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PREDICTIVE MODELLING FOR NITROGEN OXIDES EMISSION OF DIESEL ENGINES OPERATED WITH ALTERNATIVE PLASTIC FUEL

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The rapid growth of plastic manufacturing has supported industrial development, but simultaneously intensified post-consumer plastic waste generation, raising serious environmental concerns. Pyrolysis, a thermal decomposition process in an oxygen-free environment, offers a promising pathway to convert plastic waste into diesel-like fuel. This study investigates commercial B10 (10% palm methyl ester) and two plastic-derived blends: HDPE10 (10% high-density polyethylene) and PP10 (10% polypropylene), and B0 (pure diesel) as guideline tested on a Yanmar L48N6-MTMRYI diesel engine following ISO 8178 D2. The objective is to characterize fuel properties, investigate the performance and emissions trend, and predict nitrogen oxides (NO_x) emissions using machine learning (ML) techniques. HDPE10 and PP10 were found to comply with commercial fuel standards, delivering improved brake power (BP), reduced brake-specific fuel consumption (BSFC), and enhanced brake thermal efficiency (BTE) compared to B0. However, emissions analysis revealed increased carbon monoxide (CO) and carbon dioxide (CO_2) across all blends: B10 (38% CO, 50% CO_2), HDPE10 (30% CO, 15% CO_2), and PP10 (45% CO, 41% CO_2).

Hydrocarbon (HC) emissions rose in HDPE10 (31%) and PP10 (21%) but declined significantly in B10 (48%). NO_x emissions decreased for all blends, with reductions of 23% in B10, 16% in HDPE10, and 14% in PP10. For NO_x prediction, the dataset was partitioned into 70% for training and 30% for testing using three ML algorithms: Levenberg-Marquardt (LM), Bayesian Regularization (BR), and Scaled Conjugate Gradient (SCG). All models demonstrated high predictive accuracy, with a Coefficient of Determination (R^2) exceeding 0.994. Among them, BR delivered the best performance, achieving R^2 between 0.99409–0.99992 and root mean square error (RMSE) between 0.003036–0.016761 g/kWh during training. Validation confirmed BR's reliability with R^2 of 0.988473–0.990847, RMSE of $8.7e^{-5}$–0.0024 g/kWh, and normal absolute error (NAE) of $1.35e^{-7}$–$1.42e^{-5}$. These findings confirm the feasibility of HDPE10 and PP10 as viable diesel alternatives and highlight the effectiveness of ML, particularly the BR algorithm, in supporting NO_x emissions prediction for cleaner fuel development in Malaysia.

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PERMODELAN RAMALAN UNTUK PELEPASAN OKSIDA NITROGEN OLEH ENJIN DIESEL YANG DIKENDALIKAN DENGAN BAHAN API PLASTIK ALTERNATIF

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Pertumbuhan pesat dalam industri pembuatan plastik menyokong pembangunan industri secara menyeluruh, namun turut meningkatkan penjanaan sisa plastik pasca guna ketara, sekali gus menimbulkan kebimbangan serius terhadap kelestarian alam sekitar. Pirolisis, iaitu proses penguraian haba tanpa kehadiran oksigen, menawarkan pendekatan berpotensi menukarkan sisa plastik kepada bahan api seakan diesel. Kajian ini menyiasat prestasi campuran B10 komersial (10% metil ester sawit) dan dua campuran bahan api berasaskan plastik; HDPE10 (10% polietilena berketumpatan tinggi) dan PP10 (10% polipropilena), dan B0 (diesel tulen) sebagai penanda aras diuji menggunakan enjin diesel Yanmar L48N6-MTMRYI mengikut piawaian ISO 8178 D2. Objektif utama kajian adalah mencirikan sifat bahan api, menilai tren prestasi dan pelepasan, serta meramal pelepasan nitrogen oksida (NO_x) menggunakan teknik pembelajaran mesin (ML). Hasil menunjukkan HDPE10 dan PP10 memenuhi piawaian bahan api komersial, dengan peningkatan dalam kuasa brek (BP), pengurangan penggunaan bahan api spesifik brek (BSFC), serta peningkatan kecekapan terma brek (BTE) berbanding B0. Namun, analisis pelepasan menunjukkan peningkatan karbon monoksida (CO) dan karbon dioksida (CO_2) bagi semua campuran: B10 (38% CO, 50% CO_2), HDPE10 (30% CO, 15% CO_2), dan PP10 (45% CO, 41% CO_2). Pelepasan hidrokarbon (HC) meningkat dalam HDPE10 (31%) dan PP10 (21%), manakala B10 menunjukkan pengurangan ketara sebanyak 48%. Pelepasan NO_x menurun bagi kesemua campuran; B10 mencatatkan pengurangan tertinggi sebanyak 23%, diikuti HDPE10 (16%) dan PP10 (14%). Bagi tujuan ramalan NO_x, set data telah dibahagikan kepada 70% untuk latihan dan 30% untuk pengujian menggunakan tiga algoritma ML: Levenberg-Marquardt (LM), Bayesian Regularization (BR), dan Scaled Conjugate Gradient (SCG). Ketiga-tiga model menunjukkan ketepatan ramalan tinggi dengan nilai pekali penentuan (R^2) melebihi 0.994. Algoritma BR mencatatkan prestasi terbaik dengan R^2 antara 0.99409–0.99992 dan ralat purata kuasa dua (RMSE) antara 0.003036–0.016761 g/kWh semasa latihan. Pengesahan model turut mengukuhkan kebolehpercayaan BR dengan R^2 antara 0.988473–0.990847, RMSE antara $8.7e^{-5}$–0.0024 g/kWh, dan ralat mutlak normal (NAE) antara $1.35e^{-7}$–$1.42e^{-5}$. Dapatan kajian ini mengesahkan kebolehgunaan HDPE10 dan PP10 sebagai bahan api alternatif yang berdaya saing serta menunjukkan keberkesanan kaedah ML, khususnya algoritma BR, dalam meramal pelepasan NO_x bagi menyokong pembangunan bahan api diesel yang lebih bersih di Malaysia.