21st Century Locomotive Technology: Quarterly Technical Status Report 18 DOE/AL68284-TSR18

This is the quarterly status report for the 21st Century Locomotive Technology project, DOE Award DE-FC04-2002AL68284. This report covers activities performed April 2007 to June 2007.

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 second quarter of 2007, we continued engine performance testing with the common rail fuel system on GE Global Research's locomotive single cylinder engine. We showed that further improvements in fuel consumption at T2 NO_x values could be achieved with the common rail system; however, we have found that the injection strategies that give the best fuel consumption have the risk of increased PM emissions. Our goal is to optimize the nozzle geometry to maximize the SFC benefit (at constant NO_x level) while maintaining the particulate matter below regulation levels.

Overall, our work over the last quarter has been centered on nozzle optimization for a new piston bowl design. Geometry factors that have been explored include number of holes, spray cone angle, and nozzle tip design. In addition we investigated the influence of fuel sulfur level on PM emissions.

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

1. Investigated influence of number of holes on engine performance.
2. Investigated effect of spray cone angle on engine performance.
3. Quantified effect of needle seat diameter on engine performance.
4. Quantified the effect of fuel sulfur level on PM emissions.

The investigations carried out in Q2 gave insights into the performance trade-off based on the parameters studied. Given that knowledge base we are now in the position to down-select from the wide range of possible nozzle designs. The piston bowl geometry was unaltered during all tests carried out in Q2. Every nozzle configuration was tested for a range on injection timings and injection pressures. The nozzle screening test were focused on single injections at Notch 8 and Notch 4. Furthermore the opacity meter was used to monitor the PM emissions in parallel to filter measurements.

The number of holes was increased and decreased compared to the base line nozzle. The number of holes was found to have a strong effect on the PM emissions level, stronger than the injection pressure in the range tested. The specific fuel consumption seemed to be less affected by the number of holes and more a function of the fuel injection pressure. The dependence of PM emissions on fuel injection pressure was found to be fundamentally different for different number of holes.

Performed an engine performance study to explore the effect of spray cone angle: A parametric cone angle study was carried out by decreasing the cone angle by up to 3.5% from the baseline nozzle. All other parameters of the nozzle geometry were kept constant during this study. In the range studied, opposite trends were found for PM and specific fuel consumption. Changing the cone angle led to a benefit in fuel consumption while the PM emissions increased and vice versa. The cone angle resulting in lowest SFC with acceptable PM levels was considered to be the optimum.

Quantified effect of needle seat diameter on engine performance. Changing the needle seat diameter alters the needle lift profile. The needle seat diameter was increased by up to 12.5% compared to the baseline nozzle. The choice of seat diameter seems to affect the PM emissions only for low injection pressures. The fuel consumption is affected for all injection pressures, even though the effect is minor compared to the other nozzle parameters studied.

Quantify effect of sulfur level on PM emissions: Three different fuels with sulfur levels changing by more than a factor of 200 where tested. As expected, a linear dependence of PM emissions on fuel sulfur level was found. The results allow for a better comparison of the data taken on the single cylinder engine to data taken on other engines run with different sulfur levels.

Planned activity for next quarter

Over the next quarter, we plan to down-select and order the optimized nozzle geometries. In order to quantify the absolute benefit of the common rail system we will re-baseline the single cylinder engine using the production unit pump fuel system (UPS) across all notch conditions.

To provide a better understanding of the transfer function between single and multiple engine PM, high sulfur fuel (locomotive grade fuel) will be run with the UPS. Furthermore we will explore multiple injection strategies with the common rail fuel system, e.g. post injection, to reduce the PM emissions. Other multiple injection strategies to be explored or combined include split injections and pilot injections. Notch 8 will remain the focus since approximately half of the total locomotive fuel consumption occurs at notch 8. Finally, the next generation of injector hardware is scheduled to arrive within the next quarter.

Task 3: Hybrid Energy Storage

Progress since last report

The battery vendor delivered a subscale model incorporating a method to prestress the battery cell holders.