Application of Atkinson Cycle to Improve IC Engine Efficiency

LCVTP – WS5

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IC Engine speed/load operation

High Speed, Poor efficiency, NVH

Low load, Poor efficiency
Atkinson Cycle - Theory

- Conventional 4-stroke operations
  - 1:1 mechanical expansion:compression ratio
  - Blow-down pulse

- Increase expansion:compression ratio
  - Mechanical system
    - Complex crank-slider mechanism
  - Valvetrain system
    - Change trapped mass through late/early inlet valve closing
    - Geometric vs effective compression ratio

Heywood – Internal Combustion Engine Fundamentals
Atkinson Cycle

Trapped Mass
Eng Cylinder part cyl01

Std 273 IVC

Atkinson IVC. Charge pushed back out of the cylinder

Crank Angle [deg]

Mass [g]

-360 TDC
INTAKE
-180 BDC
CMP
0 TDCF
180 BDC
EXHAUST
360 TDC
Atkinson Cycle Application to Tata 273 Engine

- Modelling and conversion of Tata 273 engine to Atkinson Cycle.
- Not converting the Nano 273 engine to an APU.

- Engine Specification
  - In-line twin cylinder, 360° firing, gasoline engine.
  - Balancer shaft
  - Capacity 624cc
  - Bore 73.5mm
  - Stroke 73.5mm
  - 26kW @ 5500rpm, 48Nm @ 2500rpm

- Modifications
  - Engine modified to improve torque at 3500rpm by changing inlet system and inlet ports. This became the baseline.
1D Modelling
GT-Power Optimisation ("Atkinson")

- The model was run at 3500rpm, WOT, and inlet valve closing point was swept from ~50°ABDC to ~150°ABDC, while simultaneously changing the geometric compression ratio to maintain a constant effective compression ratio.

Optimum IVC is ~100°ABDC (640°) vs 49° ABDC for the standard Nano.
GT-Power Optimisation ("Atkinson")

- The model was re-run over a narrower range of IVC, for the following speed/load sites:
  - 3500rpm, 2500rpm and 1500rpm WOT
  - 1500rpm ~25Nm and ~14Nm

![Graph showing BSFC and BMEP vs. IVC]
GT-Power Optimisation ("Atkinson")

2500rpm WOT

BSFC (g/kWh)

1500rpm WOT

BSFC (g/kWh)
GT-Power Optimisation ("Atkinson")

- **BSFC (g/kWh)**
  - 1500rpm ~25Nm: 12.5g/kWh
  - 1500rpm ~14Nm: 50g/kWh

- **BMEP - Brake Mean Effective Pressure, Part Engine**
  - vs. IVC

**Graphs:**
- BSFC - Brake Specific Fuel Consumption, Part Engine vs. IVC
- BMEP - Brake Mean Effective Pressure, Part Engine vs. IVC

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Coventry University, JAGUAR, MIRA, RICARDO, TATA, WMG INNOVATIVE SOLUTIONS, ZYTEK AUTOMOTIVE
## GT-Power Optimisation ("Atkinson")

<table>
<thead>
<tr>
<th>CR</th>
<th>BMEP (bar)</th>
<th>BSFC (g/kWh)</th>
<th>Pmax (bar)</th>
<th>T (°C) at 20°btdc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>10.2</td>
<td>Baseline</td>
<td>47.2</td>
<td>668</td>
</tr>
<tr>
<td>Atkinson CR=17</td>
<td>9.48</td>
<td>-9%</td>
<td>64.6</td>
<td>707</td>
</tr>
<tr>
<td>Atkinson CR=16</td>
<td>9.32</td>
<td>-8.2%</td>
<td>58.5</td>
<td>693</td>
</tr>
<tr>
<td>Atkinson CR=15</td>
<td>9.26</td>
<td>-7%</td>
<td>55.7</td>
<td>687</td>
</tr>
<tr>
<td>Atkinson CR=14</td>
<td>9.16</td>
<td>-5.8%</td>
<td>53</td>
<td>680</td>
</tr>
</tbody>
</table>

- To maintain an effective compression ratio the same as a standard Nano, a geometric compression ratio of 17 is required.
- However:
  - Detonation limit
  - Effect on cylinder temperature and pressure
  - Matching end of compression temperature
  - BMEP effects
- CR 15:1 selected for testing
Atkinson Specification

- Compression ratio increased
  - > 10.6:1 -> 15:1
  - > New inlet camshaft profile

- Testing at Mira

\[\text{Inlet Cam Profile}\]

\[\text{Cam Angle}\]

\[\text{Atkinson} \quad \text{Standard}\]
Test Results - Torque

Baseline
Atkinson

Torque (ISO - Nm)

RPM
Test Results - BSFC

Power vs BSFC

BSFC (g/kWh)

Power (kW)

10g/kWh

Baseline
Atkinson
Test Results – Prediction vs Actual

Predicted vs Observed Atkinson Benefit

- Predicted BSFC Improvement - Atkinson
- Actual BSFC Improvement - Atkinson
Future Work

• LCVTP WS5 Planned:
  > Further test data analysis
  > Emissions comparison
  > Model correlation & re-optimisation

• Combustion chamber and port optimisation