21st Century Locomotive Technology: Quarterly Technical Status Report 16 DOE/AL68284-TSR16

This is the quarterly status report for the 21st Century Locomotive Technology project, DOE Award DE-FC04-2002AL68284. This report covers activities performed September 2006 to December 2006.

Task 1: Advanced Fuel Injection

Objective

Develop and demonstrate an advanced fuel injection system to minimize fuel consumption, while meeting Tier 2 emissions levels.

Progress since last report

Over the fourth quarter of 2006, we continued engine performance testing with the common rail fuel system on GE Global Research's locomotive single cylinder engine. After completing our experimental work in 2006, we performed a detailed engine inspection and installed new engine components. The primary reason for the new engine hardware is to enable improved combustion diagnostics.

There are four main accomplishments in the area of advanced fuel injection over the last quarter:

1. Completed study to examine the effect of different nozzle flow areas on engine performance.
2. Initiated an engine performance study to explore the effect of rate of injector needle raise and fall.
3. Validated performance trends of multiple injection strategies at notch 8 with second fuel injector geometry; the results indicate that the benefits observed for the multiple injection strategy are insensitive to nozzle geometry.
4. Installed new engine head and additional diagnostics tools.

Completed study to explore the performance effects of different nozzle flow areas: The nozzle area was varied by +/- 10% while all other parameters, including number of holes and spray angle, were held constant. The rates of needle velocity in the opening and closing where also unchanged throughout this study. Performance testing was completed at part load and full load. The study provided insight on particulate matter trends as a function of fuel pressure and nozzle flow area. The results will guide further down-selection and optimization of nozzle geometries.

Initiated an engine performance study to explore the effect of rate of injector needle raise and fall: By changing geometry details in the fuel injector (needle seat and orifice plate) the needle raise and fall rate can be modified. These hardware components are shown for reference in Figure 1. A study was initiated to investigate the effect of lifting and falling rate of the common rail fuel injector needle. Trends have been identified as to how the needle raise and fall rate can affect the engine performance and the fuel system characteristics. We are in the process of characterizing the performance effect of fast and slow needle lift and fall.

Validated trends from multiple injection screening study at notch 8 with second fuel injector geometry showing that the benefit of the multiple injection strategy is robust to changes in nozzle and orifice plate geometry. In the third quarter of 2006, we completed a N8 screening study to efficiently explore the design space of multiple injections. In the forth quarter of 2006, the injection strategy, which gave the best results for the old nozzle/orifice plate configuration, was repeated with a new configuration. The trends observed by changing between single injection and multiple injections are independent of hardware sets. This indicates that the performance shift between multiple injections and single injections is consistent, even with small fuel injector nozzle/orifice plate changes. We have evaluated the heat release rates to show how the combustion event is tailored by using multiple injections per stroke.

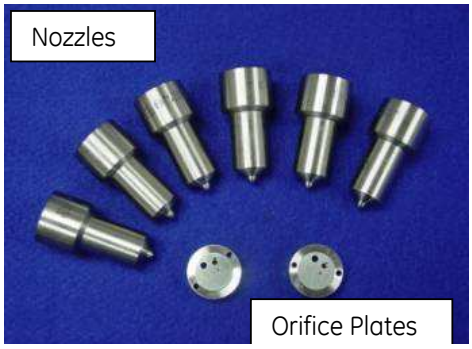

Figure 1 – Bosch common rail fuel injector nozzles and orifice plates.

Installed new engine hardware for improved combustion diagnostics

- An optically accessible engine head was installed on the single cylinder engine test bed at the end of 2006. A production engine head was modified to accommodate the optical access and allowing also for illumination of the cylinder. GE performed the design and fabrication of the system independent of the DOE-funded program, but this system is now available to the program to study the fuel spray, fuel mixing, and combustion characteristics of various fuel injection strategies and hardware. This tool is intended to help understand and improve the engine performance with high-pressure common rail.

- This new engine head also has embedded thermocouples to record the metal temperatures at eight locations, including the hottest regions of the combustion chamber. Four of the temperature measurement locations are located in the valve seats and four are positioned a few millimeters under the metal surface of the firing deck. The metal temperatures will allow us to understand shifts in the bulk gas temperature due to various fuel injection strategies and changes in other experimental parameters such as fuel type and quality.

- Another new diagnostic system added to the SCE is the engine exhaust particle sizer (EEPS). Like all of the new hardware discussed in this section, the EEPS was purchased with GE funding, but it will be used to accelerate the common rail investigations by providing a real-time indication of PM. The system is capable of measuring concentrations across the PM size range of 5 nm to 560 nm and will also provide insight into PM trends with changing fuel injection strategy.

Planned activity for next quarter

Over the next quarter, we plan will continue to explore the performance effect of nozzle/orifice geometry and multiple injections, including pilots and post injections. Bosch is providing a number of fuel injector nozzles for testing on the single cylinder engine. Our experimental goal is to down select the best fuel injector nozzle and orifice and identify multiple injection strategies at N8 that demonstrate SFC reduction at constant or lower Knox and PM levels. Notch 8 is the focus since approximately half of the total locomotive fuel consumption occurs at notch 8.

To further understand the effect of the fuel injection on performance, we will use analysis of heat release rates, the engine exhaust particle sizer, spray and combustion visualization, and in-cylinder metal temperature measurements.

We will also perform a literature review to summarize trends in the industry with respect to fuel consumption benefits with advanced fuel injection.

Task 3: Hybrid Energy Storage

Progress since last report

The battery vendor has developed a method to prestress the battery cell holders. The validation of the battery cell prestress design and manufacturing method has taken longer than initially estimated by the battery vendor. The cell prestress is believed to be the final issue to be resolved before manufacture of the vibration mockup battery. It was decided to build and test a subscale model in 1st quarter 2007 to calibrate prestress as a function of adjuster torque.