EFFECTS OF FUEL TYPE AND ENGINE SPEED ON REQUIRED INTAKE TEMPERATURE AND COMPLETENESS OF COMBUSTION IN A HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINE

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ABSTRACT

Homogeneous charge compression ignition (HCCI) engines have shown potential for both high efficiency and low emissions of NO_X and particulates. However, as the fuel/air-equivalence ratio is reduced for decreasing engine loads, CO and hydrocarbon (HC) emissions become excessive.

In a previous study, the sources of emissions at low loads were investigated using iso-octane as the fuel. It was found that the peak combustion temperature had a strong influence on the completeness of the bulk-gas combustion reactions, particularly the CO-to-CO_2 reactions. In the engine, this peak temperature is reached by a combination of intake temperature, compression, and combustion heating. However, the intake temperature required to maintain combustion phasing near top dead center (TDC) varies with both the fuel type and engine speed. Therefore, it can be anticipated that the fuel/air-equivalence ratio for onset of incomplete bulk-gas reactions is dependent on both the autoignition characteristics of the fuel and the engine speed.

To gain a better understanding of how the onset of incomplete bulk-gas combustion changes with fuel type and engine speed, a parametric study of HCCI combustion and emissions has been conducted. Four fuels with different ignition characteristics were investigated, including: a research-grade gasoline, pure iso-octane, and two mixtures of the primary reference fuels (*n*-heptane and iso-octane) with octane numbers of 80 and 60. The experiments were conducted at naturally aspirated conditions in a single-cylinder engine (0.98 liters/cylinder) fitted with a custom HCCI piston that minimizes crevice volume. For each fuel, data were acquired at four engine speeds (600, 1200, 1800, and 2400 revolutions per minute), and the fuel loading was varied from near the knocking limit to loads at or below idle (based on typical diesel-engine fueling) at each speed. Cylinder pressure and exhaust-gas data (CO_2, O_2, CO, HC, NO_X, and smoke) were acquired for each condition.

The results show that there is a strong coupling between the ignition quality of the fuel and the intake temperature required to phase combustion at TDC. The intake temperature, in turn, directly affects the completeness of combustion for a given engine speed and fueling rate. The effect of engine speed depends on the ignition characteristics of the fuel. For fuels with little cool-flame activity (i.e., gasoline and pure iso-octane), the equivalence ratio for the onset of incomplete bulk-gas reactions is independent of engine speed. This occurs because the increased compression temperatures required to maintain combustion phasing as the engine speed is increased also increase the rate of CO-to-CO_2 conversion, balancing the shorter time available to complete combustion. However, for fuels with a significant fraction of *n*-heptane (i.e., significant cool-flame chemistry), the onset of incomplete bulk-gas combustion depends strongly on engine speed, with a shift to higher equivalence ratios at lower speeds. This is due to the strong time dependence of the cool-flame chemistry, which necessitates lower intake temperatures at lower engine speeds to maintain combustion phasing. This leads to lower combustion temperatures and a commensurate rise in CO-emissions unless the fueling is increased.