Emissions of Motorcycles and Mopeds

Hearing on “Clear Internal Market Rules for Mopeds, Scooters & Motorcycles”, European Parliament IMCO Committee
Brussels, 22 March 2011

Dirk Bosteels, AECC
www.aecc.eu
Association for Emissions Control by Catalyst (AECC) AISBL

AECC members: European emissions control companies

Technology for exhaust emissions control on all new cars (OEM and Aftermarket) and an increasing number of commercial vehicles, non-road applications and motorcycles.
AECC Motorcycle Test Program

• 5 motorcycles were tested:
  – 3 Euro 3 bikes from European and Japanese OEMs.
  – 1 Euro 3-homologated bike from Asian OEM.
  – 1 Indian specification bike.

<table>
<thead>
<tr>
<th>Bike</th>
<th>Engine</th>
<th>EFI</th>
<th>Open/Closed Loop Control</th>
<th>Secondary Air Injection (SAI)</th>
<th>Catalyst</th>
<th>Spec.</th>
<th>WMTC Class</th>
<th>km at test start</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>800cc V4.</td>
<td>y</td>
<td>Closed</td>
<td>y</td>
<td>y</td>
<td>Euro 3</td>
<td>3.2</td>
<td>8000</td>
</tr>
<tr>
<td>B</td>
<td>800cc in line 2-cyl.</td>
<td>y</td>
<td>Closed</td>
<td>n</td>
<td>y</td>
<td>Euro 3</td>
<td>3.2</td>
<td>1000</td>
</tr>
<tr>
<td>C</td>
<td>1300cc in line 4-cyl.</td>
<td>y</td>
<td>Closed</td>
<td>y</td>
<td>y</td>
<td>Euro 3</td>
<td>3.2</td>
<td>1000</td>
</tr>
<tr>
<td>D</td>
<td>500cc 1-cyl.</td>
<td>y</td>
<td>Closed</td>
<td>y</td>
<td>y</td>
<td>Euro 3</td>
<td>3.2</td>
<td>1000</td>
</tr>
<tr>
<td>E</td>
<td>149cc 1-cyl.</td>
<td>n</td>
<td>N/A</td>
<td>y</td>
<td>y</td>
<td>Indian</td>
<td>2.1</td>
<td>1000</td>
</tr>
</tbody>
</table>
Euro 3 Motorcycles Failures

• Several test vehicles failed to meet emissions limits in ‘as received’ conditions.

• When received, bike A failed all emissions tests. Oxygen sensor leads were found to be crossed, so the engine was not running closed loop. OBD would have detected this failure. After correction, the bike met the Euro 3 emissions limits.

• 2 examples of the imported (Euro 3 homologated) bike D both failed Euro 3 limits initially. The 2\textsuperscript{nd} example eventually passed after a specific pre-conditioning recommended by the importer and the use of reference fuel for the Euro 3 test.
Test Results (without durability) relative to Euro 4-6 Proposed Limits
Mileage Accumulation on Bike D

- The imported Euro 3 bike tested for AECC exceeded Euro 3 CO limits after only 2,000 km and Euro 3 NOx limits after only 5,000 km.
- Tests were terminated at 20,000 km as NOx was at 2x limit value.
AECC Mopeds Test Program

• 5 European Euro 2 mopeds were tested on:
  – ECE Reg.47 cycle to current Euro 2 legislation (warm start).
  – ECE Reg.47 cycle to Euro 3 proposal (cold & hot start, 30% weighting for cold start).
  – Low-speed option of WMTC part 1 (cold & hot start, 50% weighting for cold start).

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Specifications</th>
<th>Mixture preparation</th>
<th>Emissions Control</th>
<th>Max. velocity</th>
<th>Emission standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-stroke EFI</td>
<td>4-stroke / 4-valve SOHC</td>
<td>EFI with λ-sensor</td>
<td>3-way catalyst</td>
<td>44 km/h</td>
<td>EURO 2; ECE Reg.47</td>
</tr>
<tr>
<td></td>
<td>3 kW, liquid cooled</td>
<td></td>
<td>restricted by leaning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-stroke carburetor</td>
<td>4-stroke / 2-valve SOHC</td>
<td>carburettor (constant depression)</td>
<td>1 oxidation catalyst secondary air</td>
<td>48 km/h</td>
<td>EURO 2; ECE Reg.47</td>
</tr>
<tr>
<td></td>
<td>2.88 kW, fan cooled</td>
<td></td>
<td>restricted by ignition retarding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TUG 2-stroke LPDI</td>
<td>2-stroke</td>
<td>Low Pressure Direct Injection</td>
<td>1 oxidation catalyst</td>
<td>47 km/h</td>
<td>Designed for EURO 3; ECE Reg.47</td>
</tr>
<tr>
<td></td>
<td>3.7 kW, liquid cooled</td>
<td></td>
<td>restricted by leaning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-stroke carburetor</td>
<td>2-stroke</td>
<td>carburettor (slider)</td>
<td>1 oxidation catalyst</td>
<td>&gt;50 km/h</td>
<td>Designed for EURO 3; ECE Reg. 40</td>
</tr>
<tr>
<td></td>
<td>2.3 kW, fan cooled</td>
<td></td>
<td>restricted by leaning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-stroke ASDI</td>
<td>2-stroke</td>
<td>Air Supported Direct Injection</td>
<td>1 oxidation catalyst</td>
<td>42 km/h</td>
<td>EURO 2; ECE Reg.47</td>
</tr>
<tr>
<td></td>
<td>4 kW, liquid cooled</td>
<td></td>
<td>restricted by leaning</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: 2-stroke carburettor moped was Swiss spec., where speed is not limited to 45km/h. Throttle was cut at 50 km/h for tests on this bike to give comparable results, but this may have resulted in lower emissions than if speed had been limited (part load instead of full load at high speed).
The 4-stroke carburettor moped had CO emissions well above the test limit.

All other mopeds met both the Euro 2 and proposed Euro 3 limits, although the 2-stroke carburettor vehicle was very close to the CO limit.

All results are without durability.
Test Results (incl. cold start but no durability) relative to Euro 3-5 Proposed Limits

PTW ≤ 50 cm³

HC + NOx (mg/km)

CO (mg/km)

AECC data
2009 KBA data
- Euro 1
- Euro 2 & 3
- Euro 4
- Euro 4 for 3 & 4 wheel
- Euro 5 p
- Euro 5 CI/Hybrid

2-stroke ASDI
2-stroke carb.
2-stroke LPDI
4-stroke EFI
4-stroke carb.

(1) Euro 1 for 3 & 4 wheel is not shown
(2) There is no difference between the emission limits of Euro 2 and Euro 3 but Euro 3 is cold start
(3) The emission limits of THC and NOx are actually separated for Euro 4 & 5

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Association for Emissions Control by Catalyst RISBL
Particulate Mass & Number - Motorcycles

- Similar mass levels were attained from all motorcycles on both WMTC and Euro 3 cycles.
- Particulate Mass emissions on both cycles were <2.5 mg/km, well below the 4.5 mg/km level proposed for the 3rd step (for Euro 6).
- All bikes show Particle Numbers on the NEDC emissions levels of <6x10^{11}/km.
Particulate Mass & Number - Mopeds

<table>
<thead>
<tr>
<th></th>
<th>PM</th>
<th>PN (to PMP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 3 cycle (8 x ECE) unweighted</td>
<td>mg/km</td>
<td>particles/km</td>
</tr>
<tr>
<td>4-stroke EFI</td>
<td>2.52</td>
<td>$3.84 \times 10^{12}$</td>
</tr>
<tr>
<td>4-stroke carburettor</td>
<td>5.05</td>
<td>$1.98 \times 10^{13}$</td>
</tr>
<tr>
<td>2-stroke LPDI</td>
<td>6.68</td>
<td>$2.35 \times 10^{13}$</td>
</tr>
<tr>
<td>2-stroke carburettor</td>
<td>12.39</td>
<td>$2.78 \times 10^{14}$</td>
</tr>
<tr>
<td>2-stroke ASDI</td>
<td>10.04</td>
<td>$1.09 \times 10^{14}$</td>
</tr>
</tbody>
</table>

- Only the 4-stroke EFI would meet the PM limit of 4.5 mg/km proposed for the Euro 5 stage.
- Particle Number emissions measured by PMP-based method range from $3.8\times10^{12}$/km to $2.8\times10^{14}$/km (levels similar to diesel cars without particulate filters).
- Compositional analysis shows very little elemental carbon (mostly organic carbon).
Some Considerations on COM(2010) 542

- AECC supports the final stage of emissions proposed by the EC but the intermediate stages are too weak and could be strengthened. Most motorcycles and mopeds tested already meet the next emissions stages (and one motorcycle already meets the proposed Euro 6 stage without durability).

- 3-wheel mopeds benefit from relaxed emissions limits at proposed Euro 3 and 4 stages but there is no technical justification for this.

- Better engine control (Air-to-Fuel Ratio control) is needed for mopeds to ensure low emissions. Catalysts only cannot solve the emissions problem.

- Regarding Particles emissions from mopeds, similar levels than diesel cars without Diesel Particulate Filter have been measured.

- Emissions limit values of hybrid vehicles should be defined according to the technology of their internal combustion engine (and not all aligned to CI engines as currently proposed).

- AECC strongly supports the introduction of OBD requirements and durability requirements, without which it is possible that some motorcycles might not be equipped with durable catalytic converters.
Thank you for your attention