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High efficiency natural gas engine modelling for commercial vehicle studies

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ABSTRACT

Background: Decarbonizing long haul goods transportation poses a substantial challenge. Greater engine efficiency can reduce emissions to help to meet future more stringent regulations. Vehicle system improvements, including the application of hybridization, as well as alternative low-carbon fuels such as natural gas can offer further GHG reductions. High-pressure direct injection (HPDI) of natural gas, which uses a small amount of diesel for ignition, offers diesel-like efficiency and performance with 15-20% lower GHGs. Combining high efficient combustion of low-carbon fuels with a hybridized powertrain offers a pathway to even greater GHG reductions. Appropriate sizing of the powertrain components and prediction of the net GHG benefits depends on an accurate predictive model for an HPDI engine.

Methodology: This study aims to simulate a 6-cylinder HPDI engine for a class-8 commercial vehicle in the GT-Suite modelling environment.. In this work, a cylinder-only model is first used to calibrate the phenomenological DI-Pulse predictive combustion model using experimental in-cylinder pressure data. The predictive combustion model is then applied to a validated diesel engine model for fuel consumption and GHG emissions prediction under steady-state and transient conditions.

Results: The combustion model was calibrated to predict the performance and emission behavior of the engine. DI Pulse includes four parameters: ignition delay, entrainment, premixed, and diffusion that should be optimized to minimize the burn rate error. Experimental data from six steady-state points were used to calibrate the combustion model. A single set of calibration values were found to provide an acceptable prediction of the combustion process for all six operating points. The validated combustion model was applied to a multi-cylinder engine model. Model results were found to be within 4% of the experimental data used for validation in terms of fuel consumption, engine torque, and exhaust temperature under steady-state conditions. The results of case sweep parameters were evaluated against several other operating conditions and similarly good agreement was found. The engine model was then used to assess combustion performance during transient operation, including tip-in and tip-out transients as well as real-world long-haul drive cycle using in-service vehicle data. Transient load fluctuations during cruise were found to impact exhaust emissions and fuel consumption. The ability to predict these transient behaviours indicates that the model can be used for future vehicle hybridization studies.