Comparison of volumetric efficiency direct injection diesel engine using a Biodiesel Pertamina and D70J30

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Abstract. The problem of increasing scarcity of petroleum. This encourages researchers to develop alternative fuels. This study attempts to compare and analyze the volumetric efficiency of the mixture of PER-TAMINA Biodiesel and D70J30 fuel mix (70% Biodiesel PERTAMINA and 30% Jatropha Biodiesel). The purpose of this research is to know the ratio of volumetric efficiency of fuel mixture D70J30 with PERTAMINA biodiesel in 4-stroke direct injection diesel motor, 4-cylinder engine with 2.8-liter cylinder volume, in order to find solution to improve engine performance. The method used in this study is experimental. The results showed the volumetric efficiency of diesel engines when using D70J30 mixed fuel at 25%, 50%, 75% and 100% loads was 83.71%; 83.96%; 83.96%; 83.84% decreased compared to volumetric efficiency of PERTAMINA biodiesel at 25%, 50%, 75% and 100% loads were 89.5%; 89.7%; 89.5%; 89.7%. The implications of the research results are the power and torque of the diesel engines are also down. In order to improve engine performance there are two ways that can be done, first fix the fuel mixture D70J30, the second modify the engine.

1. Introduction

The problem of increasing scarcity of petroleum. This encourages researchers to develop alternative fuels. This study attempts to compare and analyze the volumetric efficiency of the mixture of Pertamina Biodiesel and D70J30. The purpose of this research is to know the ratio of volumetric efficiency of fuel mixture D70J30 with Pertamina biodiesel, in order to find solution to improve engine performance. Before doing research there are several things we must know first:

1.1. Literature review

1.1.1. Volumetric efficiency ($\eta_V$). Volumetric efficiency is only used with four-stroke cycle engines which have a distinct induction process. It is defined as the volume flow rate of air into the intake system by the rate at which volume is displaced by the piston [1]:

$$\eta_V = \frac{2 \times \dot{m}_a}{p_a \times V_d \times N}$$

(1)

$\eta_V$ is Volumetric efficiency in %, $p_a$ is the inlet air density in kg/kW. Hour, $ma$ is the mass of air inducted into the cylinder per cycle in kg/hour, $V_d$ is displaced cylinder volume in dm$^3$, $N$ is crankshaft rotation speed in rpm.
1.1.2. Bio solar Pertamina. Biosolar Pertamina is diesel fuel production by Pertamina in 2013, have a composition, as follows [2]:

| No | Parameter                          | Restriction | Unit       |
|----|------------------------------------|-------------|------------|
| 1  | Cetane Number                      | Min 51      |            |
| 2  | Cetane Index                       | Min 48      |            |
| 3  | Density @ 150 C                    | 0.820 – 0.860 | g/cm³     |
| 4  | Viscocity @ 400 C                  | 1.6 – 5.6   | cSt        |
| 5  | Sulfur Content                     | -           | ppm        |
| 6  | Flash point                        | 55          | 0 °C       |
| 7  | Pour point                         | Max 18      | 0 °C       |
| 8  | Carbon Residue                     | Max 0.3     | % m/m      |
| 9  | Water content                      | 500         | ppm        |
| 10 | Oxidation Stability                | 25          | g / m³     |
| 11 | Biodeological growth               | -           |            |
| 12 | Biodiesel Content (FEMA)           | 10          | %          |

1.1.3. Jatropha bio diesel.

Table 2. Specification of Jatropha Biodiesel [3].

| No | Characteristics                  | Unit     | Jatropha |
|----|----------------------------------|----------|----------|
| 1  | Cetana Number                    | -        | 41.8     |
| 2  | Water Content                    | %V       | 3.16     |
| 3  | Kinematic Viscosity @40⁰ C       | mPa.s    | 3.23     |
| 4  | Density @ 15⁰ C                  | Kg/m³    | 907.8    |
| 5  | Calorific value                  | MJ/kg    | 37.97    |
| 6  | Flash point                      | ⁰ C      | 198      |

1.1.4. Specification of diesel engine. Diesel engines are used in this study is the Isuzu Diesel engine, with the following specifications:

Table 3. Specification of Diesel Engine [4].

| Model of engine type                      | Isuzu 4JB1 4 cylinder, 4 cycle, OHV, vertical in-line, direct injection |
|------------------------------------------|-------------------------------------------------------------------------------------------------|
| Cylinder number                          | 4                                                                                               |
| Cylinder bore                            | 93 mm                                                                                           |
| Cylinder stroke                          | 102 mm                                                                                            |
| Compression ratio                        | 18.2:1                                                                                           |
| Compression pressure                     | 31 kg/cm²                                                                                        |
| Total cylinder volume                    |                                                                                                 |

2. Research methods

2.1. Methods used
The method used is true experimental research. This type of research can be used to test the effect of a treatment or a new design by comparing one or more of the group without treatment.
2.2. Research flow chart

![Research Flow Chart](image)

**Figure 1.** Research flow chart.

2.3. Research variable

2.3.1. Independent variables: The independent variable is: 1) Fuel blends: D100; D90J30 2) Load: The valve openings: 0%, 25%, 50%, 75%, and 100%. 3) Diesel engine rotation: 2000 rpm.

2.3.2. Dependent variable: The Dependent Variable is: 1) Exhaust temperature 2) Intake manifold temperature 3) Diesel Engine temperature 4) Environmental temperature 5) Intake manifold pressure manometer 6) Efficiency Volumetric.

2.4. Experimental procedures
Experiments performed with the following steps: 1) the first test was conducted for Biodiesel fuel Pertamina D100. The engine speed constant 2000 rpm and a variation of the valve opening load of 25%, 50%, 75%, and 100%. This test is intended to determine the effect on the performance of diesel engines such as Volumetric Efficiency 2) the second test is done with fuel D90J30 at engine speed 2000 rpm also given variations valve load equal to the first test.
2.5. Experimental setup

![Diagram of experimental setup](image)

(1) Diesel Engine. (2) Dynamometer. (3) Dynamometer Pump. (4) Water Tank. (5) EGR Valve. (6) Load Valve. (7) Heater. (8) Manometer Input EGR. (9) Manometer output EGR. (10) Temperature Display Exhaust (T1). (11) Temperature Display Input EGR (T2). (12) Temperature Display Output EGR (T3). (13) Temperature Display Intake (T4). (14) Temperature Display Engine. (15) Display Engine Rpm. (16) Display Load. (17) Fuel Tank. (18) Fuel Valve. (19) Buret. (20) Fuel Return Valve. (21) Fuel Pump. (22) Tachometer. (23) Start Gas. (24) Smoke Analyser. (25) Hose Inlet Gas Analyzer.

3. Results and discussion

3.1. Results

| No. | Load (%) | rpm | Load (kg) | T1 (°C) | T4 (°C) | T5 (°C) | manifold U1 Air intake (cm Hg) | BB (ml) | t (s) | Q (ml/s) | Opacity (m^2/1) | Opacity % |
|-----|----------|-----|-----------|---------|---------|---------|-------------------------------|---------|------|----------|----------------|-----------|
| 1   | 0        | 0   | 0.00      | 170     | 32      | 38      | -0.9                          | 1.8     | 30   | 52       | 0.59           | 0.05      | 0.99      |
| 2   | 25       | 20.10 | 283 32 38 | -0.9    | 1.8     | 30      | 27                           | 1.11    | 0.32 | 6.19     |
| 3   | 50 2000s | 34.85 | 402 30 39 | -0.9    | 1.8     | 30      | 20                           | 1.50    | 1.24 | 21.9     |
| 4   | 75       | 40.95 | 432 32 40 | -0.9    | 1.8     | 30      | 18                           | 1.67    | 1.72 | 29.1     |
| 5   | 100      | 41.25 | 447 31 40 | -0.9    | 1.8     | 30      | 17                           | 1.76    | 1.79 | 30       |

Table 4. D100 test results.
Table 5. D70J30 test results.

| No | Load (%) | rpm | Load (kg) | T1 (°C) | T2 (°C) | T3 (°C) | T4 (°C) | T5 (°C) | T6 (°C) | manometer U1 | Air intake (cm Hg) | manometer U1 | Air intake (cm Hg) | B | Torque (Nm) | P (kW) | MEP (kPa) | bhp | sfc (kg/hr) | AFR | FAR | φ | Opacity % | Opacity % |
|----|----------|-----|-----------|---------|---------|---------|---------|---------|---------|-------------|------------------|-------------|------------------|---|------------|--------|---------|-----|-----------|-----|----|---|----------|----------|
| 1  | 0        | 2000| 0,00      | 102     | 36      | 44      | -0,9    | -0,9    | 1,8     | 30          | 49               | 0,61         | 0,03             | 0,0098 | 0,013      | 88,76   |
| 2  | 25       | 1995| 259       | 36      | 44      | -0,8    | -0,8    | 1,6     | 30      | 25          | 1,20             | 0,2          | 3,921056        |
| 3  | 50       | 3310| 344       | 34      | 44      | -0,8    | -0,8    | 1,6     | 30      | 19          | 1,58             | 0,83         | 15,29538        |
| 4  | 75       | 3710| 368       | 34      | 44      | -0,8    | -0,8    | 1,6     | 30      | 18          | 1,67             | 1,23         | 21,80778        |
| 5  | 100      | 3755| 374       | 35      | 45      | -0,8    | -0,8    | 1,6     | 30      | 17          | 1,76             | 1,27         | 22,43082        |

3.2. Discussion

The results of the measurement of engine performance using Pertamina biodiesel fuel and D70J30 biodiesel are calculated in table 4 and table 5. The results of volumetric efficiency calculations are then presented on figure 3 to compare. The comparison results show the volumetric efficiency of diesel engines using D70J30 fuel decreases compared to volumetric efficiency using Pertamina biodiesel fuel, amounting to 6.476%; 6,4731%; 6.187% and 6.4747% for a 25% load; 50%; 75% and 100%. Volumetric efficiency decreases so the engine power must decrease. The engine power decreases due to lack of oxygen because the air that can enter the combustion chamber is reduced in volume. Reduced volume of air that can enter the combustion chamber because there is residual combustion left in the combustion chamber, marked by a decrease in intake air intake pressure. There is a decrease in the volumetric efficiency of mixed fuels at all load levels because of the type of fuel [1] and the calorific value of mixed fuels is lower than the value of diesel fuel heat [5].

4. Conclusion

From the results of the comparison of the efficiency of direct injection volumetric diesel engine using Pertamina biodiesel fuel and D70J30, the following conclusions are obtained:

![Figure 3. Load VS volumetric efficiency.](image-url)
Increasing levels of jatropha biodiesel in Pertamina biodiesel decreases the volumetric efficiency of diesel engines.

The fall in the volumetric efficiency of diesel engines when using the D70J30 fuel mixture is due to the residual combustion in the combustion chamber marked by reduced air pressure entering the diesel engine intake.

The implication of the decline in volumetric efficiency in diesel engines is the decrease in power and torque of the diesel engine.

To overcome the implications of the decrease in volumetric efficiency in diesel engines without modification is to close the intake valve settings, so that the intake time of the air into the cylinder can increase in length, it is expected that volumetric efficiency can increase, besides that there is a solution with modifications, namely by the addition of a supercharger or turbocharger, can be better again plus the intercooler.

References
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