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First Investigation of Ducted Fuel Injection on a Retrofitted Heavy-Duty Multi-Cylinder Production Engine

Executive Summary

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First investigation of ducted fuel injection on a retrofitted heavy-duty multi-cylinder production engine

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ABSTRACT

Ducted fuel injection (DFI) was tested for the first time on a production multi-cylinder engine using a John Deere Model 6090 heavy-duty diesel engine. Design-of-experiments (DoE) testing was carried out for DFI with a baseline ultra-low sulfur diesel (ULSD) fuel as well as three fuels with lower lifecycle carbon-dioxide (CO_2) emissions: renewable diesel, neat biodiesel (from soy), and a 50/50 blend by volume of biodiesel with renewable diesel. For all fuels tested, DFI enabled simultaneous reductions of engine-out emissions of soot and nitrogen oxides (NOx) with late injection timings. DoE data were used to develop individual calibrations for steady-state testing with each fuel using the ISO 8178 eight-mode off-road test cycle. Over the ISO 8178 test, DFI with a 5-duct configuration and B50R50 fuel reduced soot and NOx by 87% and 42%, respectively, relative to the production hardware. Soot reductions generally decreased with increasing engine load. Hydrocarbon and carbon monoxide emissions tended to increase with DFI but were not excessive over the ISO 8178 test. Brake-specific energy consumption generally increased with DFI due to the use of retarded injection timings and exhaust-gas recirculation to achieve the desired NOx reductions but was less than or equal to that for conventional diesel combustion with ULSD at a similar NOx level. Significant deposits were encountered on one cylinder when running at idle with the ULSD fuel only, but this was mitigated by replacing the corresponding fuel injector (which showed deformation at the exits of two of its orifices) and using a fuel detergent additive in subsequent testing. In all, the engine was successfully operated for over 300 hours in the DFI configuration. Research areas for improved DFI implementation are identified.