CRC Report No. AVFL-33

Phase 1

FUEL–WALL INTERACTION EFFECTS AND DEPENDENCIES ON STOCHASTIC PREIGNITION

Executive Summary

December 2024

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Executive Summary

This work explores dependencies on fuel impingement and retention on internal engine surfaces (i.e., fuel–wall impingement) as a function of fuel properties and engine operating conditions and correlates these data with stochastic preignition (SPI) propensity. SPI rates are directly coupled with laser–induced fluorescence measurements of dye-doped fuel dilution measurements of the engine lubricant, which provides a surrogate for fuel–wall impingement. Literature suggests that SPI may be correlated with fuel–wall impingement; however, it is unclear if this is a fundamental predictor and source of SPI or if fuel-wall impingement is a causational factor of SPI.

To fundamentally explore the relation between fuel-wall impingement and SPI, engine experiments with 4 distinct fuels were used. Each fuel was based on Tier 2 certification grade gasoline fuel. The baseline fuel was the neat Tier 2 certification grade gasoline. The 3 other fuels were splash blends of 25% ethanol by volume and/or 5% tetralin by volume into the baseline fuel. All experiments were conducted in a single cylinder engine based on a production side mounted direct injection GM LNF engine operated at 2000 rpm. The single cylinder engine was operated with conventional laboratory grade sensors and measurement systems including in-cylinder pressure sensing and flow path surge tanks; the engine retained all production hardware except for a retrofit dry sump oiling system. The dry sump oiling system enabled a laser induced fluorescence diagnostic to be used for measuring fuel wall interaction in real time. The diagnostic utilized 75 ppm of a marker dye doped into the fuels, enabling quantification of fuel-oil dilution of the fired cylinder scrape-down liquid prior to mixing with the sump lubricant.

Eight operating conditions were conducted with each fuel, for a total of 32 study test points. At each condition 200,000 fired cycles were acquired and analyzed, where at each condition the spark timing was adjusted to maintain a constant 50% mass fraction burned timing (CA50) of 33°CA after top dead center firing ($aTDC_f$). For each fuel the engine was operated at lambda one exhaust, which did require different fueling rates from both a fuel energy content and fuel retention effects. For each fuel, two different direct injection timings were used: an earlier injection timing that initially targets the piston crown, 310°CA before top dead center firing ($bTDC_f$) start of injection (SOI) timing, and a later injection timing that targets the cylinder liner, 220°CA $bTDC_f$ SOI timing. At each SOI timing, the engine was operated at both 90°C and 70°C coolant temperature and 185 and 200 kPa absolute intake pressure (resulting in ~18.5 or ~20 bar indicated mean effective pressure (IMEP) respectively).

Results probed the operating space of downsized boosted engines and established conditions of elevated fuel wall impingement. The findings of this unique approach demonstrate that SPI propensity is directly proportional to fuel retained in the top ring zone, and not simply fuel–wall impingement. Fuels with the highest fuel wall impingement rates exhibited the lowest SPI propensity, the converse of the initial hypothesis. Estimations of the rate of top ring zone fuel dilution and SPI reveal that there is a minimum fuel retention, above which the SPI propensity increased in this engine. Results show that the fuels containing 25% ethanol did increase fuel wall impingement, but the fuels with increased tetralin increased fuel retention. Only when the fuel distillation temperature above the cylinder liner temperature (~15° C higher than the coolant temperature) increased did fuel retention and SPI increase. The combination of these two effects is studied in detail herein where the results demonstrate a complex relationship between fuel properties and operating conditions on SPI propensity.