**Investigators:** J. Christian Gerdes, Assistant Professor, Mechanical Engineering Department; Christopher F. Edwards, Associate Professor, Mechanical Engineering Department; Gregory M. Shaver, Matthew J. Rolle, Patrick A. Caton, Hanho Song, Graduate Researchers; Nalu B. Kaahaaina, Research Engineer

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**Description:** Homogeneous charge compression ignition holds great promise as a means to reduce $NO_x$ emissions and increase efficiency in internal combustion engines. There are several methods used to initiate HCCI, such as heating or pre-compressing the intake air, trapping exhaust gases from the previous cycle by closing the exhaust valve early, modulating intake and exhaust flows using variable valve actuation (VVA) to re-induct residual exhaust gas from the previous cycle or some combination of these. Our approach is to use VVA to re-induct exhaust gas.

Residual-affected HCCI combustion exhibits some fundamental control challenges concerning cycle-to-cycle coupling and combustion phasing. Unlike spark ignition (SI) or diesel engines, where the combustion is initiated via spark and fuel injection, respectively, HCCI has no specific event that initiates combustion. Therefore, ensuring that combustion occurs with acceptable timing, or at all, is more complicated than in the case of either SI or diesel combustion. Combustion timing in HCCI is dominated by chemical kinetics, which depend on the in-cylinder concentrations of reactants and products and their temperature. In addition, residual-affected HCCI exhibits strong cycle-to-cycle coupling through the residual gas temperature. Work output

Figure 1: Application of control in experiment - left: step change in desired in-cylinder peak pressure, right: cyclic dispersion reduction
is dependent on both the combustion phasing and the elevated in-cylinder pressure generated from the combustion event. Thus, to control HCCI with VVA it is essential to understand how the valves influence mass flows and combustion timing and how previous combustion cycles influence the temperature of the reinducted products.

Although HCCI represents a complex physical process, the aspects most relevant for control - in-cylinder pressure evolution, combustion phasing and work output - can be captured with simple physics-based models. These system models have VVA controllable parameters (residual mass fraction and effective compression ratio) as inputs, and relevant measurable parameters (peak pressure and phasing) as outputs. A control strategy that decouples phasing from peak in-cylinder pressure can then be formulated. This approach, as shown in Figure 1, has been shown to increase system stability, decrease the likelihood of misfire and allow accurate steady-state and transient control of the engine.

**Status:**
Current research efforts include experimental verification of techniques for the simultaneous control of combustion timing and load. This control framework will be investigated for use during SI to HCCI mode transitions.

**Publications:**


Gregory M. Shaver, Matthew Roelle and J. Christian Gerdes, Multi-Cycle Modeling of HCCI Engines, Proceeding of the 1st IFAC Symposium on Advances in Automotive Control, 2004


**Contact:** gerdes@stanford.edu

http://gcep.stanford.edu