

Performance Analysis of a Heavy-Duty Hybrid-Electric Truck with a Micro-pilot Natural Gas Engine in Real-World Highway Driving Conditions

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ABSTRACT

Diesel-fueled heavy-duty trucks play a major role in moving freight across Canada, consuming about 40% of the total energy used in the freight transport industry and causing substantial CO₂ greenhouse gas emissions. Electrification and using alternative fuels provide a great opportunity to reduce greenhouse gas emissions from heavy-duty trucks. Natural gas (NG) is a promising alternative fuel for heavy-duty diesel engines with the benefits of low fuel cost and lower CO₂ emissions compared to diesel engines. Among different NG engine technologies, Micro-pilot NG engines represent a competitive technology that offers high brake thermal efficiency and low CO₂ emissions, while it doesn't need a costly exhaust aftertreatment system since these engines can run at stoichiometric conditions. In this study, a micro-pilot NG engine and hybrid electric powertrain system were designed and optimized to improve fuel economy and reduce CO₂ emissions from class 8 long haul trucks. The designed hybrid electric trucks were tested for real-world driving conditions on highway 2 between Edmonton and Calgary. These included a traveling distance of about 300 kilometers with road gradients up to 7%. Plug-in hybrid and parallel hybrid electric configurations were examined and the results were compared with a baseline conventional diesel-fueled Peterbilt truck model 579 with a 335-kW engine. The simulation results for the tested conditions indicate that plug-in hybrid electric platform can reduce fuel consumption by 37.7%, while showing 7.5% decrease in fuel consumption when operating in the parallel hybrid electric configuration, compared to the baseline diesel truck. In addition, the real-world highway data shows substantial fluctuations in the truck speed and engine loads due to variations in the road gradient, varying wind speed and angle, and frequent cut-ins by adjacent vehicles. These provide a good opportunity for saving energy via regenerative braking and reducing undesirable high engine-out emissions and fuel consumption during engine transients under highway driving conditions.

Keywords: Natural gas engines, Long-haul trucks; Hybrid electric trucks; Fuel economy; CO₂ emissions