Potential motorcycle Euro 6 legislation: Content, challenges and solutions

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Agenda

- Introduction
- Historical emissions trends and motorcycle technology evolution
- Potential new testing regime for Euro 6
- Current emissions levels; future challenges and solutions
- Non-exhaust emissions
- Wrap-up

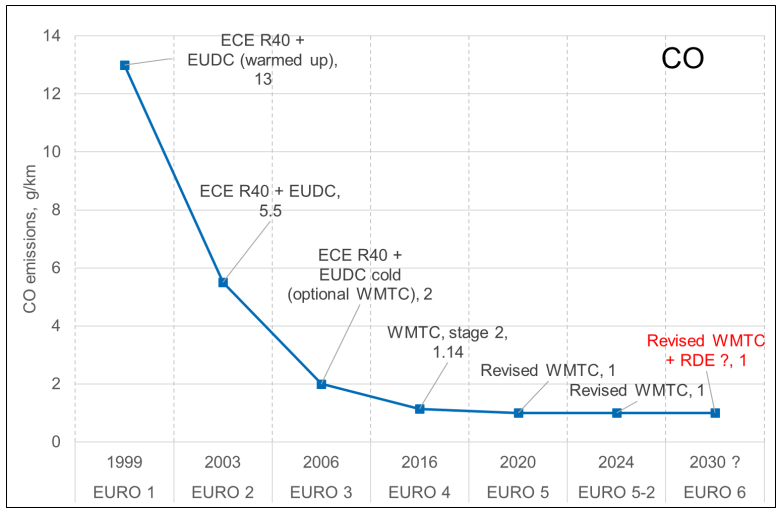
Introduction

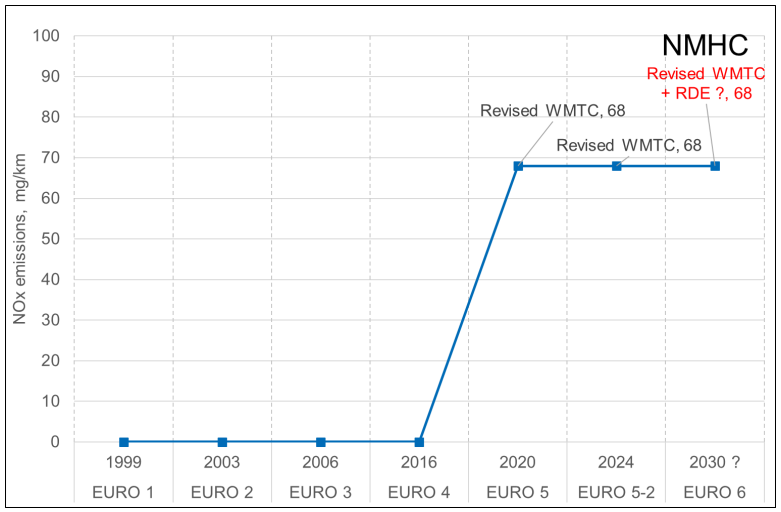
Introduction

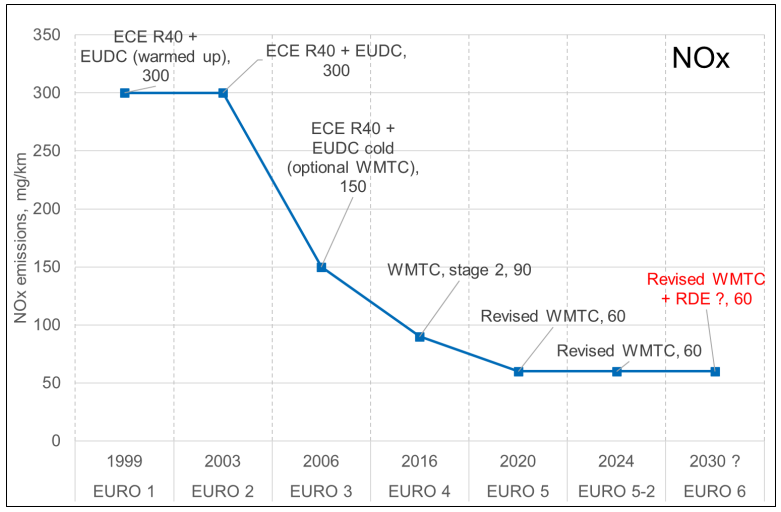
- In this presentation we look to the future and the past
- We consider prior motorcycle emissions legislation, parallels to passenger car legislation, and where Euro 7 may currently be heading, in order to understand possibilities for motorcycle Euro 6
- Aspects will include potential Euro 6:
  - Timing
  - Testing regime
  - Pollutants to be controlled
  - Emissions control technologies required

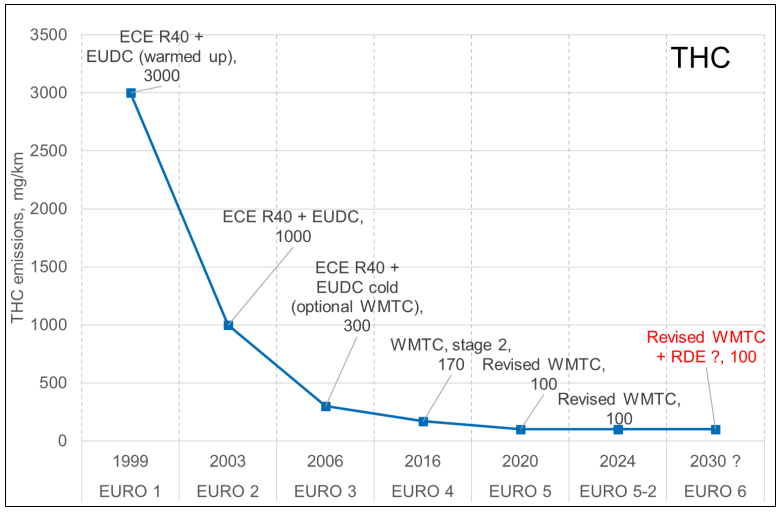
Historical emissions trends and motorcycle technology evolution

Motorcycle emissions limits – positive ignition only





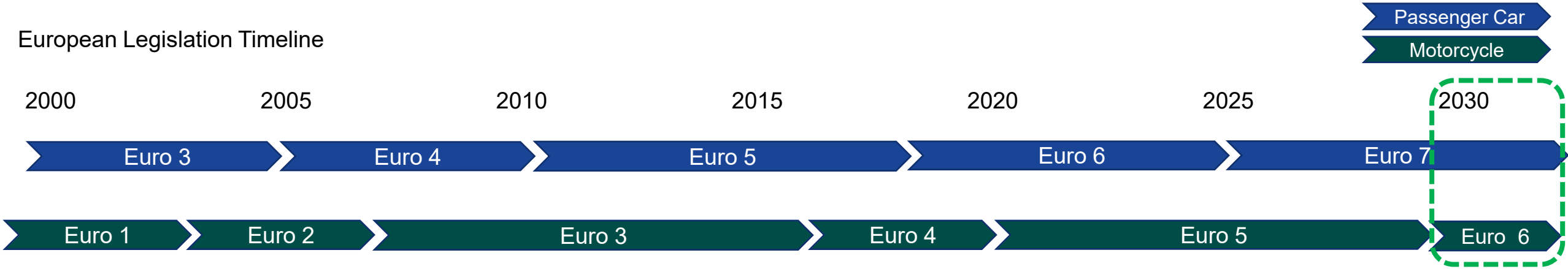




- Since 1999, at Euro 1, we have seen progressive reductions in pollutants through to Euro 5
  - and the certification cycle change to WMTC
- Recently we have seen the introduction of NMHC (Euro 5), and PM:
  - PM applies to direct injection motorcycles only, with 4.5mg/km limit
- The pollutants required for gasoline fuelled motorcycles and now harmonised with passenger car emissions and we might anticipate that remaining the case at Euro 6 (MC)
- CO, NMHC, THC, NOx will remain, but we may see new species added

Motorcycle emissions have traditionally followed passenger car legislation, but may align at Euro 6 in the timeframe of 2030

European Legislation Timeline



EURO STD	PC & MC EURO 5	PC EURO 6
CO mg/km	1000	1000
NMHC mg/km	68	68
HC mg/km	100	100
NOx mg/km	60	60
PM mg/km	4.5	4.5
PN #/km	---	$6x10^{11}$
NH_3 mg/km	---	---

Euro 5 PC and MC currently have the same regulated pollutant limits with an implementation time delay of >10 years

EU regulations development for motorcycles – **non criteria pollutant factors**

EURO STD	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 5-2
YEAR	1999	2003	2006	2016	2020	2024
Emission Cycle	ECE R40 + EUDC (warmed up)	ECE R40 + EUDC	ECE R40 + EUDC cold (optional WMTC)	WMTC, stage 2	Revised WMTC	Revised WMTC
CO_2	N/A	N/A	N/A	N/A	To be declared on homologation (it shall be met during COP tests)	To be declared on homologation (it shall be met during COP tests)
SHED test	N/A	N/A	N/A	Yes	Yes	Yes
SHED test limit mg/test	N/A	N/A	N/A	2000	1500	1500
On board Diagnostics	NO	NO	NO	Yes (OBD1)	Yes (OBD2)	Yes (OBD2 with in service monitoring)
Durability Test	N/A	N/A	N/A	20,000km	Lifetime with mathematical emission degradation optional for homologation	Lifetime with homologation ageing test mandatory

- Since Euro 4 we have seen the need to report CO_2 figures and evaporative emissions plus the need for OBD and durability requirements. These will continue at Euro 6

Motorcycle technology evolution driven by emission regulations

	EURO 1	EURO 2	EURO 3	EURO 4	EURO 5	EURO 5-2
Fuel control	Carburetor	Carburetor	Carburetor/EFi	Electronic port fuel injection	Electronic port fuel injection	Electronic port fuel injection
Catalyst	None	None	Hot tubes / Oxidation catalyst	3-Way catalyst	3-Way catalyst	3-Way catalyst
Diagnostic	None	None	None	OBD I	OBD II	OBD II Stage B
Evap emissions	None	None	None	Canister with purge valve (passive/active)	Canister with electronic purge valve	Canister with electronic purge valve

- Main changes since Euro 4 have been OBD based

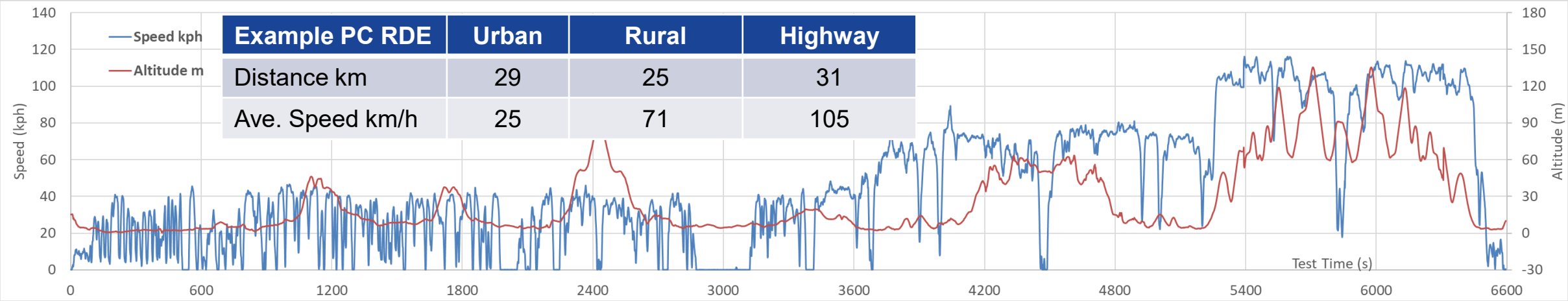
Potential new testing regime for Euro 6

Portable Emission Measurement PEMS / RDE (aip-automotive.de)

Transition from lab-based WMTC to RDE (+ WMTC)

- Euro 6 & 7 passenger emissions limits are focused on Real Driving Emissions (RDE)
- This allows driving modes in urban, rural and highway without highly prescribed driving
- Potentially motorcycles may have to follow similar test regimes
- How will the motorcycle RDE look?

Example PC RDE	Urban	Rural	Highway
Distance km	29	25	31
Ave. Speed km/h	25	71	105



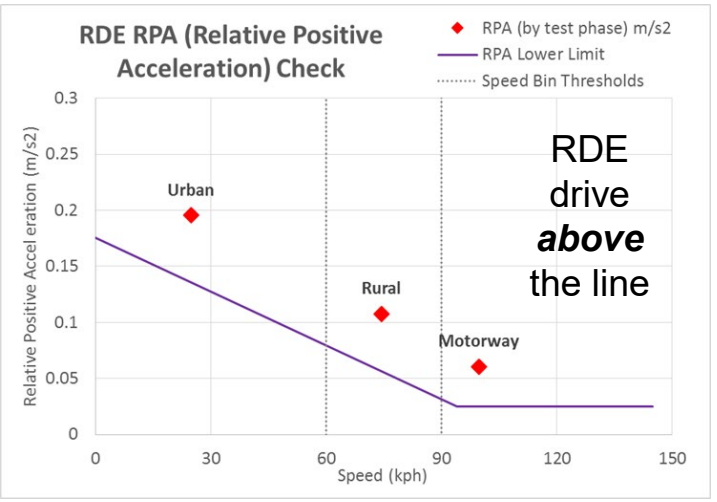
Euro 6 testing likely to include (and prioritise) Real Driving Emissions (RDE)

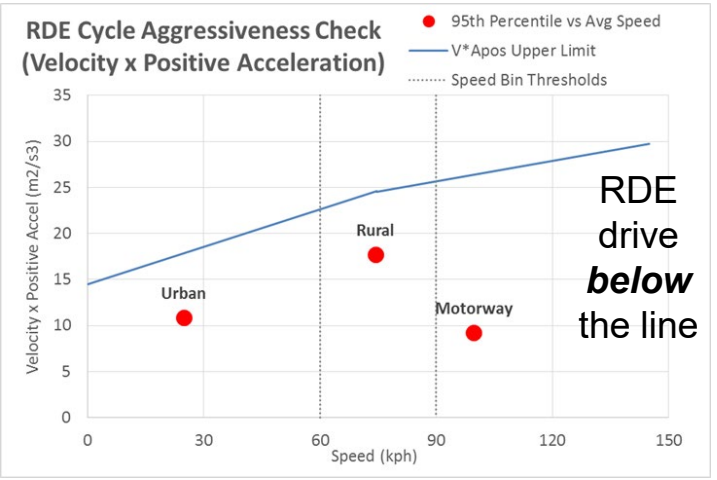
- **Main Concepts of RDE**
- Use of Portable Emissions Measurement Systems (PEMS)
- Trip requirements to ensure that relevant engine/vehicle operating regimes are covered
- RDE test a snapshot, **but all possible snapshots should comply!**
- RDE assessed in comparison with lab-based WMTC using CO_2 emissions “windows” at the basis

- **Some Boundary conditions** (moderate / extended)
  - Test duration 90-120 minutes
  - Altitude: ≤ 700m, 701 – 1300m; positive gain < 1200m
  - Route assignment (**U**rban, **R**ural, **M**otorway)
    - U: ≤ 60kph, R: 60 & ≤ 90kph, M: >90km/h (& <145kph)
  - Route shares: approx 33% each U, R, M (some leeway)
  - >16km each of U, R and M
  - Cold start included in emissions evaluation
  - Dynamics RPA (prevent too mild driving); V*apos_95 (no abuse!)
- **SOME CRITERIA WILL NEED TO BE MODIFIED FOR MC!**

Example RDE route; and dynamics checks

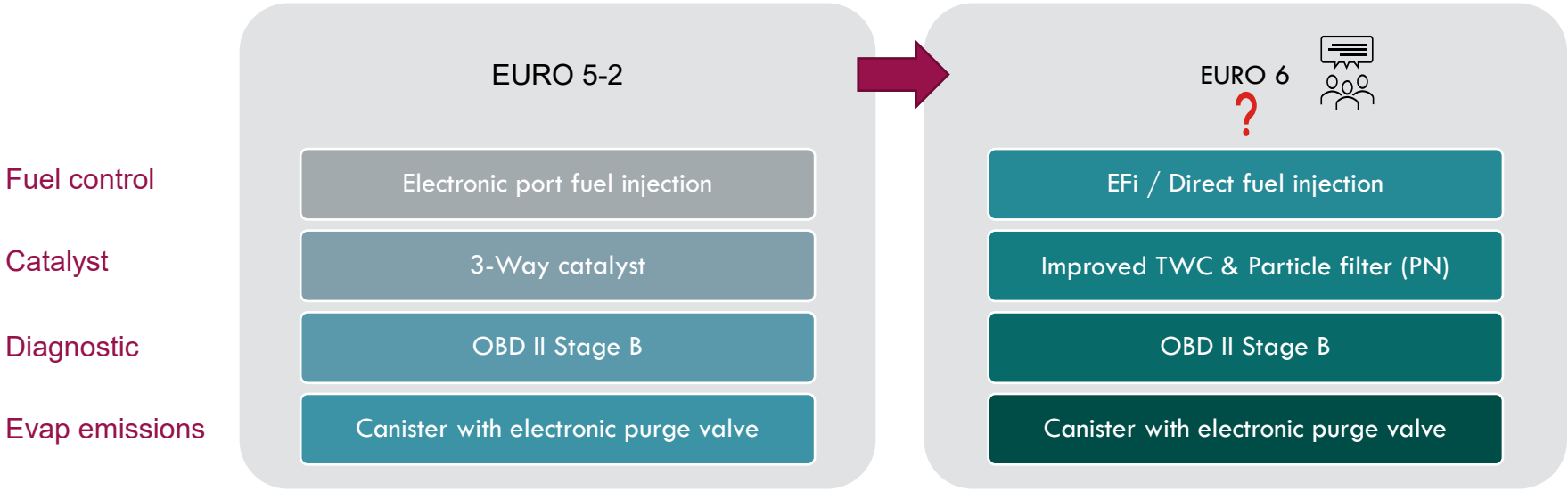
- One of the two routes available from Ricardo Shoreham
- Developed using simulation experience and iterative tests with multiple vehicles to ensure compliance





Motorcycle technology evolution will continue to be driven by emission regulations

EURO STD	EURO 5-2	EURO 6
YEAR	2024	2030 ?
Emission Cycle	Revised WMTC	RDE, will also retain WMTC
CO2	To be declared on homologation (it shall be met during COP tests)	New limit
SHED test	Yes	Yes / could change
SHED test limit mg/test	1500	1500 / could change
On board Diagnostics	OBD2 with in service monitoring	OBD2 with in service monitoring
Durability Test	Lifetime with homologation ageing test mandatory	Lifetime (extended?) with homologation ageing test mandatory



- Euro 6 may bring changes in both FIE and aftertreatment requirements

Current emissions levels; future challenges and solutions

There is a potential for Motorcycle Euro 6 to align with Passenger car Euro 7

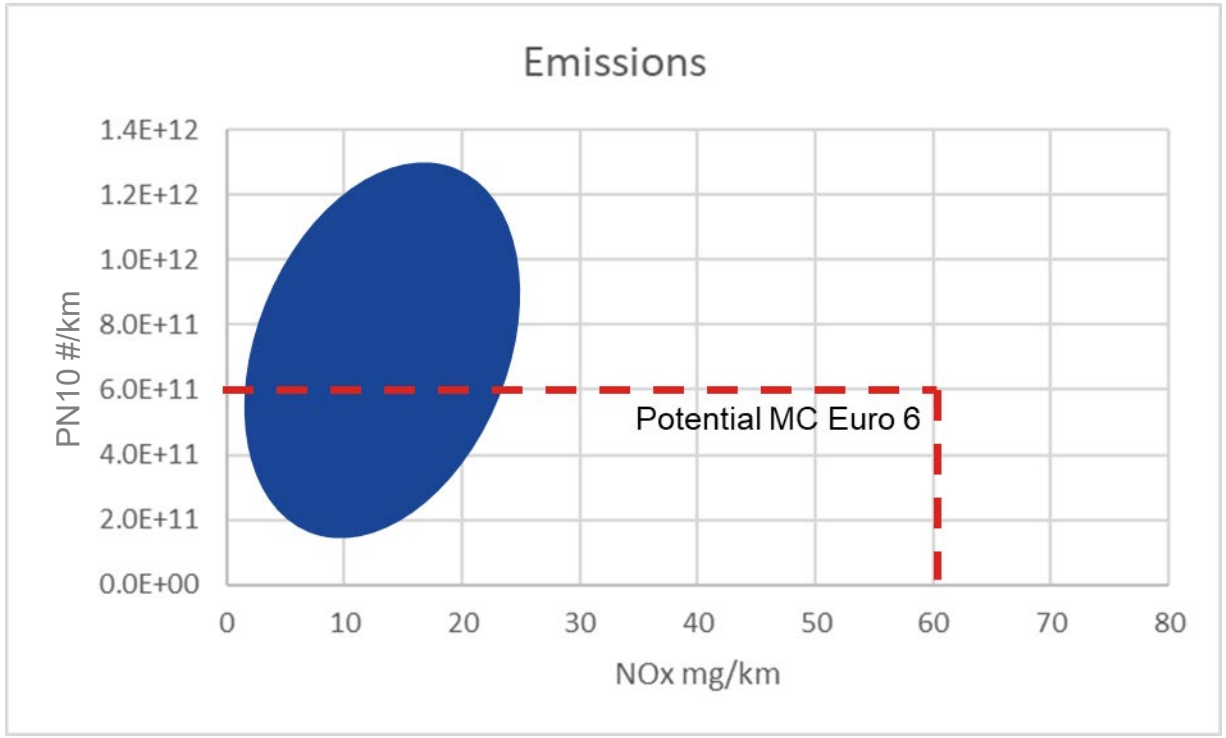
EURO STD	PC EURO 7
CO mg/km	500
NMHC mg/km	68
HC mg/km	100
NOx mg/km	60
PM mg/km	4.5 (all types)
*PN10 #/km	$6x10^{11}$
NH_3 mg/km	20

PC Euro 7 Challenge	MC Mitigation at Euro 6
CO reduction to 500 mg/km	Improved lambda 1 control Larger TWC
PN legislation (>10nm)	Combustion enhancements Filter implementation to exhaust Improved oil control
NH_3 legislation	Improved lambda 1 control
Broader Emissions Control Window	Improved lambda 1 control Optimised catalysts

- Euro Passenger car Euro 7 emissions legislation is intended to be the final passenger car emissions legislation - hence motorcycles may default to Euro 7 limits
- Real driving emissions (RDE) is expected to be the focus for Euro 7.
- Work on the nature of RDE for motorcycles will be required

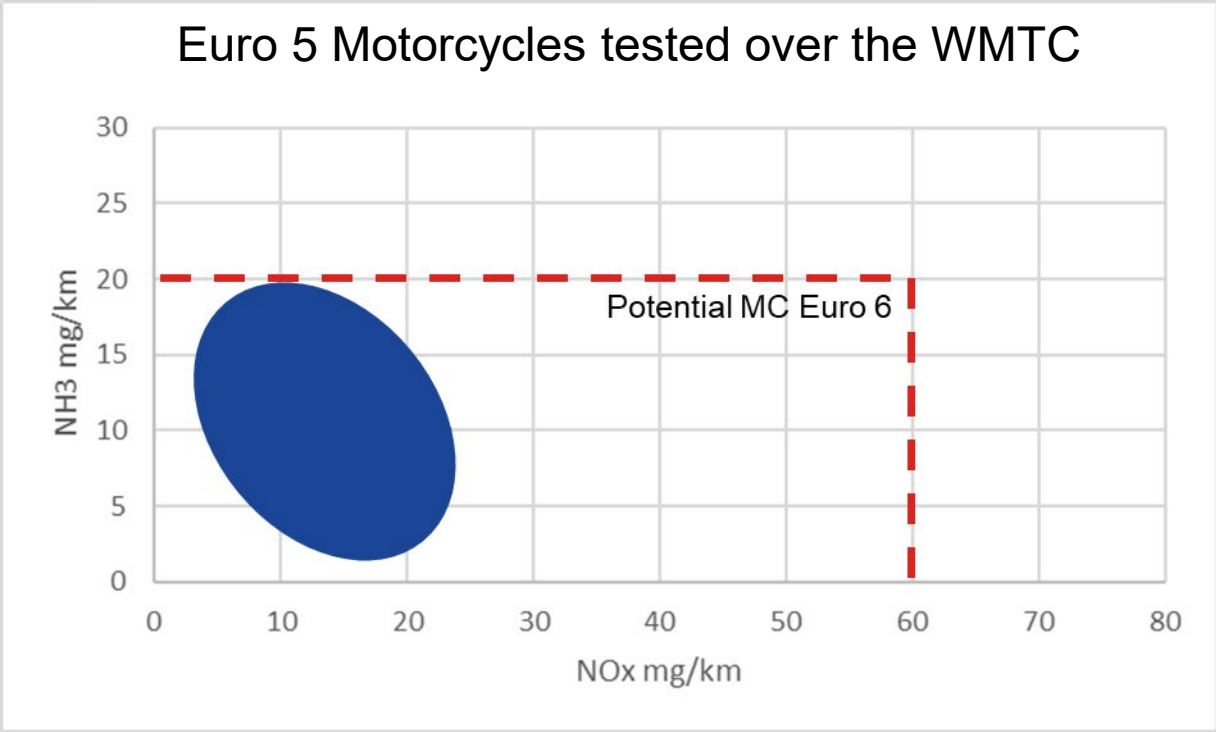
*PN10 – particles larger than 10nm

Euro 5 Motorcycles compared to potential MC Euro 6: PN10 & NOx



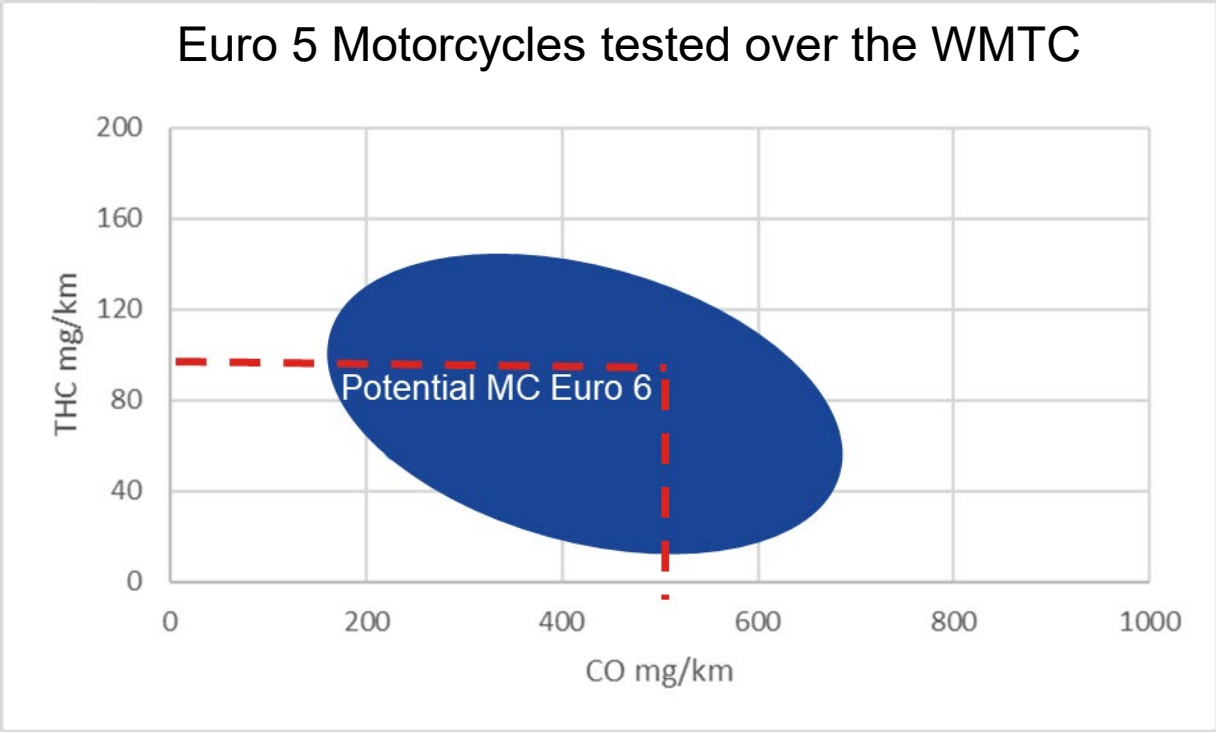
- Exceedances of the potential Euro 6 limit were measured for PN
- Filter technology will allow the potential limit to be met

Euro 5 Motorcycles compared to potential MC Euro 6: NH_3 & NOx



- Exceedances were not measured for NH_3 or NOx, but NH_3 was close to the potential limit
- More demanding RDE requirements likely to increase ammonia emissions

Euro 5 Motorcycles compared to potential MC Euro 6: THC & CO

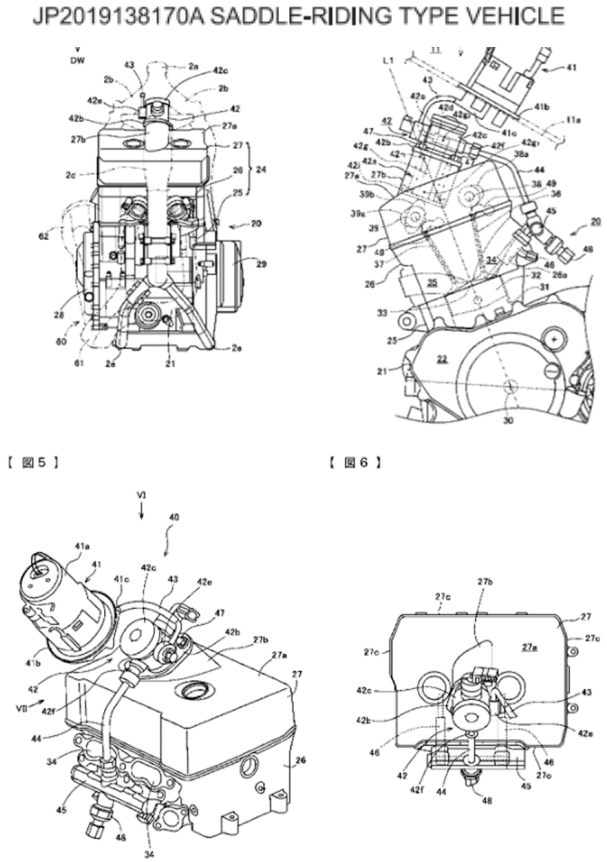


- Exceedances were measured for both THC and CO
- Advanced TWC* or larger volume TWC will be required to meet the potential limit

*Increased PGM ratio change, more OSC or less OSC, optimised formulation

Direct fuel injection potential benefits

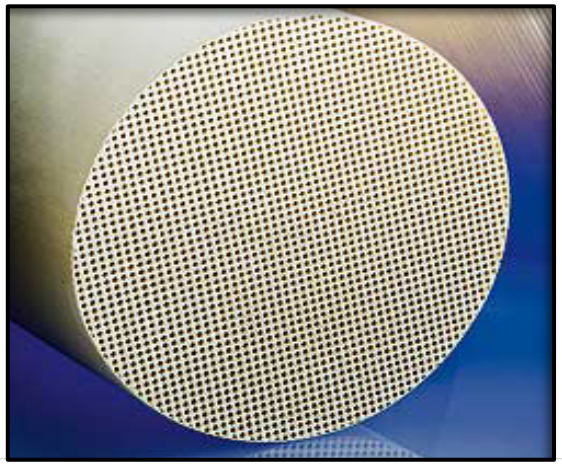
- Direct Injection dominates PC but is not yet present on motorcycles
  - cost, weight, layout...
- Introduction of DI at EURO 6 could present multiple benefits:
  - Performance Increase: enhanced power, reduced knock risk, providing a more dynamic and responsive riding experience
  - Reduced Emissions: improved fuel delivery and fuel saving reduces engine-out CO and HC - allowing optimization and cost reduction of aftertreatment system
  - Fuel Efficiency: more precise fuel metering results in better combustion, significant fuel savings and lower greenhouse gas emissions
  - Advanced Control: precise fuel injection control during transient conditions maximises the benefits and enables necessary technologies such as cylinder deactivation and power limitation



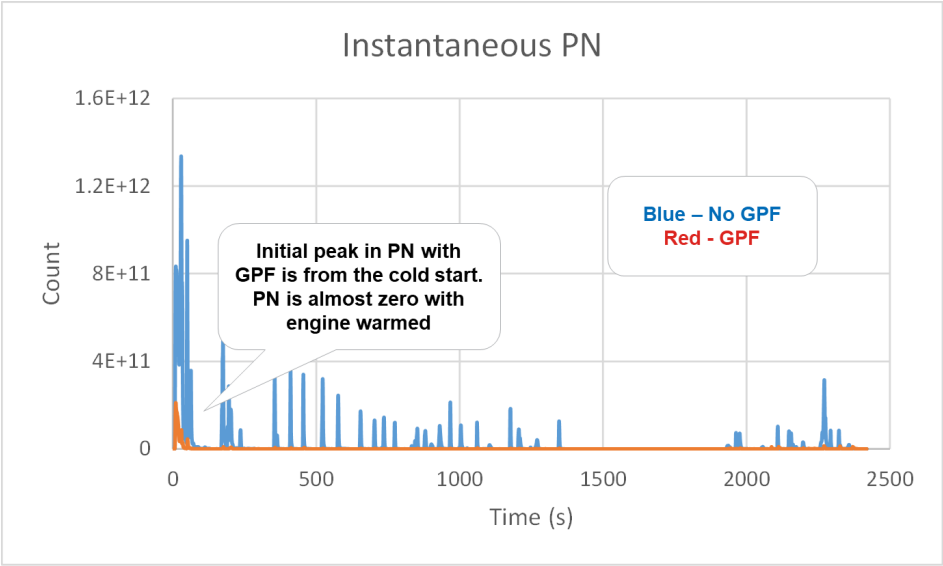
Recent Honda DI patent indicates an increasing interest from OEM in this technology

Passive particle filters are a solution for motorcycle PN control

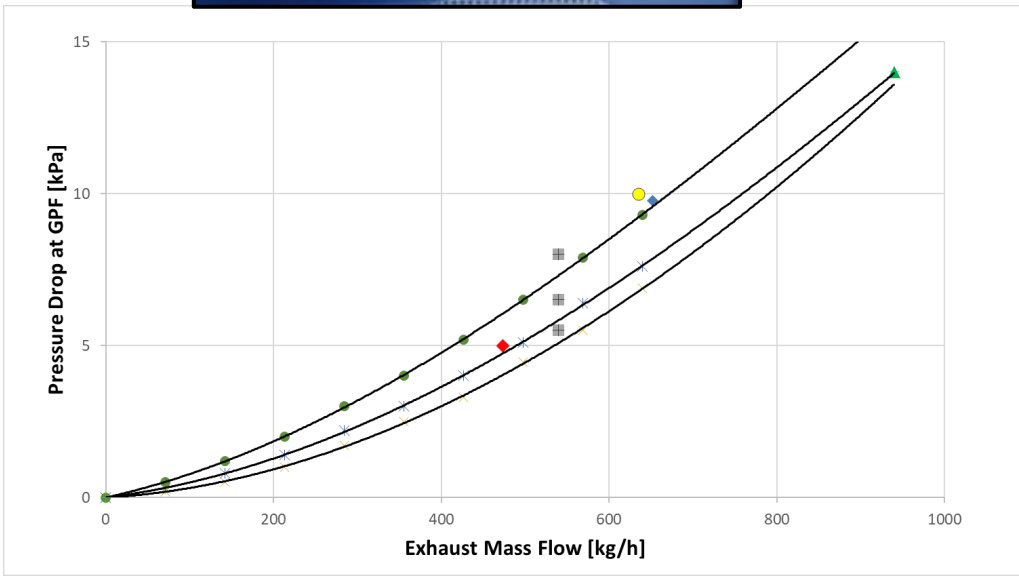
- Ceramic filters are highly efficient, enabling safe PN limit compliance for gasoline passenger cars
- Filter will trap solid particles including ash:
  - Improve trapping efficiency through life
- Backpressure will increase with soot and ash loading:
  - Need for correct filter sizing for ash storage



Cordierite passenger car particle filter

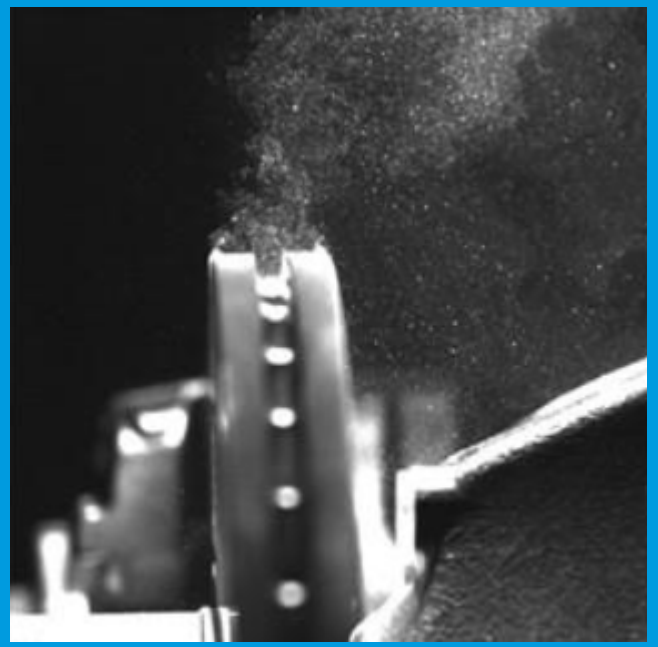


Source: Ricardo Data



Source: Ricardo Data

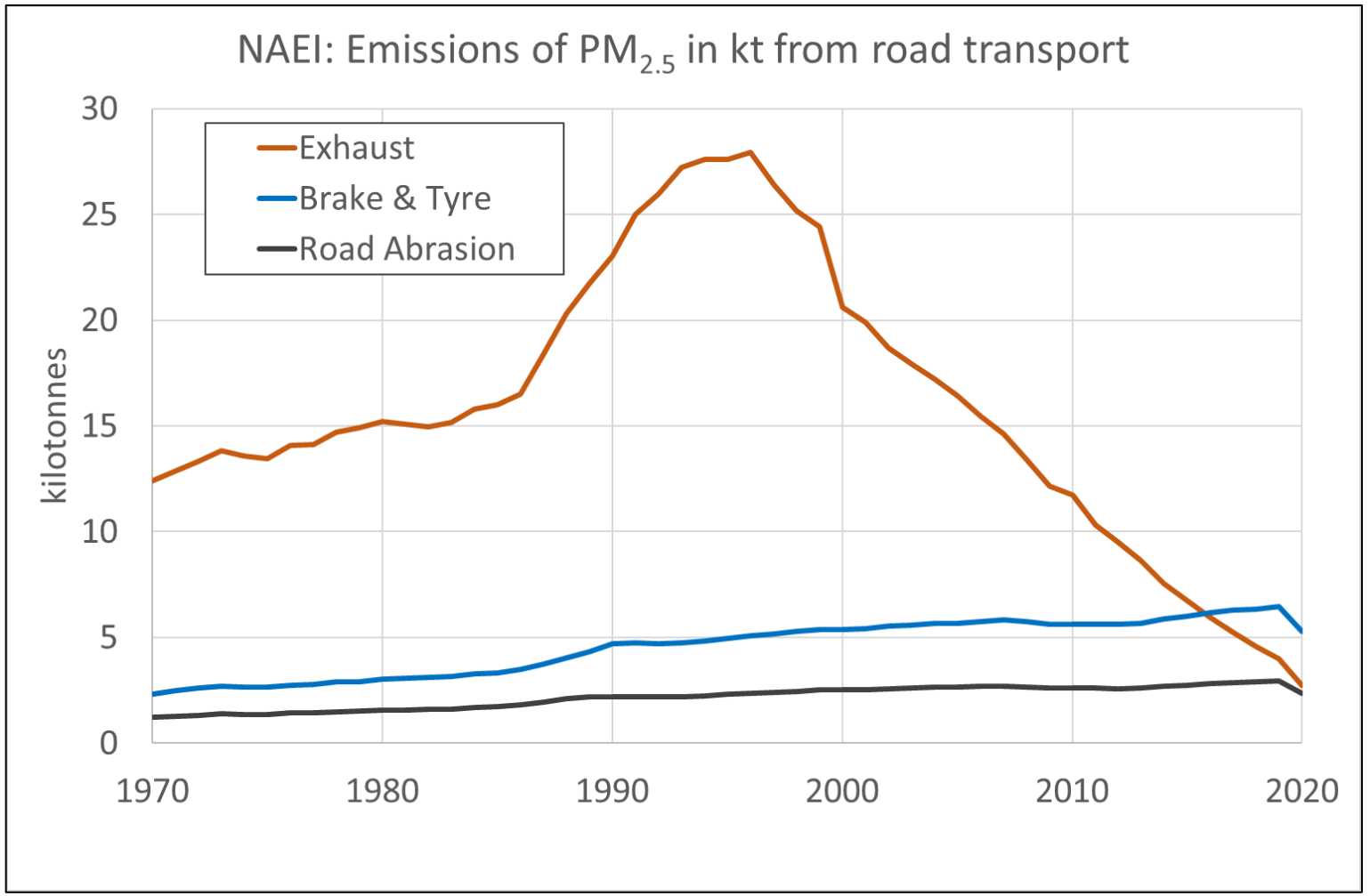
Non-exhaust emissions



https://uk-air.defra.gov.uk/assets/documents/reports/cat09/1907101151_20190709_Non_Exhaust_Emissions_typeset_Final.pdf

Non-exhaust particle emissions (NEPE)

- Fitment of particle traps (DPF and GPF) to ICE vehicles means that non-exhaust emissions now dominate the particulate emissions of road transport
- Despite zero tailpipe emissions status, EV are emitters of NEPE
- Brakes and Tyres are the main sources



NAEI – UK National Atmospheric Emissions Inventory

International work on regulations

- UNECE is developing internationally recognised test procedures to measure brake and tyre particles from PC and HDV

- Measuring tyre and road wear particles is technically very complex:
  - Ongoing work should lead to a tyre abrasion test procedure and limits in regulation in late 2023

- Work on measuring brake wear is more advanced:
  - UN GTR expected to be adopted late in 2023
  - EU has proposed limits on car (M1/N1) brake emissions within Euro 7, with initial limits set, during brake dynamometer testing, at 7 mg/km
  - Proposal for this limit to drop to 3 mg/km in 2035

- Potential for L-Class requirements to be introduced as part of Euro 6 with limits harmonised to passenger car levels

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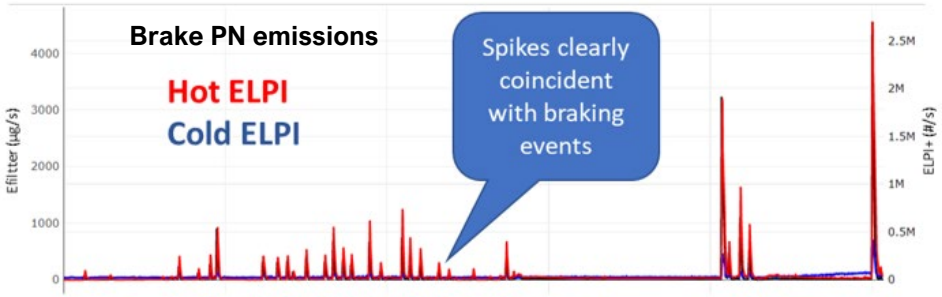
Brake and Tyre Regulations

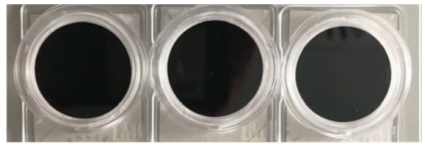
- At Euro 7, initially, neither brakes nor tyres will be measured on-vehicle
- Brake wear will be determined by tests on a brake dynamometer, with particle mass (PM10, PM2.5) and particle number (PN10, particles counted in the size range above 10nm) quantified:
  - Brake pads will be type approved, certified to meet emissions standards
- Similarly, low emissions tyres will be approved by a tyre abrasion test (total mass emitted only controlled, at least to start with)
- In the future, on-vehicle measurements may be required, on the road, or possibly during tests conducted on the chassis dynamometer
  - Ricardo is working on this approach for Pass Car

Ricardo is already exploring on-vehicle NEE measurements

Wheel removed showing mounting of tyre sample duct, and rear of brake enclosure

Tyre sample duct fitted behind wheel





Brake particle filter samples collected on-board (95% metal oxides)

Wrap-up & Q&A

Wrap-up

- Euro 6 motorcycle legislation, expected around 2030, may bring alignment of emissions limits with Euro 7 passenger cars, and harmonisation of testing approaches
- The introduction of RDE to accompany the lab-based cycle means that measurements using PEMS will be essential
- PN10 and ammonia may be introduced as new pollutants, demanding the use of particle traps, optimum oil consumption and lambda control
- Increased severity of CO emissions limits, and maintained NOx, THC and NMHC limits alongside the introduction of the more severe RDE cycle, may require DI FIE, plus lambda and TWC optimisation
- The introduction of requirements for brake and tyre wear will likely follow those of passenger cars
- Exactly what we will see from motorcycle Euro 6 will depend on current discussions on the nature of Euro 7 for passenger cars. This will be resolved in the coming few months…