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Characteristic of Variable Compression Ratio Diesel Engine Operating on Diesel and Biodiesel B20

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Abstract: The limitation of natural resources especially crude oil employed in automotive engine has made an attention to switch over to biodiesel. Biodiesel is known as carbon neutral and produce no carbon dioxide leads to decrease of pollution and potentially improve the engine performance. In this study, an experimental investigation on variable compression ratio diesel engine is observed based on the engine performance using the VCR Engine test setup 1 cylinder, 4 strokes with EGR (computerized). The effect of compression ratio change on the torque, specific fuel consumption (SFC), indicated power, and brake thermal efficiency has been studied using mineral diesel and biodiesel B20. When increasing the compression ratio from 13 to 18, it was found that torque was significantly increased when using biodiesel B20. As the torque increase resulted in higher indicated power. The decreasing of SFC were about 44% and 11% for mineral diesel and biodiesel B20 respectively. Specific fuel consumption was optimum at 0.21 g/kW.h at a compression ratio of 16 using mineral diesel.

1. Introduction

In recent years, the limitation of natural resources such as crude oil, coal and so forth that are employed in power plants, boilers, and some automotive engine has been growing fast. These condition forced to the transition towards alternative fuels. Also, there is a huge amount of pollution in the atmosphere due to the burning of those natural resources. The combustion of fossil fuel in Internal Combustion (IC) engine is one of the major sources that contribute to air pollution.

As a clean fuel produced from domestic and renewable resources, the utilization of biodiesel is gaining significant attention nowadays. Biodiesel is derived from vegetable oils or animal fats and can be blended in any proportion with diesel. It is also more environmentally friendly and non-toxic compared to ordinary diesel and can be used in diesel engines with minimal modification [1, 2]. Biodiesel can be produced from many feedstocks such as Jojoba oil [3], Jatropha oil [4], Mustard oil [5], waste frying oil [2], and palm oil [6] to name a few. The yield of biodiesel oil not only depend on the feedstock but also the catalyst and process used.

The Indonesian biofuels mandate is one of the most aggressive in the world especially biodiesel by setting an ambitious blending target. Out of 64 countries having biofuels targets and/or mandates, fewer than 10 impose biodiesel mandates. From those that do, except Costa Rica that has 20% biodiesel mix mandate, none of the countries mandate more than 10% mix. Based on the Ministry of Energy and Mineral Resources regulation 12/2015, percent of biofuel blending required is expected to increase from 15% in 2015 to 30% in 2025 [7].

Recently, the researchers have heightened that the utilization of biodiesel has a significant effect on the performance and emission characteristic of a diesel engine. In this study, the performance characteristic of the variable compression ratio diesel engine was investigated using mineral diesel and biodiesel B20 produced by PERTAMINA.

2. Literature Review

Performance of engine in terms of power output, mechanical efficiency, exhaust temperature, specific fuel consumption and thermal efficiency of biodiesel and its blend have been studied by many researchers. The effect of change in compression ratio (CR), exhaust gas recirculation (EGR) and EGR temperature on the performance and emission characteristic has been studied using diesel-biogas dual fuel. Higher compression ratio was found to improve energy and exergy efficiency and on the emission side showed a significant decrease in HC, CO, and NOx emission [8].

An investigation of the effect of compression ratio on a single-cylinder, four-stroke and direct injection of the diesel engine was conducted using biodiesel produced from mineral diesel blend with a waste fried oil methyl ester. A different blends of B0, B50, and B70 was observed at 14.5, 16.5, and 17.5 of compression ratio. It was found that higher compression ratios improve engine efficiencies such as specific fuel consumption, brake power, and brake thermal efficiency [9]. A performance test in a single cylinder four strokes variable compression ratio was conducted at 14:1, 16:1, and 18:1 using mustard oil methyl ester. It was observed that specific fuel consumption slightly increase and the brake thermal efficiency was maximum at full load when using B20 blended [5].

Experimental investigation on the effect of different blends of Jojoba Methyl Ester (JME) in diesel engine performance has been observed at different compression ratio from 18 to 23. The result showed, that compared with mineral diesel, JME at higher CR indicated greater improvement for biodiesel combustion, however, the emission produced when using JME was higher than mineral diesel [10]. The performance and emission of the diesel engine were studied using diesel and Sal seed oil methyl ester (SME). When the volume fraction of SME increase, brake thermal efficiency was found to decrease. However, in full load, brake specific energy consumption increased with the increase in the blend [11].

3. Research Method

The test was conducted using a VCR Engine test setup 1 cylinder, 4 strokes with EGR (computerized). Diesel engine connected to eddy current type dynamometer for loading. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The experiment was conducted at a constant engine speed of 1450 rpm and load 9 kg. Compression ratio was set at 13, 14, 15, 16, 17, and 18. Setup is provided with necessary instruments for combustion pressure and crank-angle measurements. The setup enables the study of VCR engine performance. Labview based Engine Performance Analysis software package "Enginesoft" is provided for online performance evaluation. The major specification is given in Table 1. The schematic diagram and engine picture are shown in Figures 1a and 1b.

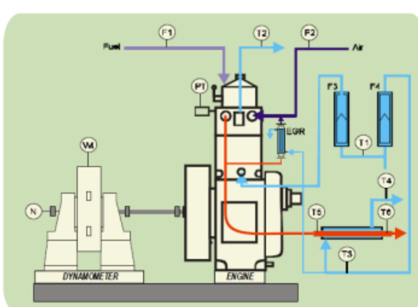

Figure 1a. Schematic diagram of engine test up

Figure 1b. Picture of engine test up

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Table 1. Engine specification

Parameters	Technical Specification
Product	VCR Engine test up 1 cylinder, 4 strokes, Diesel with EGR (computerized)
Engine	Make Kirloskar, Type 1 cylinder, 4 stroke diesel, water-cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm, 661 cc, CR 17.5. Modified to VCR engine CR range 12 to 18
Fuel Tank	Capacity 15 lit with glass fuel metering column
EGR	Water cooled, ss 304, range 0-15%
Data Acquisition Device	NI USB-6210, 16 bit, 250kS/s
Temperature Sensor	Type RTD, PT100 and thermocouple type K
Software	"Enginesoft" engine performance analysis software
Overall Dimension	W 2000 x D 2500 x H 1500 mm

4. Result and Discussion

4.1. Engine Torque

The torque values of mineral diesel and biodiesel B20 as a function of compression ratio are shown in fig.2. It is revealed that the torque increased as the compression ratio increases for biodiesel B20 and slightly stable at mineral diesel. The increasing compression ratio resulted in increasing temperature and pressure in the cylinder causing torque to increase. Compared to the mineral diesel, the torque of biodiesel B20 was lower and in a range of 16.20 to 16.43 while mineral diesel was in a range of 16.39 to 16.42 as the compression ratio increased from 13 to 18. A similar result of the torque was observed in a range of 16-20 when B20 was used at a compression ratio of 14 to 18 using supercharged VCR diesel engine[12]. Due to the low volatility and higher viscosity of biodiesel B20, the increasing compression ratio had more effect on biodiesel B20 than mineral diesel.

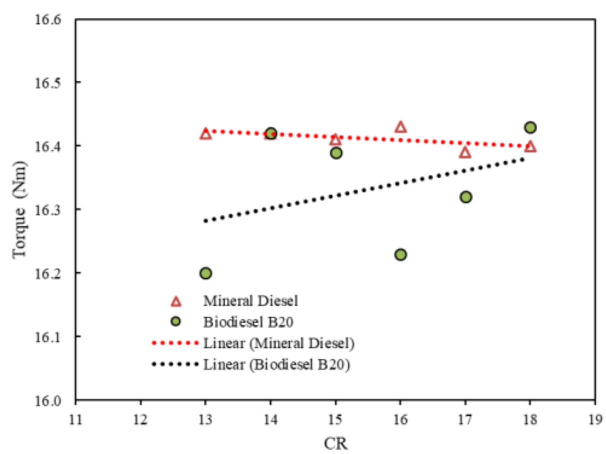

Figure 2. Variation of compression ratio on torque

4.2. Specific Fuel Consumption

The variation of specific fuel consumption on the increasing compression ratio is shown in fig. 3. The SFC is tended to decrease as the increasing of compression ratio. When using mineral diesel, the SFC is found to be lower than biodiesel B20 also the effect of increasing compression ratio had more benefit. It is assumed that in biodiesel B20 the cetane number and viscosity is lower than mineral diesel. As the compression ratio increase from 13 to 18, the decreasing of SFC were about 44% and 11% for mineral diesel and biodiesel B20 respectively.

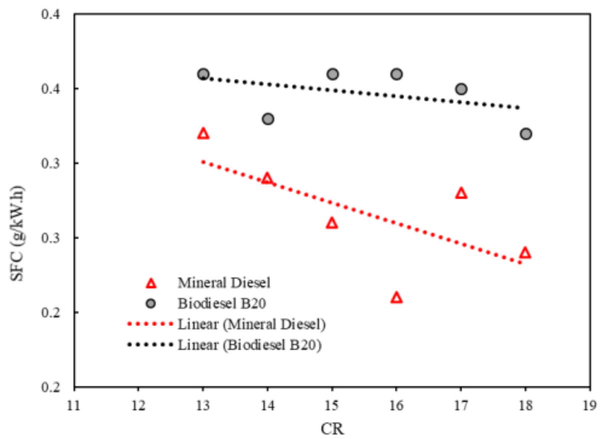

Figure 3. Variation of compression ratio on specific fuel consumption (SFC)

4.3. Indicated Power

Indicated power was defined as the power production in the cylinder. Indicated power was found to decrease by about 16% and 2.9% in mineral diesel and biodiesel B20 respectively as the increasing of compression ratio from 13 to 18 as shown in fig. 4. However, indicated power in mineral diesel is observed higher than biodiesel B20. The torque increase as the compression ratio increase due to the higher pressure inside the combustion chamber and so higher indicated power will result [13].

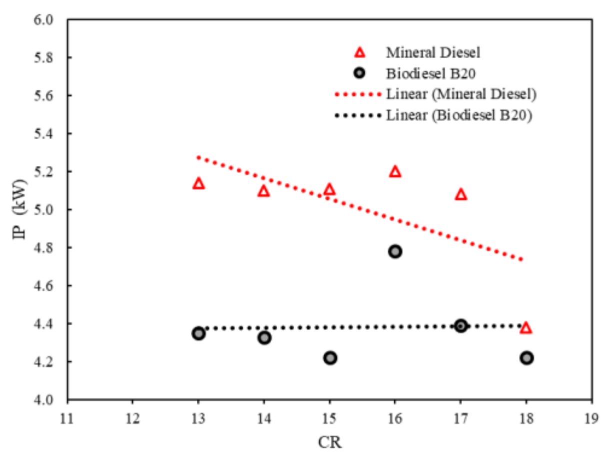

Figure 4. Variation of compression ratio on indicated power (IP)

4.4. *Brake Thermal Efficiency (BTheff)*

The brake thermal efficiency (BTheff) as a function of compression ratio using mineral diesel and biodieselB20 is shown in fig. 5. As the compression ratio increased from 13 to 18, brake thermal efficiency increased by 17% for mineral diesel and 12% for biodiesel B20. This could be attributed to the lower volatility of biodiesel B20 compared to mineral diesel. Diesel engine performance improvement at higher compression ratio because of oxygen content that resulted in the complete combustion. In accordance with the present result, the previous study on engine performance using pure diesel and biodiesel from waste cooking oil of B10,B20, B30, and B50 showed that brake thermal efficiency of all biodiesel blend was lower than pure diesel [13].

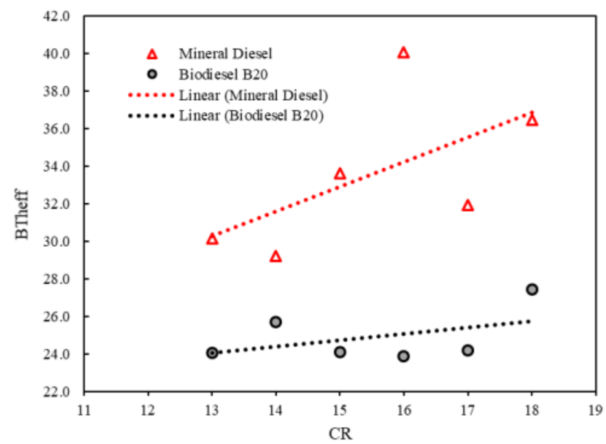

Figure 5. Variation of compression ratio on brake thermal efficiency (BTheff)

5. Conclusion

The effect of compression ratio on torque, specific fuel consumption, indicated power, and brake thermal efficiency of diesel engine fueled by biodiesel B20 have been investigated and compared with mineral diesel. Increasing compression ratio from 13 to 18 indicated a significant effect of increasing torque on biodiesel rather than mineral diesel resulted in higher indicated power. Brake thermal efficiency was higher when using mineral diesel and specific fuel consumption was optimum also when using mineral diesel. A further investigation will be conducted to study the combustion and emission of VCR diesel engine.

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