Regulated and Non-Regulated Emissions of Selected State-of-the-Art European Mopeds

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AECC members: European emissions control companies

Technology for exhaust emissions control on all new cars (OEM and Aftermarket) and an increasing number of buses & commercial vehicles, non-road applications and motorcycles.
Content

- Powered-Two Wheelers EU legislation
- Moped test program
  - Selection of vehicles
  - Test cycles and equipment
  - Regulated emissions
  - Non-regulated particulate mass and particle number emissions
- Conclusions
# Current L-Category Types (Motorcycles and Mopeds)

<table>
<thead>
<tr>
<th>Category</th>
<th>Vehicle Name</th>
<th>Characteristic Vehicles</th>
<th>Category</th>
<th>Vehicle Name</th>
<th>Characteristic Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1e</td>
<td>Moped</td>
<td>![Moped Image]</td>
<td>L5e</td>
<td>Motor tricycle</td>
<td>![Motor Tricycle Image]</td>
</tr>
<tr>
<td>L2e</td>
<td>3-wheel moped</td>
<td>![3-wheel Moped Image]</td>
<td>L6e</td>
<td>Light quadricycle</td>
<td>![Light Quadricycle Image]</td>
</tr>
<tr>
<td>L3e</td>
<td>Motorcycle</td>
<td>![Motorcycle Image]</td>
<td>L7e</td>
<td>Heavy quadricycle</td>
<td>![Heavy Quadricycle Image]</td>
</tr>
<tr>
<td>L4e</td>
<td>Motorcycle + sidecar</td>
<td>![Motorcycle with Sidecar Image]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mopeds: max. speed 45km/h max capacity: 50cc (or 4kW electric motor)

Source: European Commission, Citizens summary: EU proposal for a Regulation on L-category vehicles, October 2010
L-Category Share of HC Emissions

Source: European Commission, Citizens summary: EU proposal for a Regulation on L-category vehicles, October 2010

L-Category vehicle hydrocarbon (HC) emissions share (% of all road transport HC emissions in the EU)
## Current and Proposed Limits for Mopeds

*(COM(2010)0542)*

### L1Be 2-wheel moped (PI)

<table>
<thead>
<tr>
<th>mg/km</th>
<th>CO</th>
<th>THC</th>
<th>NMHC</th>
<th>NOx</th>
<th>HC+NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 2 (2002)</td>
<td>1000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1200</td>
<td>- hot start R.47</td>
</tr>
<tr>
<td>Euro 3 (2014)</td>
<td>1000</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1200</td>
<td>- cold start R.47</td>
</tr>
<tr>
<td>Euro 4 (2017)</td>
<td>1000</td>
<td>630</td>
<td>-</td>
<td>170</td>
<td>-</td>
<td>- cold start R.47</td>
</tr>
<tr>
<td>Euro 5 (2020)</td>
<td>1000</td>
<td>100</td>
<td>68</td>
<td>60</td>
<td>-</td>
<td>4.5 revised WMTC</td>
</tr>
</tbody>
</table>

### L2e 3-wheel moped (PI)

<table>
<thead>
<tr>
<th>mg/km</th>
<th>CO</th>
<th>THC</th>
<th>NMHC</th>
<th>NOx</th>
<th>HC+NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro 2 (2002)</td>
<td>3500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1200</td>
<td>- hot start R.47</td>
</tr>
<tr>
<td>Euro 3 (2014)</td>
<td>3500</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1200</td>
<td>- cold start R.47</td>
</tr>
<tr>
<td>Euro 4 (2017)</td>
<td>1900</td>
<td>730</td>
<td>-</td>
<td>170</td>
<td>-</td>
<td>- cold start R.47</td>
</tr>
<tr>
<td>Euro 5 (2020)</td>
<td>1000</td>
<td>100</td>
<td>68</td>
<td>60</td>
<td>-</td>
<td>4.5 revised WMTC</td>
</tr>
</tbody>
</table>
Moped Emissions Legislation in EU

* includes cold start

** includes cold start and separate HC and NOx limits.

CO [mg/km] vs. HC + NOx [mg/km] chart showing different emission standards:

- Euro 1
- Euro 2
- Proposed Euro 3*
- Proposed Euro 4**
- Proposed Euro 5**

Parameters:
- Proposed Euro 5**: HC=100, NOx=60
- Proposed Euro 4**: HC=630, NOx=170
- Proposed Euro 3*: HC=100, NOx=60

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Association for Emissions Control by Catalyst
## Mopeds Specifications

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Technology</th>
<th>Specifications</th>
<th>Mixture preparation</th>
<th>Exhaust system</th>
<th>Max. velocity</th>
<th>Emission standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<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 R47</td>
</tr>
<tr>
<td>B</td>
<td>4-stroke carburetor</td>
<td>4-stroke / 2-valve SOHC</td>
<td>carburettor (constant depression)</td>
<td>1 catalyst secondary air</td>
<td>48 km/h</td>
<td>EURO 2, ECE R47</td>
</tr>
<tr>
<td>C</td>
<td>TUG 2-stroke LPDI</td>
<td>2-stroke</td>
<td>Low Pressure Direct Injection</td>
<td>1 catalyst</td>
<td>47 km/h</td>
<td>Designed for EURO 3, ECE R47</td>
</tr>
<tr>
<td>D</td>
<td>2-stroke carburetor</td>
<td>2-stroke</td>
<td>carburettor (slider)</td>
<td>1 catalyst secondary air</td>
<td>&gt;50 km/h unrestricted. Throttle closed at 50km/h for these tests</td>
<td>Designed for EURO 3, ECE R40</td>
</tr>
<tr>
<td>E</td>
<td>2-stroke ASDI</td>
<td>2-stroke</td>
<td>Air Supported Direct Injection</td>
<td>1 catalyst</td>
<td>42 km/h</td>
<td>EURO 2, ECE R47</td>
</tr>
</tbody>
</table>

*AECC* Association for Emissions Control by Catalyst RISBL
Test Cycles

R47
• Legal requirement.
• Emissions measured from cold start.
• Euro 3 and beyond: 30% weighting for first 4 cycles and 70% for last 4 cycles.

WMTC
• Not developed for mopeds.
• Category 1 motorcycles (50-150 cc, 50 < Vmax < 100 km/h).
• Part 1, reduced speed.
• 2 repeats (cold start + hot start), 50/50 weighting.
Test Equipment

• ‘Open’ CVS avoids introduction of pressure depression in exhaust which would increase secondary air flow and so reduce emissions results.

• Measurement of regulated emissions + FTIR for N species.
• Pallflex 47mm filter plates for particulate mass.
  - Sampling over the full test cycle.
• PN analysis using dilution/heating system with TSI CPC 3775 analyzer.
Cumulative CO and HC Emissions on R47

- CO emissions highlight the effect of the poor catalyst position on the 4-stroke carburetor bike.

- For HC the effect of cold start is obvious for all bikes, but particularly for the 2-stroke carburetor.
• Despite having a $\lambda$ sensor and TWC, NOx control is poor for the 4-stroke EFI.
• NOx are mainly produced during accelerations, for all mopeds.
Regulated Emissions compared to Euro 2 (100% hot phase)

- The 4-stroke carburetor vehicle exhibited CO emissions several times higher than the legislative limit, despite procured new and only degreened for 250 km.
- All except the 4-stroke carburetor vehicle met the Euro 2 limits.
Regulated Emissions compared to Proposed Euro 3 (30% cold phase)

- Without durability and assuming 30% cold weighting, all vehicles except the 4-stroke carburetor vehicle met the proposed limits for Euro 3.
- The 2-stroke carburetor vehicle was very close to the CO limit.
Regulated Emissions compared to Proposed Euro 4 (30% cold phase)

- Without durability and assuming 30% cold weighting, the 2-stroke LPDI already meets the proposed Euro 4 limits.
- Generally, little emissions improvement needed to meet the proposed Euro 4 limits.
Regulated Emissions measured on WMTC (50% cold phase)

- Similar cold start and catalyst light-off performance than on R47.
- Confirmation of bad performance of 4-stroke carburetor.
- R47 driving pattern may be more appropriate.
Particulate Mass Emissions

- Proposed Euro 5 includes PM limit of 4.5 mg/km.
- Only 4-stroke EFI able to meet requirement (with safety margin).
- Other vehicles between 5 and 12 mg/km.
Particle Number

- Range from $3 \times 10^{12}$/km to $3 \times 10^{14}$/km.
- Both 2- and 4-stroke mopeds showed similar PM number levels to diesel cars not equipped with Diesel Particulate Filters.
- First acceleration accounts for most of particles number (cold start enrichment).
- Test cycle independent.
Particulates Composition

- Organic and Elemental Carbon fractions of collected soot.
- Very little EC despite high PM numbers.
- PM emitted by 4-stroke mopeds is largely OC
- OC > 80% for most mopeds (except 2-stroke LPDI) – comes from lube oil or fuel.
Conclusions

• Emissions levels mainly depend on quality of air-fuel mixture preparation and interaction with aftertreatment.
• Technologies are available to permit 2-stroke engines to meet proposed Euro 3 limits.
• Proper AF control is pre-requisite for effective application of catalysts to 4-stoke mopeds.
• Cold start has a major influence on gaseous and particles emissions.
• Only the 4-stroke EFI machine would have met the proposed PM limit for Euro 5.
• Solid (PMP) particle number emissions are at a similar level to diesel cars without DPF.
Thank you for your attention