# ENGINE PERFORMANCE AND EMISSION OF EMULSIFIED BIODIESEL

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**Abstract.** An emulsion of biodiesel and water is one of the possible approaches that have been used to overcome diesel engine pollution. In this work, the performance and emission characteristics of a 4-cylinder diesel engine using pure diesel, biodiesel B20 and emulsified biodiesel were investigated. Emulsified biodiesel containing 5 % and 10 % water were utilize for the engine tests. During the experimental work, the engine was set-up at 2500 rpm and 20 % to 60 % loads. The result shows the reduction in NOx formation when the water content in emulsified biodiesel increased from 5 % to 10%. For the performance, there were no significant differences between the engine break powers measured for emulsified biodiesel containing 5% water and diesel fuel.

## Introduction

Currently, diesel engines are employed as power source for power generation, agricultural and industrial machinery due to their robust and fuel efficient compared to spark ignited engine [1, 2]. However, the disadvantages of diesel engines are pollution emitted such as particulate matter (PM), carbon monoxide (CO) and other gaseous pollutants. Environmental protection agency (EPA) proposed emission control regulations require more than 90 % reductions from the current levels of emissions, especially for NOx and PM [2]. This were then attracted much researcher to develop various reduction techniques for air pollution control from diesel engines.

Biodiesel is one of the main alternative fuel due to their good properties as diesel engine fuel and can be utilized in diesel engines [3, 4]. Commonly, biodiesel contains around 10 to 15 % of oxygen content which will enhance burning efficiency, reduce emission of PM, CO and other gaseous pollutants [5]. However, under a high combustion temperature, there will be larger NOx formation, which is around 10 % higher than fossil diesel due to higher oxygen content [6]. The utilization of emulsified biodiesel were proved [7] to solve this problem due to its advantage of NOx and PM reduction in exhaust gas simultaneously.

Previous study [8] reported that vaporization of water in emulsified biodiesel reduce the combusion temperature which then reduce the NOx emissions. This phenomena were called micro-explosion. When the emulsion is heated under high temperature condition, the water droplet enveloped by fuel droplet quickly evaporates, which then breaking the fuel droplet into smaller droplets [1]. The evaporation of the water consumes heat from the combustion which will lower the peak combustion temperature. As a result, fuel saving and the reduction of NOx, PM, smoke emissions are achieved.

In this work, the emulsion was prepared using mechanical stirrer. Both Span 80 and Tween 80 were used as surfactant to increase the affinity and reduce the interfacial tension between the water and oil phases. During the experimental work, a 4-cylinder diesel engine was set-up at 2500 rpm with the load range within 20 % to 60 %. The performance and emission characteristics using pure diesel, biodiesel B20 and emulsified biodiesel were investigated.

## Materials and Method

The emulsified fuel was produced using a mechanical stirrer machine which is commonly used in the industry for emulsion preparation [9]. Both surfactant Span 80 and Tween 80 were added into biodiesel B20 and water using method that utilize in previous study [5]. The properties of biodiesel B20 were shown in Table 1. A white and creamy liquid emulsion was produce from this technique. The water content of the emulsified biodiesel was set at 5 % and 10 % and namely as BW5 and BW10. The quantity of the surfactant was set at 2 % of the total volume of water and biodiesel in the emulsion. The engine speed was fixed at 2500 rpm and the engine load was set at 20 %, 40% and 60 %.

**Table 1:** Properties of biodiesel B20 [10]

| **Properties** | **B20** |
|---|---|
| Flash Point (°C) | 110 |
| Viscosity ($mm^2/s$) | 4.514 |
| Density ($kg/m^3$) | 845 |
| Acid Value | 0.02 |
| Moisture Content (%) | 1.16 |
| Cloud Point (°C) | 16 |
| Pour Point (°C) | -7 |
| Cetane Number | 78.2 |
| Energy Content (MJ/kg) | 45.714 |

The specification of 4-cylinder diesel engine are shown in Table 2. The similar engine utilize by Rizalman etc [11]. To reduce the temperature of the cylinders and the lubricant, the cooling system of the engine is connected to a cooling-water tower by means of a cooling-water pipe. The engine was coupled to a 150 kW ECB eddy current dynamometer which equipped with Dynalec controller.

**Table 2:** Engine specifications

| | |
|---|---|
| **Engine** | Engine test setup 4 cylinder, 4stroke, Diesel (Computerized) |
| **Product** | Mitsubishi |
| **Model** | 4D68, Type 4 in-line Cylinder, 4 stroke Diesel engine |
| **Power** | 64.9Kw at 4500rpm |
| **Torque** | 177NM at 2500rpm |
| **Stroke** | 93mm |
| **Cylinder bore** | 42.7mm, 1998cc |
| **Compression Ratio** | 22:4:1 |

Two separate fuel tanks equipped with stirrer and fuel valve systems were used to deliver the diesel fuel and emulsified biodiesel. In fuel delivery system, fuel flow meter (model AIC 1204) was utilize to measure the fuel consumption rate of both fuels separately. Fig. 1 shows the engine set up components.

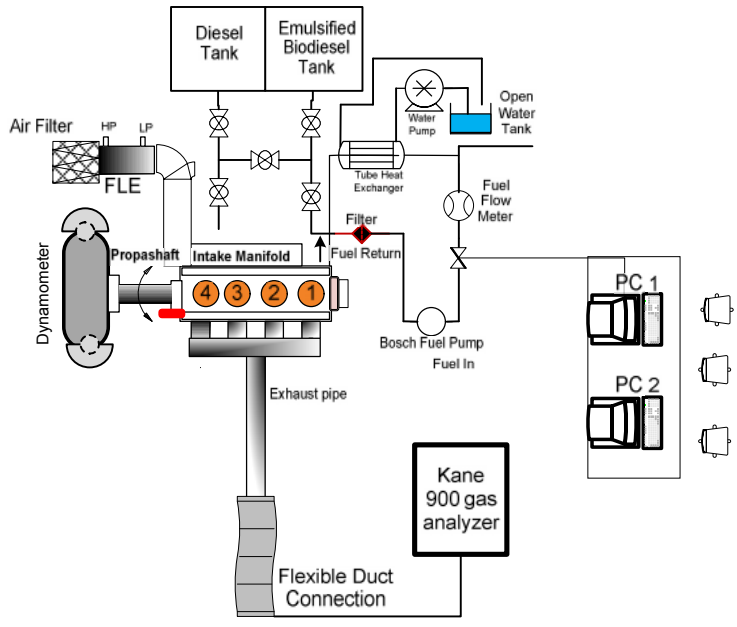


**Figure 1:** Engine test bed apparatus

The engine was fuelled with diesel in the initial operation until it reach steady condition. After that, followed by the tested fuels which is similar method applied by [12]. Each fuel test was repeated three times to provide repeatability results. During the engine testing the Kane 900 gas analyzer was used to collect the emission data.

## Result and Discussion

**Brake Power.** The result for engine brake power for all four types of fuel is shown in Fig. 2. There were no significant differences between the engine break powers measured for BW5 and diesel. However at higher load, increasing water concentration in emulsified biodiesel decreased the engine brake power. This is due to the higher energy value of diesel fuel, which would produce higher engine power compared to biodiesel and emulsified biodiesel. As mentioned by A. Bulent *etc*. [13], commonly the heating value of biodiesel is around 10 % lower than diesel fuel on a weight basis.

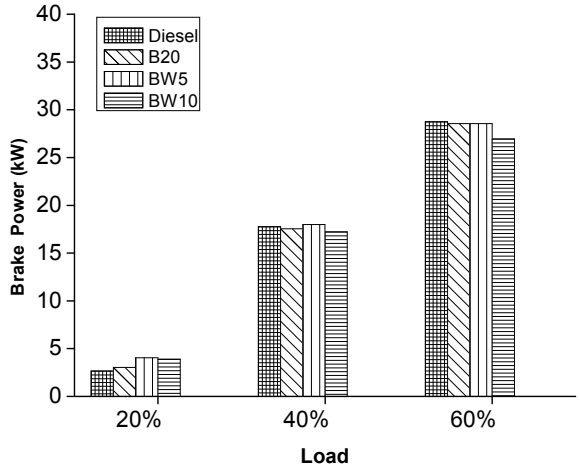


**Figure 2:** Brake power at different engine load

**Brake Specific Fuel Consumption (BSFC).** Fig. 3 shows the comparison of the brake specific fuel consumption (BSFC) for all fuels. The results shows that at higer load, the BSFC for emulsified biodiesel slightly higher than biodiesel fuel. Due to the lower calorific value of the emulsified biodiesel, it consumed more fuel to produce the same power output [14]. Hence, the absorption of partial heat release from combustion for the latent heat of the water in the emulsified biodiesel may also cause a decrease of engine power output. Thus, increased water content in emulsified biodiesel will increased the BSFC [15].

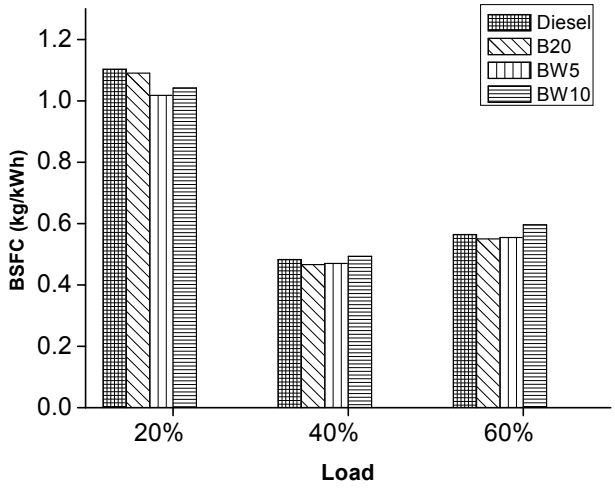


**Figure 3:** Brake specific fuel consumption at different engine load

**Carbon dioxide ($CO_2$).** The variation of $CO_2$ emission with respected to engine load for different fuel are shown in Fig. 4. Increasing the engine load from 20 % to 40 % almost doubled the $CO_2$ emission and the similar trend were found for load 40 % to 60 %. However at higher water concentartion, the $CO_2$ formation decreases at all engine loads which shows the similar result studied by Ali Alahmer [16]. This is due to the large extent of micro-explosion generated in the burning of emulsified fuels which then leading to a larger degree of mixing of reactant mixture [17].

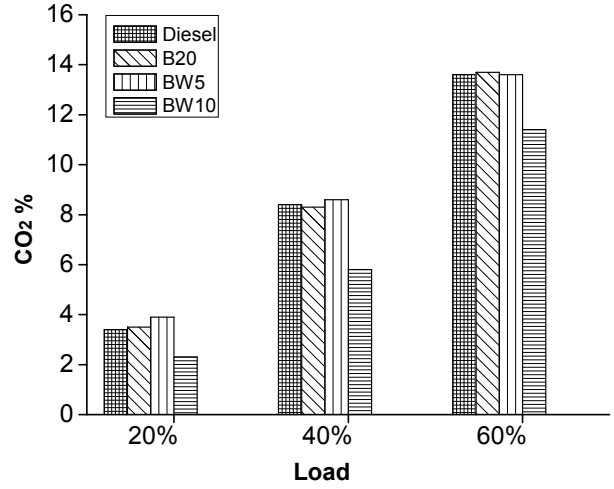


**Figure 4:** Carbon dioxide emission at different engine load

**Oxide of Nitrogen (NOx).** Fig. 5 shows the variations of NOx emissions with respected to engine loads. The NOx emission is lower for emulsified biodiesel compa
Among four fuels, B20 shows highest Nox emissions due to several facto

unsaturation and high oxygen content [18]. However, by utilizing water in emulsified biodiesel the Nox emisssion were decrease significantly. The main reason is that the heat absorption by water vaporization causes a reduction in the peak ignition temperature which then reduce the NOx formation [19].

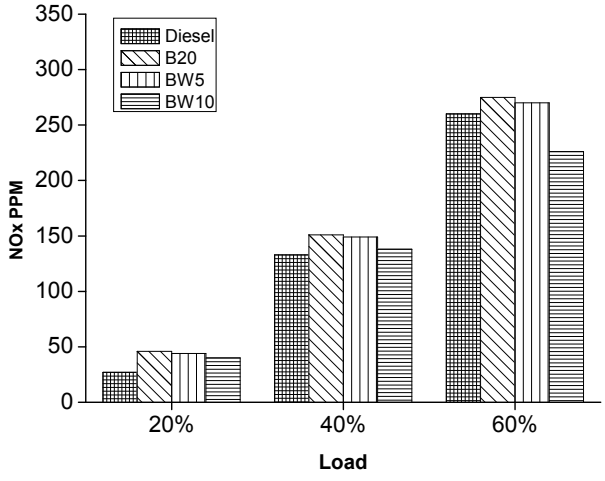


**Figure 5:** Nitrogen oxide at different engine load

## Conclusion

Emulsified biodiesel containing 5 % and 10 % water were prepared and tested for engine performance and exhaust emissions in a 4-cylinder diesel engine. The results were compared with diesel and biodiesel fuel. Based from the results, several conclusions can be made which are follows;

1. The result shows no significant differences between the engine break powers measured for emulsified biodiesel containing 5 % water and diesel fuel.
2. Increased water content in emulsified biodiesel will increased the BSFC.
3. The NOx emissions increase when diesel fuel is changed to biodiesel B20 fuel. However, increasing water content in emulsified biodiesel was then reducing the NOx formation.

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