

PERFORMANCE, COMBUSTION AND
EMISSIONS ANALYSIS OF WATER
EMULSIFIED BIODIESEL IN A DIESEL
ENGINE

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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Dedicated To

My

Parents;

Late younger brother;

Brothers and sisters

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In the Name of Allah, the Most Gracious, the Most Merciful All the praises and thanks be to Allah Almighty, the Lord of the Worlds, the Giver of bountiful blessings and gifts. Prayers and peace of Allah be upon the noblest of the Prophets and Messengers, our Prophet Mohammed and upon his family and companions, the honourable followers until the last day. I am truly and deeply indebted to so many people that there is no way to acknowledge them all or even any of them properly. Thus, I offer my sincerest apologies to anyone I ungratefully omitted from explicit mention.

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ABSTRAK

Biodiesel telah mengurangkan kebergantungan pada bahan api petroleum. Biodiesel dianggap sebagai bahan bakar yang berpotensi dengan sifat-sifat yang akan membolehkan campuran bahan api biodiesel-diesel dengan peratusan rendah untuk beroperasi dengan lancar dalam enjin pencucuhan mampatan konvensional tanpa pengubahsuaian. Pada masa ini, mandat biodiesel untuk Malaysia berada pada 7% dan berkemungkinan meningkat sehingga 10%. Penggunaan biodiesel dalam enjin diesel mengurangkan pelepasan gas rumah hijau tertentu, tetapi pengeluaran NO_x masih tinggi berbanding dengan diesel. Objektif kajian ini adalah untuk mengenalpasti ciri fizikokimia bahan api campuran B20 dan kesan kewujudan air dari segi emulsi, untuk menganalisis ciri-ciri pembakaran bahan api campuran B20 yang diemulsikan dengan peratusan kandungan air yang berbeza dan untuk menilai prestasi dan pelepasan ekzos bahan api B20 yang diemulsikan dengan air dalam enjin diesel. Bahan api emulsi telah disediakan menggunakan kuasa luaran. Tempoh kestabilan untuk bahan api emulsi diperhatikan dari segi hari dan pengukuran zarah titisan dilakukan menggunakan mikroskop metalurgi terbalik yang disambungkan ke komputer. Pencirian eksperimen bahan api bahan api dan emulsi bahan api seperti kelikatan kinematik, ketumpatan dan nilai kalori dijalankan mengikut standard ASTM D7467 dan dibandingkan dengan bahan api diesel. Kerja-kerja eksperimen dijalankan pada enjin diesel suntikan langsung berbilang silinder untuk menyiasat ciri-ciri pembakaran, prestasi enjin dan parameter pelepasan ekzos. Tempoh kestabilan emulsi semakin berkurangan apabila kadar air meningkat. Sebaliknya, purata saiz zarah titisan meningkat apabila kandungan air meningkat. Keputusan sifat bahan api menunjukkan bahawa kelikatan kinematik dan ketumpatan untuk semua bahan api emulsi dikurangkan berbanding dengan bahan api diesel. Penurunan ini meningkat apabila peratusan kandungan air meningkat. Sebaliknya, berbanding dengan diesel konvensional, terdapat pengurangan ketara dalam nilai kalori pada semua bahan api emulsi kecuali gabungan emulsi dengan 5% air. Nilai kalori untuk bahan emulsi dengan 5% air menunjukkan hasil setanding dengan bahan bakar asas. Pada keadaan operasi yang sama, kesan tekanan silinder untuk bahan api campuran dan bahan api campuran yang diemulsi adalah setanding dengan diesel konvensional. Walau bagaimanapun, pada semua beban, bahan api emulsi dengan nisbah air 5% menunjukkan pengurangan ketara dalam puncak tekanan silinder dan kadar pelepasan haba maksimum berbanding diesel dan campuran bahan api. Daya kilas enjin untuk kandungan air rendah menunjukkan peningkatan berbanding dengan diesel dan campuran biodiesel-diesel. Begitu juga, kuasa brek untuk bahan emulsi dengan 5% air meningkat dengan ketara pada beban rendah dan setanding dengan beban tinggi. Semua bahan api emulsi menunjukkan kecekapan terma yang lebih baik berbanding bahan api diesel di semua keadaan operasi kecuali bahan api emulsi dengan 30% air semasa beban 40%. Pembentukan pelepasan NO_x dikurangkan dengan ketara dengan peningkatan kadar air di semua keadaan operasi. Pengurangan tertinggi diperolehi oleh bahan api emulsi dengan 30% kandungan air pada beban enjin 40%. Sebaliknya, pelepasan HC dan CO_2 untuk bahan api emulsi meningkat berbanding dengan diesel konvensional. Kesimpulannya, pengemulsian campuran biodiesel-diesel fuel adalah cara yang terbukti untuk mengurangkan pembentukan gas NO_x . Secara keseluruhannya, penemuan ini menyumbang kepada pemahaman asas pengemulsi air dengan campuran biodiesel-diesel POME yang dikendalikan dengan enjin diesel.

ABSTRACT

Biodiesel is fast becoming a major role in lessening the dependency on petroleum fuel. Biodiesel is considered as promising fuel with properties that will allow low percentage biodiesel-diesel fuel blends to operate smoothly in a conventional compression ignition engine without modifications. Currently, the biodiesel mandate for Malaysia stands at 7% and is likely to rise to 10%. The use of biodiesel in diesel engines reduces certain greenhouse gas emissions considerably, but NO_x production remains high compared to diesel. The objectives of this study are to characterize the physicochemical properties of blended fuel B20 and effect of water in terms of emulsion, to analyze the combustion characteristics of blended fuel B20 emulsified with different percentages of water to evaluate the performance and exhaust emissions of fuel B20 emulsified with water in diesel engine. The emulsion fuels were prepared using external force. The stability period for the emulsion fuels were observed in terms of days and the droplet particle measurement was carried out using inverted metallurgical microscope connected to a computer. The experimental characterization of the blended fuel and emulsion fuel properties such as kinematic viscosity, density and calorific value was conducted according to standard ASTM D7467 and compared with diesel fuel. Experimental works were carried out on a multi-cylinder, direct injection diesel engine to investigate the combustion characteristics, engine performance and exhaust emission parameters. The days of stability of the emulsion is decreased when the water proportion is increased. On the contrary, the mean particle size of the droplet increased when water content increased. The fuel properties results showed that the kinematic viscosity and density for all emulsion fuels reduced compared to diesel fuel. The reduction increased as the water percentage increased. On the other hand, compared to conventional diesel, there was significant reduction in all emulsion fuel calorific values except the emulsified blend with 5% of water. The calorific value for emulsion fuel with 5% of water showed comparable results with the base fuel. At same operating conditions, the in-cylinder pressure traces for blended fuel and emulsified blended fuels are comparable to the conventional diesel. However, at all loads, the emulsion fuel with 5% water proportion showed significant reduction in peak in-cylinder pressure and maximum rate of heat release compared to diesel and blend fuel. The engine torque for low water content showed some improvements compared to diesel and biodiesel-diesel blend. Similarly, the brake power for emulsion fuel with 5% of water increased significantly at low loads and comparable at high loads. All the emulsion fuels exhibited better thermal efficiency compared to diesel fuel at all operating conditions except for emulsion fuel with 30% of water during 40% load. The formation of NO_x emissions was reduced significantly with increase of water proportions at all operating conditions. The highest reduction obtained by emulsion fuel with 30% of water at 40% engine load. On the other hand, the HC and CO₂ emissions for emulsion fuels increased compared to conventional diesel. In conclusion, the emulsification of blend biodiesel-diesel fuel is a proven method to reduce the formation of NO_x emissions. Overall, these findings have contributed to the fundamental understanding of water emulsification with POME biodiesel-diesel blend operated with diesel engine.

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LIST OF SYMBOLS

k_v	Viscometer constant
\dot{m}_f	Fuel mass flow rate (g/hr)
O/W	Oil-in-water
O/W/O	Oil-in-water-in-oil
t	Time
W/O	Water-in-oil
W/O/W	Water-in-oil-in-water
w/w	Weight by weight
γ	Specific heat ratio

LIST OF ABBREVIATIONS

ABDC	After Bottom Dead Centre
AFR	Animal fat residue
ANOVA	Analysis of variance
ASTM	American Society of Testing Materials
ATDC	After Top Dead Centre
BBDC	Before Bottom Dead Centre
BDC	Bottom Dead Centre
BP	Brake power
BSFC	Brake specific fuel consumption
BSFC	Brake-Specific Fuel Consumption
BTE	Brake Thermal Efficiency
BTDC	Before Top Dead Centre
CHR	Cumulative heat release
CI	Compression ignition
CIA	Central Intelligence Agency
CN	Cetane number
CO	Carbon monoxide
CO ₂	Carbon dioxide
CSOME	Cottonseed oil methyl ester
DAG	Diacylglycerol
df	Degree of freedom
DI	Direct injection
EGR	Exhaust gas recirculation
EGT	Exhaust gas temperature
EN	European Standard
EU	European Union
FA	Fatty acid
FAAE	Fatty acid alkyl esters
FAC	Fatty acid compositions
FAME	Fatty acid methyl esters
FFA	Free fatty acid

GHG	Greenhouse gas
HC	Hydrocarbon
HLB	Hydrophilic-lipophilic balance
IEA	International Energy Agency
IFP	Inferior calorific power
ISO	International Organization for Standardization
KOME	Karanja oil methyl ester
MAG	Monoacylglycerol
NO _x	Nitrogen oxides
PM	Particulate matter
POME	Palm oil methyl ester
PPME	Pongamia pinnata methyl ester
SCP	Superior calorific power
SFA	Saturated fatty acids
SOME	Soybean oil methyl ester
TAG	Triacylglycerol
TWh	Terawatt-hour
UBHC	Unburnt hydrocarbon
w.r.t.	with reference to

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