

**PERFORMANCE & EMISSION CHARACTERISTIC OF
EMULSIFIED BIOFUEL APPLICATION IN DIESEL ENGINE**

by

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LIST OF SYMBOLS

P	Pressure
T	Temperature
t	Time
N	Engine speed
ρ	Fluid density
T	Torque
ω	Angular acceleration
m	Mass
L	Litre
h_{tot}	Total enthalpy
λ	Thermal conductivity
v	Velocity
v_{max}	Maximum velocity
θ	Crank angle degree
τ	Strain rate
S_M	Momentum source
\vec{u}	Three dimensional flow
R	Radius
l	Length
x,y,z	Cartesian coordinates

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
EB	Emulsified biofuel
CPO	Crude palm oil
W/O	Water in oil
O/W	Oil in water
V	DC voltage
GVSTD	Guide vane swirl and tumble device
GVD	Guide vane device
BP	Brake power
BSFC	Brake specific fuel consumption
SFC	Specific fuel consumption
BTE	Brake thermal efficiency
BMEP	Brake mean effective pressure
CO ₂	Carbon dioxide
NO _x	Nitrogen oxide
O ₂	Oxygen
TKE	Turbulence kinetic energy
GVD	Guide vane design
GVSTD	Guide vane swirl and tumble device
R _T	Tumble ratio
R _s	Swirl ratio
R _{CT}	Cross tumble ratio

CIRI-CIRI PRESTASI & PELEPASAN PENGGUNAAN BIOBAHANAPI TEREMULSI PADA ENJIN DIESEL

ABSTRAK

Pengurangan bahan api fosil dan kenaikan dan penurunan harga minyak di pasaran global telah mencetuskan kesedaran dan minat untuk membangunkan bahan api alternatif. Isu-isu bahan api fosil telah menjadi kebimbangan besar kepada pencemaran alam sekitar. Minyak sawit mentah (CPO) adalah salah satu daripada bio bahan api paling berpotensi yang boleh digunakan dalam enjin diesel, di mana sifat-sifat kimia CPO menghampiri sifat-sifat kimia bahan api diesel. Walau bagaimanapun, kelikatan yang lebih tinggi dan molekul yang lebih berat boleh menyumbang kepada beberapa masalah enjin seperti pengabusan rendah semasa suntikan, pembentukan mendakan karbon, penyuntik tersumbat, pencampuran rendah dengan udara dan kecekapan pembakaran yang lebih rendah. Biobahanapi teremulsi dan pengubahsuaian kepada beberapa komponen kritikal enjin termasuk peranti pandu bilah di pancaroga salur masuk dan penerokaan reka bentuk mangkuk omboh baru telah dikenal pasti sebagai penyelesaian yang menjanjikan untuk mengurangi isu-isu. Kajian ini membentangkan keputusan kedua-dua siasatan berangka dan eksperimen yang menunjukkan kesan berbeza peranti pandu bilah (GVD) dari segi variasi ketinggian 0.25R, 0.3R dan 0.35R di pancarongga salur masuk dan reka bentuk tidak serupa mangkuk omboh dengan OCB, OCC dan SCC penambahbaikan ciri-ciri aliran udara. ANSYS FLUENT 15 digunakan untuk menjalankan simulasi enjin tiga dimensi (3D) aliran sejuk pembakaran dalaman (IC). Kedua-dua simulasi dan keputusan eksperimen menunjukkan bahawa pancarongga salur masuk dengan GVD meningkatkan prestasi ciri-ciri aliran udara terutamanya pusingan, angin junam dan

nisbah angin junam melalui pancarongga salur masuk untuk enjin. GVD dengan ketinggian $0.3R$ didapati adalah reka bentuk yang optimum dengan peningkatan keseluruhan ciri-ciri aliran udara. Peningkatan ciri-ciri aliran udara dengan penggunaan ombok GVD dan SCC dalam enjin itu terbukti berjaya menyumbang kepada percampuran bahan api udara dan bahan api pengabusan yang lebih baik berdasarkan keputusan ciri-ciri prestasi enjin peningkatan sepanjang eksperimen.

PERFORMANCE & EMISSION CHARACTERISTIC OF EMULSIFIED BIOFUEL APPLICATION IN DIESEL ENGINE

ABSTRACT

The depletion of fossil fuel reserve and the fluctuation of oil prices in the global market have triggered global awareness and interest in developing alternative fuels. Fossil fuel has become a major environment concern due to its detrimental pollution effect. Crude palm oil (CPO) is one of the most potential biofuels that can be applied in the conventional diesel engines, since its chemical properties are comparable to that of diesel fuel. However, its higher viscosity and heavier molecules can contribute to several engine problems such as low atomization during injection, carbon deposit formation and injector clogging. An emulsification of biofuel and modifications of few engine critical components that include the incorporation of Guide Vane at the inlet manifold and the search for new piston bowl design have been identified as a promising solutions to mitigate the issues. This study presents the results of both numerical and experimental investigations showing the effects of dissimilar guide vane design (GVD) in terms of height variation of $0.25R$, $0.3R$ and $0.35R$ at the intake manifold and dissimilar piston bowl designs with respect to OCB, OCC and SCC to the in-cylinder air flow characteristics improvement. The GVD designs and Piston modifications have been fabricated and tested to the Yanmar L70AE engine. The GVD designs and Piston modifications have been modelled using SOLIDWORK 2014, and ANSYS FLUENT 15 is employed and utilized to run a three dimensional (3D) cold flow internal combustion (IC) engine simulation. Both simulation and experimental results show that the intake manifold with GVD improved the performance of the air

flow characteristic particularly swirl, tumble and cross tumble ratios from the intake manifold to the engine. The GVD with the height of $0.3R$ was found to be the optimum design with respect to the overall improvement of the air flow characteristic. The improvement of the air flow characteristics with the application of GVD and SCC piston in the engine was proven to be successfully contribute to a better air fuel mixing and fuel atomization as based on the results of engine performance characteristics improvement throughout the experiment.

CHAPTER ONE

INTRODUCTION

1.0 Overview

In this chapter, the introduction of emulsified biofuel (EB) and its potential application in internal combustion engine is presented. Included, are the possible strategies of modifying the existing internal combustion engine to enable the EB application for the engine performance characteristic improvement to perform comparably with diesel fueled engine.

1.1 Diesel engine

Diesel engine is a major propulsion power source nowadays and has been powering for both inland and sea transportation machines due to its high thermal efficiency, reliability, high fuel economy and relative power performance. The first compression ignition (CI) engine was introduced by Dr. Rudolf Diesel where the CI engine was fueled by peanut oil for demonstration in the late 1900 (Sharma et al., 2008). However, the widespread availability and low cost of fossil fuel at that time did not help in promoting the vegetable-oil biofuel engine. It was not until the risk of depletion and the recent fluctuation of fossil fuel in the last two decades that attention began to gradually shift to vegetable-oil engine.

The demand for energy continues to rise every year and through the application of fossil fuel in CI engines, emissions of undesired gas nitrogen oxide (NO_x) and hazardous particulate matter (PM) have risen relentlessly over the years and caused

great concern. Consequently, and if left unchecked, it can proved detrimental to human health and destructive to the environment. In addition to the above, more stringent regulations on emissions which were mostly implemented in European countries have motivated many researchers and scientists to continue their researches on alternative fuels and explore their potential energy.

1.1.1 Potential application of biofuel in compression-ignition engines.

Biofuel is a fuel that is produced through cotemporary biological process. Biofuel can be derived either directly from plant or indirectly from agricultural, commercialized, domestic or industrial waste. Bioethanol, simply ethanol and biodiesel are among the most commonly extracted fuel from biofuel. Biofuel, which is blended with gasoline and diesel is known as biodiesel and is a recognized alternative fuel and among the popular choices for researchers and scientist to investigation further. Indeed, burning biodiesel could reduce the emission of carbon monoxide (CO), total hydrocarbon (THC), particulate matter (PM) and polyaromatic hydrocarbon (PAH), (S. M. Palash et al., 2013). However, using biofuel did not totally solve the emission problem particularly nitrogen oxide (NO_x) since pure biofuel requires high temperature to ignite.

1.1.2 Limitation of biofuel for diesel engine application

Biofuel particularly crude palm oil (CPO), is edible vegetable oils that has great potential in replacing existing fossil fuel due to its renewability, ease of handling and lower pollution emission. CPO is naturally reddish in colour and has rich of beta-carotene content. It is one of the highly saturated vegetable fats and is semi-solid at

room temperature. CPO is extracted from plants and corps. However, utilizing pure CPO as a primary fuel has been reported to shorten the engine life span, has a short-term usage, causing deposit built-up in the combustion chamber, injector coking, piston ring sticking and lubrication oil thickening (George et al., 2006), (Califano et al., 2014). These will lead to frequent engine repairs and overhauls, particularly to critical components such as fuel filter and oil filter. The main problem of biofuel is its high viscosity that contributes to several problems to the engine such as clogging of fuel lines, fuel filter and injector. Thus, a direct application of CPO in diesel engine is highly not recommended unless major modifications are to be done onto the engine.

1.1.3 Emulsified biofuel

Emulsion is defined as a mixture of two or more immiscible liquids and later become a dispersed droplet. The dispersed droplet consist of two liquid immiscible stability, an internal phase and an external phase as shown in Figure 1.1. The formation of disperse phase relies on the surfactant agent HLB number that influences the formation either to be oil or water soluble, better known as (W/O) and (O/W). In this study, the formation of (W/O) is utilized due to the water is situated in internal phase and presented as a dispersed droplet and the oil is situated in an external phase or better known as continues phase. Figure 1.2 depicts the biofuel-water droplet size and micro-explosion phenomena.

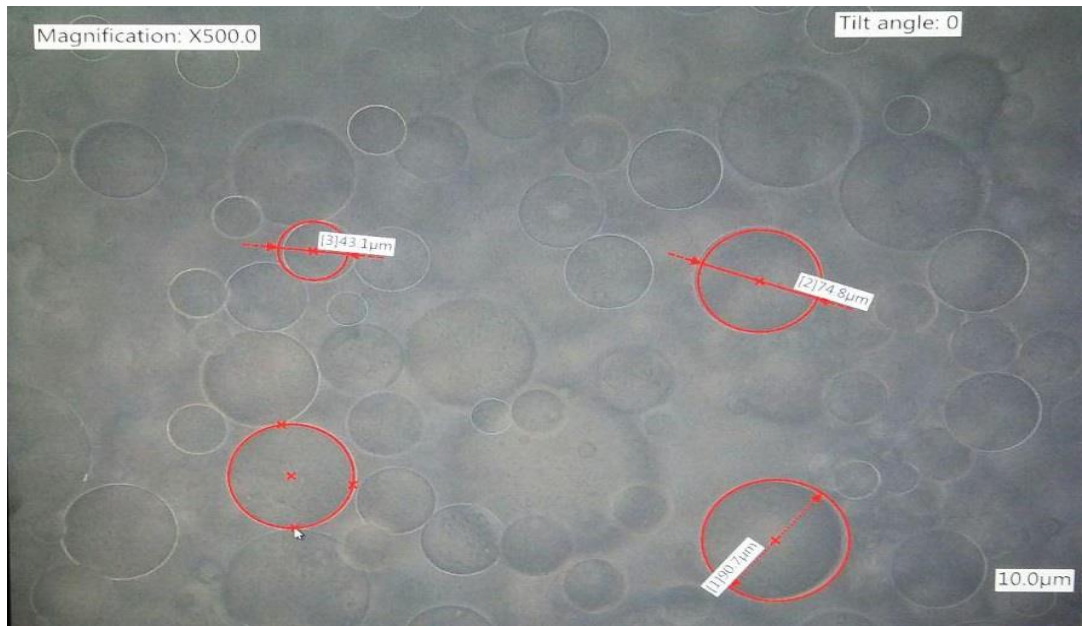


Figure 1.1: Water dispersed droplet size (red circle) into the biofuel continues phase.

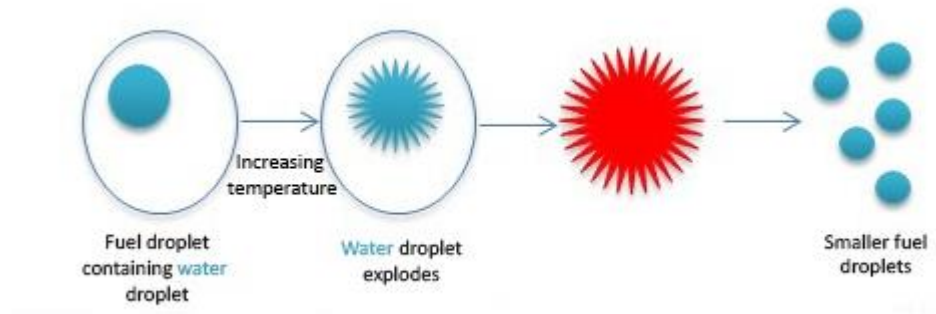


Figure 1.2: Micro-explosion phenomena (Koc et al., 2013)

The (O/W) working operation is different due the main concern on different boiling points. The huge amount of water in the external phase will initially evaporate and failure to break up the oil composition in the internal phase to become an ultra-fine droplet size. It is important to create an ultra-fine droplet size in order to rapidly assist the initial combustion. It also facilitates the heat transfer to penetrate the molecular size composition via convection and radiation. This will eventually avoid the build-up of carbon deposit at the piston resulting from inadequate heat transfer to penetrate the molecular. Emulsified biofuel produce a micro-explosion phenomena

during injection which comprises primary and secondary explosions. EB working operation is dissimilar from emulsified conventional diesel. The different working operation means that there are differences in temperature between diesel fuel and biofuel, particularly CPO, during auto ignitions; 220°C at atmospheric pressure and 316°C at atmospheric pressure, respectively. When EB is injected into the engine, the molecular of spraying is exposed to higher temperature. Water, which has lower boiling point approximately 100°C, will evaporate and expand in the initial stage. Subsequently, the particles of oil will particulate and thereby dispersing the biofuel molecules to forcefully blend with surrounding air with micronization size. The micronization size of the biofuel molecules after dispersed by water evaporation has a wide excessive contact area with oxygen (hot air) and high temperature during compression as shown in Figure 1.3. Thus facilitates in initiating the ignition, enabling efficient and complete combustion. Furthermore, micro-explosion phenomenon aids in the reduction of NO_x gas emission when water vaporizes and dilutes with the reactive region thus air is cooled progressively. In addition, by adding water which has higher density than biofuel, it indirectly increases the momentum of fuel spray and improves the mixture with air. As a result, a more complete combustion is achieved thus reducing PM and soot efficiently leading to the release of green gases.