

# Study on Modeling of Combustion Chamber Deposits in High-Efficiency Gasoline Spark-Ignition Engines

- (Third report) Sensitivity Evaluation of Carbon-Neutral Fuel Components on Deposit Formation Using a Visualized Constant-Volume Vessel -

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Reducing carbon dioxide emissions requires further improvements in the thermal efficiency of spark-ignition engines. Increasing the compression ratio is an effective approach; however, deposits formed inside the combustion chamber can increase knock propensity, thereby limiting improvements in thermal efficiency. Elucidating the mechanisms of combustion-chamber deposit formation and developing effective suppression strategies are therefore essential for achieving highly efficient engines. In particular, the effects of blending gasoline with carbon-neutral (CN) fuels, which are expected to be increasingly used in the future, on deposit formation remain poorly understood.

In this study, combustion-chamber deposit formation experiments were conducted using an optically accessible constant-volume vessel to clarify the effects of fuel composition on deposit formation. The vessel was designed to simulate the combustion chamber of a direct-injection engine. A deposit-collection plate representing the piston surface was equipped with a heater to reproduce the temperature distribution observed in an actual engine. Three fuels were examined: premium gasoline (PG), PG blended with 20 vol.% toluene (PG + Tol20), and PG blended with 20 vol.% ethanol (PG + E20). Each experiment comprised 100 cycles, with each cycle consisting of intake, fuel injection, combustion, and exhaust processes. After 0, 30, 60, and 100 cycles, the vessel was cooled, and the deposit thickness was measured using a gap sensor.

Figure 1 shows the evolution of deposit thickness with the number of combustion cycles for each fuel. Relative to PG, toluene addition increased the deposit thickness, whereas ethanol addition reduced it. To investigate the causes of these differences, numerical simulations were performed using a detailed chemical kinetic mechanism to evaluate the formation of polycyclic aromatic hydrocarbons (PAHs), which have been identified as precursors of deposits formed in various combustion systems.

A gasoline surrogate mechanism incorporating PAH growth pathways was employed. Three fuel compositions were considered: the gasoline surrogate, the surrogate blended with 20 vol.% toluene, and the surrogate blended with 20 vol.% ethanol. Fuel-rich combustion conditions were assumed, with an equivalence ratio of 3. Figure 2 shows the calculated concentrations of phenol and representative PAHs. Toluene addition increased the PAH concentrations, whereas ethanol addition decreased them. These trends were consistent with the experimentally measured deposit thicknesses. The results suggest that fuels with a greater propensity to form PAHs produce thicker combustion-chamber deposits, indicating that PAH formation is an important factor governing deposit accumulation.

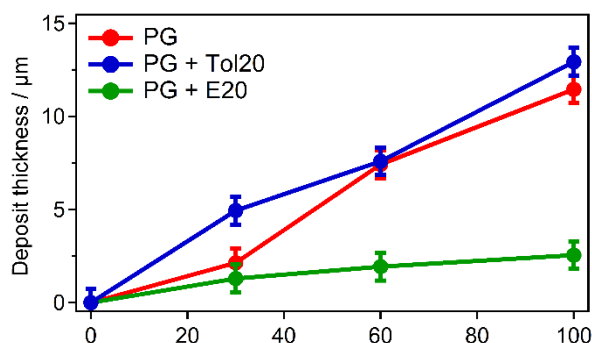


Fig. 1 Time profiles of combustion chamber deposit thickness for each fuel.

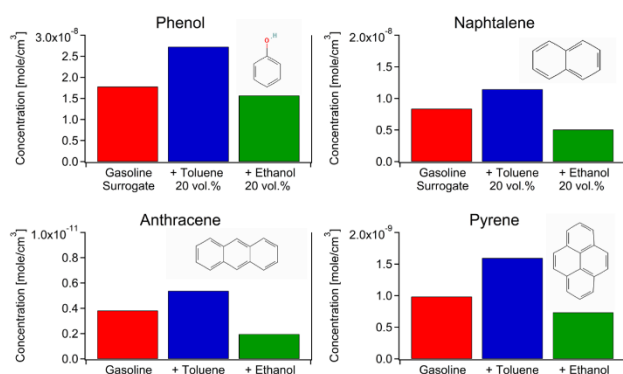


Fig. 2 Concentrations of phenol and typical PAHs.