# EFFECTS OF OXYGENATED DIESEL FUELS ON IN-CYLINDER COMBUSTION AND SOOT FORMATION PROCESSES

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Blending oxygen-containing compounds ("oxygenates") with diesel fuel can lead to reduced soot and $NO_x$ emissions, as well as reduced fuel consumption. The detailed mechanisms that cause such reductions are not well understood. For instance, the literature contains conflicting results as to whether overall blend oxygen content is the only important parameter in determining the soot-reduction potential of a given blend, or if oxygenate molecular structure or other variables also play significant roles. To begin to resolve this controversy, in-cylinder measurements of direct luminosity (DL) coupled with heat-release and efficiency analyses were made using three oxygenated blends. For comparison purposes, results also are presented for a 45-cetane non-oxygenated blend of two $C_{16}H_{34}$ primary reference fuels (CN45). The DL image sequences show the evolution of regions of high soot concentration and temperature throughout the combustion event. A 1200-rpm, moderate-load operating condition was studied using a modern-technology, 4-stroke, heavy-duty DI diesel engine that has been modified to provide extensive optical access into the combustion chamber. Injection timing was optimized independently for each fuel such that the engine always operated at peak efficiency.

In an attempt to isolate molecular structure effects on ignition, combustion, and soot-formation processes, the overall oxygen contents of two of the three oxygenated blends were matched at 26 wt% by blending with $C_{16}H_{34}$ primary reference fuels. Combustion phasing also was matched by adding an ignition improver to the lower-cetane blend. The first blend, denoted GE80, was composed of 80 vol% tri-propylene glycol methyl ether and 20 vol% heptamethylnonane. The second blend, denoted BM88, was composed of 88 vol% di-butyl maleate, 7 vol% *n*-hexadecane, and 5 vol% ethylhexyl nitrate ignition improver. Whereas no dramatic differences between ignition or combustion processes between blends are evident from the DL images, spatially-integrated DL data (used as a measure of the amount of in-cylinder soot) are twice as great for BM88 as for GE80. Although further experiments are required, these initial results suggest that overall oxygen content may not be the only important parameter in determining the soot-reduction potential of an oxygenated blend.

The third oxygenated fuel had an oxygen content of 50 wt% and a cetane number < 5 such that glow plug (GP) assisted ignition was essential for stable engine operation. The fuel, denoted M100, was composed of methanol and 95 ppmv of a commercially-available corrosion-inhibiting additive. The M100 data show significant departures from the traditional diesel combustion features exhibited by CN45. Whereas CN45 readily autoignites at the conditions studied, M100 does not. The GP-assisted ignition of M100 was found to be strongly dependent on GP temperature and proximity to a fuel jet. The DL images show that M100 ignition occurs at the GP, followed by combustion propagation first to the two jets straddling the GP, then to the adjacent two jets, and finally to the last two jets emanating from the 6-hole, centrally-located injector nozzle. Three spikes in the apparent heat release rate are observed to correspond to these pair-wise jet ignition events. Spatially integrated DL image data suggest that in-cylinder soot concentrations during M100 combustion are at least 2 orders of magnitude lower than those during CN45 combustion. Peak heat release rates during M100 combustion are only half of those achieved during the premixed burn phase of CN45 combustion, resulting in noticeably quieter engine operation.