Smart coatings and their contribution to emission reduction in combustion engines

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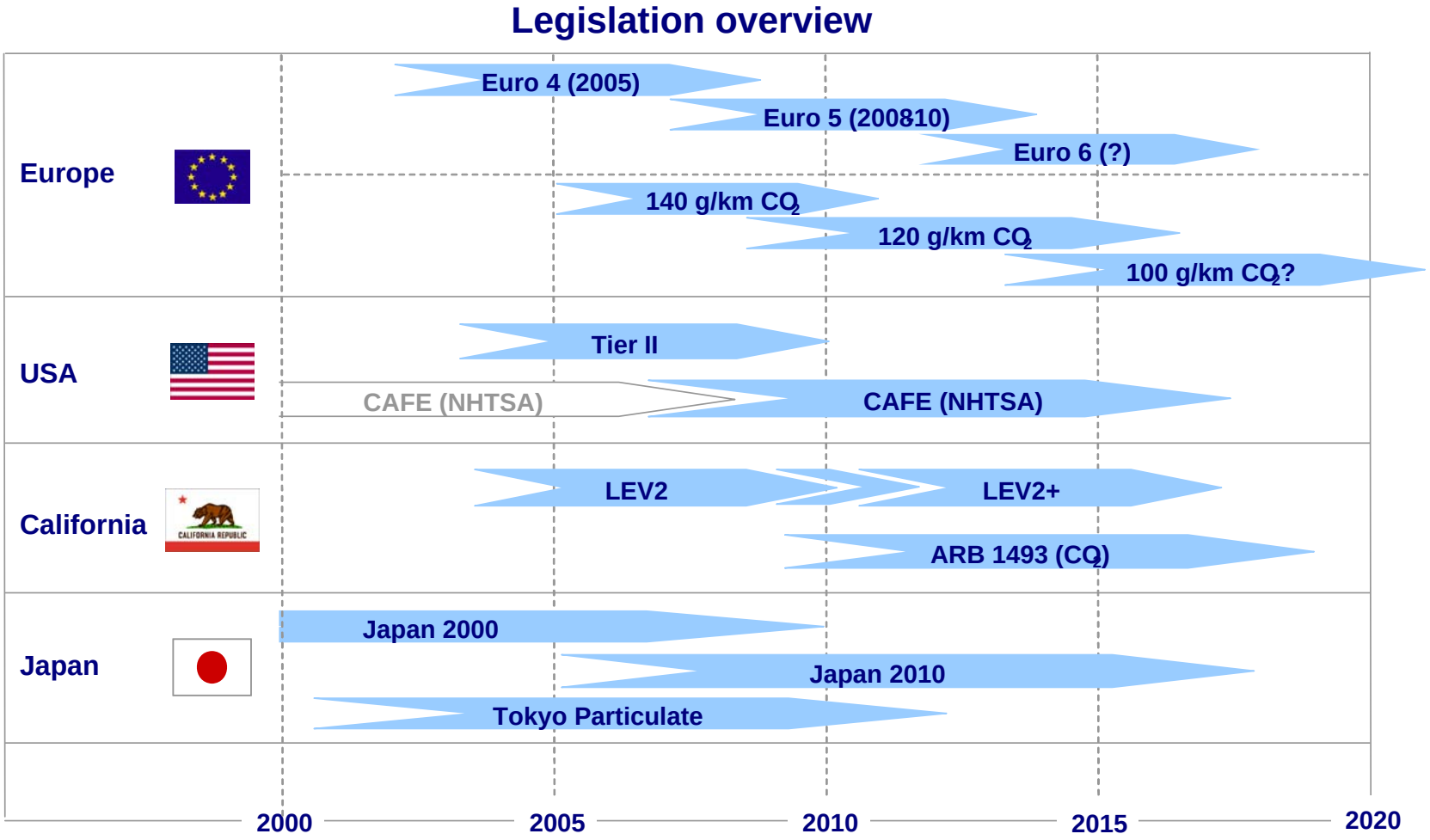
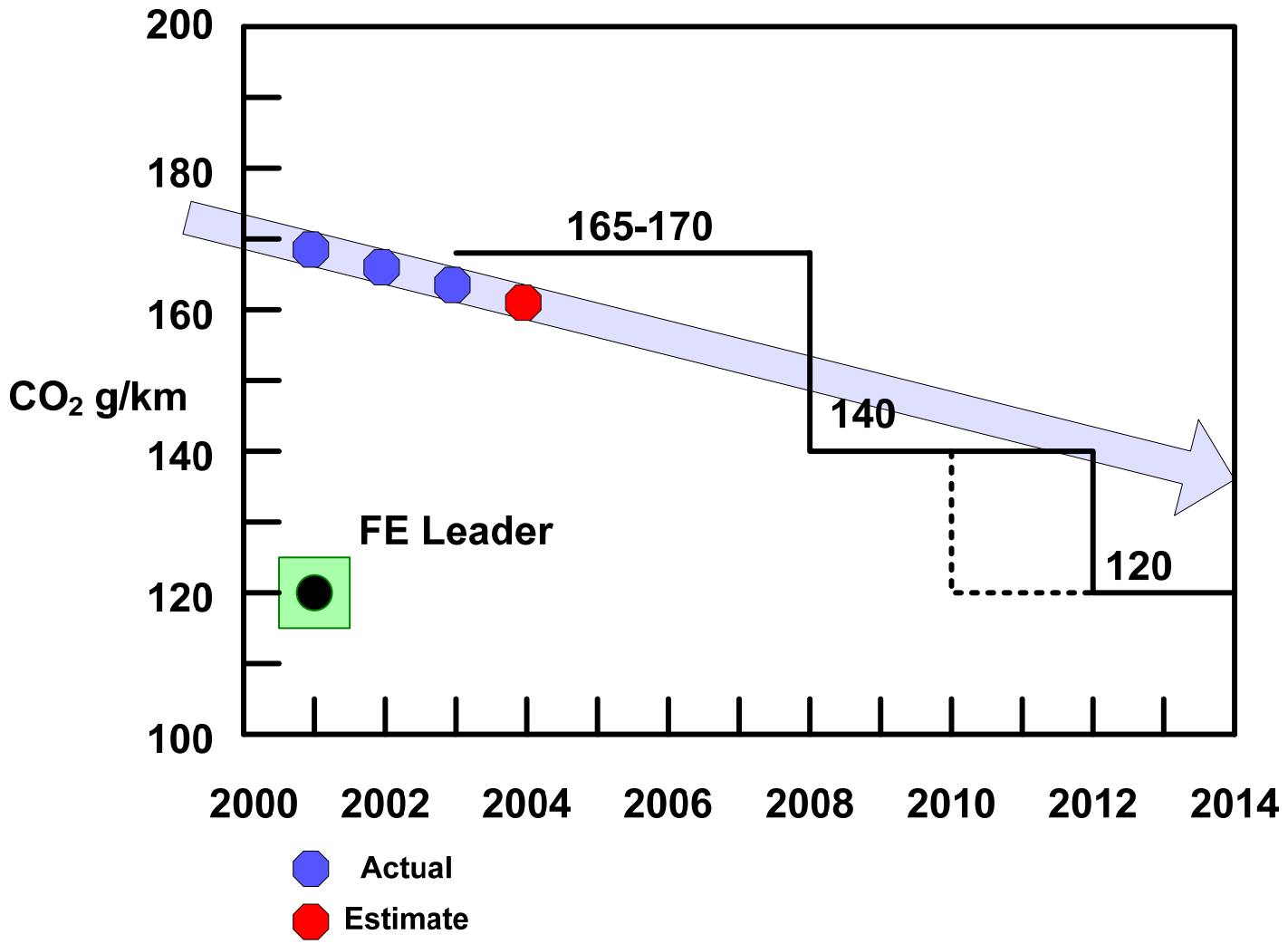
Emission impossible – How improvements made to the drivetrain could improve emissions output

Dr. P. Ernst; U. Christoffer; Dr. M. Spreckels | February 21, 2008

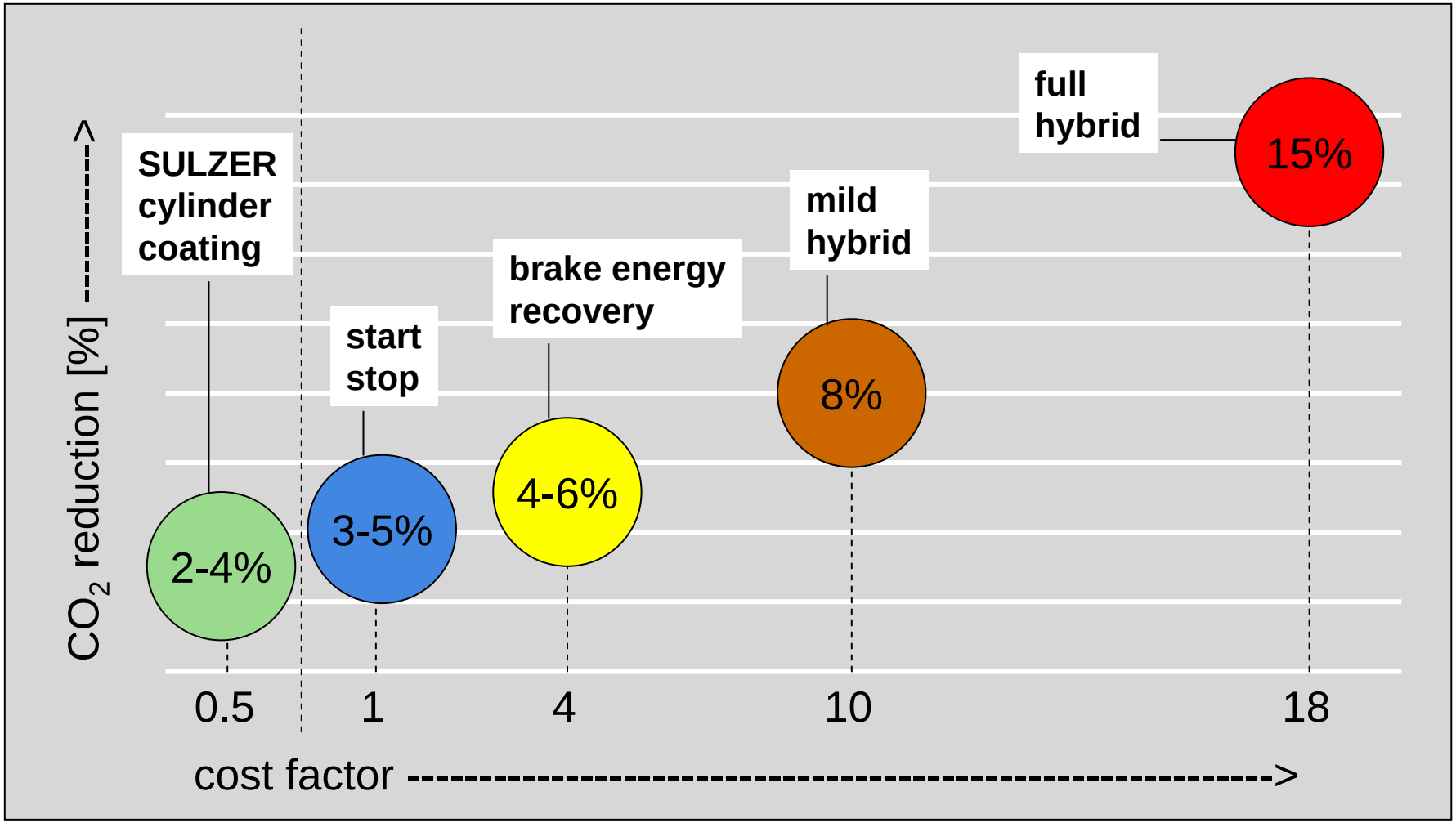
Legislation on Emissions influences technology



Fuel Economy & CO_2



CO_2 reduction methods and their potential



source: AMS 24 / 2007 and SULZER estimate of plasma coating of cylinder walls

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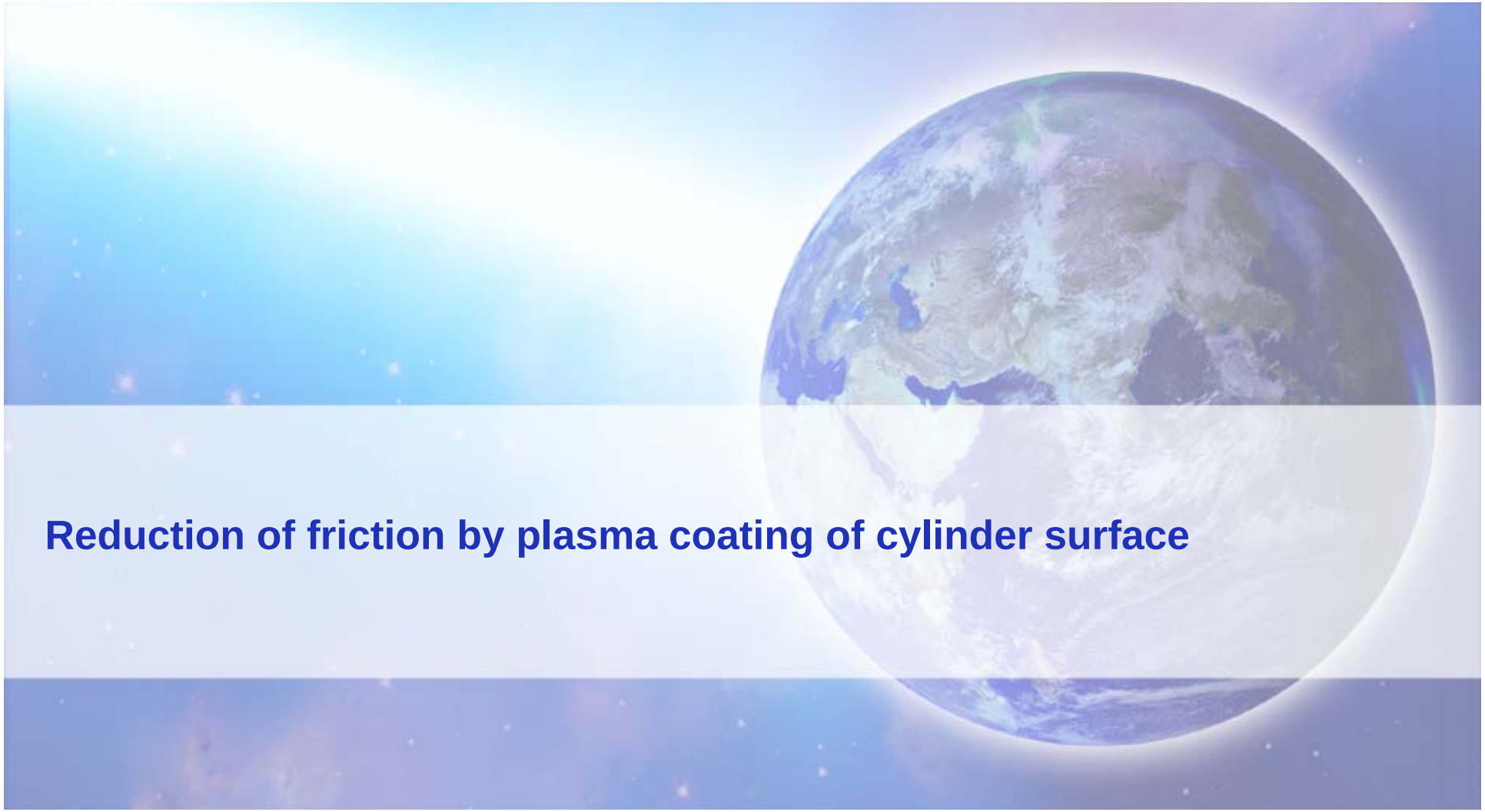


Reduction of friction by plasma coating of cylinder surface

Trend in engine development

- Size and weight reduction
- Friction reduction for better efficiency
- Lower fuel consumption
- Lower emission (reduction of oil consumption)
- Low maintenance frequency
- Low wear rate
- Introduction of exhaust gas recirculation (EGR)
- Lower cost

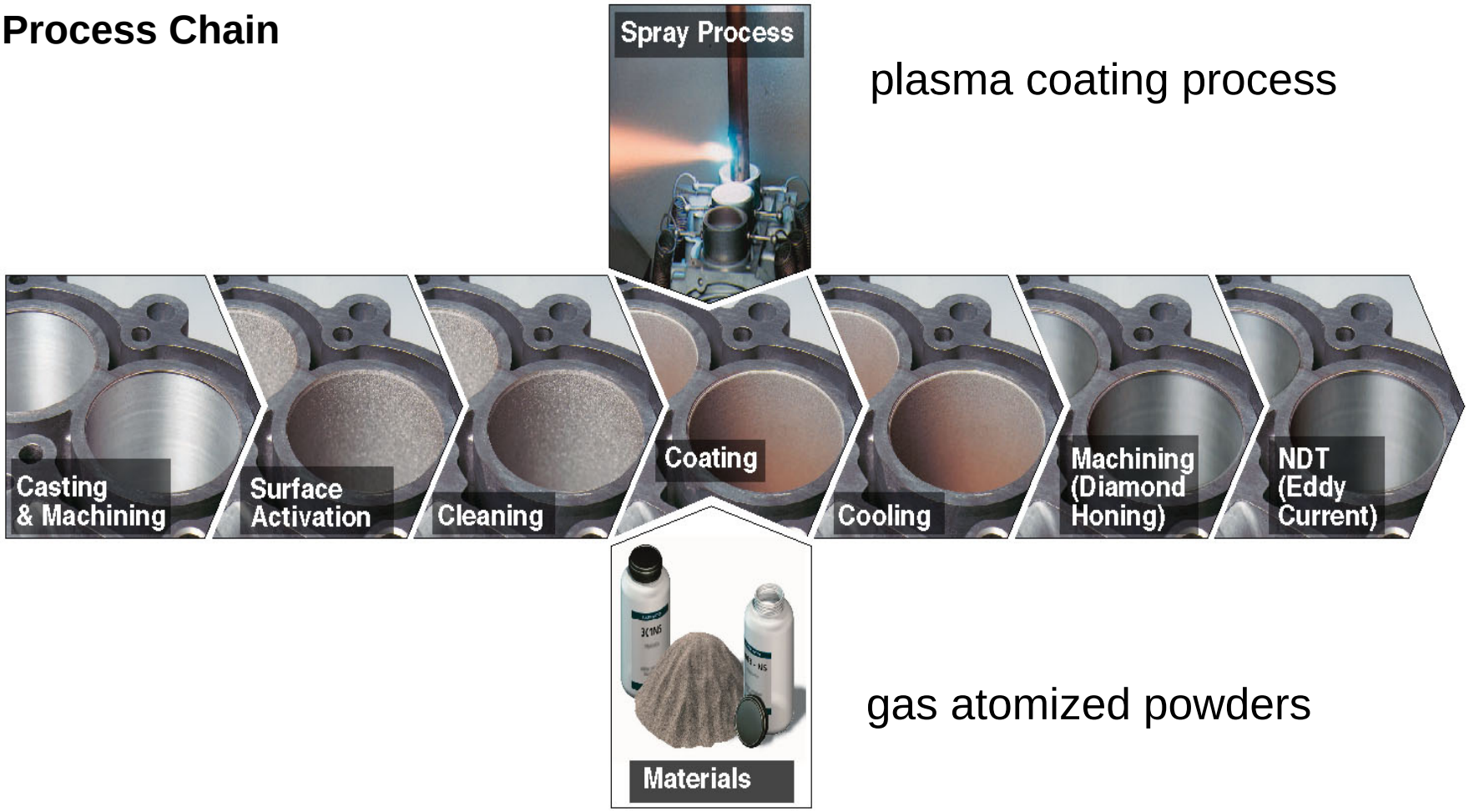
Sulzer Metco‘s automotive market

- Car
- Truck
- Recreational Vehicles
- Motorbikes
- Racing Cars, Go Karts

The solution

Sulzer Metco‘s Cylinder Bore Solution

Process Chain



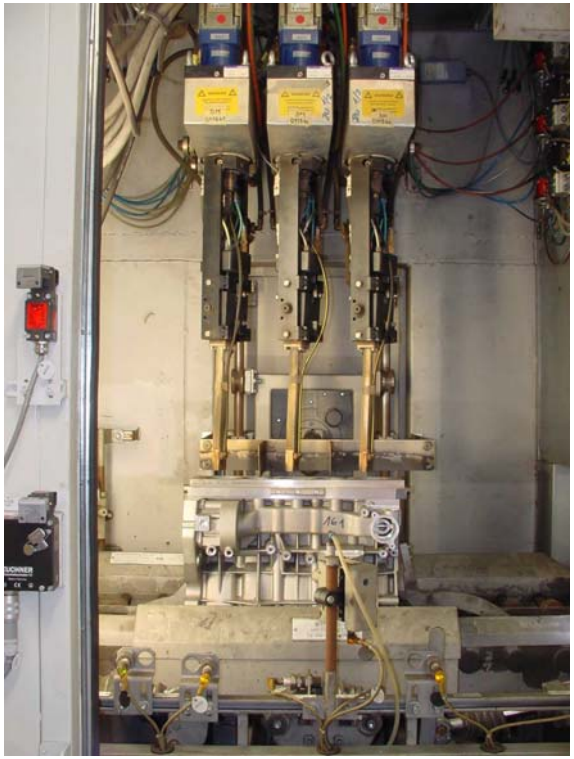
plasma coating process

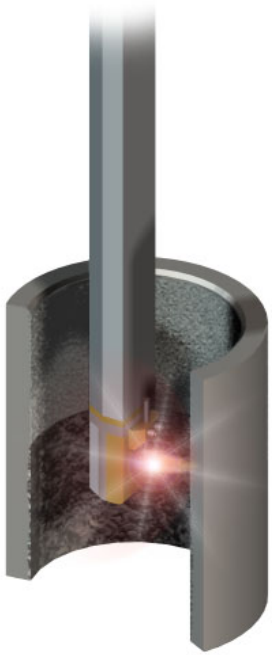
gas atomized powders

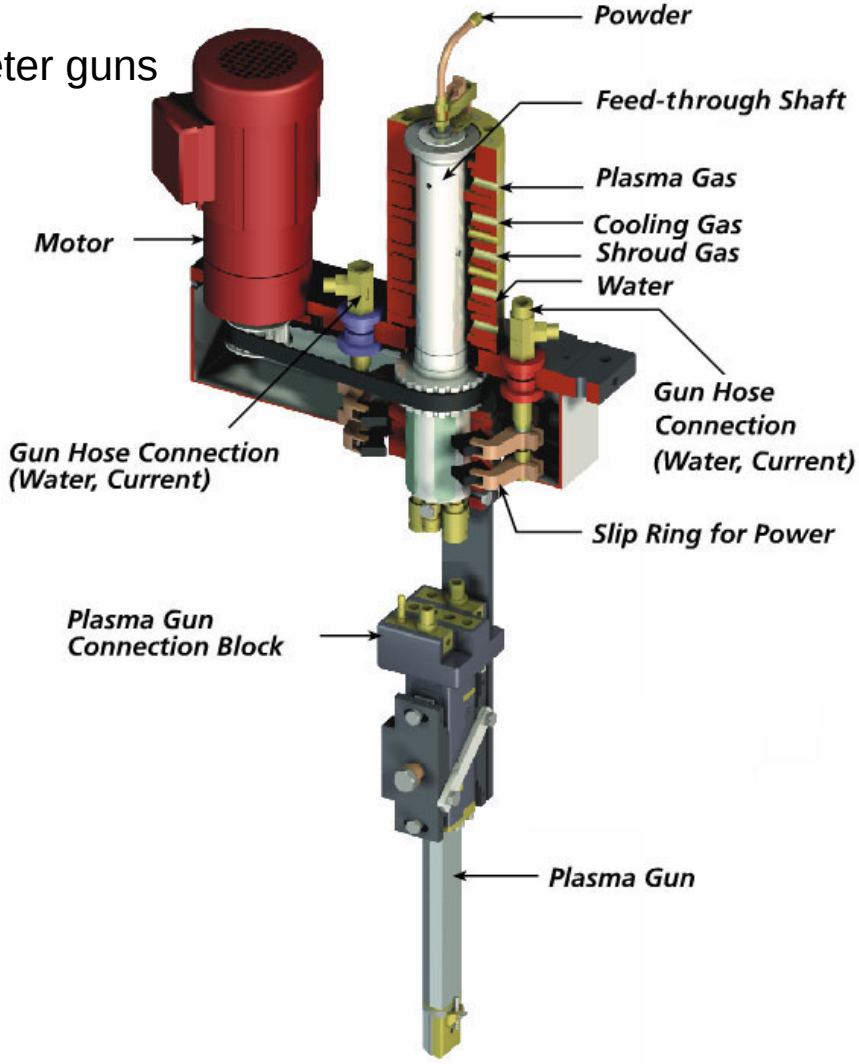
Process technology - coating

RotaPlasma®

Endless rotation gun support for all internal diameter guns





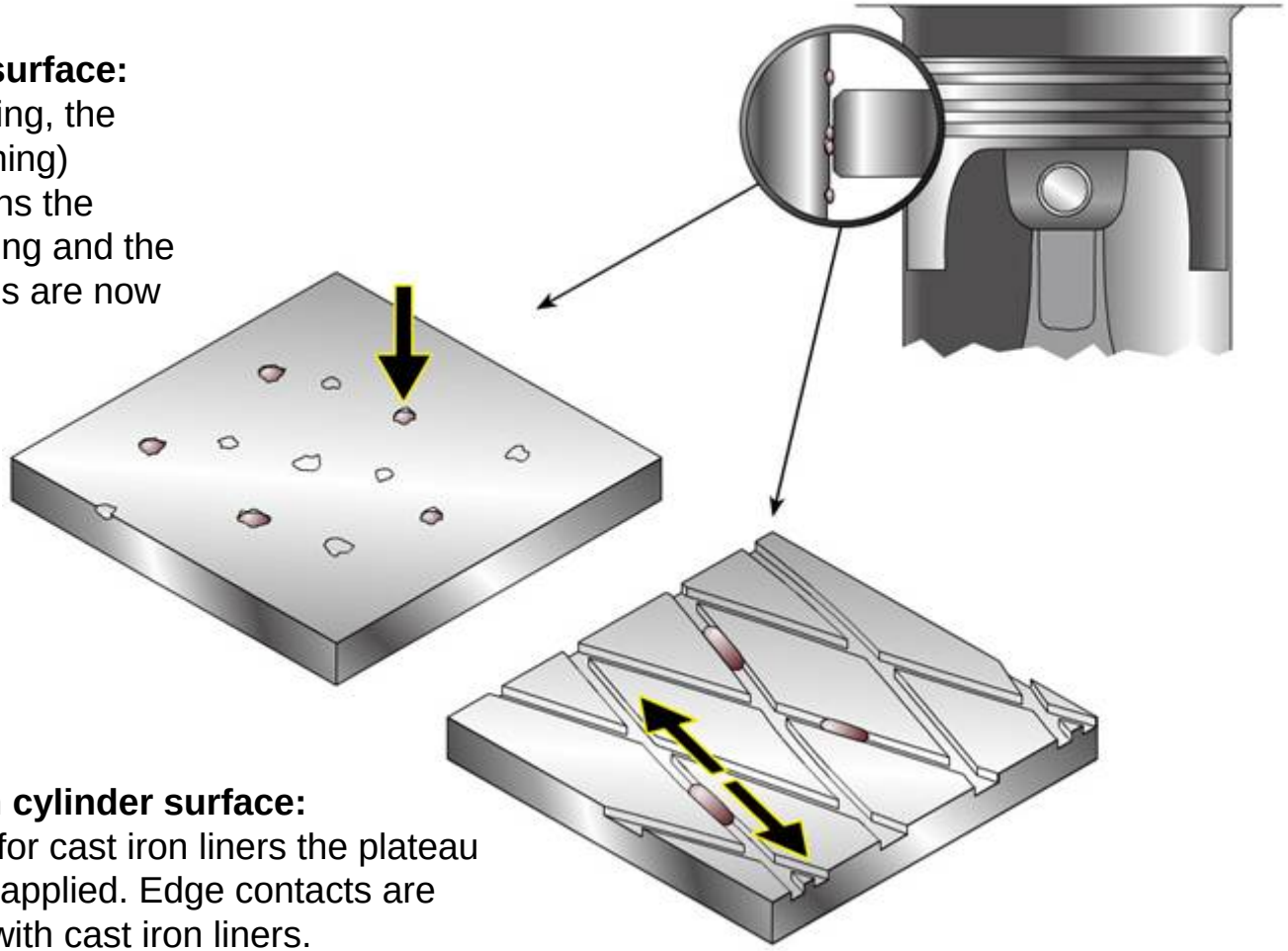


Rotation speed	from 0 to 200 min^{-1}
Coating diameter	from 40 to 500 mm
Coating depth	up to 500 mm

Process technology – honing

Comparison of plasma sprayed and cast iron liner topography

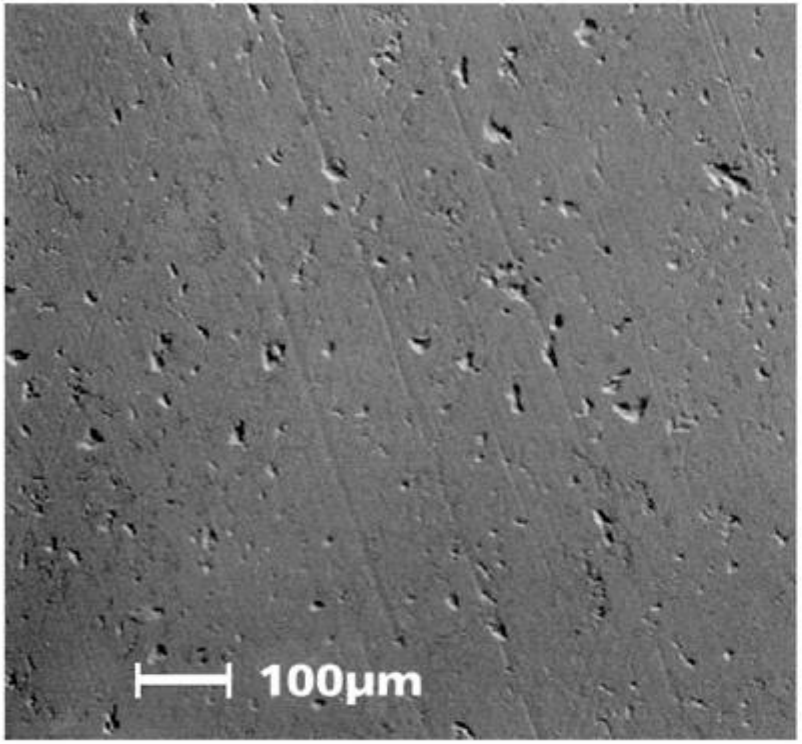
Plasma sprayed cylinder surface:
Together with plasma spraying, the honing process (smooth honing) creates a surface that lessens the friction between the piston ring and the cylinder liner; the piston rings are now float-mounted.

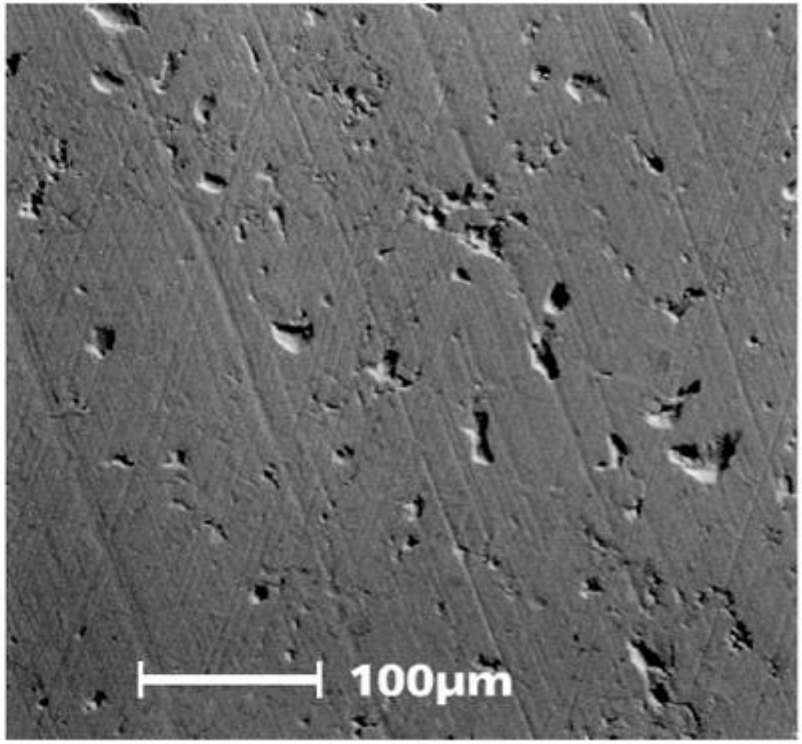


Cast iron cylinder surface:
Typically for cast iron liners the plateau honing is applied. Edge contacts are possible with cast iron liners.

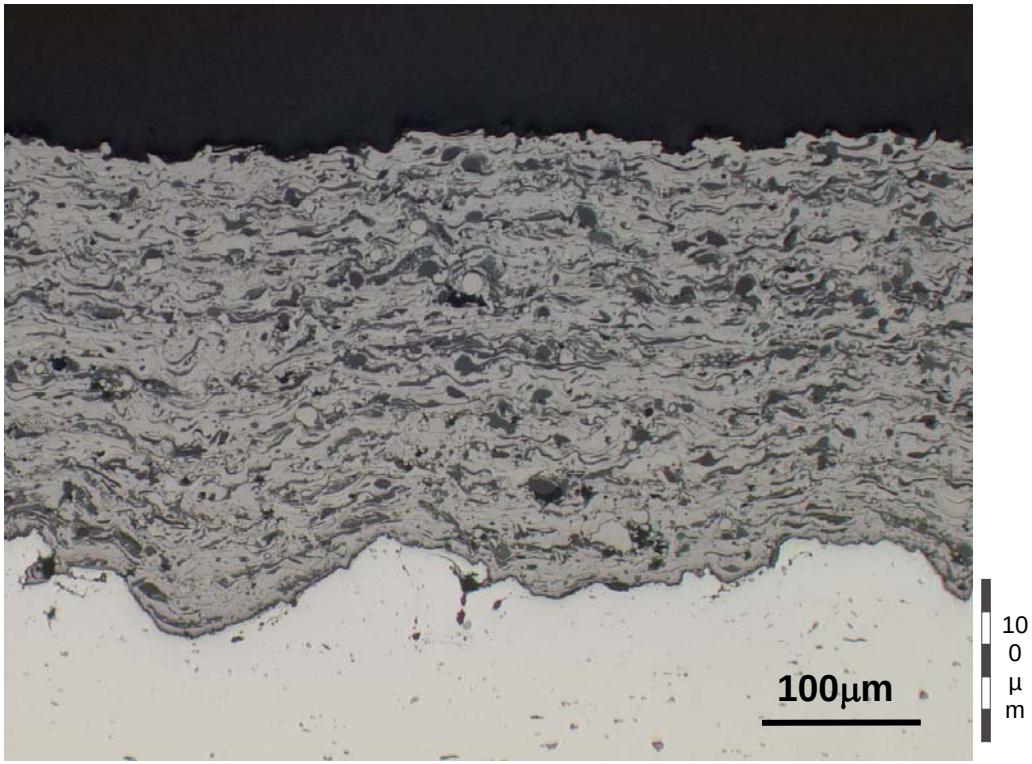
Process technology – honing - II

Smooth honing, recommended for the SM plasma coating
Typical topography after honing with diamond tool
Low alloyed carbon steel ($HV_{0.3}$ = 450)





Microstructure of plasma coating F2056



Typical MMC coating (F2056) for heavy duty Diesel engines with HV = 500

Improvements: **Compressive strength**
Abrasion resistance for EGR
Scuffing resistance

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Qualified engines with SM plasma coatings

Engine	Number of cylinder	Year of introduction	Vehicles	Power [KW]
GASOLINE ENGINES				
LUPO FSI 1.4L	4	2000	LUPO VW	77
SWISS AUTO Biland	2	2000	Go-Kart Racing	20
Suter Racing	1	2002	Go-Kart Racing	20
BUGATTI W 16	16	2003	Exclusive car	> 700
V 10 Racing	10	1999	Formula1	> 550
V 8 Racing	8	2004	Formula1+2,	> 450
		2007	NASCAR	> 600
V 4 Motorcycle Racing	4	2004	Moto Grand Prix	> 150
DIESEL ENGINES				
V 10 TDI	10	2002	Touareg, Phaeton	230
L 5 EA 115	5	2003	Touareg, Van T 5	130
Thielert L4	4	2006	small aircraft	100
V 12 (liners)	12	2007	LMP1 Le Mans	> 600

Volkswagen other engines in Wohlen

Blow-by measurement during the 300 hours rated power test at AVL Austria (150kW engine)

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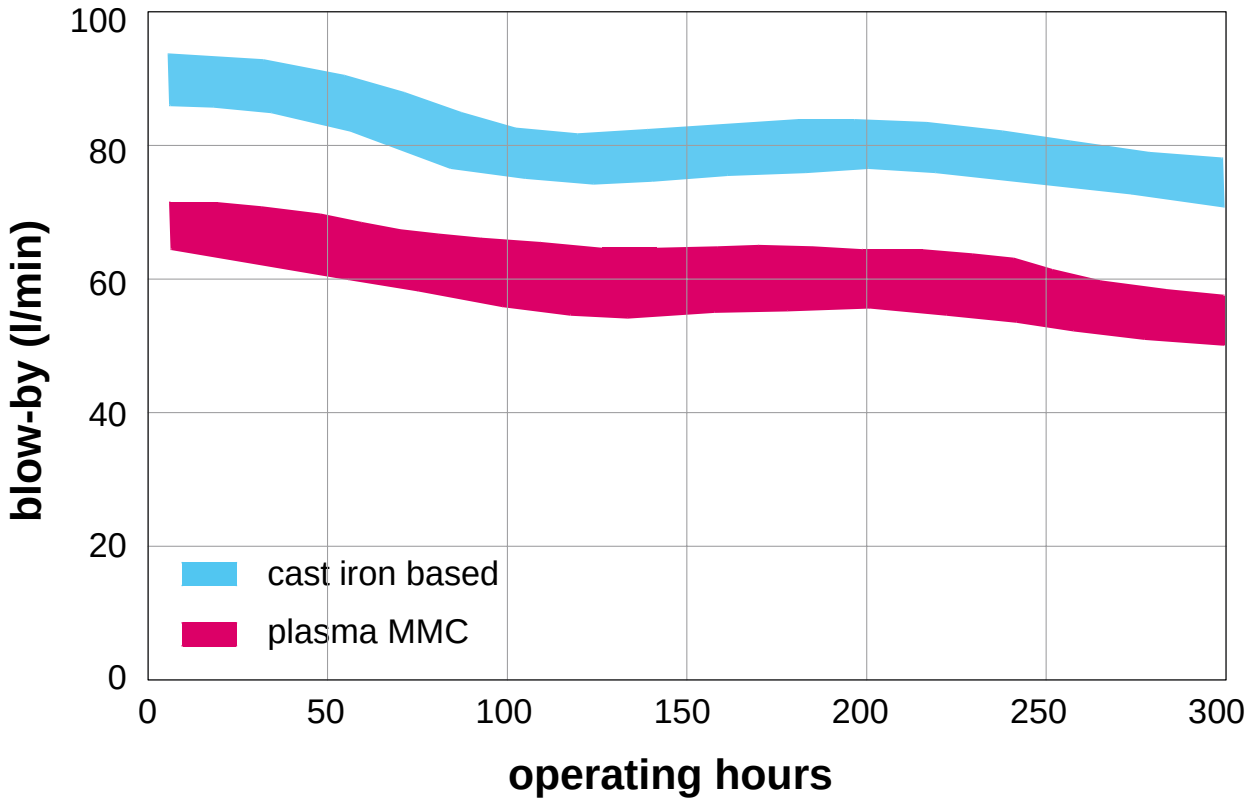

Plasma coating has the potential to reduce blow-by

Lube oil consumption measurements during a 250 hours rated power test

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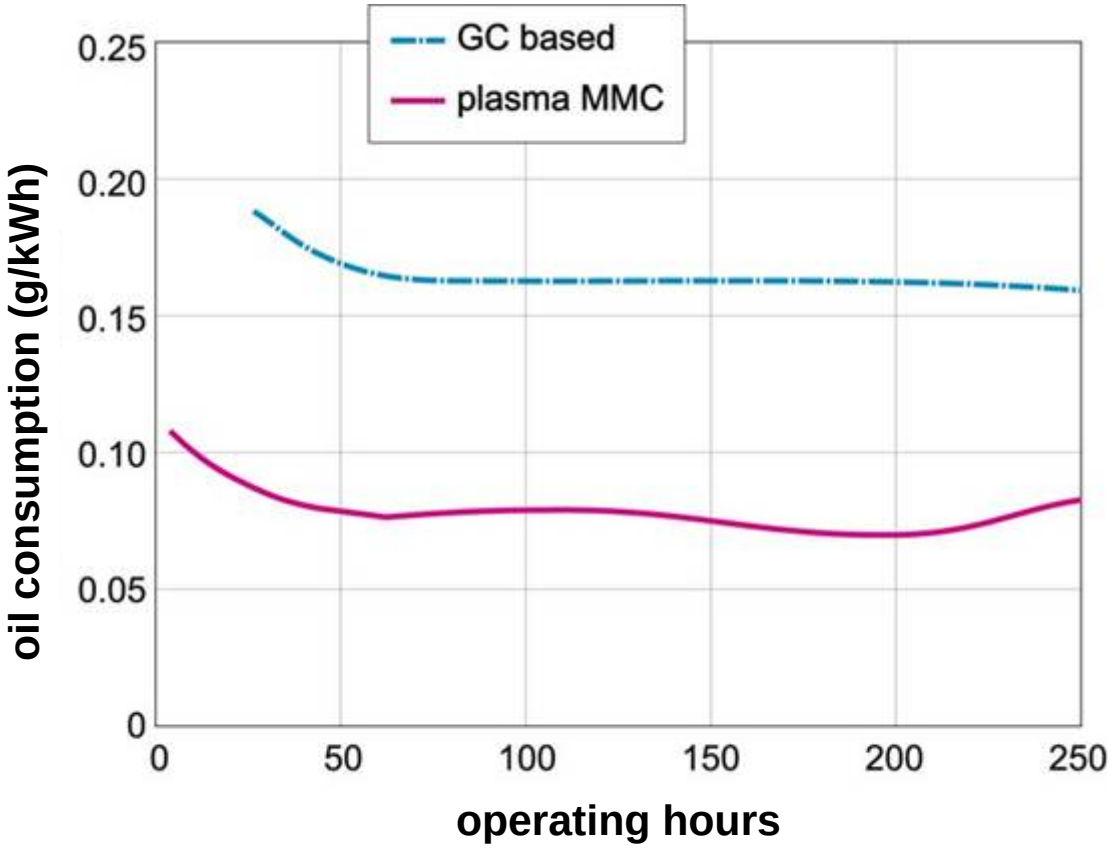
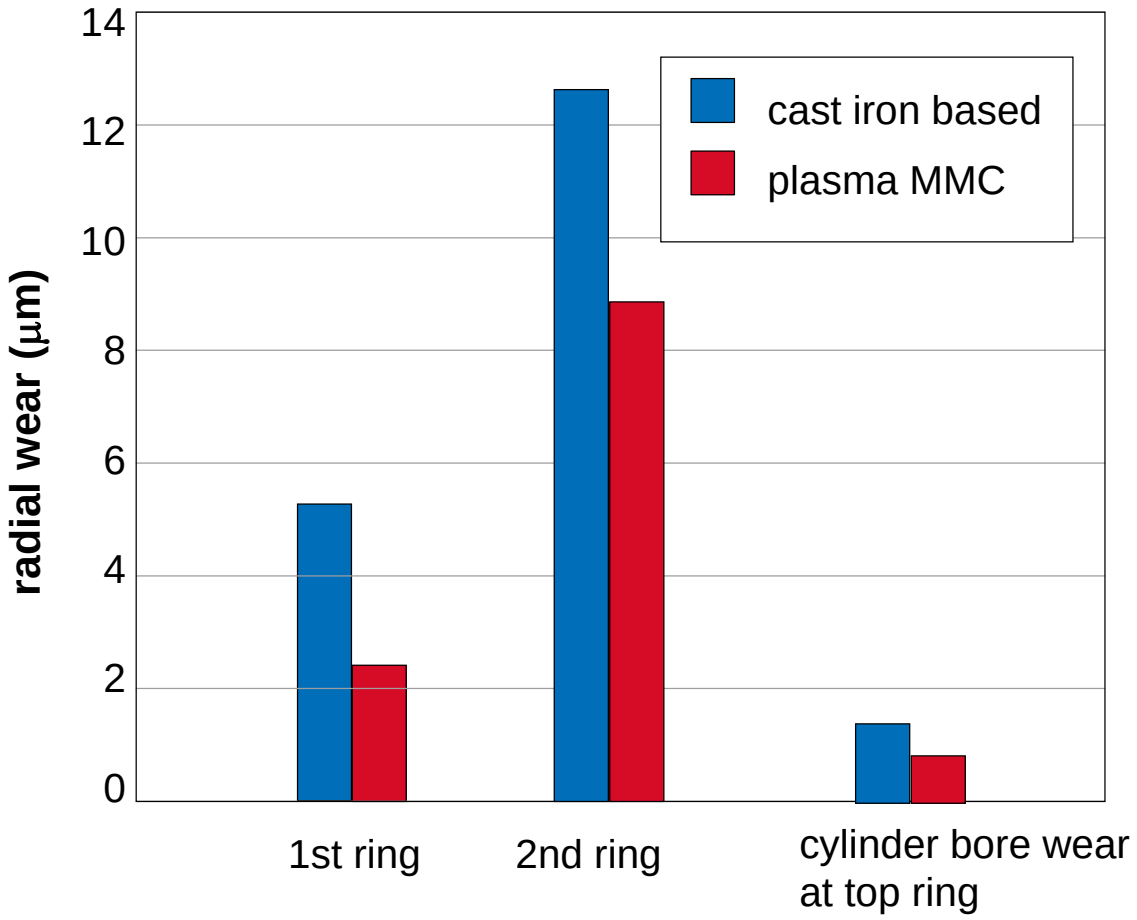


Test results prove that the plasma coating reduces the oil consumption by a factor of two

Radial piston ring wear and cylinder wear at top ring



300 hours test results:

The plasma coating always shows the least radial wear

Comparison of friction between cast iron and plasma coating (FEV Motorentechnik, PIFFO engine)

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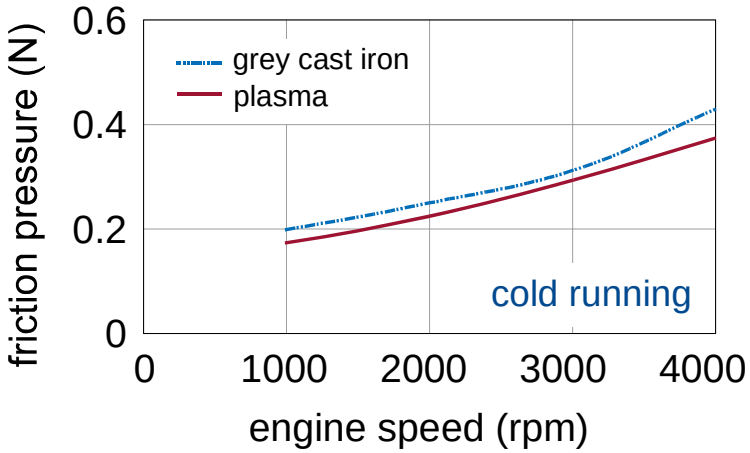

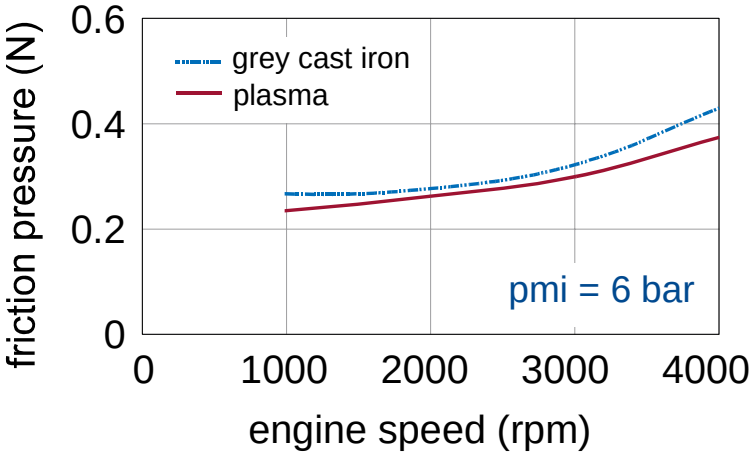

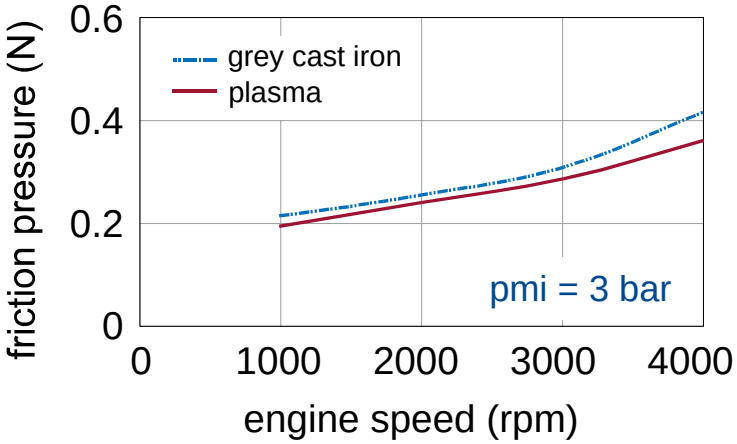

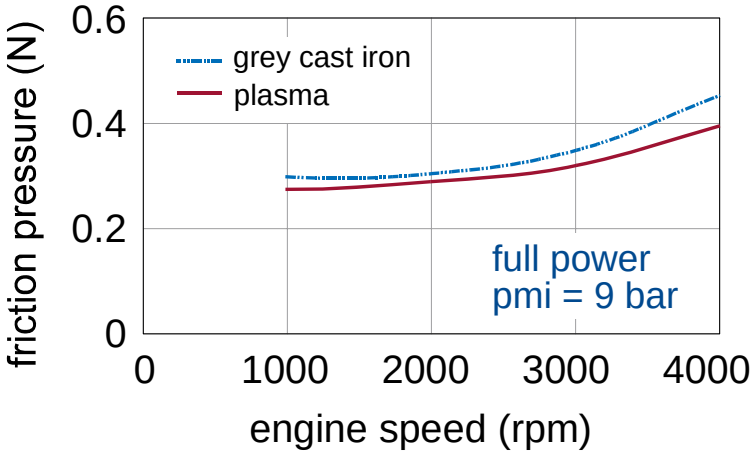

- **The friction pressure of plasma coating is always lower in all conditions of RPM and power**
- **With increased RPM the difference is growing in favor of the plasma coating**

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Modern transmission technology to reduce emissions

Economy and comfort of different design concepts (6 speed transmission)

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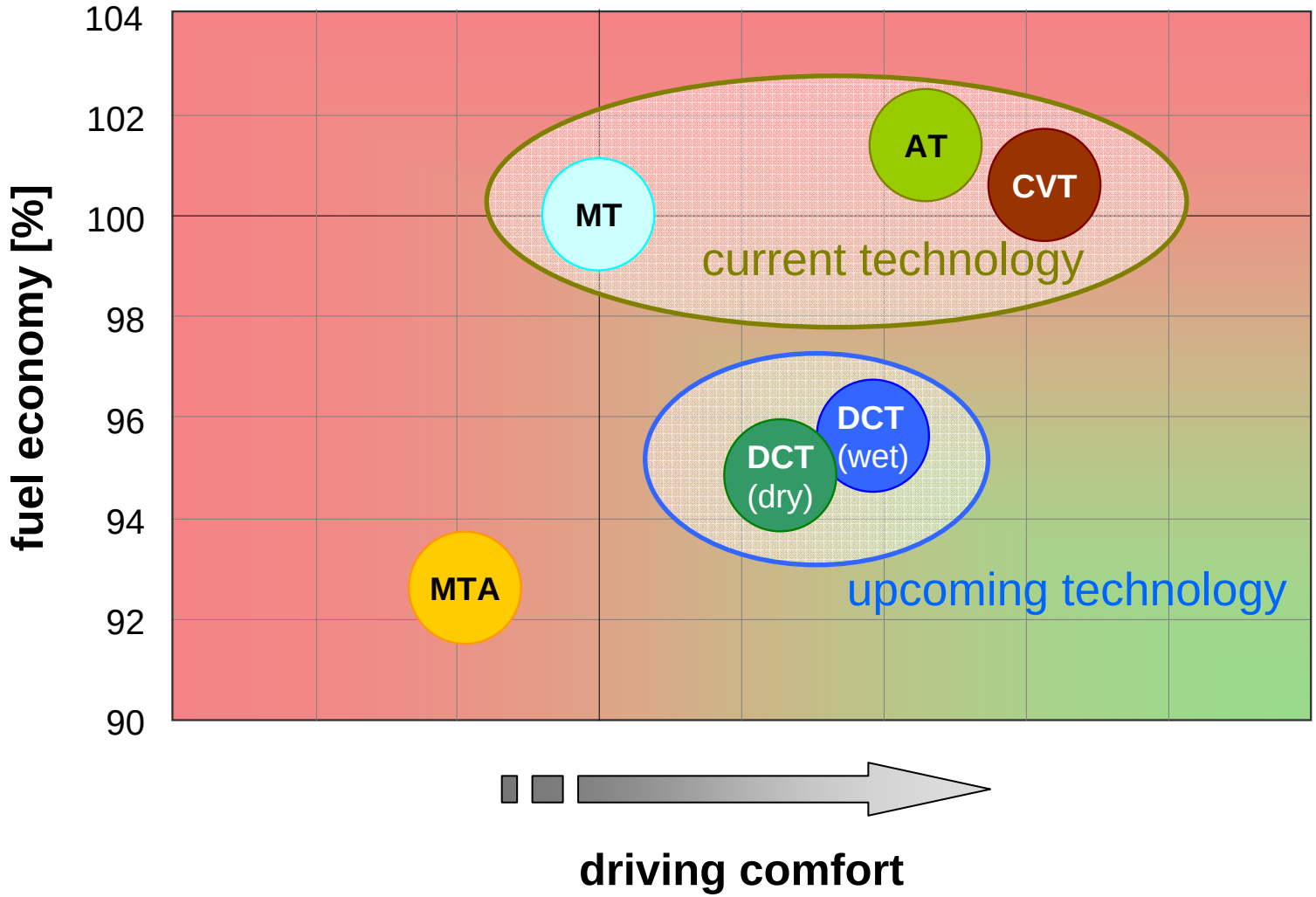
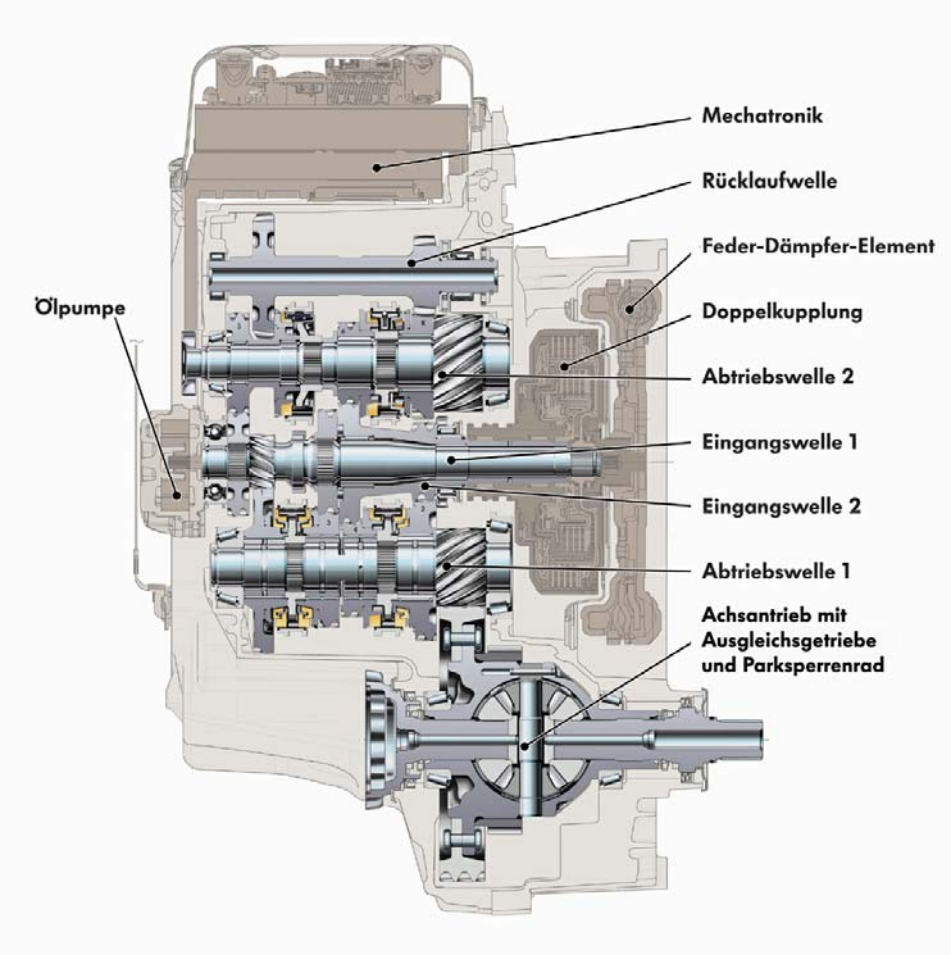
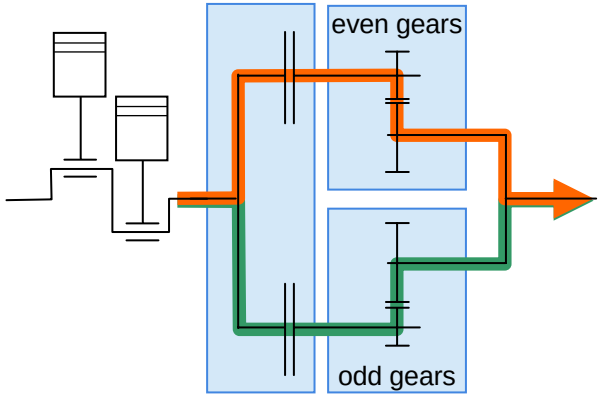


DCT technology



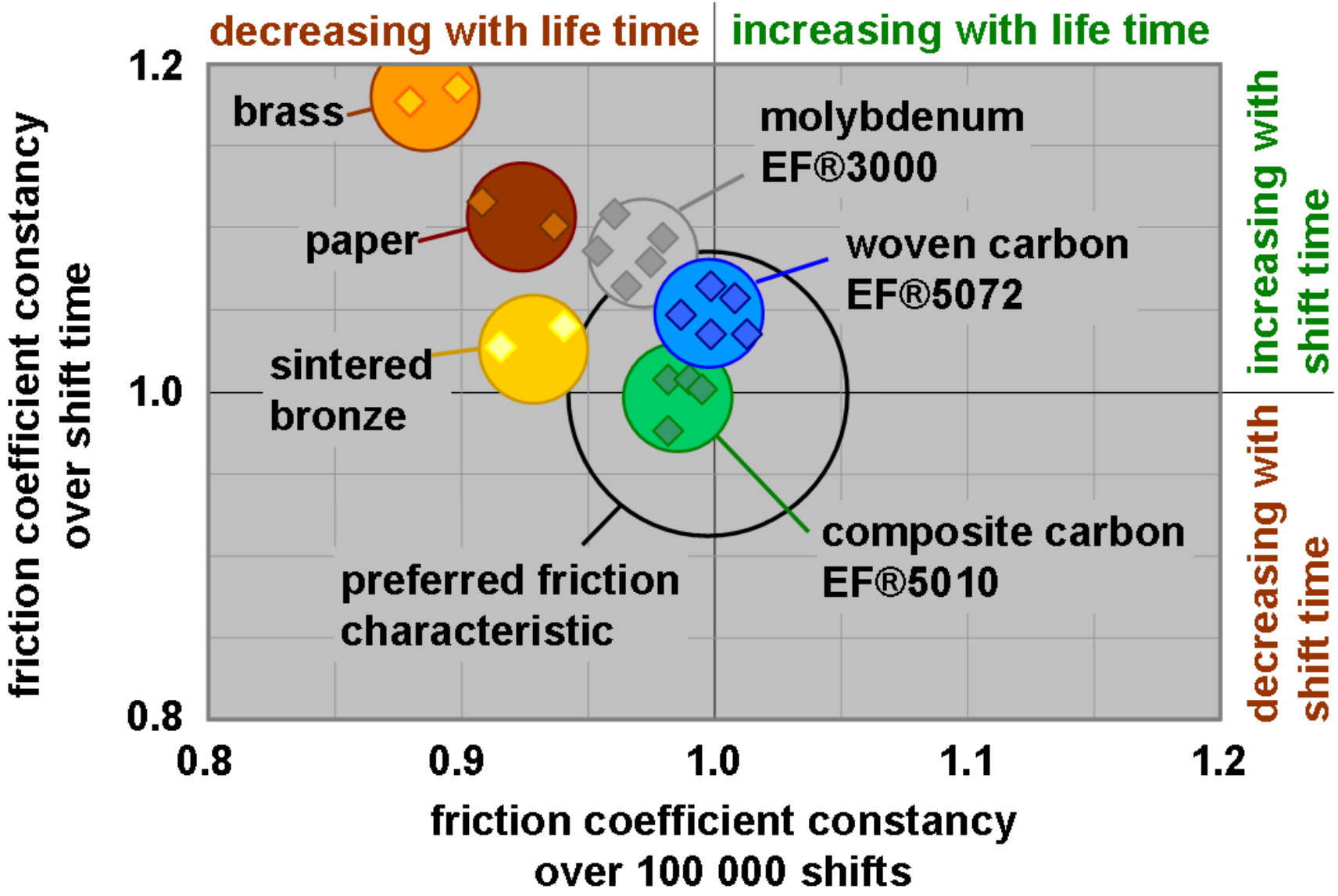
- well known production technology (design and layout similar to MT)
- no torque interruption



- fuel efficient

  - reduced internal friction
  - optimized shift pattern
  - increased number of gears

Carbon friction materials with constant COF



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Conclusions

- Internal plasma spraying is a proven technology for cylinder bore coating
- The mechanical losses of the piston gorup can be reduced by ca. 30%
- The fuel consumption can be reduced by around 2-4% (Diesel and gasoline engines)
- The oil consumption can be reduced by more than a factor of 2
- Extremely low wear rate for heavy duty Diesel engines have been measured (as low as 1 nm/hour of operation)
- More than 6 years industrial production experience in Europe
- Plasma sprayed bore coating is a low cost solution with high productivity (see Volkwagen)
- There are ways for a significant reduction of the cost for large liners
- carbon friction material provides high synchronizer torque that allows reducing the number of components associated with lower weight and lower costs
- Stamped steel synchronizers with EF® 5010 carbon are the preferred choice for advanced transmission technologies