Improved Vehicular Technologies for Compliance of Stringent Emission Norms

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Workshop on “Cleaner liquid fuels and improved vehicular technologies”
May 31, 2011, Silver Oak, India Habitat Centre, New Delhi
Contents

- Improvement avenues
- Challenges of stricter compliance
  - Fuels & Lubricant quality
  - Power-train technologies
  - Exhaust treatment devices
  - Vehicle construction
  - Eco-driving practices
- Conclusions
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To become a growth engine of Indian economy by propelling the Indian auto industry to a global $145bn industry by 2016 whilst by promoting sustainability by addressing the multiple challenges arising out of emissions, climate change, energy security and safety.

“Need for safer & affordable mobility for developing economy can not be ignored.”
On-road Vehicle Population Projection in India

Data Source: Segment y Ltd.

2-W = motorcycle; 3-W = 3-wheeler; HCV = heavy-duty commercial vehicle;
LCV = light-duty commercial vehicle; SUV = sport utility vehicle
Note: Total may not add due to rounding. Source: Segment Y Ltd.
Technology Improvement Focus for Stricter Emission

- Fuels & Lubricants
- Weight & Rolling resist.
- Aerodynamics
- Eco-drive & Smart Tech.
- Exhaust treatment devices
- Engine
- Gearbox
- Power train Management
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Fuel & Lubricant Quality

Fuel has an influence on...

- the engine
- service
- durability
- the materials
- the exhaust gas after treatment
- the components

Data Source: VW
Petrol
- Reduction of benzene
- Reduction of olefins
- Reduction of sulphur
- Increase in Octane

Diesel
- Sulphur reduction
- Cetane increase
- Aromatic control
- End point reduction
- Density reduction

Data Source: MSIL
<table>
<thead>
<tr>
<th>SN</th>
<th>Problem</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FP Coil corrosion</td>
<td>Acidic nature of fuel</td>
</tr>
<tr>
<td>2</td>
<td>FP bearing Sulphuration</td>
<td>More “S” in fuel</td>
</tr>
<tr>
<td>3</td>
<td>Injector clogging</td>
<td>More “S”, Gum</td>
</tr>
<tr>
<td>4</td>
<td>Abnormal bore wear</td>
<td>More Chlorides &amp; KOH</td>
</tr>
<tr>
<td>5</td>
<td>Rust problems</td>
<td>Traces of H$_2$O</td>
</tr>
<tr>
<td>6</td>
<td>Intake valve deposits</td>
<td>More Gum</td>
</tr>
<tr>
<td>7</td>
<td>O2 sensor poisoning</td>
<td>Pb in fuel</td>
</tr>
<tr>
<td>8</td>
<td>More vapor formation &amp; wear</td>
<td>Addition of ethanol</td>
</tr>
</tbody>
</table>

Data Source: MSIL
Effect of Low Fuel & Lubrication Quality

Fuel Pump Problem
Fuel Injector Problem
Intake Valve Deposits

Abnormal Bore wear

Data Source: MSIL
## Sulphur Effects on Gasoline Passenger Vehicle Emission

<table>
<thead>
<tr>
<th>Study</th>
<th>Vehicles</th>
<th>Sulphur Level</th>
<th>Test Cycle</th>
<th>NMHC/HC%</th>
<th>CO%</th>
<th>NOx%</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>AQIRP</td>
<td>Tier 1</td>
<td>320→35</td>
<td>US FTP</td>
<td>-18.5%</td>
<td>-16.4%</td>
<td>-8.9%</td>
<td>Rutherford et al. -1995</td>
</tr>
<tr>
<td>EPEFE</td>
<td>Euro 2</td>
<td>382→18</td>
<td>NEDC</td>
<td>-8.6%</td>
<td>-9.0%</td>
<td>-10.4%</td>
<td>Petit et al.-1996</td>
</tr>
<tr>
<td>CRC E-60</td>
<td>LEV and SULEV</td>
<td>150→5</td>
<td>FTP</td>
<td>-2.2%</td>
<td>-6.4%</td>
<td>-31.0%</td>
<td>Durbin et al.-2003</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>US06</td>
<td>-64.1%</td>
<td>-10.2%</td>
<td>-70.8%</td>
<td></td>
</tr>
</tbody>
</table>

Data Source: icct
### Sulphur Effects on Diesel Vehicle After-treatment Devices

<table>
<thead>
<tr>
<th>After-treatment</th>
<th>Test Conditions</th>
<th>Effects</th>
<th>S level → Efficiency</th>
<th>Reference study</th>
</tr>
</thead>
<tbody>
<tr>
<td>DPF</td>
<td>ESC-13 mode on Caterpillar I-6, 7.2L, 275 hp</td>
<td>• Increasing sulphur level reduces DPF efficiency with respect to engine-out values &lt;br&gt; • Filter regeneration temperature increases with S level &lt;br&gt; • No deterioration in PM control &lt;br&gt; • Fuel economy was reduced by 7%</td>
<td>PM reduction eff. 3 ppm→95% &lt;br&gt; 30 ppm→73% &lt;br&gt; 150 ppm→0% &lt;br&gt; 300 ppm→-130%</td>
<td>DECSE (NREL, 2001)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No effect on DPF efficiency</td>
<td>JCAP (2003)</td>
</tr>
<tr>
<td>DOC</td>
<td>FTP 75 on Cummins ISM370, I-6, 11L, 280 hp</td>
<td>• PM emission increases if S ≥150 ppm at high load. &lt;br&gt; • HC oxidation capacity is reduced for some DOCs (depending on catalyst formulation) &lt;br&gt; • CO emissions are not affected.</td>
<td>HC reduction eff. 3 ppm→100% &lt;br&gt; 350 ppm→91%</td>
<td>DECSE</td>
</tr>
<tr>
<td>LNT</td>
<td>Engine prototype I-4, 1.9L, 81hp</td>
<td>• Sulphur compounds interfere with NOx storage function.</td>
<td>NOx reduction eff 3 ppm→90%</td>
<td>DECSE &amp; MECA (2007)</td>
</tr>
<tr>
<td>SCR</td>
<td>Simulated diesel exhaust gases</td>
<td>• Vanadium SCR system can operate at S level of 50-500 PPM &lt;br&gt; • Zeolite SCR systems are susceptible to S&gt;50 ppm levels</td>
<td>For Zeolite SCR: Exposure at 600 ppm reduced the NOx conversion efficiency from 90 to 50%.</td>
<td>Girard-2009, Chatterjee-2008</td>
</tr>
</tbody>
</table>

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Power Train Technologies

- Combustion System
- Fuel Injection System
- Turbocharger System
- In-Cylinder Emission Reduction System
- Exhaust After-Treatment System
- Base Engine Friction Reduction
Power-train Technology Movement – Diesel Engine Passenger Cars

- PM Trap and/or DeNOx catalyst for MUV range
- New engine with centralised injection and 4 valves
- Variable Geometry Turbocharger (VGT)
- Common Rail
- On Board Diagnosis (OBD) on MUV range
- On Board Diagnosis (OBD)
- Electronic Diesel Control
- Direct Injection (MUV range)
- Oxycat
- Exhaust Gas Recirculation (EGR)
- Turbocharger and intercooler
- IDI engines

Euro IV
Euro III / Bharat Stage III
Euro II / Bharat Stage II
Euro I / Bharat Stage I

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**Combustion System Technology Evolution - Diesel Engine**

**Intake Swirl:**
- Plays a major role in Diesel Combustion
- Swirl is generated by intake Port & valves
- Helical Port Design increases the Swirl.
- Variable Swirl is used to vary the Swirl ratio at different conditions.

**Nozzle type**
- Technology Improvement from low SAC to Zero SAC Nozzles

- Low SAC Nozzles
  - Small fuel gallery (SAC) between needle & nozzle body

- Zero SAC Nozzles
  - Zero SAC volume
  - Further reduction in HC
  - Improved design to overcome nozzle clogging
Fuel Injection System Technology Evolution - Diesel Engine

Power Train Technologies

Injection System

Mechanical Fuel Injection Pump 300 bar

Mechanical injection with Electronic Timing Control 300 bar

Common Rail 1400-1600 bar

Next gen FIE > 2000 bar

Distributor FIP
- Pressures up to 300 bar
- Injection quantity, timing & pressure dependent on engine speed

Distributor FIP
- Pressures up to 300 bar
- Injection quantity & pressure dependent on engine speed
- Injection timing Controlled Electronically

Common Rail
- Pressures up to 1600 bar & beyond
- Flexibility in Quantity, timing & Pressure
- Multiple injections possible
Future – Two Stage Turbocharger

- High Power Output (entire speed range)
- Good Drivability
- Good SFC
EGR System Technology Evolution

Future: Electrical EGR System with EGR Cooler & Bypass
Engine Friction Reduction - Technology

- Low Friction leads to
  - Low emissions
  - Low Fuel Consumption
- Friction reduction trend over years

**Valve Train Friction**
- Valve train Friction – 2%
- Currently, Roller Finger Follower is being used for the following reasons
  - Low Friction
  - Low Maintenance
  - Adequate Engine Performance
- Future - Coatings like DLC, CrN

![Graph showing friction reduction trend over years](image)
Power-train Technology Movement – Heavy Duty Diesel

More Focus on Exhaust Treatment Devices

- Centralized injection / 4 valves / Extended block, ladder frame
- High pressure ratio Turbocharging
- Electronic Diesel Control (EDC) / VP37 FIE
- LPG engines for bus and LCV
- CNG engines for bus and LCV
- Intercooler
- EGR on 207DI
- High Pressure rotary FIP
- Turbocharger
- Re-entrant torroidal combustion chamber
- PM Trap and/or DeNOx catalyst
- On Board Diagnosis
- Common Rail
- Cooled EGR

- Euro IV
- Euro III / Bharat Stage III
- Euro II / Bharat Stage II
- Euro I / Bharat Stage I

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Predominantly used After-treatment system till meeting BSIV Emission norms is Diesel Oxidation Catalytic converters (DOC).

Future Evolution: DPF / SCR
Exhaust Treatment Devices

Data Source: ARAI

Reference: Haldor Topsoe A/S
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Eco-Driving

• The Eco-driving has significant potential to reduce emission pollutants

• However, India is losing the benefits due to –
  » inadequate driving schools,
  » lack of motivation for eco-driving
  » technical unawareness among the drivers.

• Most of the drivers are unaware that emission performance of vehicle can be improved by -
  » optimum vehicle speeds,
  » reduced idling time,
  » better acceleration practices,
  » right gear shifting technique,
  » route choice,
  » minimizing number of stops.
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Need for an Integrated Approach for Successful Control of Emissions from Transport Sector

Data Source: ARAI
Proper inspection and maintenance of vehicle help to reduce emission pollutants.

In India most of the old vehicles, maintenance and servicing is done at road side garages.

Generally maintenance is done after breakdown instead of preventive maintenance.

Many 2 & 3 wheeler drivers are least habitual about regular servicing and maintenance of their vehicles.

There is need of strong legislative mechanism for inspection of in use vehicles.
Fleet Renewal / Modernization

- Older vehicles are more emission pollutants compared with new vehicles.
- In India, since 1951, 100 million vehicles registered till 2007 (Approximately 80 million vehicles registered after 1991 and most of them are plying on the road).
- In 2006-07, 10 million new vehicles registered which contributes 10% of overall fleet.
- Unlike other developed countries there is no administrative mechanism to ensure end-of-vehicle life.
- It leads to use of very old and more emission pollutant vehicle in large numbers.
There is no limit on the age of the vehicle that one can ply on the Indian roads.

Given the progressive degeneration of the engines of these vehicles due to lack of proper maintenance as well as their being manufactured when emission norms were far lax, they tend to emit inordinate level of pollutants.

Hence, development of a rationale vehicle phase out program all over the country hold an important place in future govt. policies.

Further assessment of exact working life of a catalytic converter in vehicles needs to be carried out for development of policies.

Development of appropriate vehicle scrappage guidelines are very essential after implementation of old vehicle phasing out program in India.
Conclusion

Integrated Approach for Meeting Stringent Emission Norms

- **Technology**
  - Engine technologies
  - Vehicle technologies
  - Bio-fuels
  - Hybrid Vehicles
  - Downsizing
  - Alternate fuels

- **Infrastructure**
  - Fuel Quality
  - Inspection & Maintenance
  - Fleet management
  - Roads
  - Traffic management
  - Sectoral management

- **Consumer Awareness**
  - Good purchase habits
  - Good driving habits
  - Good maintenance & disposal habits
  - Good living habits

Road Transport Sector

3 - Pillar “TInCA” Approach
THANK YOU!!

Questions?