Cylinder Deactivation System Overview

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A Brief History of Jacobs, the original compression release retarder manufacturer…

• Roots go back to a pioneer of the diesel engine and inventor of the “Jake Brake”: Clessie L Cummins

• Cummins (pictured below with his famous Indiana truck) designed, and later tested his compression release engine brake concepts, which were later to be made by Jacobs Manufacturing.
  – Leading producer of drill chucks since 1903
  – Engine brake patent rights bought in 1959 for diversification

• Jacobs became part of Danaher in 1986
Jacobs Vehicle Systems is a worldwide provider of engine brakes and valve train products.

- Headquarters, main Manufacturing & Engineering in Bloomfield, Connecticut, USA
- Manufacturing & Application Engineering in Suzhou, China
- Global Offices
  - Beijing, China
  - Paris, France
  - Pune, India
  - Tokyo, Japan
  - Seoul, Korea
Engineered by Jacobs. Driving Value Across the Globe.
The JVS Design & Analysis group consist of approximately 15 people with various specialties in design, valve train kinematics, hydraulics and engine performance.

Collocated group experienced with a variety of tools and methodologies:

- **CAD/CAE**
  - 3D modeling using Pro-Engineer/Creo
  - Kinematic and dynamic modeling using Pro/Mechanism MDX
- **FEA and CFD**
  - Structural, thermal, and electromechanical analysis using ANSYS & Creo
  - Pro/Mechanica also used concurrently in design
- **Hydraulic/Kinematic Analysis**
  - MATLAB Simulink using a proprietary hydraulic block library
- **GT-Suite**
- **AMESim**
- **Engine Performance Analysis and Cam design**
  - GT-Power used for both combustion simulation and engine retarding
  - Cam design using in-house code
The JVS Engineering Laboratory

- 2,000 m² Engineering R&D Laboratory
- Over $6 M in Capital Invested Over Last 15 Years
- 70+ different types of Diesel Engines have been tested

Facility
- 2 Double-ended Motoring Dynamometers (900hp)
- 8 engine durability test cells
- 3 Special test cells
- MTS room with 8 test frames
- Fatigue Room with 5 Mechanical fatigue testers
- Flex Room with 4 spring testers

Computerized Data Acquisition System
- High Speed Data Acquisition
- 45 Analog Channels up to 100 kHz sampling rate
- 360 or 1440 point/rev encoders

Low Speed Data Acquisition (A&D Technology - ADAPT)
- 96 Channel Engine Condition Monitor

Staff
- Engineering Laboratory Manager
- Test Engineer
- 7 Engineering Technicians
### Current Product Portfolio

**Technologies**

**Developed Technologies**

<table>
<thead>
<tr>
<th>Exhaust Brake &amp; After-treatment Management</th>
<th>Bleeder Brake</th>
<th>Compression Release Brake</th>
<th>Positive Power Systems</th>
<th>IEGR</th>
<th>Lost Motion VVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Orifice</td>
<td>Integrated (full/partial cycle)</td>
<td>Bolt On</td>
<td>Integrated</td>
<td>IEGR &amp; Braking</td>
<td>Emissions Reductions using Jacobs IEGR™</td>
</tr>
<tr>
<td>Constant Pressure</td>
<td>Common Rail</td>
<td></td>
<td>Lost Motion</td>
<td></td>
<td>Emissions Reductions using Jacobs IEGR™</td>
</tr>
</tbody>
</table>

**Technologies in development**

<table>
<thead>
<tr>
<th>High Power Density (HPD) brake</th>
<th>Lashless Systems</th>
<th>Decompression Rocker Stop Device (RSD)</th>
<th>Cylinder Deactivation</th>
<th>2-Position VVA</th>
<th>Automated &quot;Jake Shifting&quot;</th>
</tr>
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<tbody>
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*Image of various mechanical components and diagrams representing the technologies.*
JVS recently developed an advanced braking system (HPD) that uses cylinder deactivation to achieve high braking power.

The Cylinder Deactivation system can be configured in a bridge system for OHC engines or pushtube system for CIB engines.

System has been developed using JVS engine brake design practices for durability and reliability.

Key Benefits:

- Advanced Braking - HPD
- Fuel economy improvement at light or part load operating conditions
- Aftertreatment thermal management
Collapsing Valve Bridge for OHC engines

Collapsing Pushrod for CIB engines is also available
MaxxForce 13 Engine

- Navistar Development Engine (B783 / B718 model)
  - Cylinder 1, 2, 3 fueling – Cylinder 4, 5, 6 deactivated
- HPD 2 system being used
  - Brakes deactivated so Cylinder deactivation bridges can be activated
Smooth engine operation with 3 cylinders deactivated, and smooth transitions.
Collapsing Pushrod System

Inline 6 cylinder engine
4 valve/cylinder with CIB
Independent rocker assemblies

Collapsing Pushrods: Intake and Exhaust

Solenoid Activation: Cylinders 1,2,3 or 4,5,6
Project: After treatment Thermal Management (ATM)  
   – Part 1: *Cylinder Deactivation*

Objectives:

- Explore benefits of Cylinder Deactivation
  - Research indicates it is the most effective method of ATM
  - Can HPD system be adapted to provide cost effective independent 3 cylinder deactivation
  - How does deactivation impact steady state and HD FTP cycle exhaust temperatures
Experimental Program Result: Cylinder Deactivation

SwRI Study Reference:
Southwest Research Institute
Clean Diesel Program
Year 4 Report Jun-22-23, 2011
Shown on a CAT C-15 engine,
At 30% load, increase from
~640°F to ~1000°F (+56%) In 3 cylinder deactivation

Smooth engine operation with good temperature increase, but 40% less airflow
Impact of cylinder deactivation on active diesel particulate filter regeneration at highway cruise conditions

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Primary
1. The largest engine outlet temperature achievable during six-cylinder operation is 420°C, achieved with late SOI resulting in a 22% increase in fuel consumption (compared to the most efficient six-cylinder operating condition).
2. Deactivation of valve motions and fuel injection in two (of six) cylinders enables engine outlet temperatures of up to 520°C as a result of reduced air-to-fuel ratio.
3. Cylinder deactivation increases the rate at which the DPF will heat-up.
4. Per above, cylinder deactivation can be used to generate the 500–600°C diesel particulate filter-inlet temperatures required for particulate matter regeneration with oxygen without the need for a fuel doser, diesel oxidation catalyst, or burner.

**FIGURE 6** Normalized exhaust gas-to-DPF heat transfer rate comparison – higher fuel consumption modes.
Steady-state results

- Cylinder deactivation provides significant increase in exhaust temperature at low load conditions
- Enables SCR NOx conversion and DPF regen at low load operation
• Modify first 200 sec of HD FTP cycle to run on JVS dyno
• Cylinder deactivation of 3 cylinders increases exhaust temperature 40°C during first 200 sec of FTP cycle
  – Non-optimized calibration
  – JVS dyno has limited capability, simulated FTP cycle
• Predictive cruise control allows the vehicle to coast based on topographical data
• Cylinder deactivation provides 25-30% reduction in parasitic power to drive engine preserving vehicle inertia for longer
Test Data under varying load

100NM
- 6 cylinder
- 3 cylinder

200NM

300NM
650 RPM – 91°C Oil – Turn on Time is 100 ms to the first missing event.
650 RPM – 91°C Oil – Turn OFF Time is 47 ms to the first missing event. Less than 1 cam cycle to re-lock.
HPD Validation Status

• HPD1 R&D program completed
• Design, Development, and Validation of HPD2 & 1.5 Stroke production ready system on multiple engines completed:
  • 200 hours of performance dyno work complete
  • 600 Hours of endurance testing complete
  • 500+ hours of head rig testing complete
  • 70,000 cycles of head rig activation complete
  • 20MM cycles of accelerated fatigue testing complete
  • Implementation Readiness Vehicle demonstration in Colorado with 200 miles completed at Eisenhower tunnel (7% grade, 120K lbs completed)
• Technology transitioned from R&D to Production Intent ready
  • 2 HPD Production intent development programs in progress
  • Daimler HPD Actros open Demonstration 4/2016
  • Multiple cylinder deactivation only production intent programs in process
Summary of Demonstrated Benefits

- Base HPD design allows for cost effective cylinder deactivation
  - Only need provision for separate hydraulic circuits
  - Smooth engine operation with 3 cylinders deactivated
- Higher exhaust temperature for SCR efficiency
  - Able to maintain higher exhaust temperature for more efficient SCR operation at partial loading (<40% load)
    - Quicker light-off time for SCR
    - Less use of fuel during warmup
- Partial load fuel efficiency
  - Testing indicates slight improvement at low load, no improvement at higher load.
- Value proposition
  - Future regulations with lower requirements?
  - Evaluate customer value for emissions – fewer precious metals in SCR, less urea use, compliance to new regulations, etc.
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