# HCCI COMBUSTION RESEARCH USING LIQUID-PHASE FUELS

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Homogeneous charge, compression ignition (HCCI) engines have advantages in terms of efficiency and reduced emissions over conventional internal combustion engines. However, research is required to overcome the technical barriers to the implementation of HCCI, such as controlling ignition timing, slowing of the heat-release rate, and limiting emissions of hydrocarbons and carbon monoxide (HC and CO). To address this need, an HCCI research project has been established, including both an HCCI engine laboratory and chemical-kinetic modeling of HCCI ignition/combustion. The laboratory will include both an all-metal engine to establish HCCI operating points and combustion-control techniques and an optically accessible engine for the application of advanced laser diagnostics to investigations of the in-cylinder processes. Some of the features of these engines include: speeds up to 3600 rpm, an open combustion chamber to minimize crevices and surface area, a compression ratio variable from 13:1 to 21:1 by interchangeable pistons, and modifications to provide variable swirl. In addition, the engine is being equipped with three fueling systems: fully premixed fueling with an electrically heated fuel vaporizer, port fuel injection, and direct injection (DI) with a gasoline-type fuel injector (optionally, a DI diesel injector can also be installed). The all-metal engine and supporting laboratory subsystems are in place, and shakedown testing is under way. The basic design of the optically accessible engine has been completed, and its features are discussed.

Computational investigations of HCCI combustion have also been conducted using the CHEMKIN kinetics-rate code with the full chemistry for iso-octane. Iso-octane was used because it is a reasonable surrogate for gasoline and its kinetic mechanisms are known. Low-load HCCI operation was investigated to determine the role that chemical kinetics play in smoothing the HCCI heat release rate at these conditions, and to determine whether bulk-gas reactions (gases in the central part of the combustion chamber) are a significant source of HC and CO emissions for fully homogeneous HCCI at light loads (in addition to the cooler gases near walls and in crevices). The results show that as fueling is reduced below an equivalence ratio in the range of 0.25-0.20, the chemical kinetics slow considerably causing significant smoothing of the heat release rate, which is beneficial. However, when the fueling rate is further reduced to equivalence ratios of 0.15 and lower (very light load and idle), combustion temperatures become so low that the CO-to-$CO_2$ reactions no longer go to completion, even in the bulk gases. This leads to inefficient combustion and emissions of CO and HC from these bulk gases. This understanding has significant implications for the design of HCCI combustion strategies for light loads. In addition, a computational investigation has been initiated into the effects of exhaust gas recirculation (EGR) on the heat release rate and ignition timing. In order to separate these two effects, intake temperatures were adjusted to compensate for the reduced compression heating with EGR. Results are presented showing that EGR does increase the heat release duration, but that when ignition timing is maintained, the improvement is substantially reduced.