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Performance of a Compression Ignition Engine Four Strokes Four Cylinders on Dual Fuel (Diesel –LPG)

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INTRODUCTION

World energy demand in recent years has increased sharply. Increased energy demand is proportional to the increasing rate of population growth, economy, and rapid development in the transport and industrial sectors. Until now the problem of world energy demand is still dominated by energy derived from fossil fuels which are non-renewable fuels. The transportation sector is growing along with the increase of national and global economy. Diesel Engine becomes the main choice for transportation sector especially for heavy vehicles because it is more efficient. Diesel fuel engines use hydrocarbon fuel derived from petroleum which is a non-renewable potential source. Diesel engines have a higher efficiency when compared to gasoline engines. Transportations fuel mostly uses hydrocarbon fuel. Hydrocarbon fuels come from petroleum which is a potentially non-renewable resource in the future [1][2]. However, Diesel engines emit greater environmental pollution such as carbon dioxide, carbon monoxide, nitrogen oxides, particles, hydrocarbons and other insecure compounds that are responsible for increasing global warming [3].

Natural gas has the ability to be used as fuel. Gas can be used as an alternative fuel in addition to fuel oils such as gasoline or diesel. In Indonesia, gas fuel for the transportation sector uses liquid petroleum gas (LPG) as fuel. This type of gas fuel is considered cleaner when compared to two petroleum fuels (gasoline and diesel) due to environmentally friendly gas emissions. The level of air pollution generated by a motor vehicle depends on the fuel used. The level of emissions generated by the engine that uses the fuel in accordance with the type of fuel used.

The Government of Indonesia issues regulations on exhaust gas emissions limits as per EURO IV standards [4]. The new regulations will be implemented in September 2018, while existing transport vehicles still use the old emission standards. It is a special challenge to utilize Diesel engines that have been commonly used before this rule is applied, most widely used Diesel engines still use current injection (CI) and have not used electronic control

arrangements for dual fuel injectors. Thus, research needs to be done for that matter. The main advantage of dual-fuel CI engines is that they can work with a variety of gas fuel without engine modifications [5].

Researchers have developed multiple fuel studies in recent years. The dual fuel method has a major influence on engine performance. Govindaraju et al. has been investigated at dual fuel engines, with medium loading of the amount of diesel that can be substituted well is good enough while at low loading still cannot be replaced properly. While at high loading, the risk of knocking is quite high due to the burning delay. The volumetric efficiency of the engine decreases at each loading due to a portion of the volume on the cylinder occupied by LPG gas thus limiting the amount of air entering into the cylinder [6]. Ambarita et al [7] states using a single cylinder and can replace 87.5% of diesel to biogas. The effect of dual fuel Diesel-LPG method can boost the performance of diesel engines by 30%.Thedual-fuel methanol-gasoline effect has been able to decrease the fuel consumption decreases with the use of methanol. It has also been shown that CO and HC emissions are reduced by increasing methanol levels while CO2 increases[8].

The addition of diesel fuel increases thermal efficiency. It can happen because of high pressure and temperature and increased duration of combustion process. However, increasing the amount of diesel fuel at high loading results in tapping [9]. In dual fuel, this mode causes the reduction of NO emissions, the biggest decreasing effect when maximum loading with AFR approaches stoichiometry. Increasing the amount of diesel fuel leads to an increase in CO emissions. In dual fuel mode, there is an increase in exhaust emissions from unburnt fuel [10]. In the use of dual fuel, methane produces higher strength and efficiency and resistance to taps from NG and LPG. The timing injection setting causes a decrease in output torque and decreases thermal efficiency and increases maximum pressure. Increasing the level of diesel fuel causes increased torque output, thermal efficiency, and maximum pressure. Tap occurs early when a high compression ratio is used during dual fuel mode, especially on LPG. Thus, for dual fuel, it should use a lower compression [11].

Variations of LPG composition cause variations in exhaust emissions, exhaust gas temperature, and engine efficiency. The higher the butane will decrease the NOx and the higher the propane will decrease the CO level. LPG with 30% butane is the best composition because of its performance close to normal diesel engine performance. NOx and SO2 decreased 27% and 69% at maximum load and 35% and 51% at 25% loading. The 5% EGR rate leads to an increase in engine efficiency, with EGR of 5% -15% overcoming NOx and SO2 emissions [12]. Increasing the percentage of gas causes an increase in BSFC and HC emissions but the greatest effect occurs when loading 20% of the machine's maximum load. In addition, the timing injection setting causes an increase in combustion pressure and temperature but does not reduce the duration of combustion that occurs [13].

The literature review has shown that studies of operational properties such as the percentage increase in gas, loading, and additives in diesel fuel for the performance of a CI engine have been carried out by several researchers. This parameter has shown a strong effect on the performance of a CI engine that has been running in dual fuel mode. In this experiment, the effect of engine loading and LPG flow rate on engine performance was investigated. The purpose of this research is to know the influence of percentage of LPG mixture to diesel, LPG flow rate, loading, rotation speed and performance of dual fuel CI engine on engine performance.

METHOD AND MATERIAL

Current injection machine (CI) operates normally to identify multiple fuel characteristics. 4 cylinder 4 cylinder C223 diesel engine used in this study. The specifications of the C223 diesel engine are shown in Table 1.

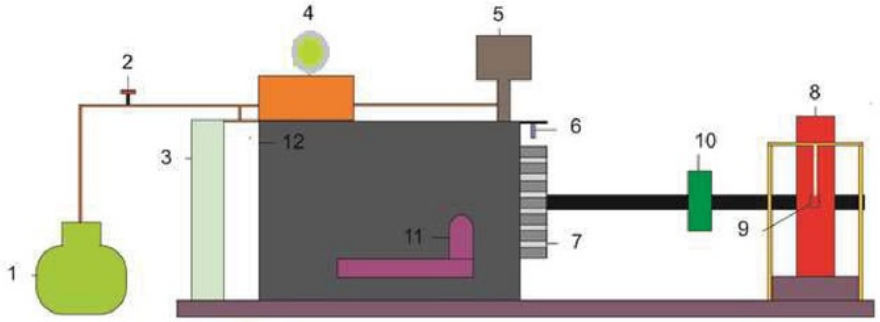
TABLE 1 C223 engine specification[14]

No	Parameter	Value
1	Engine	C223
2	Number of cylinders	4 in line
3	Bore x stroke (mm)	88 × 92
9	Displacement (cm3)	2238
5	Dimensions L x W x H	740×547 ×668
6	Weight (kg)	213
7	Compression ratio	21
8	Power output (kW)	45
9	Cylinder Volume (cc)	2238

This type of water brake dynamometer is used to measure the performance of the test machine. Dynamometer coupled with C223 to provide load variation and measure torque. Included in tachometer mounted dynamometer, K type thermocouple, load cell, and converter kit. Double fuel performance (diesel-LPG) will be compared with the performance of one fuel (diesel). The indirect injection method is used in this dual fuel system, which means the converter kit will supply LPG through the machine's inlet. This research has used diesel fuel and liquid petroleum gas (LPG). Fuel has been tested for composition content in accordance with Indonesian government regulatory standards. The Diesel low heating value (LHV) is 42.64 MJ/kg and for LPG specification is 45,277 MJ/kg[15][16].

The water brake dynamometer used has the following specifications

Type	:	water brake dynamometer
Maximum Power Steady Speed	:	500 HP
Maximum Torque Steady Speed	:	1800 Nm
Maximum Speed rotation	:	6500 rpm



Description:

1	LPG tank	7	Flywheel
2	Valve	8	Water brake dynamometer
3	Radiator	9	Load cell
4	Converter kit	10	Flexible coupling
5	Intake manifold	11	Exhaust manifold
6	Proximity sensor	12	Diesel engine (c223)

FIGURE 1. Experimental Block Schematic

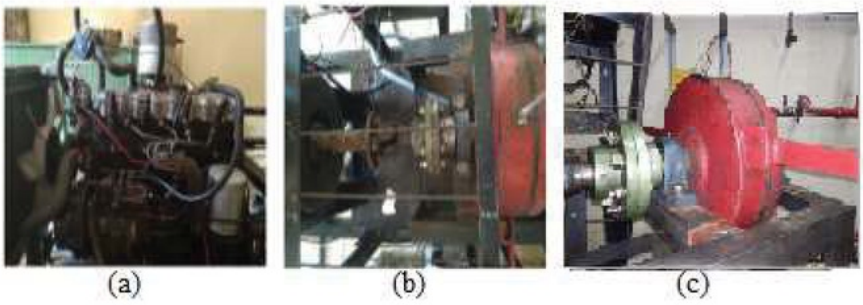


FIGURE 2 (a) engine stand unit; (b) coupling engine to dynamometer; (c) dynamometer water brake

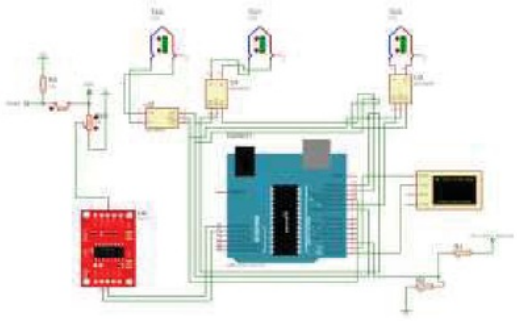


FIGURE 3 Data Acquisition

Data acquisition records machine performance. Recorded data is displayed in real time using DAQ PLX software via Arduino Uno board microcontroller connection, the data presented in the table is the speed of engine speed, torque, and intake and exhaust manifold temperature. Methods of data retrieval is done with several variations. The engine speed is varied from 1500 rpm to 2700 rpm with 300 rpm intervals. Then the rate of fuel was reduced 35%, 55%, and 75% from baseline were replaced by LPG. Torque data capture is done on each dual fuel at a rotation speed 1500, 1800, 2100, 2400 and 2700 rpm.

TABLE 2. Ratio of Fuel Index

Symbol	Comparison Of Percentage	
	Diesel	LPG
G0	100	0
G35	65	35
G45	55	45
G75	25	75

Equation

The main indicator of engine performance usually described by power output and its torque. The following equation was used to calculate torque:

$$T = m \times g \times L \ (N.m) \qquad (1)$$

Engine load (kg) denoted as m was obtained from load cell at water brake dynamometer, gravity (m/s2) denoted as g, and its length (m) denoted as L was measured from the center point of dynamometer to load cell. The power equation follow:

$$P = \frac{2 \times \pi \times T \times \omega}{60000} \ (kW) \qquad (2)$$

Engine speed which are denoted as ω was measured using proximity sensor which are placed near the flywheel. Equation for brake specific fuel consumption (BSFC) follow:

$$BSFC = \frac{FC}{P} \times 3600 \ \left(\frac{g}{kW.h}\right) \qquad (3)$$

Fuel consumption (g/s) denoted as FC. Brake thermal efficiency may be defined as the ratio of output brake power (BP) of an engine to the input power of the engine. As Equation for the brake thermal efficiency (BTE) follow:

$$BTE = \frac{P \times 3600}{FC \times LHV} \times (100\%) \qquad (4)$$

Low heating value (LHV) for dual fuel was calculated total for diesel fuel and LPG fuel. And equation for the substitution ratio follow:

$$r = \frac{m_{LPG}}{m_{LPG}+m_{Diesel}} \times (100\%) \quad (5)$$

RESULT AND DISCUSSION

Torque

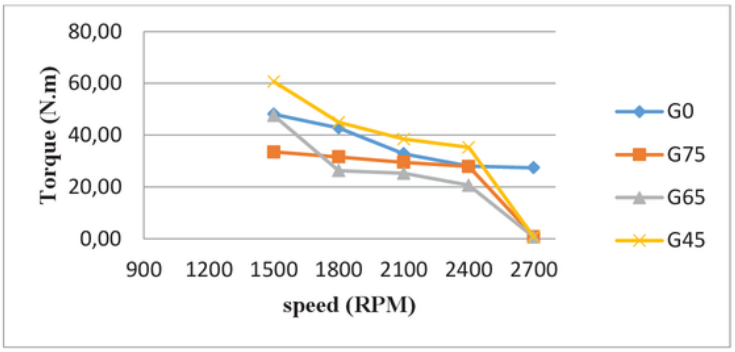


FIGURE 4. Comparison of Torque and Speed

Figure 4. shows the dual fuel mode has increased engine torque compared to the baseline method. Increased torque in dual fuel mode occurs in G45, where the composition is 55% diesel and 45% LPG. Increasing diesel fuel quantity would make the torque increased, it is because the burned AFR is met. In dual fuel G65, the torque decreases compared to the baseline. But the higher the rpm on the resulting torque engine becomes smaller it shows that the dual fuel mode will produce optimal torque at low rpm.

Brake Specific Fuel Consumption (BSFC)

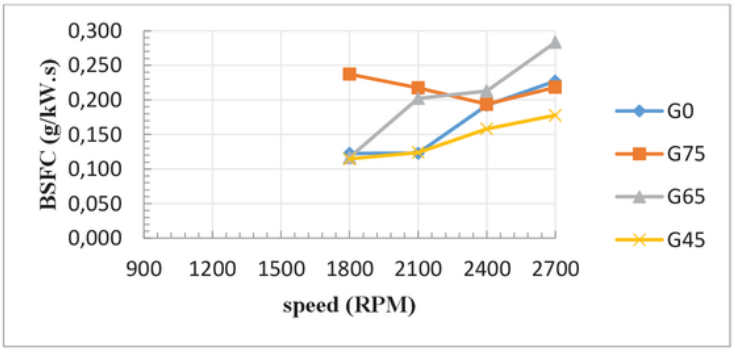


FIGURE 5. Comparison of BSFC and Speed

As shown in Fig. 5, there is an increasing trend of BSFC for G75 and G65 compared to pure diesel operation. It also found that the highest BSFC rate occurred at G65 which operated at a speed of 2700 rpm higher than that of baseline diesel operations. The decrease in BSFC occurs in G45 of all variations in speed to baseline diesel. So when compared to baseline diesel, the specific fuel consumption equivalent of higher brakes for dual fuel operations.

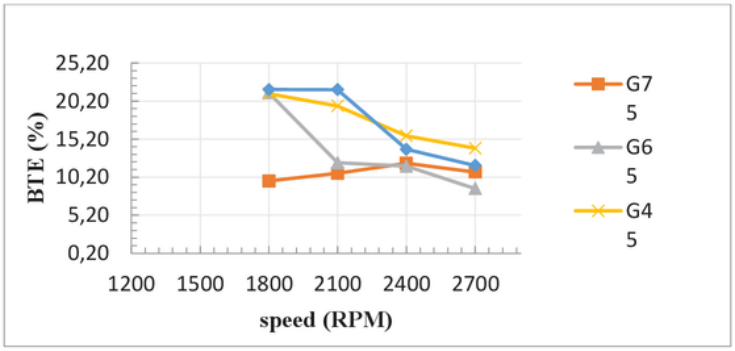


FIGURE 6. Comparison of BTE and Speed

BTE can be defined as the ratio of brake power output (BP) of the engine to the engine input power. As summarized in Fig. 6 it is clear that BTE in dual fuel operations illustrates the downward trend in G45 at low speeds, compared to diesel operations. Also, minimum BTE is displayed and G75. But for G45 on high rotation has increased BTE. Finally, it can be suggested that the brake thermal efficiency for dual fuel operation is lower than at the baseline.

CONCLUSIONS

In this research c223 engine are used as dual fuel engine diesel-LPG by varying LPG concentration at 35%, 45%, and 75% with various speed at 1500, 1800, 2100, 2400, and 2700 rpm. Main result of the dual fuel diesel engine can be summarized as follow:

1. There is improvement of brake specific fuel consumption (BSFC) when dual fuel mode is used. The best improvement of BSFC is appear when LPG concentration are 45% (G45). This improvement indicated that it required appropriate LPG concentration when dual fuel is used at various speed or engine load.
2. Better torque also acquired when dual fuel is used. Better torque indicates better power which mean dual fuel are proved to increase performance of diesel engine in term of engine power.
3. Brake thermal efficiency (BTE) of dual fuel engine with 45% LPG concentration are better than single fuel engine. However, at some point especially heavy load condition BTE of dual fuel are lower than single fuel. It can be caused by poor combustion of the engine so that the unburnt of LPG fuel are increased too which is lead to poor performance until knocking.

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