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Investigation of Performance Characteristics of Diesel Engine Fueled with B5 Diesel

M. N. Ahmad*, A. H. Ab Halim and R. N. Raja Ab Kadir

Department of Mechanical Engineering, Port Dickson Polytechnic, Negeri Sembilan, Malaysia

*Corresponding author: mnahar@polipd.edu.my

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ABSTRACT – *A Yanmar 1-cylinder diesel engine was used to investigate the performance of the diesel engine. Standard experimental protocols were followed. Engine fuel consumption, brake fuel consumption, brake power, and torque were all measured with B5 diesel fuel. At varying engine speeds, different engine loads were established. As the engine speed is raised from 1400 to 1700 RPM under constant loads of 2, 4, and 6 kW, there will be a reduction in brake-specific fuel consumption alongside an increase in fuel usage, brake power, and torque. At a constant engine speed of 1400, 1500, 1600, and 1700 RPM, a rise in engine load from 2 kW to 6 kW will lead to higher fuel consumption, braking power, and torque while still resulting in lower brake-specific fuel consumption.*

KEYWORDS: Fuel consumption, brake fuel consumption, brake power, torque, diesel engine, Diesel B5

1. INTRODUCTION

Modern diesel technology, which combines the engine’s natural low fuel economy with exceptional driving performance and low-emission characteristics, has altered the perception of diesel engines as noisy, smoky, and slow generators. Worldwide, two- or four-stroke compression ignition engines with airless fuel injection are referred to as “diesel engines”. These engines can run on a variety of fuels and provide more power (Kowalewicz and Wojtyniak, 2005). Internal combustion engines are under increasing pressure to perform significantly better, though improving fuel consumption has become more challenging due to emission control regulations. Since then, much research has been conducted on the use of alternative fuels in place of diesel (Kowalewicz & Wojtyniak, 2005; Rao et al., 2007). Diesel engines, renowned for their high thermal efficiency and robust performance, are the workhorses of various sectors, including transportation, agriculture, and power generation (Douvartzides et al., 2019). A comprehensive investigation into the performance characteristics of diesel engines fueled with B5 diesel, a blend of 5% biodiesel and 95% conventional diesel fuel, is crucial for assessing the feasibility and benefits of this biofuel blend (Moshiri et al., 2006).

The use of biodiesel blends in internal combustion engines offers a multifaceted approach to mitigating the environmental impact of conventional fossil fuels and enhancing engine performance (El-Seesy et al., 2017). B5 diesel, a blend of 5% biodiesel and 95% conventional diesel, has emerged as a viable alternative fuel in the automotive industry, balancing sustainability and operational compatibility (Ku et al., 2013). Comprehensive investigations into the performance characteristics of B5-diesel-fueled diesel engines are crucial for assessing their feasibility and potential benefits in real-world applications. The evaluation encompasses a spectrum of parameters, including engine power output, fuel consumption, combustion characteristics, and exhaust emissions, providing a holistic understanding of the fuel's behavior within the engine (Izzudin et al., 2020). Furthermore, long-term durability assessments are essential to ascertain the impact of B5 diesel on engine components and overall system longevity (Ku et al., 2013). The inherent physicochemical properties of biodiesel, notably its oxygen content, elevated viscosity, and cetane number, exert a complex influence on the combustion dynamics and overall performance of diesel engines.

Particularly, the lower heating value (LHV) of the fuel plays a vital role in determining engine performance, as it directly influences parameters such as brake-specific fuel consumption and thermal efficiency (Tesfa et al., 2013). Studies indicate that biodiesel blends exhibit performance characteristics comparable to conventional diesel, with slight variations in power output and thermal efficiency, as noted in the findings where biodiesel produced lower emissions of CO2, CO, and hydrocarbons, while increasing NOx emissions (Kamil et al., 2019).

The evaluation of key performance indicators, specifically power output and efficiency, is essential in assessing the operational effectiveness of diesel engines, particularly those fueled with B5 diesel blends. The combination of biodiesel and conventional diesel not only influences fuel characteristics but also significantly impacts combustion dynamics and performance metrics. Enhanced power output is often associated with the optimized combustion process facilitated by the fuel’s composition, as noted in research emphasizing the role of nanoparticles in biodiesel applications (Ampah et al., 2022). Moreover, the quest for higher efficiency is intertwined with the need to reduce harmful effects. The engine will be loaded with 3 different loads: 2 kW, 4 kW, and 6 kW. Different engine speeds will be set based on the load, including 1400 RPM, 1500 RPM, 1600 RPM, and 1700 RPM. The engine's torque and the time it takes to consume 20 milliliters of B5 diesel will be recorded.

2. METHODOLOGY

The experiment was conducted on a horizontally mounted, naturally aspirated, single-cylinder, four-stroke, air-cooled engine. The engine specifications are given in Table 1. A single-cylinder diesel engine and a dynamometer test bed were used to gather experimental data, as shown in Figure 1. The single-cylinder diesel engine was connected to a dynamometer, which applies workload to the engine. All parameters required for this experiment, such as torque and engine speed, can be read on the dynamometer test bed display. The diesel fuel is filled to the correct level in the tank, and the amount needed for this test is measured using a fuel flow meter. The engine speed is controlled by the throttle lever on the engine. The single-cylinder diesel engine was started by disconnecting the starter handle from the mounting fixture and attaching it to the starter shaft. A load of 2 kW was set on the engine, and the engine speed was adjusted to 1400 RPM. For this experiment, B5 diesel fuel was used at a volume of 20ml. The fuel consumption was recorded until the 20ml of B5 diesel fuel was consumed.

The torque reading was taken on the dynamometer test bed. The procedure was repeated using engine speeds of 1500 RPM, 1600 RPM, and 1700 RPM. The engine loads were adjusted to 4kW and 6kW. Table 2 shows the speeds and loads to be set along with the data to be collected for this test.

TABLE 1: Diesel engine specification

Particulars	Specifications
Make and Model	Yanmar TF90M/ME
Continuous Rating	8.5hp@2400rpm
Output Cylinder	1
Combustion Cooling	Direct Injection Water
System Bore x Stroke	85 x 87 mm 0.493 liter
Displacement Length	662 mm
Width	330.5 mm
Height	496 mm

TABLE 2: Experimental data

1400 RPM			1500 RPM			1600 RPM			1700 RPM		
2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW

FIGURE 1: Single cylinder diesel engine

3. RESULTS AND DISCUSSION

The results of this experiment for 2 kW, 4 kW, and 6 kW loads at various speeds of 1400, 1500, 1600, and 1700 RPM are exhibited in Table 3. According to the results, as speed increases, the time required to use 20 ml of fuel decreases. Overall, the torque results likewise indicate an increasing value across various speeds and workloads.

TABLE 3: Performance of the engine for 2 kw, 4 kw and 6 kw of load

	1400 RPM			1500 RPM			1600 RPM			1700 RPM		
	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW
Time (s)	144	82.8	67.2	138	77.4	63	130.8	72.6	57	122.4	66	51.5
Torque (Nm)	6.1	14.7	21.2	6.6	15.7	22.4	6.9	16.7	23.4	7.4	17.8	25

The brake power $\dot{W}_b$ can be calculated as follows:

$$\dot{W}b = (2\pi N{*}\tau) / 60 \qquad (1)$$

Where,

$\dot{W}b$ = *brake power (kW)1*
N = *RPM*
T = *torque*

Table 4 shows the results of brake power at different engine speeds.

TABLE 4: Results of brake power at different engine speeds

	1400 RPM			1500 RPM			1600 RPM			1700 RPM		
	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW
Torque (Nm)	6.1	14.7	21.2	6.6	15.7	22.4	6.9	16.7	23.4	7.4	17.8	25
Torque (Nm)	0.89	2.15	3.10	1.03	2.46	3.51	1.15	2.79	3.92	1.31	3.16	4.45

The value of fuel consumption $\dot{m}f$ can be calculated as follows:

$$\dot{m}f = (20 \times 10\text{-}6^{*}\ \rho)/(time\ (sec)) = kg/sec \tag{2}$$

Where

$\dot{m}f$ = *mass flow rate of fuel*
ρ = *Density of biodiesel B5*

From the result in (2), the specific fuel consumption *bsfc* can be determined as follows:

$$bsfc = (\dot{m}f)/\dot{W}_b \tag{3}$$

Where
bsfc = *brake specific fuel consumption*
$\dot{m}f$ = *mass flow rate of fuel*
$\dot{W}_b$ = *brake power (kW)*

The results of fuel consumption and specific fuel consumption are shown in Table 5.

TABLE 5: Fuel consumption and brake-specific fuel consumption

	1400 RPM			**1500 RPM**			**1600 RPM**			**1700 RPM**		
	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW	2kW	4kW	6kW
Fuel consumption (x10-4) (kg/sec)	1.2	2.1	2.62	1.28	2.27	2.79	1.35	2.42	3.09	1.44	2.67	3.42
Brake specific fuel consumption (kg/kW.hr)	0.49	0.35	0.30	0.44	0.33	0.28	0.41	0.31	0.28	0.39	0.30	0.27

The results of the experiment are shown in Figure 2, illustrating the relationships between engine speed and fuel consumption and brake-specific fuel consumption for loads of 2 kW, 4 kW, and 6 kW. When the engine speed increases from 1400 RPM to 1700 RPM, Figure 2 shows the rising fuel consumption values for loads of 2 kW, 4 kW, and 6 kW. This is due to the engine's friction losses. This is accurate since higher engine speeds lead to greater heat loss, which raises fuel consumption (Pulkrabek, 2004).

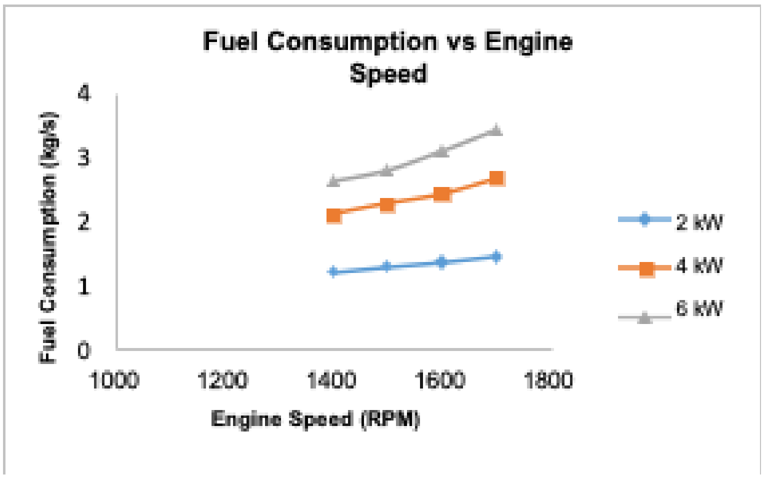

FIGURE 2: Relation between fuel consumption and engine speed

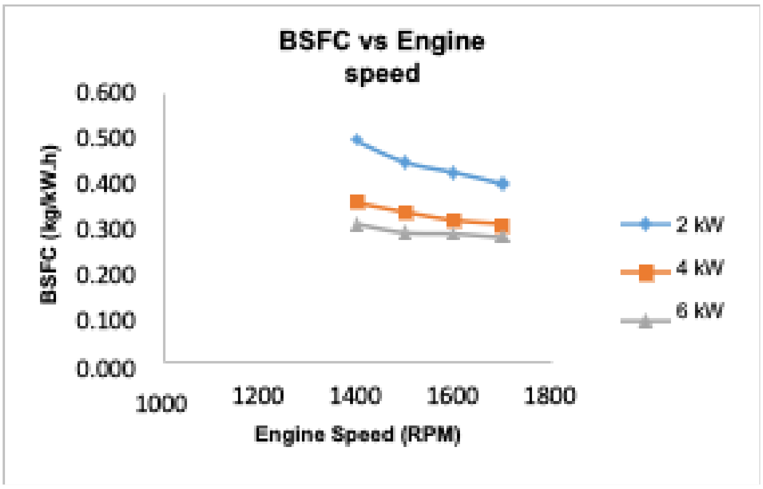

FIGURE 3: Relation between brake-specific fuel consumption and engine speed

Figure 3 illustrates the relationship between brake-specific fuel consumption and engine speed for loads of 2 kW, 4 kW, and 6 kW. The data show that the value of brake-specific fuel consumption decreases as engine speed increases, due to shorter heat loss duration during each cycle (Pulkrabek, 2004). This finding was supported by an experiment conducted by Özkan et al. (2005). Özkan et al. (2005) found that brake-specific fuel consumption of a diesel engine decreases as engine speed increases. Özkan et al. (2005) experimented using a single-cylinder diesel engine at speeds ranging between 1000 RPM and 2000 RPM at 100% load. Figure 4 shows the comparison between the results of Özkan et al. (2005) and the result at 6 kW of load.

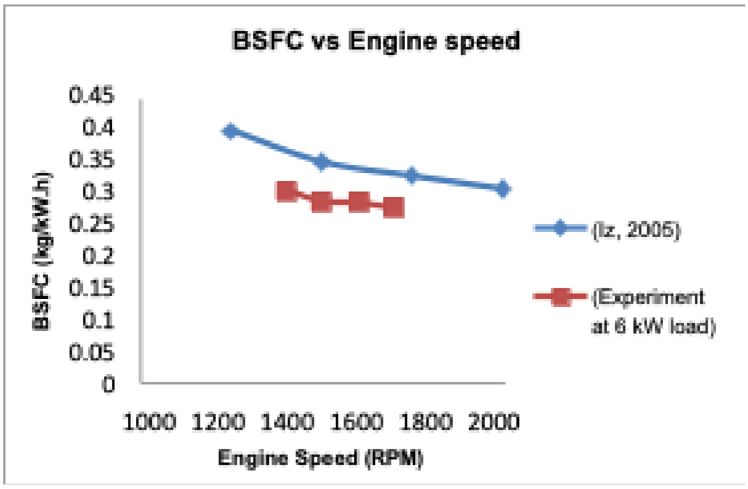

FIGURE 4: Comparison between Özkan et al. (2005) and experiment

Figure 5 shows the brake power as a function of load and engine speed. From Figure 5, the brake power increases with the engine speed. All applied loads, including 2kW, 4kW, and 6kW, display similar behavior. The brake power of the 6-kW load is 29.3% higher than the brake power at the 4-kW load and 70.7 % higher than at 2 kW of load. The graph rises until reaching its maximum value, then is predicted to decrease until the engine speed reaches 2400 RPM. This is because friction losses increase with speed and become the dominant factor at very high speeds (Pulkrabek 2004). This finding is also supported by the experiment conducted by Liaquat et al. (2013), where 5% of coconut oil was blended with 95% of diesel fuel (CB5). The brake power increases as engine speed rises, reaching a maximum value at 2200 RPM, then decreases until the engine reaches 2400 RPM.

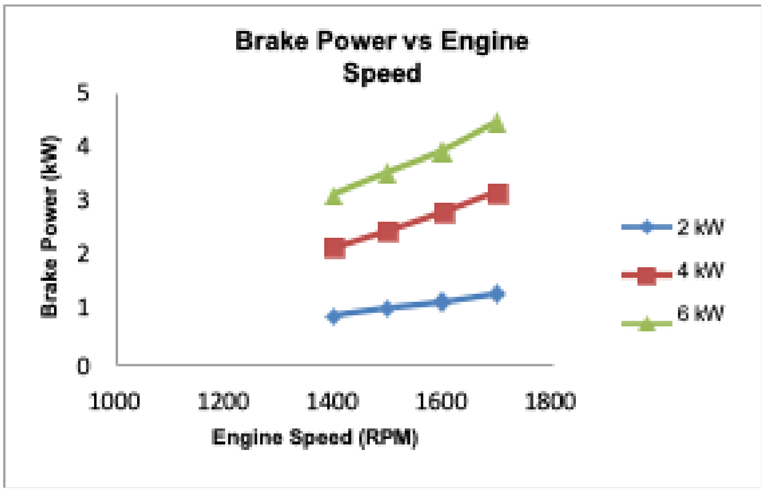

FIGURE 5: Brake power vs. engine speed at different loads

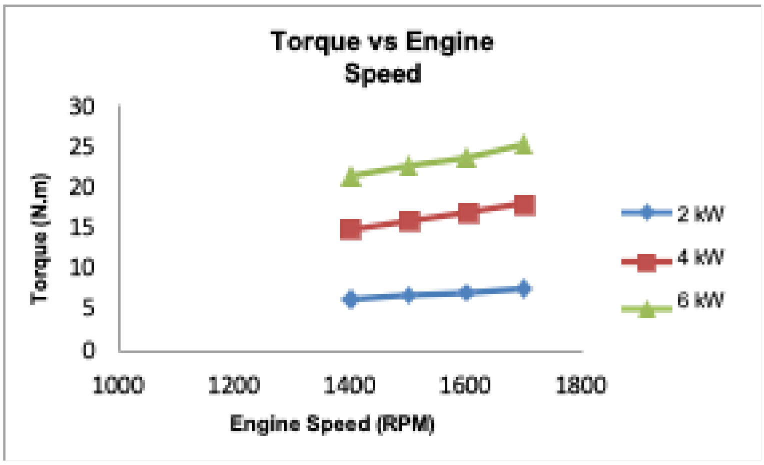

FIGURE 6: Torque vs. engine speed at different loads

Figure 6 shows the relationship between torque and engine speed for indicated loads of 2 kW, 4 kW, and 6 kW. For 2 kW of indicated load, the torque increased from 6.1 Nm to 7.4 Nm at 1400 RPM to 1700 RPM. From this, the point of MBT speed is 7.4 Nm at engine speed 1700 RPM. At 4 kW indicated load, torque also increased from 14.7 Nm to 17.8 Nm, higher than at 2 kW of indicated load. From this, the point of MBT speed is 17.8 Nm at 1700 RPM. For 6 kW indicated load, torque increased more than at the lower loads, from 21.2 Nm to 25 Nm at 1400 RPM to 1700 RPM. The MBT point here is 25 Nm at 1700 RPM. Liaquat et al. (2013) observed a similar relationship between torque and engine speed. By using a blend of 5 % of coconut oil with 95% diesel fuel, the relationship shows that torque increases with engine speed until reaching a maximum value at 2200 RPM, then decreases as the engine speed approaches 2400 RPM.

4. CONCLUSION

The performance characteristics of the 1-cylinder, 4-stroke diesel engine were analyzed and compared using various parameters such as fuel consumption, brake-specific fuel consumption, power, and torque. Increasing the engine speed from 1400 to 1700 rpm resulted in higher fuel consumption, brake power, and torque, while reducing brake-specific fuel consumption by 2 kW, 4 kW, and 6 kW for each constant load. As the load increased from 2 kW to 6 kW, the fuel consumption, brake power, and torque also increased, whereas the specific fuel consumption of the brake decreased at each constant engine speed of 1400, 1500, 1600, and 1700 RPM. In many diesel engines (CI engines), the maximum braking power is approximately one and a half times the maximum torque obtainable at an engine with higher torque operating at a slower speed.

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