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STUDY ON PERFORMANCE OF DIESEL ENGINE USING PALM OIL BIOFUEL DIESEL BLENDS

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Abstract:

Biodiesel fuel is one of the alternative energy sources that can be renewable and environmentally friendly. Processing biodiesel from crude palm oil can be carried out through esterification and transesterification. The performance and exhaust gas emission testing was performed on a Daihatsu Taft 2.5 L diesel engine without any modifications. The fuel blend ratios between diesel and biodiesel were varied to include 90 %, 75 %, 50 % and 25 % biodiesel. The engine speeds examined were 1000, 1200, 1400, 1600, 1800, 2000, 2200 and 2400 rpm. The test results showed that brake specific fuel consumption with biodiesel was higher than with regular diesel, ranging roughly from 2.37 % to 8.43 %. Increasing the biodiesel proportion in the mixture tended to lower exhaust emissions such as HC, CO, and CO_2. The exhaust gases produced by biodiesel were generally lower than those from diesel fuel.

Key terms: Diesel Engine, Biodiesel, Palm Oil Biodiesel, Engine Performance, Emissions

1. INTRODUCTION

Vegetable oil is emerging as a notable alternative energy source, and biodiesel derived from it can replace conventional diesel in diesel engines, offering a renewable fuel with reduced exhaust emissions. In Indonesia, biodiesel can be produced from crude palm oil, known as CPO (Crude Palm Oil). Indonesia ranks as the world's second-largest CPO producer and retains substantial development potential. Projections for 2023 estimate CPO output at 48.1 million tonnes [1]. The development and use of biodiesel provides an alternative energy route while addressing possible surpluses of domestic CPO production. Actually, the idea of utilizing vegetable oil as a fuel was first introduced by DR. Rudolf Diesel in 1985 with the intention of being compatible with a range of fuels, including vegetable oils5). At the World Exhibition in Paris in 1900 Dr. Rudolf Diesel demonstrates his motorbike using peanut oil as fuel5). In the last decade, the United States Department of Energy got a recommendation from the Environmental Protection Agency (EPA) to sell bio-diesel freely as a fuel for diesel engines without altering the motor. Popular biodiesel sold in Indonesia uses the code B-20 (20% biodiesel and 80% diesel oil blend), B-35 (35% biodiesel and 65% diesel oil blend). Biodiesel serves as an alternative to petroleum diesel, aimed at reducing pollution without engine modifications. This study aimed to investigate the engine performance and emissions characteristics of a passenger car engine (Hilux 2.4G Double cabin (4x4) M/T) fuelled by two different fuels, which is biodiesel (B100) and dieselbiodiesel fuel blend (B20). The study was conducted at the Bioenergy Laboratory of Balittri, the Thermodynamics and Propulsion Engine Research Center of BPPT, and the Research Center for Oil and Gas Technology Development (LEMIGAS), from November 2019 to February 2020. The result showed that the traction and power for diesel-biodiesel fuel blends were obtained slightly higher than biodiesel. Biodiesel has marginally higher fuel consumption than diesel- biodiesel fuel blends. According to the emission analysis, biodiesel produces lower exhaust emissions of unburned fuel emissions, carbon monoxide, and carbon dioxide content in the exhaust gas than diesel-biodiesel fuel blends [2].

Investigate how varying the compression ratio influences the performance and emission traits of a single-cylinder, four-stroke compression-ignition (CI) engine operating on biodiesel and conventional diesel. Corn-oil biodiesel mixtures were formulated as B5 (5 %), B10 (10 %), B1 (15 %) and B20 (20 %) by volume. Experiments were carried out at full load, a steady speed of 1500 rpm, and several compression ratios—14, 15, 16, 17, and 18 %. Measurements included engine performance parameters such as brake thermal efficiency (BTE), brake specific fuel consumption (BSFC), and emissions of CO, CO_2, HC, NOx, and smoke opacity for each biodiesel blend. Findings indicated that raising the compression ratio generally raised BTE and lowered BSFC for every fuel tested; however, for the biodiesel blends B5, B10, B15 and B20, BTE fell modestly by 2, 4.2, 6.5 and 8.3 % while BSFC rose by 3.3, 6.3, 9.4 and 13 % respectively relative to pure diesel, attributed to the greater viscosity and density of biodiesel [3].

Recently, the use and study of biodiesel have grown in popularity because it cuts emissions, costs less, and can help attain energy self-sufficiency. A promising application of biodiesel is in diesel engines, where it can replace conventional petroleum diesel. Camelina sativa is an oilseed plant suitable for biodiesel production because it yields a large harvest annually, offers a favorable net-energy ratio, contains a substantial amount of seed oil, and involves low extraction costs. Biodiesel obtained from Camelina sativa L. is produced through transesterification. In this work, the produced biodiesel was mixed with diesel in different ratios and tested in an engine to assess combustion performance and emission traits. The results show that the CMB 20 blend (20 % camelina biodiesel and 80 % diesel) delivers the best performance among all tested blends. CMB 20 exhibits a brake thermal efficiency of 23.45 %, a specific fuel consumption of 0.355 kW/kg·h, and generates lower emissions than the other blends [4].

An experimental investigation was carried out to examine the impact of Cresson oil biodiesel on the emissions and performance of CI engines. The study sought to determine how novel biodiesel blend formulations derived from Cresson oil influence CI engine performance and exhaust emissions. Cresson oil biodiesel was blended with standard Iraqi diesel fuel at volume fractions of 10%, 20%, 40%, 60%, 80%, and 100%. The engine operated with a compression ratio of 18 and a fuel-injection timing of 23° before top dead centre (bTDC). Experimental results indicate that this biodiesel lowers thermal efficiency, heat release, ignition delay, and cylinder pressure, while raising exhaust gas temperature (EGT) and brake-specific fuel consumption (BSFC). An elevation in nitrogen oxides (NOX) and carbon dioxide (CO2) emissions was observed, alongside a decrease in carbon monoxide (CO), soot, and unburned hydrocarbons (HC) emissions [5].

Research experimental test with a mixture of used cooking oil biodiesel and fuel. Before testing, the temperature of each fuel is increased to determine the effect of temperature on the density and viscosity values. The highest density value is found in B50 fuel at 26 °C, with a density of 0.854 gr/ml, while the lowest density is found in diesel fuel at 60 °C, with a density of 0.822 gr/ml. The highest viscosity value is found in B50 fuel at 26 °C and 60 °C, which is 3.26 cSt. After that, testing was carried out on a diesel engine, which produced the highest thermal efficiency value of 21.16 % on B50 fuel with a temperature of 60 °C at 1000 rpm rotation and a load of 4000 watts. The lowest thermal efficiency of 6.43 % was found in B50 fuel with a temperature of 26 °C at 800 rpm and a load of 1000 watts. The lowest consumption was found in B30 with a temperature of 60 °C at 1200 rpm, which was 420.78 gr/kWh [6].

A comprehensive review on the use of biodiesel for diesel engines, Fossil fuels constitute the primary energy supply for global transportation activities. Nonetheless, they generate severe environmental damage and display an uneven geographic distribution, heightening energy vulnerability. In recent years, biodiesel has emerged as a viable and practical solution to these energy challenges. As a renewable, low-carbon fuel, biodiesel is being adopted increasingly as a substitute for conventional fossil fuels, especially in diesel engines. It offers multiple advantages, including lower greenhouse-gas emissions, better air quality, and enhanced energy self-sufficiency. Yet, several obstacles persist, such as ensuring biodiesel's compatibility with current engine designs and infrastructure, and the variability of production costs, which depend on location, climate, and competing feedstock applications. Moreover, comprehensive research evaluating biodiesel's effects on engine power, performance, and emissions remains scarce, posing a significant hurdle to broader adoption. Consequently, this work aims to deliver an extensive analysis of the physicochemical characteristics of biodies [7].

A research investigation examined the characteristics of biodiesel derived from diesel-palm cooking oil blends with methanol, ethanol, or butanol, focusing on diesel engine performance and possible exhaust emissions. Palm cooking oil was incorporated at levels of 30%, 40%, 50%, 60%, 70%, 80%, and 85%. A 15% proportion of each alcohol—methanol, ethanol, and butanol—was employed. Chemical and physical analyses indicated that biodiesel containing greater amounts of palm oil exhibited inferior properties. A mixture of diesel, palm oil, and methanol can achieve nearly diesel-fuel levels of engine performance and exhaust emission characteristics [8].

Among the renewable liquid fuels that can be employed in a diesel engine, biodiesel from various sources—particularly glycerol derivatives. have been performed with diesel-biodiesel-ethanol blends in a diesel-cycle engine to evaluate performance (power, torque, fuel consumption) and pollutant emissions (particulate matter, volatile organic compounds, metals and others). The ethanol fraction in the tested blends varied from 1 % up to 50 %.

2. Materials and Experimental Procedure

2.1. Engine Configuration

The test was carried out using a diesel engine. The diesel motor is connected to the dynamometer via the shaft and coupling. For the cooling system used a separate heat exchanger from the motor with cooling water fluid. Mass flow rate of fuel is measured by a volumetric flask at a certain volume which is installed between the fuel pump

and the fuel tank separate from the motor. Temperature sensors (thermocouples) are mounted on the motor inlet and outlet water lines and on the air ducts. Measuring air flow rate, temperature sensors, speed and load on the dynamometer are connected to the data acquisition system. Data retrieval in the test was carried out in several parts, firstly, motor performance data from sensors connected to the data acquisition system, exhaust emissions measured by exhaust gas analysis.

The experiment will be conducted with two fuel types, namely diesel fuel and biodiesel-CPO. Different blend ratios of diesel and biodiesel were evaluated to observe how their properties affect engine performance and exhaust emissions. First, a blend of 100% diesel fuel and 90% biodiesel-CPO was examined, followed by mixtures containing 75%, 50%, 40%, 30%, 25%, 15%, 10% and 5% biodiesel. The results of a diesel engine running on these biodiesel blends are compared with those of the same engine operating on pure diesel.

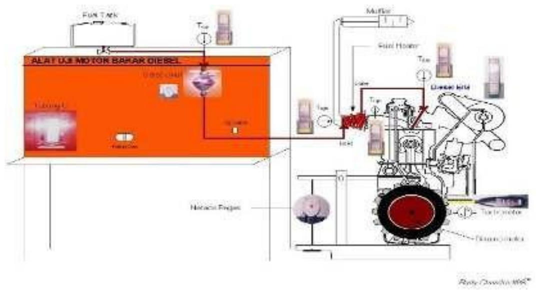

Figure 1. Diagram of Diesel Motor Testing Equipment

Table 1. Diesel engine specifications

Engine Type	**Daihatsu Taft**
Kind	Four-cylinder, four-stroke
Volume of a Cylinder	2,765 cubic centimeters
Power	72 horsepower
engine speed	6,000 rev/min
Count of valves	8 parts

3. RESULTS AND DISCUSSION

3.1 Engine Output

Introducing biodiesel into the fuel blend in different ratios led to a reduction in the produced power at multiple diesel engine speeds when compared with pure diesel. This mainly stems from the lower calorific value of biodiesel relative to straight diesel, meaning that combining the two lowers the overall heating value of the fuel. An additional cause of the power drop is the improper injection timing; as mentioned earlier, biodiesel has a higher cetane number than diesel, which shortens the ignition delay and thus requires earlier injection. Consequently, adjusting the injection timing is necessary to achieve maximum power. As the proportion of biodiesel in the mix increases, the generated power decreases. Figure 4.1 illustrates how engine speed influences diesel engine power for different diesel-biodiesel blend ratios.

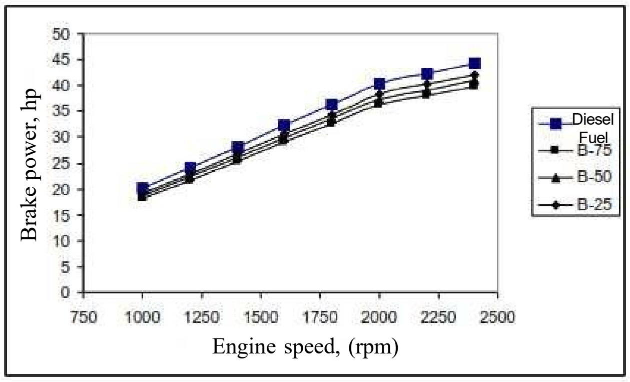

Figure 2. Brake power versus engine speed

3.1 ENGINE TORQUE

Diesel motor engine torque decreases with the addition of biodiesel content in the fuel mixture. Figure 2. shows a graph of the effect of motor torque on diesel motor torque. In various compositions of the fuel mixture with biodiesel there is a slight decrease in torque on the motor, this is a logical consequence because power is directly proportional to torque. Increasing the concentration of bio-diesel in the mixture will also increase the torque reduction at various speed levels. The ratio of the average torque of the motor with diesel fuel for the B- 25 is 97.09%, the B-50 is 94.18% and for **the B-75 it is 91.28%.**

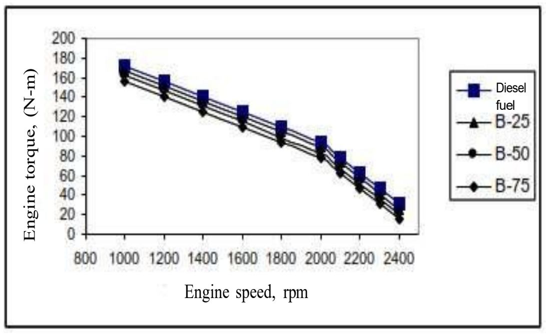

Figure 3. Brake power versus engine speed

3.2 FUEL CONSUMPTION PER UNIT OF POWER (SFC)

The addition of biodiesel to the fuel blend raises the expense of operating a diesel engine with specific fuel consumption (Sfc). In various biodiesel blend ratios, the average Sfc relative to diesel is 2.37% for B-25, 4.77% for B-50, and

8.43% for B-75. Figure 4 illustrates how diesel engine speed influences specific fuel consumption for diesel motors.

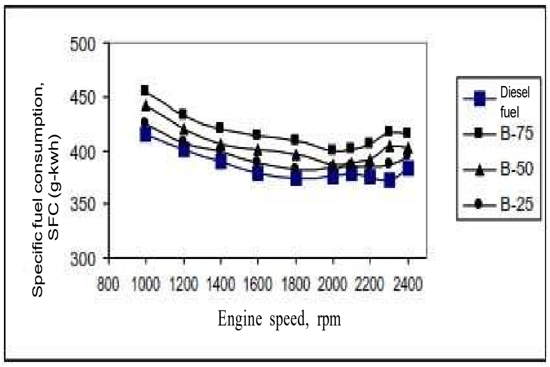

Figure 4. Brake fuel consumption per unit output, SF plot versus diesel engine speed

3.3 THERMAL EFFICIENCY

The thermal efficiency declines as more biodiesel is added to the fuel blend. Figure 5. displays a chart illustrating how variations in the diesel motor shaft speed affect thermal efficiency at a constant load for different biodiesel-CPO fuel mixtures. In the various biodiesel blends, the mean thermal efficiency ratio of diesel for biodiesel-CPO is 99.41 % for B-25, 97.68 % for B-50, and 92.21 % for B-75.
%.

Thermal efficiency represents the proportion of useful power generated by the engine relative to the energy supplied by the fuel. Thermal efficiency is linked to specific fuel consumption (SFC), with higher efficiency corresponding to lower SFC, and the opposite relationship holding true. Biodiesel exhibits a lower thermal efficiency compared with diesel, as indicated by its higher specific fuel consumption and the fact that diesel possesses a greater calorific value. The thermal efficiencies of the biodiesel-CPO blends B-25, B-50, and B-75 are roughly comparable.

Raising the shaft speed while maintaining a constant load above 2000 rpm generally lowers thermal efficiency; with the load unchanged the output power stays roughly the same, and a higher shaft speed shortens the fuel-air mixing period, leading to poorer combustion, reduced combustion energy, and consequently a drop in thermal efficiency. When the load is increased at a fixed shaft speed, the amount of oxygen attached to the biodiesel rises proportionally with the added fuel mass, resulting in more fuel being burned and a higher effective power, which enhances thermal efficiency.

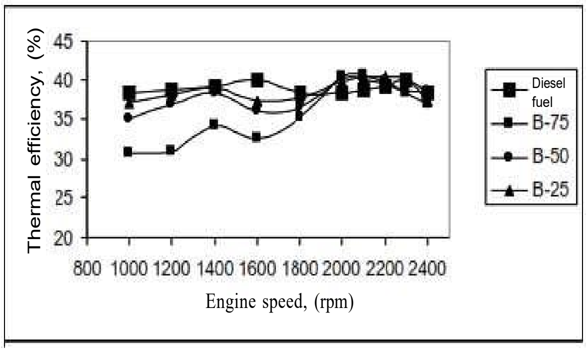

Figure 5. Heat efficiency graph versus engine speed.

3.3 Volumetric Efficiency

The volumetric efficiency slightly decreases when biodiesel is added to the fuel blend. The lowest volumetric efficiency under steady load is observed at shaft speeds exceeding 2400 rpm, with values of 97.17 % for B-75, 99.10 % for B-50 and 99.22 % for B-25. Continuous increase in load does not change the volumetric efficiency. Figure 5. illustrates the influence of diesel engine shaft rotation on volumetric efficiency at constant load for various biodiesel fuel mixture compositions.

Volumetric efficiency indicates the proportion between the real quantity of air drawn in and the theoretical quantity that would fill the piston displacement for each intake stroke. Biodiesel and diesel exhibit roughly comparable volumetric efficiencies. The influence of employing biodiesel-CPO on volumetric efficiency is modest, volumetric efficiency is governed primarily by the operating conditions of the diesel motor.

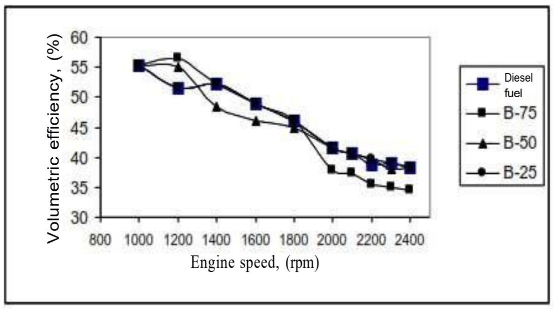

Figure 5. Volumetric efficiency plot against engine speed.

The volume of air drawn rises as shaft speed increases under a constant load. Changing the load while keeping shaft speed steady has little impact on volumetric efficiency, as the efficiency value does not vary with higher load.

4. CONCLUSION

4.1 Summary

Based on the analysis of the test data for diesel and biodiesel-CPO as alternative fuels in a diesel engine, the ensuing conclusions are:

1. Biodiesel-CPO offers superior characteristics compared to conventional diesel when used as an alternative fuel, featuring a higher heating value and cetane number, along with relatively low emissions of HC, CO, CO_2, and black smoke.
2. Increasing the proportion of biodiesel in a diesel-biodiesel blend generally raises specific fuel consumption (SFC) and residual O_2 in the exhaust, while lowering thermal efficiency and emissions of HC, CO, CO_2 and black smoke, with volumetric efficiency staying roughly unchanged.
3. Utilizing biodiesel-CPO modestly raises fuel-energy consumption in relation to diesel fuel, and does so without needing any modifications to the diesel engine.
4. Based on this investigation of palm oil biodiesel mixtures regarding performance and emissions in diesel engines, we find that these blends exhibit greater brake specific fuel consumption and higher brake thermal efficiency relative to diesel. The brake torque generated by the palm oil biodiesel mixtures is lower than that obtained with diesel fuel. Moreover, CO, UHC, and NOx emissions from the palm oil biodiesel blends show a declining pattern versus diesel. Thus, the research indicates that palm oil biodiesel constitutes a feasible and sustainable substitute for diesel, markedly cutting emissions without any.

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