissions are inevitable
- Direct coatings can reduce friction losses the size and/or number of components

→ therefore reduced weight and costs

Thank you:

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Globales Netzwerk

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