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Investigation into Brake Power for Performance of the Dynamic Behavior of Alternative Fuel

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ABSTRACT – *Over the years, some researchers have said that the performance of biodiesel fuel has surpassed diesel fuel in terms of brake power and is slightly lower in terms of brake-specific fuel consumption in the same situation for the amount of air and fuel it has injected into the combustion. Studies have shown that long-term exposure to high levels of this brake power affects alternative fuel performance. For this purpose, several research methods were arranged, including the compilation of literature data on engine performance. Preparation of materials and equipment, and preparation of different types of fuel, as well as engine experimental setups to establish comparisons between various studies. The alternative tested fuel types were B5M10, B10M10, B5M10E3, B10M10E3, where B stands for biodiesel, M for methanol, E for emulsion fuel, and the number stands for the ratio. The competition to produce better brake power and environmentally friendly fuels has made emulsion fuel and biodiesel renewable fuels believed to be new alternative fuels that emit very few particles into the atmosphere.*

KEYWORDS: Brake power, alternative fuel, emulsion, biodiesel, environmental

1. INTRODUCTION

Diesel engines have been found to produce a wide range of complex hazardous gases and particulate matter, especially at high load. Moreover, diesel exhaust also contains a variety of heavy metal gases, including aerosols and soot, sulfates, metallic abrasion particles, silicates, and ash particulates (Chien et al., 2009). The purpose of including 5% and 10% biodiesel ratios in alternative fuels is that the amount of oxygen in a combustion system affects particulate matter formation. A high oxygen content will aid the combustion process and improve energy efficiency (Wu et al., 2010). Meanwhile, a 10% methanol additive will reduce the effect of fuel blending and improve fuel quality. A properly mixed small amount of water at a 3% ratio will enhance the properties of fuel, as water in small quantities can help isolate the oxygen in the fuel, which indirectly aids combustion. Alternative fuels with additives will form two advantages in terms of their chemical formation and their physical properties (Kumar et al., 2016; Mohankumar & Senthilkumar, 2017; Xiao et al., 2017). All alternative fuels tested are compared with diesel fuel in this study. The operation to determine the performance of the 5 types of fuel was carried out in a one-cylinder engine. The YANMAR TF120M diesel engine and test equipment are ready to operate, and there is some major testing equipment, including a 15-kW eddy current dynamometer, TFX data acquisition, dump load (high voltage), a blue container for the ventilation system, and two barrels of oil. Equipment and engines should always be maintained to ensure they are always safe for operation.

2. METHODOLOGY

2.1 Brake Torque and Power

The maximum output power of the engine brake is known as engine performance. The rotor dynamometer, connected with a shaft to the test bed, will give the engine torque readings. The dynamically controlled diesel engine rotor dynamometer depends on the adjusted load and speed.

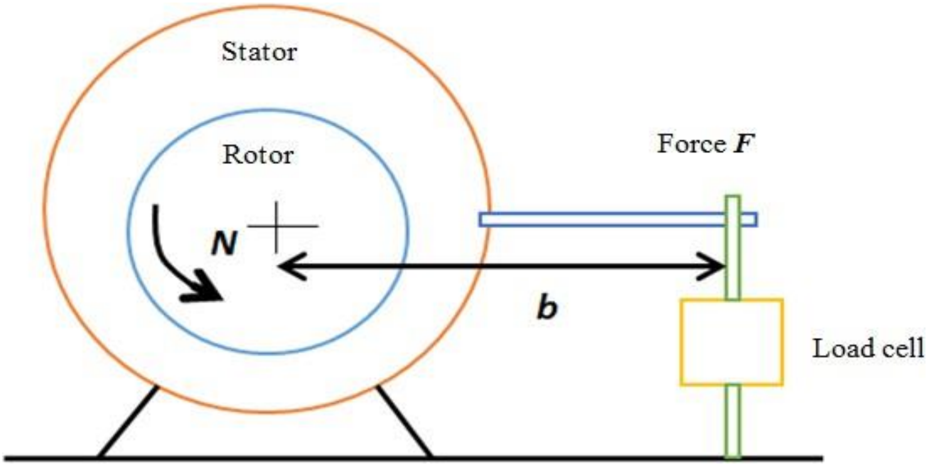

FIGURE 1: Principle of dynamometer operation (Heywood, 1988)

The hydraulic and electromagnetic devices attached to the rotor are in the stator, supported by the bearing. Figure 1 shows T as the engine torque and can be obtained from the formula:

$$T = Fb \tag{1}$$

The torque with angular speed obtained from the dynamometer can produce P as the engine power.

$$P = 2\pi NT \tag{2}$$

where crankshaft rotation speed is N in SI units:

$$P(\mathrm{kW}) = 2\pi N\ (\mathrm{rev/s})\ T\ (\mathrm{N.m}) \times 10^{-3} \tag{3}$$

The combination of torque (Nm) and speed (rpm) function produces brake power. From the formula, the torque is a measurement of the engine's ability to do work, while brake power is the percentage of work that has been done.

2.2 Experimental of Engine Power

The operation to determine the performance of the five types of fuel was carried out in a one-cylinder engine laboratory. The YANMAR TF120M diesel engine and test equipment are ready to operate. There are several major testing equipment items, including a 15-kW Eddy Current Dynamometer, TFX data acquisition, dump load (high voltage), a blue container for the ventilation system, and two barrels of oil. Equipment and engines should always be maintained to ensure they are safe for operation at all times.

2.2.1 Dynamometer system

The dynamometer used in this study is the Eddy Current Dynamometer type. Engine operation will generate power that rotates the generator rotor. The current from the dynamometer regulates the rotor. The more current is generated, the stronger the rotor's magnetic field. This will result in an increase in power at the stator coils. Dump loads located away from the dynamometer will receive power from the coil stator. The dynamometer is placed on the bearing, where the load cell serves to provide the torque reading. Figure 2 shows the dynamometer functional block diagram.

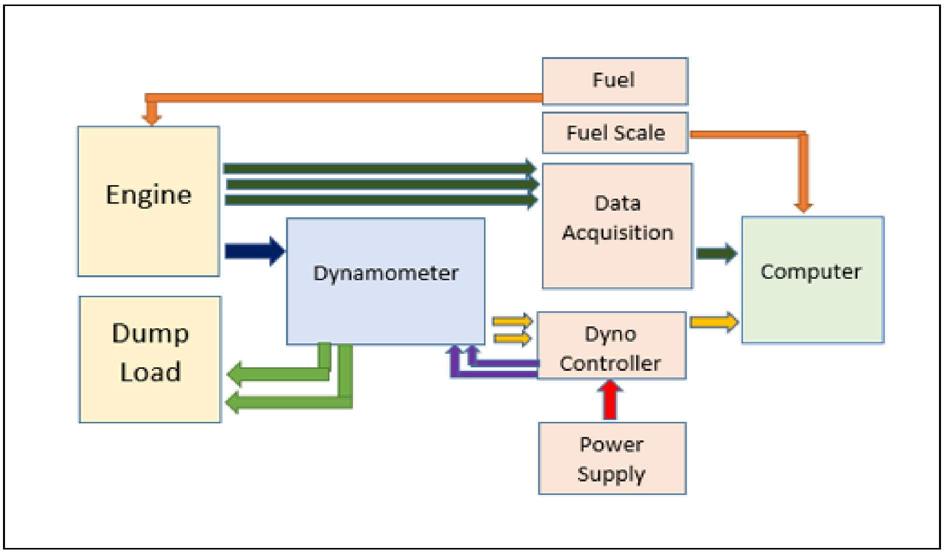

FIGURE 2: The Dynamometer functional block diagram

Figure 3 (a) is a BD−15 KW SR modeled dynamometer, numbered 1−1016 series. The 15-kW eddy-current dynamometer is supplied by Focus Applied Technologies. The specifications for dynamometers are as described in Table 1. The speed characteristics are obtained from tests performed under engine conditions. Meanwhile, torque is obtained from the dynamometer brake operation. To control high and low engine speeds manually, the throttle engine position lever is placed on the engine body as shown in Figure 3 (b). It is important to ensure that the dynamometer brake has more power than the engine at any speed to obtain the perfect rig test operation. The dynamometer should always be adjusted and measured accurately by using levers and weights each time before carrying out the experiments.

(a) (b)

FIGURE 3: A dynamometer is a device for simultaneously measuring the torque and rotational speed of an engine – (a) Dynamometer power BD−15 kW (b) Manual throttle position lever

TABLE 1: Dynamometer power BD−15 kW specification

Detail	Specification
Mechanical Power	15 kW max
Torque	60 Nm max
Speed	2400 rpm max (direct coupling)
Electrical Power	7.5 kW max
Voltage output	300 V max
Current	40 A max

2.2.2 The Dynamometer Controller Unit

High-power cables are used to connect (Dyno + / Dyno −) output electrical power control of the Dynamometer's Rotor coils. The signal can reach 400V AC at over 10A, using non-polar resistance loads. During the operation of taking data running, attention to safety factors is a priority. High-voltage factors that may cause electrical shock from the equipment are present in the Dyno +/− control lines. In fact, the Dump Load Lines can also result in severe injuries. A schematic diagram of the whole external dyno control unit is illustrated in Figure 4.

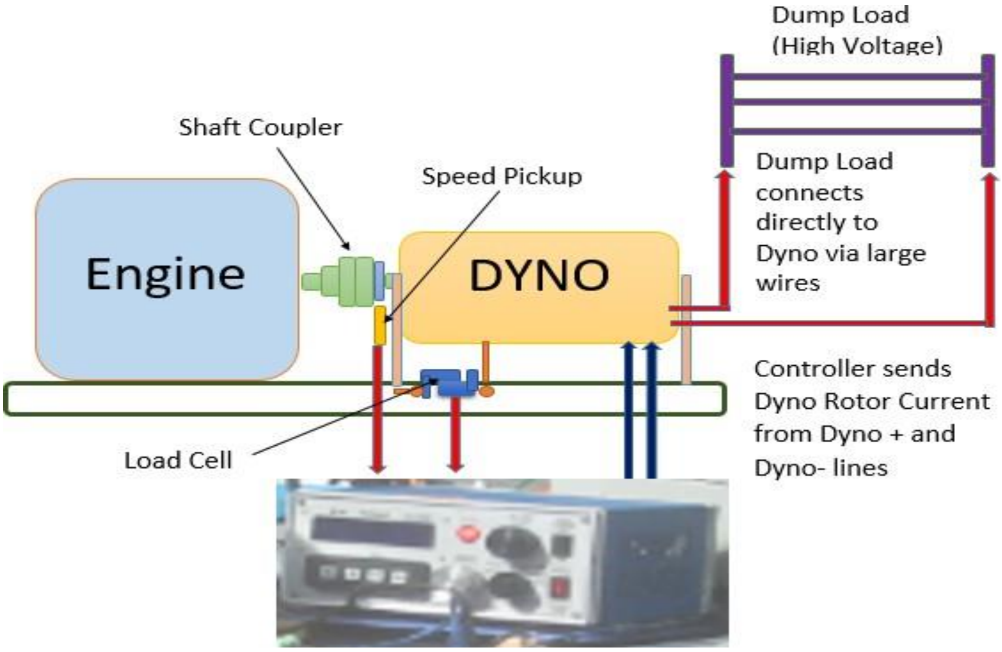

FIGURE 4: A schematic diagram of the whole external dyno controller unit

2.2.3 Engine Testing

Data obtained from the study are analyzed for decision-making. The scope of the study is focused on engine performance, namely brake power, brake specific fuel consumption, and brake thermal efficiency. The formula as an equation is used to obtain a brake power engine value, which is derived from the torque engine operation and engine speed (Heywood, 1988).

$$P = \frac{2\pi NT}{60}$$

where,

P = engine brake power (kW)
T = engine brake torque (Nm)
N = engine speed (rpm)

Good engine performance is deemed to have high torque and high power with low fuel consumption. The equation shows how the value of brake specific fuel consumption is obtained, where the mass flow rate is divided by output power (Heywood, 1988).

2.2.4 Engine Performance

The alternative biodiesel blends (B5M10, B10M10) and emulsion fuel (B5M10E3, B10M10E3) compared to diesel have been investigated for their performance in terms of brake power. The engine that performs well is equipped with high brake power and high torque, but low BSFC usage. The relationship between torque and angular velocity will produce brake power of BP = Tω. A good BSFC gives the lowest fuel consumption and is an indication of engine efficiency when using fuel to produce brake power. There are various modes that can be controlled manually and automatically by the dynamometer controller with the help of a computer. Among these modes are speed, torque, and load that are used in accordance with the prerequisites of test requirements. The description of the dynamometer controller and computer tools is shown in Figure 5. This study uses a Hot Wire Anemometer as a tool to measure the speed or velocity of air entering the blue barrels. Air is a vital element because oxygen is needed in the fuel combustion process. Air condition factors entering the combustion chamber may also affect engine performance. Among the things to be identified are relative humidity and ambient pressure. The fan is used to control the ambient air temperature so that the temperature is always stable at 25 °C. Figure 6 gives an overview of the air obtained during engine operation.

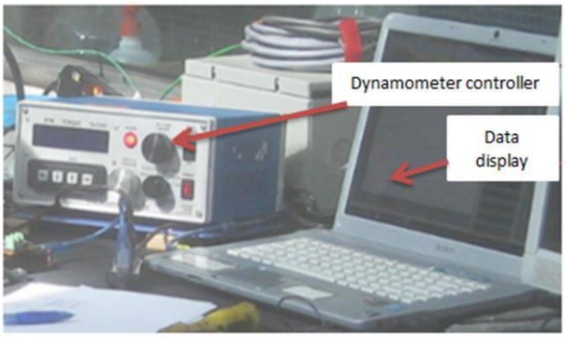

FIGURE 5: Dynamometer controller

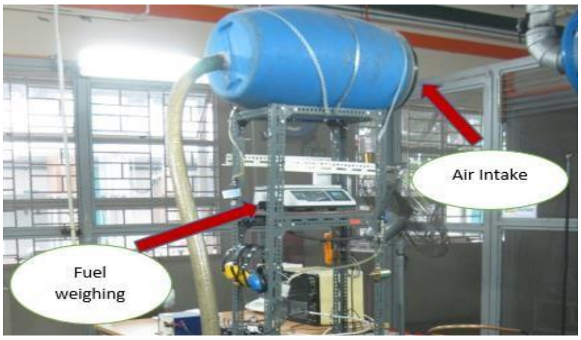

FIGURE 6: Air intake and fuel weighing measurement system in a diesel engine

3. RESULTS AND DISCUSSION

3.1 Analysis at Low Load Condition

The trend for engine brake power increased from 1200 rpm to 2400 rpm for all fuels tested. Figure 7 shows that the brake power for biodiesel blends and emulsion fuels was lower compared to diesel fuel at varying engine speeds and at low load conditions. This is due to the low calorific value, which will cause low temperature in the cylinder. Biodiesel blends' engine brake power was low compared to diesel and emulsion fuel due to high viscosity, which tends towards the formation of big fuel droplets. However, biodiesel has high potential for substituting conventional mineral fuel as its biodegradable, clean-burning, non-toxic properties can minimize the level of greenhouse effects (Rodrigues, 2012). Emulsion fuel has higher engine brake power compared to biodiesel blends due to micro-explosion and better combustion efficiency. The brake power for B5M10, B10M10, B5M10E3 and B10M10E3 fuels was lower than diesel fuel at 2400 rpm speed in percentages of 23.91%, 16.74%, 11.91% and 7.84% respectively, while the range for engine brake power at low load with speed 1200 rpm to 2400 rpm was 0.20 kgf.m until 0.80 kgf.m.

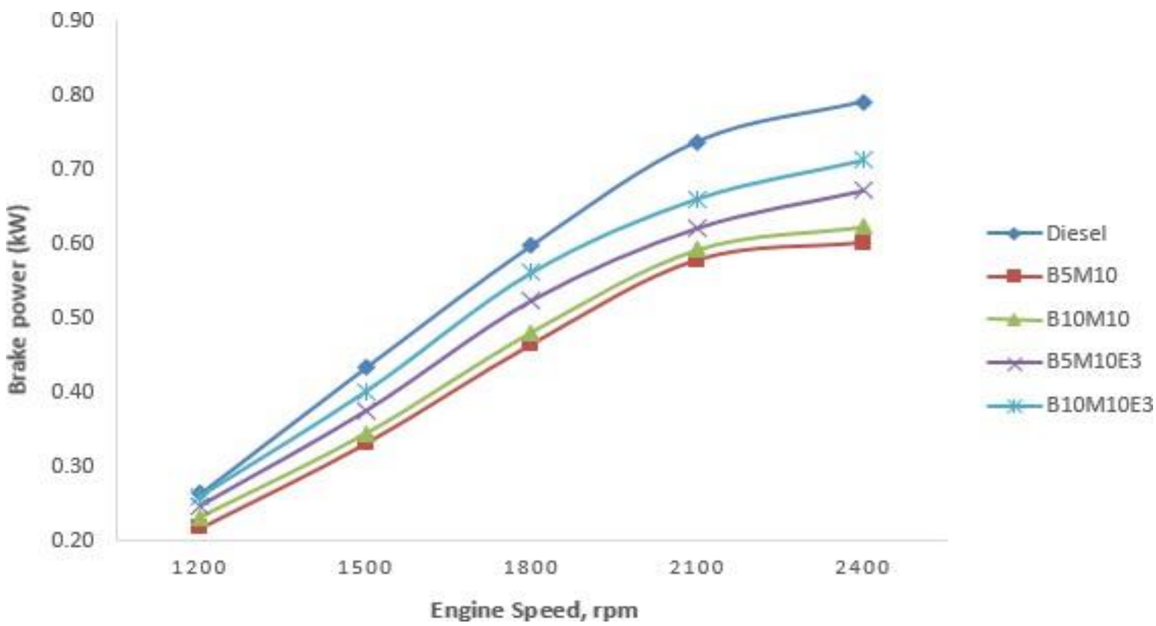

FIGURE 7: Variation of brake power vs. engine speed at low load

3.2 Analysis at Partial Load Condition

Engine brake power at engine speeds of 1200 rpm to 2400 rpm showed an increasing trend from a range of 0.60 kgf.m to 1.30 kgf.m for all fuels tested. Figure 8 shows that at partial load conditions, the brake power for biodiesel blends and emulsion fuels was still low compared to diesel due to a decrease in the heating value. The engine brake power at 2400 rpm for B5M10, B10M10, B5M10E3 and B10M10E3 fuels was lower than diesel by percentages of 5.31%, 3.74%, 1.87% and 1.73%, respectively. The main factor for biodiesel blends to have lower brake power as compared to diesel and emulsion fuel is because of their high fuel density properties, which result in large oil droplets and a reduction in combustion efficiency. Emulsion fuel was found to have higher engine brake power compared to biodiesel blends due to its 3% water content. Water that has a low boiling point will cause a micro-explosion phenomenon where an embedded droplet blows up, and this will improve combustion. On the other hand, emulsion fuel will lower the engine temperature and cause a long ignition delay. This is because water has a low volatility rate and high viscosity (Huo et al., 2014).

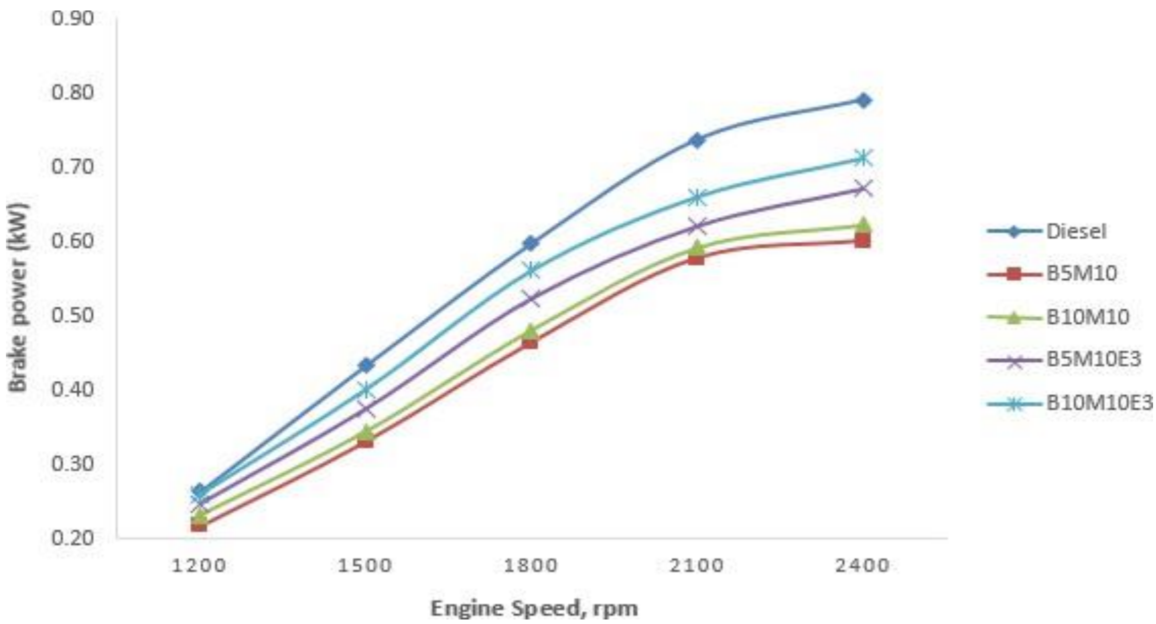

FIGURE 8: Variation of brake power vs. engine speed at partial load

3.3 Analysis of Full Load Condition

Figure 9 shows the trend as the speed was increased from 1200 rpm to 2400 rpm. Engine brake power ranged from 1.40 kgf.m to 3.50 kgf.m. At high load and speed of 2400 rpm, the brake power for B5M10, B10M10, B5M10E3 and B10M10E3 fuels was lower than diesel fuel by percentages of 2.54%, 2.07%, 1.64% and 1.56%, respectively, due to high density and viscosity. Biodiesel blends were found to have lower engine brake power compared to diesel and emulsion fuels due to lower calorific value. Biodiesel also has high density and oxygen, which gives lower energy content compared to diesel (Pullen & Saeed, 2014). Engine brake power is high for emulsion fuels as compared to biodiesel blends due to secondary atomization and increased rate of fuel subsidization. However, emulsion fuels have lower engine brake power compared to diesel due to their high density and viscosity. Nonetheless, the advantage of emulsion fuel is that it can increase both the combustion and thermal efficiency of the diesel engine (Ithnin et al., 2018).

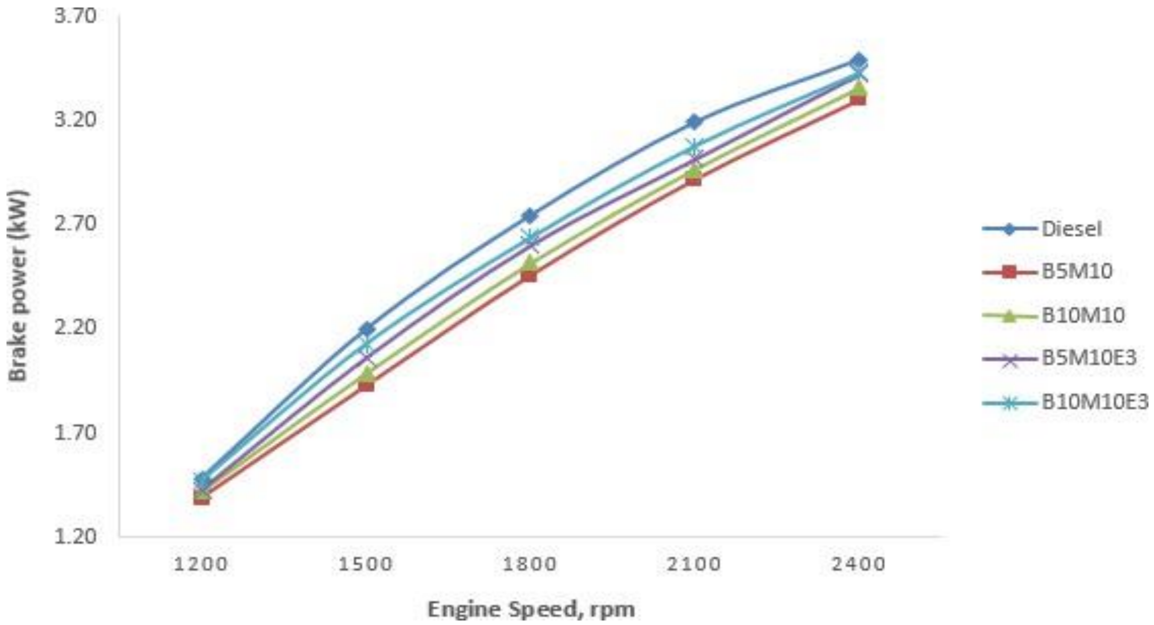

FIGURE 9: Variation of brake power vs. engine speed at full load

4. CONCLUSION

Engine brake power for B5M10, B10M10, B5M10E3, and B10M10E3 is low compared to diesel fuel due to low calorific value, high density, and high viscosity. The engine that performs well is equipped with high brake power and high torque, but low BSFC usage. The relationship between torque and angular velocity will produce brake power of BP = Tω. A good BSFC gives the lowest fuel consumption and is an indication of engine efficiency when using fuel to produce brake power. Biodiesel blends were found to have lower engine brake power compared to diesel and emulsion fuels due to lower calorific value. Engine brake power is high for emulsion fuels compared to biodiesel blends due to secondary atomization and increased rate of fuel subsidization.

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