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Study of diesel-biodiesel fuel properties and wavelet analysis on cyclic variations in a diesel engine

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Abstract

Continuous searching in new energy sources has been a crucial issue for sustaining the increasing energy demand. Due to the present economic and social modernization as well as petroleum oil depletion crisis, makes promising alternatives such as renewable energy sources an important choice for the next power generation. Petroleum fuel includes diesel currently used in power generation, transportation, and industrial sectors. The introduction of biodiesel as a secondary fuel for diesel engines has revolutionized the use of different fuels with fuel blending in current diesel. Though biodiesel-diesel fuel can substitute diesel fuel at an acceptable blending ratio rate up to 20%, fuel properties could be affected with beyond the limit from the engine manufacturer's standard when blending at high volume ratio. Thus, in the present study, the use of the diesel-biodiesel fuel (B20) was investigated corresponding to the fuel properties and engine cyclic variations. Also, the tested fuels include mineral diesel were tested experimentally in a diesel engine with the in-cylinder pressure data measurement for 1000 cycles. These data were analyzed using the coefficient of variation (COV) and wavelet power spectrum (WPS). Fuel properties test results showed significant differences in density and acid value with a significant reduction in viscosity when diesel is blended with biodiesel at 20%. Despite that, the low heating value was significantly affected for B20 compared to pure biodiesel. While as for the wavelet analysis results, the short period oscillations appear periodically in pure biodiesel and mineral diesel, but in contrast, the long and intermediate-term periodicities has are found in B20. Moreover, the spectral power has increased with B20, which attributed significantly to the engine cyclic variations. This characteristic validated the coefficient of variation (COV) for the indicated mean effective pressure (IMEP) time series that B20 produces the lowest fluctuation in cyclic variations compared to other fuels.

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Keywords: diesel-biodiesel; fuel properties; wavelet analysis; cyclic variations; diesel engine

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1. Introduction

The current situation of fossil fuel is very critical, and it is become urgent to look for a suitable alternative due to the continuous increasing demand for these fuels and depleting of their sources. The transportation sector is the primary consumer of these fuels because of the huge number of vehicles that uses in different walks of life [1]. Diesel fuel occupies the larger share of fuel trade in 2010 resulting from the extensive usage of a diesel engine in the different a applications [2]. Furthermore, the usage of fossil fuel can be considered as the main contributor to air pollution and global warming. Diesel engine designed and developed to operate using mineral diesel fuel, therefore, it is important to look for a suitable alternative with similar characteristics to suit the existing diesel engines. Though many alternative fuels have been suggested to replace mineral diesel in a diesel engine, it is still facing the challenge of high engine modification cost. Therefore, the implemented alternative fuel should be suit the current engine design. Biodiesel fuel has been considered as the unique alternative fuel that can be used directly for a diesel engine with no or little modification. The different sources of biodiesel are available in mostly all the regions of the world and can be considered as a domestic product. Furthermore, these fuels can be adopted to mitigate the environmental pollution from diesel engine due to the high CO_2 saving and fewer engine emissions [3]. In general, the properties of biodiesel from different sources are slightly different depending on the biodiesel feedstock according to the ASTM biodiesel fuel standard. The blending of biodiesel with mineral diesel is one of the common methods to introduce biodiesel as a fuel for direct usage in diesel engine under the ASTM blended fuel standard [4,5]. Accordingly, selection of the maximum percentage of biodiesel for blending with diesel according to the blended fuel standard depends on the biodiesel feedstock property. Therefore, evaluating the blended fuel properties is the most important criteria to choose the suitable blend ratio.

Engine cyclic variation has been investigated recently by many researchers as it is related to the output power and fuel consumption [6,7]. The earlier studies mainly focused on spark ignition engine. However, recent studies were conducted to analyze diesel engine cyclic variations with different alternative fuels [8]. These fuels have different chemical combustion and therefore, different combustion behavior is expected. Accordingly, the engine stability for long-term operation should be considered and evaluated using diesel fuel as the threshold.

The aim of this paper is to characterize the blended fuel, B20 properties compared to the palm biodiesel and mineral diesel as well as according to the biodiesel blended fuel standard ASTM D7467. Moreover, this study also evaluates the engine cyclic variations at 2500 rpm with engine load of 60%, operating with the test fuels at 1000 cycles each using the coefficient of variation of the indicated mean effective pressure (COVimep) and wavelet spectrum analysis approach.

Nomenclature

COV	coefficient of variation
WPS	wavelet power spectrum
IMEP	indicated mean effective pressure
COVimep	coefficient of variation of the indicated mean effective pressure

2. Methodology

Palm biodiesel is also known as palm oil methyl ester (POME) which purchased from a local biodiesel production company in Pahang, Malaysia. While as for mineral diesel fuel to be a reference fuel was provided by a commercial fuel supplier. Samples of palm biodiesel and mineral diesel were prepared using an electric, magnetic stirrer for mixing and blending into B20 fuel (80% vol. mineral diesel + 20% vol. palm biodiesel). These blend fuels were stirred continuously for an hour to achieve well blending and left for an hour to reach the stability before being tested. The use of biodiesel in different blending could provide some limitations such as higher lubricity, reduction in ignitability, shorter ignition delay, lower volatility and higher cetane number. Test fuel samples were analyzed for the density measurement at the temperature of 15 °C using the Portable Density/Specific Gravity Meter (model DA-130N). Also, the viscosity analysis was conducted on the test fuels using a digital constant temperature kinematic viscosity bath model K23376-KV1000 at a steady temperature of 40 °C ±0.01. While as for the acid value content, the test fuels were measured by a Metrohm test instrument model 785 with referring to the method procedure proposed by American