High-fidelity machine learning modelling of GO–Al_2O_3 assisted ethanol–MBD20 dual-fuel CI engine combustion

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Klinmalee, Tossaphorn [a] ; Elumalai P.V. [b] ; Alwetaishi, Mamdooh [c] ; Hussain, Fayaz [d] ; Chan, Choon Kit [e] ; +3 authors

[a] Faculty of Engineering and Technology. Shinawatra University, Pathum Thani, 12160, Thailand

Abstract

The implementation of ethanol-assisted dual-fuel operation in conjunction with nanoparticle-enhanced biodiesel combustion has garnered significant interest as an effective method for improving the efficiency and reducing the emissions of compression ignition (CI) engines. Most of the existing studies focus on these methods independently, thereby challenging the integration of data-driven optimisation with sustainability assessments. This experimental study examines the performance, emissions and sustainability characteristics of a single-cylinder dual-fuel compression ignition engine with 20 vol% Chlorella vulgaris biodiesel (MB20), 5–15% ethanol energy share and hybrid graphene oxide–aluminium oxide (GO–Al_2O_3) nanoparticles at 25–100 ppm. Of all the fuel formulations analysed, MB20GA25E15 performed best with a maximum brake thermal efficiency of 34.8% (6.1% over diesel), together with 4.2% lower brake-specific fuel consumption. The CO levels were reduced by 18 to 22%, the concentrations of HC by 15 to 19%, and the smoke opacity measurements by 12 to 18%. However, a minor increase in NO_x emissions (3–7%) associated with the increase in cylinder temperatures and additional available oxygen was observed. Nine machine learning models were created to generalise and interpret the trends seen experimentally. Gradient boosting was the model that predicted the most accurately. The output analysis based on SHAP illustrated that engine load, ethanol share, and nanoparticle dosage are the main contributors driving the results. From the Pugh matrix sustainability assessment, it is determined that MB20GA25E15 is the best fuel blend, providing balance between efficiency, emissions, cost and environmental benefit. A practicable strategy for achieving sustainable operation A CI engine is proposed that consists of a detailed framework based on experimental methods, machine learning, and sustainability principles for applying an ethanol-assisted microalgae biodiesel dual-fuel CI engine equipped with hybrid GO–Al_2O_3 nanoparticles.

Author keywords

Dual-fuel CI engine; Energy efficiency; Ethanol share; Hybrid nanoparticles (GO–Al_2O_3); Machine learning prediction; Microalgae biodiesel (MBD20); SHAP explainability; Sustainability assessment

Indexed keywords

Engineering controlled terms

Algae; Aluminum oxide; Biodiesel; Blending; Brakes; Data integration; Diesel engines; Dual fuel engines; Engine cylinders; Ethanol fuels; Fuel consumption; Ignition; Learning algorithms; Learning systems; Machine learning; Smoke; Sustainable development; Uncertainty analysis

Engineering uncontrolled terms

Compression ignition engine; Dual-fuel compression ignition engine; Dual-fuels; Energy; Ethanol share; Hybrid nanoparticle; Hybrid nanoparticle (GO–al_2o_3); Machine learning prediction; Machine-learning; Micro-algae; Microalga; Microalga biodiesel (MBD20); SHAP explainability; Sustainability assessment

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Corresponding authors

Corresponding author P.V. Elumalai