Cleaner two stroke technology

Regional Workshop for Reducing Vehicle Emissions:
Reduction of Emissions from 2-3 Wheelers
5-7 September 2001, Hanoi, Vietnam

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Executive Director
Orbital Engine Corporation
The traditional two stroke engine

Advantages

- Low manufacturing cost
- High power to weight ratio
- High power to displacement ratio
- Lower engine friction
- Lower pumping work
- Low Oxides of Nitrogen

Disadvantages

- Unburnt HC burden
- Fuel inefficiency
- Exhaust ‘smoke’
- Misfire at idle/light loads
- “Reputation” as dirty engine
The solution: Direct Fuel Injection

- Air assisted Direct Injection allows stratified combustion on both 2 and 4 strokes
- Eliminates 2 stroke ‘short circuiting’ of unburnt HC
- Improves combustion efficiency
- Dramatic reduction in 2 stroke exhaust emissions
- Retains the superior 2 stroke power to weight ratio and low engine manufacturing cost
- Maturing technology
  - on 2 strokes marine engines since 1996
  - experiencing rapid growth on European 2 wheelers
- Compared with equivalent 4 stroke has similar, or better emissions with improved fuel economy
Stratified Charge Combustion Process

Conventional Engine with Carburettor:
- Fuel & Oil
- Intake
- Carburettor
- Exhaust
- Exhaust up to 70% fuel charge lost: poor fuel economy & exh emissions

Direct Injected Engine:
- Stratified fuel injection after piston covers exhaust port
- Intake
- Air & Metered Oil
- Exhaust
- Exhaust only air lost
Air Assisted Direct Injection Combustion Process
Air Assisted Direct Injection

- Fuel injector
- Compressed air
- Direct injected pre-mixed charge

Diagram showing the timing of fuel metering event from 360° TDC to 180° TDC, followed by the direct injection event at 180° TDC and ignition at 0° TDC.
50cc 2 and 4 stroke emission capability comparison

ECE R47 MOPED CYCLE
50cc 2 stroke fuel and oil consumption

**BENZINA FUEL**

- ECE 47: SR 50 LC CAT 29, SR 50 LC DITECH 29
- 45 km/h: SR 50 LC CAT 50, SR 50 LC DITECH 58
- 40 km/h: SR 50 LC CAT 36, SR 50 LC DITECH 36
- 30 km/h: SR 50 LC CAT 37, SR 50 LC DITECH 64
- 20 km/h: SR 50 LC CAT 39, SR 50 LC DITECH 70

**OLIO OIL**

- ECE 47: SR 50 LC CAT 35, SR 50 LC DITECH 35
- 45 km/h: SR 50 LC CAT 85
<table>
<thead>
<tr>
<th>Feature</th>
<th>DITECH</th>
<th>2 CYCLE + CAT</th>
<th>4 STROKE L.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potenza/Accel. / Power/Accel.</td>
<td>Ottima / Excellent</td>
<td>Buona / Good</td>
<td>Scarsa / Poor</td>
</tr>
<tr>
<td>Emissioni CO / CO Emissions</td>
<td>-85%</td>
<td>-75%</td>
<td>-40%</td>
</tr>
<tr>
<td>Emissioni HC + NOx / Emissions</td>
<td>-80%</td>
<td>-70%</td>
<td>-90%</td>
</tr>
<tr>
<td>Decadimento / Loss</td>
<td>Assente / Absent</td>
<td>Medio / Medium</td>
<td>Assente / Absent</td>
</tr>
<tr>
<td>Consumi / Consumption</td>
<td>-60%</td>
<td>-20%</td>
<td>-40%</td>
</tr>
<tr>
<td>Fumosità / Exhaust smoke</td>
<td>Assente / Absent</td>
<td>A freddo / When cold</td>
<td>Assente / Absent</td>
</tr>
<tr>
<td>EURO2</td>
<td>Possibile / Possible</td>
<td>Poss. + SAI + CAT</td>
<td>Poss. + EFI + CAT</td>
</tr>
<tr>
<td>Guidabilità / Rideability</td>
<td>Ottima / Excellent</td>
<td>Buona / Good</td>
<td>Discreta / Fair</td>
</tr>
<tr>
<td>Costi industriali / Production Costs</td>
<td>+20%</td>
<td>+10%</td>
<td>+40%</td>
</tr>
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</table>

EFI = Electronic fuel injection  SAI = Secondary Air Injection  L.C. = Carburazione magra / Lean carburation
Valori rispettati ad un 2 tempo tradizionale / Values respect to a traditional 2 cycle engine
### 2 and 4 Stroke emission capability comparison

<table>
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<tr>
<th>Description</th>
<th>Cycle</th>
<th>Emissions (gm/km)</th>
<th>Fuel Cons L/100 km</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>HC</td>
<td>NOx</td>
</tr>
<tr>
<td>EU III proposal</td>
<td>ECE 40</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>OCP DI 2S (100 cc)</td>
<td>ECE 40</td>
<td>0.7 to 1.1</td>
<td>0.15 to 0.25</td>
</tr>
<tr>
<td>Carb 4S (125 cc)</td>
<td>ECE 40</td>
<td>0.8 to 1.2</td>
<td>0.2 to 0.3</td>
</tr>
<tr>
<td>PI 4S (125 cc)</td>
<td>ECE 40</td>
<td>0.5 to 0.8</td>
<td>0.2 to 0.4</td>
</tr>
</tbody>
</table>

**100 cc**

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</thead>
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<td>HC</td>
<td>NOx</td>
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<td>EU III proposal</td>
<td>ECE 40</td>
<td>0.3</td>
<td>0.1</td>
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**150 - 180 cc**

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<tr>
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<td>ECE 40</td>
<td>0.9-1.1</td>
<td>0.2</td>
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* Both DI2 and 4 stroke engines will require catalyst
Particulate Matter

California ARB Standard for Hand Held Utility Engines  PM10
50cc 2 stroke scooter engine with Orbital DI
Standard for 1999 of 0.33g/kWhr (0.25g/hphr) set for 2 stroke and 4 stroke
Air Assisted Direct Injection system schematic
Major components

Fuel Rail Assembly/Injector

Compressor

ECU

Fuel Pump
Production (1)

- Aprilia ‘DITECH™’ SR50 and Scarabeo
- Sundiro ‘Hi-jetor’
- Peugeot Motocycles ‘TSDI’ display at international exhibitions
- Further European DI 2S product for release this year
- Mercury Marine – 6 models (outboard)
- Tohatsu – 2 models (outboard)
- Bombardier – 4 models (PWC and jet-boat)
  (Marine products meet EPA 2006 levels)
- Advanced automotive 4 stroke programs, with ULEV II and Euro V capability – protects for the future requirements of motorcycle applications
A projected >300,000 direct injectors will be produced from dedicated high volume manufacturing line at Synerject (USA)

Localised supply base being established in Asian countries

Technical support from Orbital and Synerject

Synerject is a JV between Orbital and Siemens

Delphi secures automotive technology and manufacturing rights

Aprilia have begun selling 2 strokes in USA
The future

<table>
<thead>
<tr>
<th>Engine Complexity / Cost</th>
<th>First Market Introduction</th>
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<tbody>
<tr>
<td>Carbu + SAI: 4 Stroke</td>
<td>Europe</td>
</tr>
<tr>
<td>Direct Injection: 4 Stroke</td>
<td>Stage 1</td>
</tr>
<tr>
<td>Port Injection: 2 Stroke</td>
<td>Stage 2</td>
</tr>
<tr>
<td>P.I. + Cat: 4 Stroke</td>
<td>Stage 3</td>
</tr>
<tr>
<td>D.I. + Cat: 2 Stroke</td>
<td>India / China</td>
</tr>
<tr>
<td>D.I. + Cat: 4 Stroke</td>
<td>Stage 1</td>
</tr>
<tr>
<td></td>
<td>Stage 2</td>
</tr>
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</table>
Conclusion

- Direct injection can enable 2 strokes to meet emission laws
- Direct injection is a proven and cost effective solution
- Direct injected 2 strokes provide reduced fuel consumption hence CO$_2$ reduction
- Emission regulations should mandate emission levels not engine type
- Emission laws should be enforced
- In a regulated market the consumers will make the product choice.
Thank you