The Use of Exhaust Gas Recirculation to Optimize Fuel Economy and Minimize Emissions in Engines Operating on E85 Fuel

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Outline

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Purpose of Work

- Develop a flex-fuel internal combustion engine that is optimized to operate efficiently with ethanol fuels
- Set up and exercise engine and vehicle simulations to synthesize and optimize the following design parameters of a V-6 engine to meet the required performance targets
  - Turbocharger sizing
  - Exhaust gas recirculation system architecture and components sizing
  - Charge air cooler
  - Fuel variation

Barriers

- Current flex-fuel vehicle owners' experience: Reduced vehicle fuel economy (in mpg) and performance degradation when switching from gasoline to ethanol based fuels due to the reduced energy content of ethanol
- System design optimization including
  - Turbocharger sizing to meet the desired flow, air plus EGR gas, requirements
  - EGR system architecture and components sizing to meet flow and temperature requirements
  - System transient response
  - Underhood packaging
  - Durability and reliability of the components
- Lack of data on combustion characteristics of ethanol based fuels under boosted conditions with the presence of EGR gas

Approach

- Conduct initial engine simulation study by applying our best engineering knowledge
  - To help define the requirements in air flow, EGR flow and exhaust temperature for both E85 and gasoline over the engine operating speed range
  - Simulation results to be validated with test data
  - Simulation models to be updated and exercised to reflect the learning from the test data and any revised hardware specification to ensure that the vehicle will be capable of meeting the targets
- Establish contacts with major turbocharger, charge air cooler and EGR system vendors
  - To understand hardware availability
  - To obtain necessary engineering information
  - To acquire initial CAD data for vehicle packaging study

Performance Measures and Accomplishments

- Engine and vehicle simulation models have been set up for the target engine and vehicle
- Engine simulation has been exercised to study the effects of
  - EGR system architecture on EGR flow over the entire engine speed range
  - EGR flow on turbocharger sizing
  - Fuel, E85 vs. gasoline, on system requirements
- Two system optimization options are recommended by simulation
- Engine simulation results have been translated into design specifications for turbocharger, charge air cooler, EGR system and engine management system

Performance Measures and Accomplishments
(continued)

- Initial vehicle packaging looks promising
- Engine management system to incorporate the required functionalities is being developed
- Phase 1 Gate Review was held on February 13, 2008

Technology Transfer

- Align this program with GM Powertrain's product plan by focusing the development on a future variant of a state-of-the-art engine
- The outcomes of this program are expected to further strengthen GM's already extensive flex-fuel vehicle lineup and fulfill the commitment of having 50% of production engines flex-fuel ready by 2012

Plans for 2008 Fiscal Year

- Prototype engine parts will be designed and procured based on the initial analysis results
- A state-of-the-art prototype GM engine will be built with the updated parts to the new specifications and instrumented for temperature and pressure measurements for dynamometer testing
- Develop the required engine management system functions and implement the new system for dynamometer testing
- Dynamometer evaluation of the potential of the initial specification system will be conducted for both E85 and gasoline
- Preliminary control strategies will be developed based on both steady state and transient dynamometer testing

Summary

- Develop a flex-fuel internal combustion engine that is optimized to operate efficiently with ethanol fuels by integrating the following fuel economy technologies
  - Downsizing and turbocharging
  - Direct fuel injection
  - Continuously variable cam phasing on both intake and exhaust
  - Cooled exhaust gas recirculation under boosted conditions, which enables engine operation at stoichiometric air-fuel ratios and more favorable spark timings
- Optimize the system design iteratively thru simulation and dynamometer development to ensure achieving the program targets

Summary
(continued)

- Completed initial engine simulation to generate the required specifications for meeting the performance and fuel economy targets
- Expect to meet the milestone of March 31, 2008 for completing Initial System/Component Design
- Align this program with GM's product plan for consideration for future production rollout
- Proceed the program by leveraging GM's product development efforts and engine management system expertise as well as Ricardo's expertise in powertrain development