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Study of a diesel engine performance with exhaust gas recirculation (EGR) system fuelled with palm biodiesel

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Abstract

The increase in world population leads to the growth in energy demand. The primary sources of this energy come from the combustion of fossil fuel which producing oxides of nitrogen and other harmful greenhouse gas emission. However, biodiesel offers a solution as an alternative fuel for internal combustion engine but higher in NOx emission. Exhaust gas recirculation (EGR) system is used to lower the NOx emission. This paper focuses on determining the effect of EGR and palm biodiesel on fuel consumption (SFC), exhaust gas temperature (EGT) and exhaust emissions (NOx, CO, UHC, and CO_2). Experimental works using a multi-cylinder diesel engine with EGR and simulated works using Diesel-RK were performed at a constant engine speed of 2500 rpm in full load condition. The results showed that, from the simulated and experimental works, palm biodiesel significantly increased fuel consumption, increased NO_x and slightly decreases in other emissions including CO_2, CO, and unburned hydrocarbon (UHC). However, the use of EGR shows a significant reduction in the NOx emission and exhaust temperature but increases in fuel economy, CO, CO_2, and UHC emissions.

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Keywords: Diesel engine; exhaust gas recirculation (EGR); engine performance; exhaust emission; palm biodiesel;

1. Introduction

Renewable and alternative fuels from sustainably available feedstock sources have been the vital subject of research in recent years for replacing current petroleum fuels. These alternate fuels are suggested for opposing the adverse effects contributed by the present use of petroleum fuels in transportation and power generation [1, 2].

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Harmful gasses such as NOx and CO are emitted by the petroleum fuels which cause severe effects to the human health and environment [3]. Interestingly, these substitute fuels are mainly produced from edible and non-edible oils, originated from living feedstocks [4, 5]. Therefore, numerous studies on biofuels including biodiesel have been conducted regarding performance and emission characteristics of diesel engines with partial or complete replacement with the petroleum fuels [6, 7]. Biodiesel or methyl ester is originated from monoalkyl esters of long chain fatty acids which mainly produced from edible and non-edible oils of plants and animal fats [8]. Due to the molecular similarities between biodiesel and petroleum-based diesel and able to be used directly or partially without any engine modification, this substitute fuel secures possible high chances in replacing the current fuel in the future. However, biodiesel has drawbacks such as higher density and viscosity. Through transesterification process, the higher viscosity is reduced to achieve a closer value with petroleum diesel whereas cetane number and heating value are preserved. In general, the combustion of biodiesel in diesel engines contributes lower carbon monoxide (CO), unburned hydrocarbon UHC), particulate matters (PM) and smoke emission while conversely emits higher oxides of nitrogen (NOx). Many experimental works can be conducted to investigate the effect of EGR on a different type of fuels such as biodiesel based on the engine performance, combustion and emission characteristics [9, 10]. Previous research work results [10-13] significantly disclosed that EGR in modern engines is one of the most efficient methods for reducing NOx emissions. On the other hand, despite experimental works require a possible cost, time and manpower, there are some proposed approaches including numerical simulation and modeling methods [14, 15]. One of the engine simulation software that proposed is Diesel-RK software that purposely for the calculation and optimization in the internal combustion engines. The software, Diesel-RK is a multi-zone, full cycle, 1-D engine simulation software, which established by Razleytsev, Andrey Kuleshov, and others at Bauman Moscow State Technical University (BMSTU) and is still developed until the present day [16, 17]. It is designed to simulate and optimize the thermodynamic working processes of two and four stroke engines that covered all kinds of air boosting including turbocharging [18].

Since the comparison for both EGR and normal modes is required for the fuel testing, both experimental work and numerical investigation are needed to determine and analyze the effect of EGR on different fuels at different engine operating modes [19-21]. This aim of this paper is to identify the palm biodiesel characteristics and mineral diesel as a reference fuel regarding specific fuel consumption (sfc), exhaust gas temperature (EGT) and emissions of NOx, CO, CO2 and unburned hydrocarbon (UHC) in the experimental and simulated study operating with EGR. The test for both fuels is conducted at a constant engine speed of 2500 rpm in full load condition.

Nomenclature

EGR	exhaust gas recirculation
NOx	oxides of nitrogen
CO	carbon monoxide
CO_2	carbon dioxide
UHC	unburned hydrocarbon
EGT	exhaust gas temperature

2. Methodology

In the present work, palm biodiesel and mineral diesel were purchased from Mission Biofuels Sdn. Bhd and a commercial petrol station. Palm biodiesel is produced by a transesterification process which using KOH as alkali catalyst and methanol as alcohol. Then, the purchased palm biodiesel was analyzed for the fuel properties at UMP Central Lab according to the manufacturer standard. The important properties of palm biodiesel and mineral diesel are listed in Table 1 correspondingly.The experimental work was performed using a four-stroke, four cylinder diesel engine with EGR type diaphragm as shown in Fig. 1. This engine is a naturally aspirated (NA) diesel engine with a bore of 82.7 mm, stroke 93 mm and a compression ratio of 22.4:1. The engine is an air-cooled with the maximum power was 64.9 kW at 4500 rpm. More details are listed in Table 2. Test engine is directly coupled to an eddy-current brake *ECB* dynamometer and controlled using a Dynalec load controller.