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Real-Time Prediction of Gas Flow Dynamics in Diesel Engines using a Deep Neural Operator Framework

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The objective of this work is to address the need for fast and accurate models for analyzing transient gas flow dynamics in diesel engines. To this end, we employ a neural operator-based surrogate model, called DeepONet, to learn and predict the transient gas flow dynamics in real-time. The neural operator maps the relationship between engine control stimulus, namely engine speed, fuel injection per cycle, EGR, and VGT valve openings with seven output states that include intake and exhaust manifold pressures, oxygen mass fraction in the intake and exhaust manifolds, as well as the dynamics of the EGR and VGT actuators. To establish a benchmark, we compare results from the DeepONet model to a mean-value gas flow engine model simulated with Simulink. We observe a maximum relative L_2 error of 6.5%, a reasonable accuracy for transient dynamics. The DeepONet model also exhibits good robustness to noisy input functions. Additionally, to evaluate the epistemic uncertainty in our model predictions, we adopt a mean ensemble approach, yielding a worst-case error of 12% at a standard deviation of 2 sigma from the mean value. In summary, our proposed framework offers real-time prediction capabilities and facilitates data-driven learning of complex input-output operator mappings. This makes the DeepONet surrogate particularly useful for preliminary analyses of system dynamics, control system optimization, and health monitoring of sub-systems.