VI.H.1 Evaluation of Technical Feasibility of Homogeneous Charge Compression Ignition (HCCI) Engine Fueled with Hydrogen, Natural Gas, and DME

Mike Chol-Bum Kweon
Gas Technology Institute (GTI)
1700 South Mount Prospect Road
Des Plaines, IL 60018
Phone: (847) 768-0967
E-mail: chol-bum.kweon@gastechnology.org

DOE Technology Development Manager:
Dan Cicero
Phone: (412) 386-4826
E-mail: Daniel.Cicero@netl.doe.gov

DOE Project Officer: Robie Lewis
Phone: (304) 285-4445; Fax: (304) 285-4403
E-mail: Robie.Lewis@netl.doe.gov

Contract Number: DE-FC26-04NT42236

Start Date: September 2004
Projected End Date: September 2006

Objectives

Confirm the feasibility of using blends of hydrogen and natural gas to improve the performance, efficiency, and emissions of a homogeneous charge compression ignition (HCCI) engine.

Introduction

This project seeks to confirm the feasibility of using blends of hydrogen and natural gas to improve the performance, efficiency, and emissions of a homogeneous charge compression ignition (HCCI) engine. The project team will utilize both engine simulation and laboratory testing to evaluate two novel technical approaches to achieve the project objectives: (1) add dimethyl ether (DME) to blends of hydrogen and natural gas to improve control of HCCI combustion and (2) use micro-pilot Fischer-Tropsch (F-T) synthetic diesel fuel injection to handle the cold-start of the HCCI engine. In the proposed work, hydrogen will help to extend the operating range of the HCCI engine and decrease regulated emissions significantly, while DME will play a major role in controlling the auto-ignition timing of the HCCI combustion. Micro-pilot F-T diesel fuel injection during cold start, a significant problem for HCCI engines, will enable the HCCI engine to operate at very light loads with significantly lower HC and CO emissions.

Approach

- Modify the GTI single-cylinder research engine to be able to test our proposed approach for improving performance, efficiency, and emissions of the HCCI engine. This will include the addition of hydrogen and DME fuel trains to the existing engine bench - a necessary modification to validate the HCCI engine's capability to use coal-derived hydrogen in advanced combustion systems.
- Configure the HCCI engine, which will include mapping the engine based on natural gas only operation for various engine speed and load ranges. This will provide the baseline data for all subsequent experiments.
- Calibrate a finite-volume, 1-D gas dynamics engine performance program, WAVE v5.1 with Chemkin as the combustion model to the GTI HCCI engine.
- Perform engine simulations with WAVE v5.1/ Chemkin for various engine operating conditions and fuel blends of natural gas, hydrogen, and DME.
- Perform experimental design, laboratory HCCI engine testing, and data analyses.
- Evaluate the technical feasibility of operating the HCCI engine with blends of natural gas, hydrogen, and DME, in terms of engine performance, efficiency, and emissions.
- Prepare and provide quarterly and final reports to DOE-NETL.

Accomplishments

- Prepared the existing engine bench (AVL Model LEF/VOLVO 5312 research engine) for the HCCI engine test project. Completed primary modification for adding hydrogen and DME fuel trains to the engine intake system. Submitted selected proposals to DOE for approval.
- Configured the established HCCI engine to operate with natural gas only within a range of values for the parameters of air/fuel ratio, engine speed, and brake mean effective pressure. Using boundaries of the operating range of the HCCI engine as ignition and knocking limits, obtained baseline data for the calibration of the engine simulation program.

- Calibrated the WAVE/Chemkin engine simulation program for the GTI single-cylinder HCCI engine, using some baseline data from the HCCI engine testing. This calibration is critical for reliable optimization simulation.
- Completed the calibrated WAVE/Chemkin engine simulation program to simulate the performance, efficiency, and emissions of the HCCI engine. The main goal was to find the optimum operating conditions of the HCCI engine with the minimum number of the laboratory engine tests.

Conclusions and Future Directions

Based on the experiment design, GTI will test the HCCI engine to investigate the technical feasibility of burning blends of natural gas, hydrogen, and DME to improve engine performance, efficiency, and emissions (NOx, CO, CO_2, THC, and PM are of interest). Cold-start of the HCCI engine will be handled with the micro-pilot F-T synthetic diesel fuel injection. All engine performance parameters (i.e. indicated mean effective pressure, indicated specific fuel consumption, temperatures, pressures, flowrates, etc.) and emissions (NOx, CO, CO_2, THC, CH_4, and O_2) data will be collected and analyzed. GTI will also measure particle number, size distributions and mass loadings emitted from the HCCI engine in this task.

This task may be delayed because the PI on this project left GTI starting January 2006. The current recovery plan seeks to put in place a subcontracting effort in order to finish the testing. Future updates will identify the subcontractor and provide an estimate for a revised completion date, once the subcontracting effort is in place.