VOLVO

Impact of Vehicle Efficiency Improvements on Powertrain Design

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SuperTruck
Project Overview

- **Objective#1**: Improve Freight Efficiency by 50%
  - Requires a powerplant capable of 50% Brake Thermal Efficiency

- **Objective#2**: Demonstrate a 55% Brake Thermal Efficiency Concept
  
  Baseline = MY2009 ‘best in class’ highway vehicle

- **Duration**: 5 years

- **Project Cost**: $38M (cost share: $19M)
SuperTruck: a Complete Vehicle Effort

- Advanced Driver Aids
- High Efficiency Combustion
  - Waste Heat Recovery
  - Turbo-Compound
  - Downspeeding
  - ...
- Idle Reduction
- Auxiliary System Improvements
- Rolling Resistance Reduction
- Aero. Drag Reduction
- Advanced Materials
## Vehicle and Powertrain Descriptions

<table>
<thead>
<tr>
<th></th>
<th>Baseline 2009 VNL Truck</th>
<th>VEV1 Updated VNL Trailer Aero</th>
<th>VEV2 Complete truck &amp; Trailer re-design</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aero Cd</strong></td>
<td>--</td>
<td>22% reduction</td>
<td>39% reduction</td>
</tr>
<tr>
<td><strong>Rolling Resistance</strong></td>
<td>--</td>
<td>12% improvement compared to baseline</td>
<td>20% improvement compared to baseline</td>
</tr>
<tr>
<td><strong>Rankine</strong></td>
<td>--</td>
<td>Gen 1</td>
<td>Gen 2</td>
</tr>
<tr>
<td><strong>Auxiliaries</strong></td>
<td>--</td>
<td>25% reduction</td>
<td>25% reduction</td>
</tr>
<tr>
<td><strong>Engine</strong></td>
<td>13L</td>
<td>13L</td>
<td>11L</td>
</tr>
<tr>
<td><strong>Axle Config</strong></td>
<td>6 x 4</td>
<td>6 x 2</td>
<td>6 x 2</td>
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</tbody>
</table>
Total Vehicle System Design

- Lightweight intelligent efficient drivetrain
- Parasitic Loss Reduction
- High Strength Lightweight Suspension
- Lightweight Chassis and Cab Materials
- Vehicle Aerodynamic Drag Reduction
Powertrain Design for 50% BTE

BTE Improvement: Impact of Technologies

- Improve Combustion Systems
- Recover Wasted Heat
- Improve Air Handling
- Downsspeed Engine
- Downsize Engine
- Improve Accessories
- Reduce Friction
- Efficient Aftertreatment
- Improve Idle Efficiency

VEV1

VEV2
Simulating real-life conditions

Virtual Duty cycles match >1,000,000,000 miles of data

Figure 52 Comparison of Engine Exhaust Mass Flow versus Model Output
Global Simulation Platform

Total Vehicle

Operation Profiles → Driver → Powerplant → Transmission → Auxiliaries → Chassis

System Models

Dynamic Engine

WHR APU EATS

Component Models
Impact of Vehicle Efficiency Improvements on Powertrain Design

Simulation results have been used to identify and quantify the effect of reduced aerodynamic drag, improved PT efficiency and rolling resistance on the road load conditions for a highway truck.

- Baseline RH 65mph:
  - Air Drag: 54.1
  - Rolling Resistance: 31.6
  - Auxiliaries: 9.5
  - Driveline Loss: 4.4
  - Brake Loss: 0.4

- VEV-2 RH 65mph:
  - Air Drag: 46.2
  - Rolling Resistance: 36.4
  - Auxiliaries: 7.3
  - Driveline Loss: 5.5
  - Brake Loss: 4.6
Influence on Power Demand

- If we assume improvements that are aggressive enough to meet the SuperTruck project goals, average power demand could be reduced by as much as 35%.

- Requirements on acceleration & gradeability limit the degree of engine size reduction.

Sample of Sensitivity Analysis
Engine Efficiency Impact at Cruise Condition

Analysis of typical diesel engine efficiency profile.
- 1-2: Chassis improvements reduce load (areo, friction)
- 2-3 Downspeeding improves efficiency
- 3-4 Downsizing increases percent load

RESULT:
- Overall improvement in engine brake specific efficiency
- Major improvement in vehicle fuel consumption
Influence on Vehicle Speed Management

- The braking energy required to regulate cruise speed of the vehicle over hilly terrain will increase due to lower drag, rolling resistance and friction forces.
- And advanced vehicle controls become more valuable (e.g. terrain predictions, vehicle communication, torque management, etc)

GSP Prediction: Added brake energy needed to control speed in cruise

Highly Aerodynamic VEV picks up speed on down hill grades
Influence on EATS Management

- The distribution of power and brake demand is affected by complete vehicle improvements.
- Both trends result in lower EATS temps (one attribute among many)
Volvo is successful in using simulations to:

- minimize the predicted increase in brake energy for concept trucks
- design advanced control strategies e.g. using “Look-ahead” and terrain based torque controls
- quantify potential fuel savings with various concepts
- pre-size components and systems for the new concepts
Conclusions

- Complete vehicle integration and system analysis is key to achieving the SuperTruck efficiency goals.
- Initial VEV prototype data and simulations indicate:
  - Reduced power demand for long haul duty-cycle cruise conditions
  - Challenges for future EATS application
  - Opportunity to optimize vehicle brake energy
  - Highlighted need for terrain based, torque management tools
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