A Comparison of Ethanol and Butanol as Oxygenates Using a Direct-Injection, Spark-Ignition Engine

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Abstract

This study was designed to evaluate a "what if" scenario in terms of using butanol as an oxygenate in place of ethanol in an engine calibrated for gasoline operation. No changes to the stock engine calibration were performed for this study. Combustion analysis, efficiency, and emissions of pure gasoline, 10% ethanol, and 10% butanol blends in a modern direct-injection four-cylinder spark-ignition engine were analyzed. Data were taken at engine speeds of 1000 rpm up to 4000 rpm with load varying from 0 N m (idle) to 150 N m. Relatively minor differences existed between the three fuels for the combustion characteristics such as heat release rate, 50% mass fraction burned, and coefficient of variation in indicated mean effective pressure at low and medium engine loads. However at high engine loads the reduced knock resistance of the butanol blend forced the engine control unit to retard the ignition timing substantially, compared with the gasoline baseline and, even more pronounced, compared with the ethanol blend. Brake specific volumetric fuel consumption, which represented a normalized volumetric fuel flow rate, was lowest for the gasoline baseline fuel due to the higher energy density. The 10% butanol blend had a lower volumetric fuel consumption compared with the ethanol blend, as expected, based on energy density differences. The results showed little difference in regulated emissions between 10% ethanol and 10% butanol. The ethanol blend produced the highest peak specific NO_x due to the high octane rating of ethanol and effective antiknock characteristics. Overall, the ability of butanol to perform equally as well as ethanol from an emissions and combustion standpoint, with a decrease in fuel consumption, initially appears promising. Further experiments are planned to explore the full operating range of the engine and the potential benefits of higher blend ratios of butanol.

Keywords: additives, calibration, fuel, ignition, internal combustion engines