HCCI COMBUSTION: DETAILED ANALYSIS AND PERFORMANCE EXPERIMENTS

Salvador Aceves and Daniel Flowers
Lawrence Livermore National Laboratory

and

Robert Dibble
University of California at Berkeley

Homogeneous charge compression ignition (HCCI) is a new engine technology that allows both high efficiency and low emissions for cars, trucks, and sport utility vehicles (SUV's). The high efficiency of diesel engines is highly desirable for improving the fuel economy of light-duty trucks and SUV's. However, diesel engines are well known as significant sources of NO_x and particulate matter emissions. The use of HCCI combustion systems represents a promising approach that needs further research and development.

Our research work on HCCI is divided into two major tasks: analysis and experimental work. On analysis, we have developed two powerful HCCI analysis tools: a single-zone HCT model and a multi-zone HCT model. The single-zone model has proven very successful in predicting the start of combustion and providing reasonable estimates for peak cylinder pressure, indicated efficiency, and NO_x emissions, with very little computational cost (5 minutes on an engineering workstation). The multi-zone model is capable of very accurate predictions of the combustion process, including HC and CO emissions, at the cost of substantially longer running times (8 hours on an engineering workstation). The two models complement each other very nicely. Most of the work can be done with the single-zone model, and the multi-zone model can be used for a detailed analysis of important operating points and to learn more about the fundamentals of HCCI combustion.

We are currently conducting detailed analysis of experiments at other institutions, such as University of California at Berkeley, Sandia National Laboratories in Livermore, California, and Lund Institute of Technology. The purpose of the detailed analysis is to determine the fundamentals of HCCI combustion, study the effect of mixing on HCCI combustion, and develop methodologies for controlling the engine. We are also working in collaboration with the chemical kinetics group at Lawrence Livermore National Laboratory (LLNL) to develop surrogate mechanisms for practical HCCI fuels, mainly gasoline.

On experimental work, we are working on validating the application of the modified HCT code and implementing strategies for HCCI engine startability and control. We currently have a 4-cylinder Volkswagen TDI engine and a Caterpillar 3401 engine operating in HCCI mode in the University of California at Berkeley Engine Laboratory. Experiments on the TDI engine are focused on balancing combustion between the cylinders and on

obtaining combustion at the appropriate timing. The experiments on the Caterpillar engine are dedicated to performing fundamental experiments on HCCI combustion in collaboration with the LLNL Accelerated Mass Spectroscopy team.