Driving Automotive Innovation – Cylinder Deactivation

Dr. James McCarthy, Jr
September 13, 2016
902 Senate Hart Building, Washington, D.C.
Challenge: Move Peak Efficiency Islands to the Driver Operating Zone

CITY AND HIGHWAY DRIVING (gasoline)

Moving the high-efficiency island down:

- **Downsize + Boosting**: Retains power and improves low-load efficiency
- **Cylinder Deactivation**: Fewer cylinders at better efficiency
- **Variable Valve Lift**: Reduces throttle losses at low loads

LOW LOAD OPERATION (diesel below 250°C)

Raising diesel exhaust temperature to the peak aftertreatment efficiency island:

- **Internal EGR**
- **Early Exhaust Valve Opening**
- **Cylinder Deactivation**
Cylinder Deactivation (CDA) & Benefits

**How It Works**
- Fuel cut off
  - Intake and exhaust valves stop opening
  - Charge trapped

**Cylinder = Air Spring**

**Activated Cylinders**

**Deactivated Cylinders**

**Gasoline Benefits**
- Fuel Economy

**Diesel Benefits**
- Exhaust Temperature
- Fuel Economy
Various Methods For Cylinder Deactivation (CDA)

**Solution for Past Decade**
(cam in block)

- Rocker Arm
- Pushrod
- Valve
- Oil Control Valve
- Deactivating Roller Follower
- Oil Pressure Compresses Double Latch Pin

2015 Production Release
(overhead cam)

- Oil pump
- Oil Control Valve
- Single lobes camshaft
- De-Activating Switching Roller Finger Follower
- Standard INT-EXH valves
- Dual feed HLA (DF HLA)
- Oil Pressure Retracts Latch Pin
- Inner Arm
- Latch

Cylinder Deactivation Improves Fuel Economy between 2% and 12%

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### CDA Vehicles Over Past Decade

<table>
<thead>
<tr>
<th>GEN 5 Engine</th>
<th>GM Vehicles for 2016 (^[1])</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3L V-6</td>
<td>Silverado and Sierra</td>
</tr>
<tr>
<td>5.3L V-8</td>
<td>Silverado, Sierra, Suburban, Tahoe, Yukon</td>
</tr>
<tr>
<td>6.2L V-8</td>
<td>Silverado, Sierra, Escalade, Yukon, Corvette, Camaro</td>
</tr>
</tbody>
</table>

*Implemented for Past Decade (Cam in block engine)*

<table>
<thead>
<tr>
<th>Engine</th>
<th>More Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5L V-6</td>
<td>Honda Odyssey, Pilot, Accord, Acura</td>
</tr>
<tr>
<td>5.7L V-8</td>
<td>Dodge Ram, Chrysler 300, Dodge Durango, Jeep Grand Cherokee</td>
</tr>
<tr>
<td>5.5L V-8</td>
<td>Mercedes-Benz</td>
</tr>
<tr>
<td>4.0L V-8</td>
<td>Audi</td>
</tr>
</tbody>
</table>

*Cylinder Deactivation is Proven Technology to Reduce Fuel Consumption*
### Recent Implementation of CDA

**GM Improving Fuel Economy by 6%+ using CDA as part of the solution**

<table>
<thead>
<tr>
<th>HFV6 Engine</th>
<th>MY</th>
<th>GM Vehicle</th>
<th>Fuel Economy</th>
<th>Main Technology Cited</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0L Twin Turbo</td>
<td>2016</td>
<td>Cadillac CT6</td>
<td>Est. 6% Over Prior Model [2]</td>
<td>Twin Turbo + CDA + Start/Stop</td>
</tr>
<tr>
<td>3.6L</td>
<td>2017</td>
<td>Cadillac ATS/CT6/CTS Camaro</td>
<td>Est. 9% Over Prior Model [3]</td>
<td>CDA + Start/Stop</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acadia</td>
<td>25 mpg Highway [5,6]</td>
<td>CDA + New Chassis</td>
</tr>
</tbody>
</table>

**Volkswagen and Ford Showing 6% Fuel Economy Improvement with CDA on 4 & 3 Cylinder Engines**

- Volkswagen 1.4L 4-cyl. engine [http://www.greencarcongress.com/2013/06/vwact-20130605.html]
- Ford 1.0L 3-cyl. demo engine [http://www.greencarcongress.com/2015/05/20150512-ford.html]
Variable Cylinder Deactivation
(3-cylinder engine example)

Standard CDA:
- Specific cylinders are deactivated, keeping these continuously inactive for the deactivation period
- Switch from 3 to 2 active cylinders

Dynamic or Rolling CDA:
- Each cylinder is continuously changing from active to de-active each cycle.
- Switch from 3 to 1.5 active cylinders

Next Steps for CDA include
- Electrically Actuated CDA and Deactivating Lash Adjuster

Fuel Savings Can Be Increased By Deactivating More Cylinders
Diesel Cylinder Deactivation Benefits

- Diesel CDA improves Aftertreatment temperatures/efficiencies and yields fuel economy benefits

- CDA at low load operation for Medium-Duty Diesel
  - Adds ~100°C to exhaust temperature
  - Shifts Aftertreatment from “Too Cold” to “Peak Efficiency” Zone (NOx removal)
  - Fuel savings of up to 25%

- Drive cycle fuel savings depends on time spent in low load operation
Poll Question: What percentage of the three markets will require variable valve actuation (as defined by variable lift, deactivation or duration) by 2025?

**Gasoline**
- 0% ○ <10%
- 10.5% ○ 10-30%
- 24.6% ○ 30-60%
- 53.9% ○ 60%-100%
- 11.0% ○ No opinion

**Light Duty Diesel**
- 4.7% ○ <5%
- 14.1% ○ 5-15%
- 34.0% ○ 15-50%
- 30.2% ○ 50%-100%
- 16.7% ○ No opinion

**Medium Duty Diesel**
- 5.2% ○ <5%
- 18.8% ○ 5-15%
- 32.8% ○ 15-50%
- 25.5% ○ 50%-100%
- 17.7% ○ No opinion

Technical Audience is Bullish for Variable Valve Actuation Implementation for Multiple Markets by 2025
Summary
Cylinder Deactivation Solutions

• Implemented over Past Decade
  • GM V-6 and V-8 Engines
  • Honda, Chrysler, Mercedes-Benz, Audi

• Recent Implementations
  • GM V-6, Part of 6%+ fuel economy solution
  • Volkswagen I-4 & Ford I-3 Demo with 6% Fuel Economy

• Medium-Duty Diesel Research with CDA at low load operation
  • Improves Exhaust Temperature for Improved Aftertreatment
  • Improves Fuel Economy

Cylinder Deactivation Hardware Proven, Durable and Ready to be Implemented on More Engines
Thank You

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References

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7) http://www.greencarcongress.com/2013/06/vwact-20130605.html
8) http://www.greencarcongress.com/2015/05/20150512-ford.html
10) SAE Webinar: https://event.webcasts.com/starthere.jsp?ei=1109742
Biography

James McCarthy, Jr.

Jim McCarthy is the Engineering Manager for Eaton’s Advanced Valvetrain Actuation focused on North American and Asian markets and is located in Marshall, Michigan. His previous role at Eaton focused on development of Exhaust Aftertreatment Solutions. Prior to joining Eaton, Jim worked on diesel engine technologies at Detroit Diesel.

Jim has focused his engineering career on product innovation and growth to develop and integrate serial production solutions for engine technologies while optimizing power generation to conserve fossil fuels and reduce emissions.

McCarthy received his Ph.D., Masters of Science and Bachelors of Science in Mechanical Engineering from Purdue University.