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Engine Performance and Exhaust Emission Effect of Increasing Euro5 Diesel Fuel Blended with 7% to 30% Palm Biodiesel

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ABSTRACT

Biodiesel blend fuels have gained popularity over the year due to their ability to be used in conventional diesel engines without any modifications and have proven to be a cleaner fuel. The Malaysian National Automotive Policy (NAP) 2020 projects the usage of biodiesel blend B30 (30%) to be implemented by the year 2025 or earlier. Most manufacturers approve its usage but do not suggest using a higher blend than 20%. This paper focuses on the difference in engine performance and exhaust emissions between 7 % and 30% Euro 5 diesel-biodiesel blend. The fuels used are Euro 5 diesel fuel blend with 7% (B7) and 30% (B30) palm biodiesel. The fuel is tested on a Toyota Hilux model KUN 25 with a 2KD-FTV engine. Chassis dynamometer tests were conducted on a steady-state condition for speeds 30, 60, 90, and 110 km/h with accelerator pedal positions (APP) of 45% and 90% measuring its brake power, BSFC, and exhaust emissions of CO2, CO, and NOx. It was found that B30 produced slightly lower brake power than B7 and slightly higher BSFC than B7. Both CO2 and CO emissions for B30 are lower than B7, with a more significant difference at speed 30 km/h at all APP conditions. NOx emission for B30 is higher at speed 30 km/h but slightly lower at speed 60, 90, and 110 km/h than B7. Therefore, increasing Euro 5 biodiesel blend from 7% to 30% slightly lowers brake power, increases BSFC, lowers CO2 and CO emissions, and increases NOx emissions.

Keywords:
Biodiesel; engine performance; exhaust emission

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1. Introduction

Diesel engines are currently one of the most common requirements in a wide range of industries due to their superior fuel economy, improved efficiency and long-lasting capacity [1]. Using petroleum diesel fuel in CI engines causes depletion of both fossil fuels and the environment where the combustion of these fuels resulting in deteriorated air quality due to the emission of air pollutants such as nitrogen oxides (NOx) and particulate matter (PM), as well as igniting the climate change issue due to the release of carbon dioxide (CO2) [2]. In order to overcome some of the environmental problems, Euro emission standards is introduced and it starts in 2005 with Euro 4 that sets a maximum sulphur of 50 ppm in automotive fuels however it reduced lubricity of fuel [3]. The process

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of removing sulphur is called desulphurization[4]. Nevertheless, every country is attempting to address environmental challenges by imposing strict emission standards on a daily basis. The widespread use of non-renewable fuels prompted the researcher to concentrate on alternative renewable fuels and finding initiatives for the manufacture to use [5].

Seed oil biodiesel, a low-cost renewable biofuel with clean-burning properties, has been discovered to have the ability to decrease global dependency on petroleum diesel fuels[6]. Another source for biodiesel is microalgae due to its capability of rapid growth that produces high biomass yield [7]. Biodiesel may be mixed with diesel and used in diesel engines without any modifications [8]. The transesterification process produces biodiesel by reacting oils and alcohol in the presence of acids, bases, enzymes, or other catalysts [9]. The lubricity of biodiesel is significant since most diesel engine components, such as fuel injectors and fuel pumps, are self-lubricated. Due to the lack of polar molecules removed during the desulphurization process, high-speed diesel has poor lubricity [10].

The research found that the best biodiesel/diesel fuel mix was a 20/80 biodiesel/diesel fuel blend. It lowered PM, THC, and CO emissions while increasing NOx [11]. Studies show that palm biodiesel blend B20 produced lower thermal efficiency, increased BSFC, reduced emission of CO and HC, and increased NOx emission [12]. Increasing biodiesel ratio to 30% reduced engine brake power by 2.6% and increased BSFC by 3% without a significant difference in thermal efficiency [13]. Another study shows that in the range of biodiesel blend B10 to B40, BSFC is at its best without sensible change in engine power [14]. The use of 100% palm biodiesel shows a difference in application between low, mid, and high speed where at high speed, NOx and CO emission is equal to diesel, but CO2 emission is higher than diesel [15]. A study using castor biodiesel B20 shows the same power output as diesel with better combustion and lower PM, CO, and HC emissions compared to diesel [16].

National Automotive Policy (NAP) 2020, projecting the usage of biodiesel blend B30 to be implemented by the year 2025 or earlier [17]. Most car manufacturers approve biodiesel usage but do not suggest using biodiesel blends higher than 20%. This paper aims to show the difference in engine performance and emissions between 7% (B7) and 30% (B30) Euro 5 diesel biodiesel blend.

2. Methodology

This test is done in a Toyota Hilux 2.5L as a test vehicle. Table 1 shows the specifications of the test vehicle. The test vehicle is mounted to the 4022 Dynapack chassis dynamometer hub via a coupling mechanism to the tires to measure brake torque and brake power. Fuel consumption is measured using Ono-Sokki FZ 2100, which uses the Coriolis force principle, generated when the movement of mass and rotation coincide. Exhaust gas emissions are measured using Kane AutoPlus emission analyzer detecting CO2, CO, and NOx. Innovate Motorsport LM-2 Digital AFR Meter is used to measure its air-fuel ratio. Bosch diagnostic scan tool KTS 570 V1.2 is used in the experiment to monitor and record vehicle speed, accelerator pedal position, coolant temperature, intake air temperature, and engine load. Fuel tested are palm biodiesel diesel Euro 5 blend B7 and B30 provided by MPOB. Biodiesel diesel blend B7 is the baseline as it is commonly found in fuel station. The fuel properties are shown in Table 2. The experiment is conducted in a steady-state setting with a constant speed of 30, 60, 90, and 110 km/h simulating rural, urban, and motorway speed. Gear is set at position four, where the gear ratio is 1:1. The accelerator pedal position represents the load on the engine with a value of 45, and 90%. The experiment setup is shown in Fig 1.

Table 1
Test Vehicle Specification

Item	Specification
Engine	4x4, 2.5 litre D-4D Diesel
Engine Code	2KD-FTV
Number of Cylinder	4 *In-line*
Valve Mechanism	16 valve DOHC
Fuel System	Common-rail Direct Injection
Engine Displacement	2494 cc
Bore	92 mm
Stroke	93.8
Compression Ratio	17.4:1
Max Power	120 DIN 80 kW/3600 rpm
Max Torque	325Nm/2000 rpm
Fuel Tank Capacity	80 litre

Table 2
Test Fuel Properties

Properties	**B7 (Baseline)**	**B30**	**Method**
Density at 15°C, kg/L	0.8247	0.8336	ASTM D4052-18a
Kinematic Viscosity at 40°C, mm^2/s	3.025	3.369	ASTM D445-19a
Flash Point, °C	72.0	79.0	ASTM D93-20
Cetane number	57.6	58.2	ASTM D613-18a
Sulfur, mg/kg	2.82	2.45	ASTM D5453-19a
Calorific Value, kJ/kg	45790	44409	ASTM D240-19

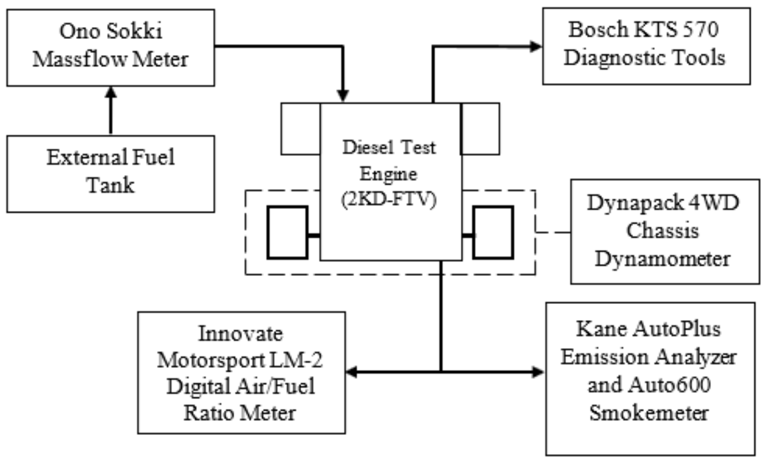

Fig. 1. Experiment testbed setup

3. Results

3.1 Engine Performance

The performance of diesel engines at various degrees of road speed and accelerator pedal position is explained in the subsections below. The correlations between various road speeds and accelerator pedal positions with brake power and brake specific fuel consumption are presented in Fig 2 and Table 3. The highest brake power produced for APP 45% is at road speed 60 km/h, while APP 90% is at road speed 110 km/h. Percentage difference for BP range from 2.85% to 15.65%. The output BP decreases with the increase of biodiesel blend percentage. The decrease in BP as the percentage of biodiesel blend increase might be attributed to lower calorific value and higher cetane number of B30 compared to B7. The BSFC is highest at APP 45% for road speed 60, 90, 110 km/h. At APP 90%, road speed does not affect the BSFC. Percentage difference for BSFC range from 0.36% to 7.76%. It is also observed that BSFC increased as the biodiesel blend percentage increased. As the percentage of biodiesel in the blend increases, the calorific value decreases while the specific gravity increases, resulting in higher fuel consumption for the same amount of energy produced.

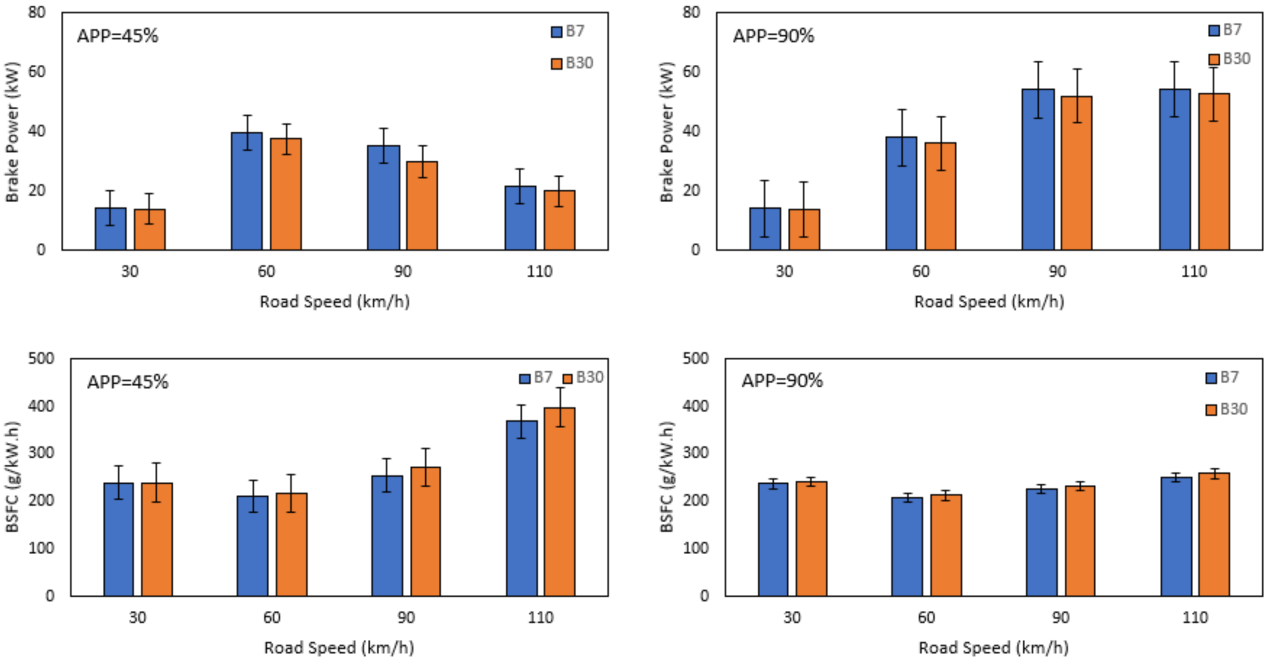

Fig. 2. BP and BSFC comparison between B7 and B30

Table 3
Percentage difference for engine performance and exhaust emissions

	Percentage Difference (%)							
Road Speed (km/h)	APP 45				APP 90			
	30	60	90	110	30	60	90	110
BP	3.30	5.64	15.65	8.52	2.85	5.18	4.09	3.06
BSFC	0.36	2.98	6.47	7.76	1.99	2.35	2.26	2.57
CO_2	4.20	3.15	9.03	4.47	4.12	2.97	4.90	4.10
CO	53.33	0.00	66.67	0.00	47.62	0.00	0.00	0.00
NOx	7.91	0.20	10.92	88.51	7.57	1.59	3.53	1.93

3.2 Exhaust Gas Emission

The exhaust emission results for various road speeds and APP are presented in this subsection. The correlation between various road speeds and APP with emission gases is presented in Fig. 3, Fig. 4 and Table 3. Emissions of carbon dioxide and carbon monoxide produced by the combustion of B7 and B30 are shown in Fig 3. Emission of CO_2 decreases when road speed increase. When the APP increases from 45 to 90%, an increment is detected for road speeds 90 and 110 km/h. Increasing biodiesel blend decreases the CO_2 emission. However, the change is small range from 0.16 to 0.4 volume percentage. When the road speed increase from 30 to 110 km/h, the CO emission decrease. As the biodiesel blend increased, the CO emission decreased. This can be observed clearly at road speed 30 km/h where at APP 45, and 90 %, the percentage difference is 53.33%, and 47.62% respectively. This might be due to renewable fuel's greater cetane number, which has strong igniting qualities.

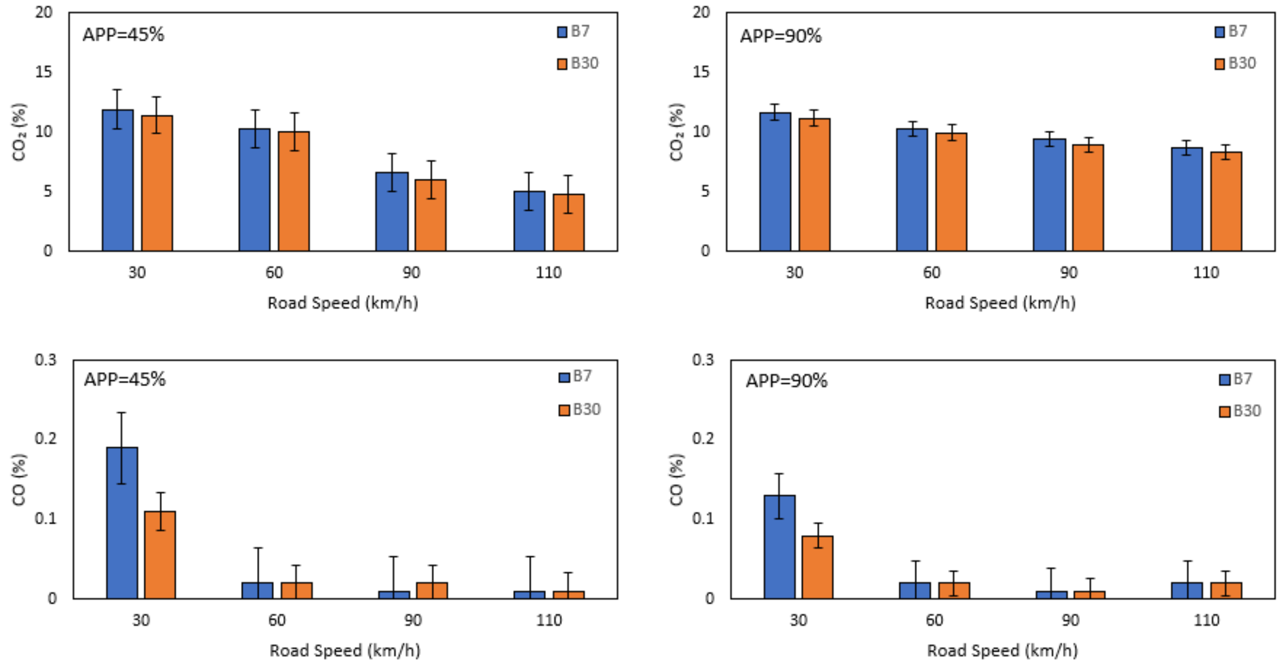

Fig. 3. CO_2 and CO (%) comparison between B7 and B30

Figure 4 and Table 3 shows the variation of NOx emissions with different road speeds and APP comparing between B7 and B30. When the road speed increase, the value of NOx decreases for all APP. B30 produced higher NOx emissions compared to B7 at lower speed and the difference is narrower as the road speed increases. Percentage difference range from 0.2% to 10.92% with an exception for APP45, road speed 30km/h. The presence of oxygen and greater cetane number might be the reasons.

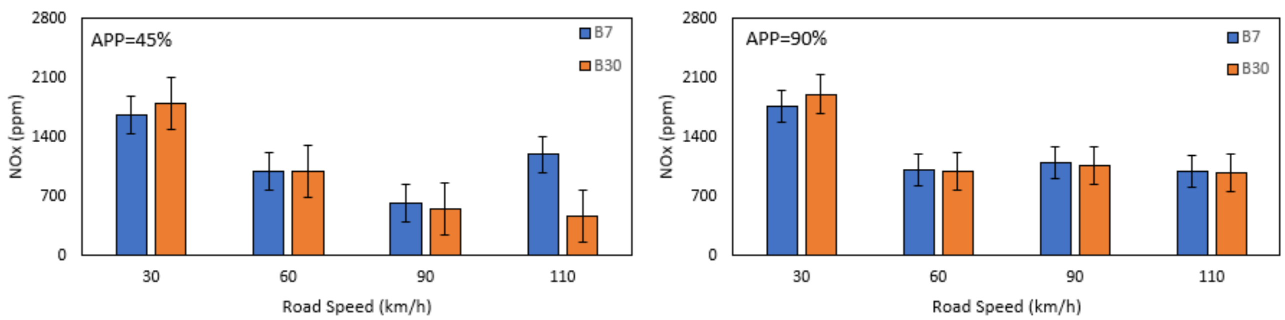

Fig. 4. NOx comparison between B7 and B30

4. Conclusions

In conclusion, increasing the percentage of palm biodiesel from 7% to 30% in Euro 5 biodiesel does not drastically change its engine performance and exhaust emission. B30 produced slightly lower BP compared to B7. B30 has a slightly higher BSFC compared to B7. The emission of CO2 and CO decreased for B30 compared to B7. Emission of NOx increases for B30 compared to B7 for lower speeds but not significantly for higher speeds. Overall, difference obtain does not exceeds 30%.

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