COMPUTATIONAL APPROACHES FOR OPTIMAL DESIGN OF TAILOR MADE BIOFUEL BLENDS

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Dedicated with deepest gratitude and heartfelt thanks
To my beloved family, for their endless love and care
To my angel Huppysha, for his infinite love and joy
To myself, for my hardwork and persistence
And to HIM for every second of my life.

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ABSTRACT

Diminishing fossil fuel supplies and increasing awareness on environmental issues surged the need for renewable and environmentally friendly alternative fuel options for the transportation sector. Diverse biofuel components can be produced from exploitation of biomass as an energy source. Malaysia having abundant palm biomass waste is prompted to efficiently utilize the available resources for production of second generation biofuel blends. However, complexity arises in designing suitable biofuel blends that comply to fuel regulation standards and generate reduced emissions while having equal performance as conventional diesel fuel. Experimental methods consume immense resources and time, require highly sophisticated equipments, and are difficult to conduct for fluid flow variations. Computational approaches adopt a systematic blend formulation process that assists on focused experimental work. In this study, optimal tailor made biofuel blends were designed and evaluated for engine performances, emissions, and in-cylinder fluid flow analyses through implementation of various computational approaches that follow an integrated framework. Systematic model based approach was applied to design tailor made biofuel blends that comply to EN590 fuel reference standard using B5 diesel, butanol, ethanol, and butyl levulinate as building blocks. Fuel blends were generated through Generalized Algebraic Modelling System and predicted fuel properties validated with experimental tests. In-cylinder fluid flow profiles were simulated through computational fluid dynamics model using ANSYS Fluent software version 13.0. Engine performances such as indicated power and indicated thermal efficiency were predicted through mathematical models where experimental validation was done for indicated power. Semi-empirical emission correlations were applied to predict nitrogen oxide, carbon monoxide, unburnt hydrocarbon, and smoke. Among the five tailor made biofuel blends formulated, Blend 4 was the most promising with enhanced performances and lower emissions in comparison to B5 diesel though nitrogen oxide emissions were higher.

ABSTRAK

Kemerosotan bekalan bahan api fosil dan peningkatan kesedaran terhadap isu-isu alam sekitar telah membangkitkan usaha berterusan untuk mencari bahan api alternatif yang mesra alam dan boleh diperbaharui bagi penggunaan di sektor pengangkutan. Pelbagai komponen bahan api bio dihasilkan daripada sisa buangan biojisim sebagai sumber tenaga. Malaysia antara negara pengeksport utama kelapa sawit kaya dengan sisa buangan kelapa sawit yang boleh digunakan secara cekap dan berkesan untuk penghasilan bahan api bio. Namun begitu, wujud kerumitan dalam merekabentuk bahan api bio yang mematuhi piawaian sekaligus menjana prestasi setanding diesel biasa dengan penghasilan emisi yang rendah. Kaedah eksperimen memakan masa dan sumber manakala variasi pembolehubah sukar dilaksanakan tanpa penggunaan peralatan canggih. Pendekatan komputasi pula mengikut proses berstruktur bagi pemilihan campuran bahan api bio dan ini membantu perjalanan eksperimen tertumpu. Kajian ini merekabentuk campuran optimum bahan api bio dan menilai prestasi enjin, penghasilan emisi serta menganalisis pengaliran bendalir di dalam enjin diesel melalui pelbagai jenis pendekatan komputasi yang mengikut satu rangka bersepadu. Pendekatan sistematik berasaskan model diaplikasi bagi merekabentuk campuran optimum bahan api bio yang mengandungi komponen-komponen B5 diesel, butanol, etanol, dan butil levulinat serta mematuhi piawaian EN590. Campuran optimum bahan api bio dijana menggunakan *Generalized Algebraic Modelling System* dan ciri-ciri khas yang diramal disahkan melalui kaedah eksperimen. Pengaliran bendalir di dalam enjin diesel disimulasi menggunakan program ANSYS Fluent versi 13.0. Prestasi enjin seperti kuasa dan kecekapan haba diramal menggunakan model matematik dan disahkan dengan keputusan eksperimen. Emisi nitrogen oksida, karbon monoksida, hidrokarbon tidak terbakar, dan asap pula diramal melalui korelasi empirikal. Antara lima campuran optimum bahan api bio yang dijana, Campuran 4 mempunyai prestasi enjin yang terbaik dan menghasilkan emisi rendah berbanding B5 diesel walaupun emisi nitrogen oksidanya agak tinggi.