Simulating Fuel Condensation in Low Temperature Combustion Engines

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I. Motivation
Particulate matter (PM) from advanced combustion strategies such as RCCI has been found to have a high concentration of organic hydrocarbon species [1]. There are currently no models available to separate the organic fraction from the elemental carbon.

II. Approach
2) Thermodynamic phase equilibrium analyses based on Gibbs free energy minimization [3].

III. Particulate Matter

Figure [1] above shows that particulate matter (PM) composition from Low Temperature Combustion is quite different from diesel combustion. The close to white color indicates that there is a large amount of organic species other than elemental carbon.

Condensation of fuel in RCCI combustion is predicted to play an important role in the PM formation. At low load (5.2 bar IMEP), about 90% of the PM is composed of condensed fuel. At higher load (9.0 bar IMEP), only about 50% of the engine-out PM is composed of condensed fuel, of which 80% is from the premixed gasoline.

Condensation is first observed within the spray where the evaporative cooling favors condensation.

Engine-out condensed fuel originates in the piston-liner-crevice region where temperature is low and unburned gasoline is located.

References:

IV. Observation of condensation

9bar IMEP with nC16H34 as diesel surrogate.

Condensation in the crevice region

V. Simulation of dual fuel RCCI combustion

The above figure presents the evolution of the two fuels in each phase. It is seen that the amounts of condensed gasoline and diesel peaks during injection (before -200 ATDC), but the condensed fuels experience continuous evaporation due to the increase of cylinder temperature due to both compression and combustion. During the expansion stroke, the unburned fuels, especially premixed gasoline that survives combustion, experiences another condensation, as seen from the sharp increase in the amount of condensed fuel due to charge cooling with expansion.

VI. Future work
1) Studying condensation processes in supercritical jets.
2) Modeling particulate formation processes with condensation in Low Temperature Combustion engines under other RCCI-like conditions.