

ABSTRACT

FLEX-FUEL PRECHAMBER ENABLED MIXING-CONTROLLED COMBUSTION (PC-MCC)

Jared J. Zeman, B.A., M.S.

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There is an imminent need to displace fossil diesel fuel with cleaner burning, domestically produced, renewable fuels for use in heavy-duty engines. Bioethanol is a prime candidate as it widely adopted in the U.S. as a gasoline additive ranging in volume percentage from 10% (E10) up to 85% (E85). Direct substitution of market available ethanol-gasoline blends for diesel fuel is not plausible as the stark reactivity differences would not constitute the same ignition quality nor achieve auto-ignition at all. This work focuses on the development of prechamber enabled mixing-controlled combustion (PC-MCC) as an advanced combustion strategy to facilitate reliable ignition and diffusion style combustion ethanol-gasoline fuel blends. PC-MCC involves integration of an actively fueled prechamber (PC) into a conventional compression ignition (CI) combustion system. When ignited, the PC ejects hot turbulent jets into the main combustion chamber that then interact with the direct injected fuel, prompting immediate ignition. The PC jet flames provide a robust thermal ignition source that allows the engine to operate agnostic of fuel composition, or flex-fuel.

Computational fluid dynamics (CFD) modeling was used to assess critical design features of the PC while garnering insights into the ignition strategies that facilitate robust performance. A key finding was the ignition performance benefits of fuel-rich PC operation which yield exothermic jets. Based on the numerical findings, a prototype igniter was tested experimentally on both single and multi-cylinder engine platforms at a variety of operating conditions. The experimental results indicate flex-fuel PC-MCC is well capable of diesel-like combustion processes by demonstrating matched or improved gross thermal efficiencies and load variability within 2%. Fuel grade ethanol (E98) exhibited consistently lower NO_x and immeasurable soot across the load space. E98 also demonstrated a significant improvement in thermal efficiency at light loads. Lastly, PC-MCC ignition phenomenology was imaged on an optically accessible heavy-duty engine to support the trends identified in CFD and metal engine testing. The rudiments of jet timing and PC stoichiometry were assessed, revealing the primary source of main chamber combustion variability is linked to the variability in the spark ignition process of the PC, supporting the metal engine findings.