Model-Based Diesel Engine Control With On-Board Fuel Efficiency Optimization

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Outline

- Objectives
- Technical Approach
- Experimental Set-up
- Experimental Results
- Summary & Next Steps
Objectives

- Develop a map-less, predictive, empirical engine controller
- Reduce calibration and controller complexity
- Include an on-board fuel efficiency optimizer

Calibration Constraints

- Drivability
- Durability
- Fuel economy
- Life-cycle cost
- NOx / PM / NMHC / CO2
- OBD
- Exhaust temperature
- GPS / Route / Traffic info.

Goal: Mitigate increased calibration complexity

- More degrees of freedom
- Calibration optimization more complex
Technical Approach

- Controller with built-in knowledge of system interactions
  - Nonlinearities
  - Individual system response times
- Inputs: Performance targets
- Outputs: Actuator signals
- Includes an optimizer
  - Cost function that minimizes emissions and fuel consumption
  - Optimizes engine operation in real-time
Controller based on predictive engine models
- First principle models
- Neural networks trained with transient engine data

Approach made viable by
- More accurate actuators
- More repeatable systems
Technical Approach

- On-board models based on extensive engine mapping
- Transient test cell data
  - Filtering
  - Time-alignment of emissions data

**CO₂ vs. fueling rate correlation**

Requires input “history”
Experimental Setup

Baseline engine
- 2010 Detroit Diesel DD15
  - 14.8-liter inline 6-cylinder

ECM bypass
- Air / EGR / Fuel / SCR
Experimental Setup

- 20-minute dynamometer cycle
- Shortened version of Detroit-Ann Arbor vehicle load cycle

![Graph showing RPM vs. Brake Torque for Ann Arbor-Detroit Cycle and Short Cycle]
Experimental Results

Multiple cycles with varying NOx / CO / CO₂ setpoints

- Controller provides real-time NOx flexibility
**Experimental Results**

- Flexible engine control
- Modulates NOx & CO\textsubscript{2} output

\[ \text{CO}_2 \]

![Graph showing 20-minute truck cycles with NOx vs. g/hp-hr and CO2 vs. NOx relationships](image)

- Higher NOx setpoint
- Lower CO\textsubscript{2} setpoint
- 6% reduction
- SCR efficiency increase
- Reduced Heat Rejection

\[ \text{NOx} - \text{g/hp-hr} \]

\[ \text{PM} \]

\[ \text{NOx} - \text{g/hp-hr} \]
Summary & Next Steps

- Empirical, predictive engine control concept is viable
  - Concept demonstrated in test cell on truck cycles
  - Provides flexible engine control
  - Significant reduction in calibration effort

- Main limitation of the approach
  - Vehicle-to-vehicle variability
  - Mitigated by over-the-road adaptation

- Next Steps
  - Integration of additional control variables
    - Vehicle Predictive information
    - Waste Heat Recovery
    - Electrified Accessories
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