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The Performance of a Spark Ignition Engine using 92 RON Gasoline with Varying Blends of Bioethanol (E40, E50, E60) Measured using a Dynamometer Test

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Abstract. Indonesia's increasing energy dependence on fossil fuels amid the country's declining petroleum reserves requires the development of an effective solution in the form of renewable fuels such as fuel-grade bioethanol. This study investigated a potential way of reducing dependence on fossil fuels for motorcycle engines by using fuel-grade bioethanol blended with gasoline to produce a novel marketable fuel type. The present paper focuses on the effect of various fuel blends >40% ethanol on the performance of a spark ignition (SI) engine. This study used a standard, off-the-shelf, 150cc SI engine as the test engine, running on RON 92 gasoline with varying mixtures of bioethanol (40% (E40); 50% (E50); and 60% (E60)), connected to a dynamometer to obtain performance data (torque, power, and specific fuel consumption) and emission data (hydrocarbon, carbon monoxide, and carbon dioxide). The results showed that E60 represented the optimum mixture as it produced the highest torque, power and specific fuel consumption optimum used E50.

Keywords: Bioethanol; Engine dyno test; Performance; Renewable energy

1. Introduction

Energy dependence on fossil fuels and the associated environmental problems this causes are becoming an increasing cause for concern. In the transportation sector, one of the most common environmental problems of burning fossil fuels in internal combustion engines is the air pollution produced by combustion products (De Simio et al., 2012). Motorcycles produce emissions that contain CO_2, HC, CO, and NO_x; however, these emissions can be reduced with the use of blended bioethanol fuels (Wibowo et al., 2020). One of the options available to address this task is substituting fossil fuels with renewable fuels such as bioethanol. The characteristics of gasoline can be altered using blended bioethanol; for example, boiling temperature points (distillation), density, Reid vapour pressure (RVP), and research octane number (RON) (Kheiralla et al., 2011; Kheiralla et al., 2012).

In recent years, ethanol-based fuels have been favored because their physical properties and characteristics share many similarities with gasoline. Bioethanol is

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produced from biomass (Hossain et al., 2017) and provides a range of benefits, such as mixing with gasoline to increase the fuel's RON rating. An inadequate RON value causes knocking in SI engines, which can be overcome by using a fuel with a higher RON value to reduce knocking (Adian et al., 2019). However, despite its merits in improving RON, bioethanol suffers from having a lower Low Heating Value (LHV) than gasoline, which causes the requirement for a higher air-fuel ratio, resulting in higher fuel consumption (Adian et al., 2020). Market-available gasoline-blend fuels include (ethanol) E10 for conventional engines, E85 for use in flex-fuel vehicles (Kim and Dale, 2006; Petrolia et al., 2010) and a 20% ethanol blend for use in unmodified vehicles (Tibaquirá et al., 2018). The present study investigates a bioethanol fuel blend of 40–60% in an unmodified test engine.

Specifically, the present study investigates the use of Indonesian-specification RON 92 gasoline (content: 99,5%) with varying blends of bioethanol (namely, 40% (E40), 50% (E50), and 60% (E60)) in terms of the effect characteristics, performance, and emission results produced using a standard 150cc SI motorcycle engine.

2. Methods

In this study, we prepared commercial RON 92 gasoline as the base fuel, which was then blended with fuel-grade ethanol/bioethanol at concentrations of 40%, 50%, and 60%, respectively. The density of fuel was determined in accordance with ASTM D 4052-11 Annual Book of ASTM Standards (2012) and RON was determined with ASTM D 2699-12 Annual Book of ASTM Standards (2012) and Kheiralla et al. (2011). The specifications of the engine used in testing are outlined in Table 1.

Table 1 Engine test specification

Parameter Engine	Value
Engine Type	4 Stroke, SI Engine, DOHC, Air Cooled
Cylinder	1 (Single)
Bore × Stroke	57.3 mm × 57.8 mm
Volume	149.4 cc
Compression Ratio	11.3:1
Fuel Supply System	Injection (PGM-FI)
Spark Ignition	NGK MR9C-9N / ND U27EPR-N9

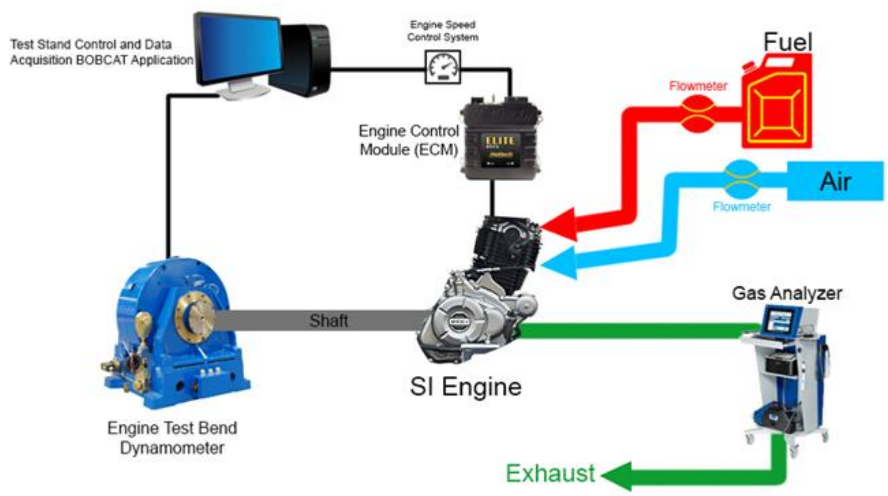


Figure 1 AVL engine dynamometer test bench scheme

The testing was performed at the engine test laboratory of the Research and Development Center for Oil and Gas Technology Center (LEMIGAS), Jakarta, Indonesia. The engine dynamometer used in this research was an eddy current dynamometer. Under testing, the electrical current in the dynamometer exerted a load on the test engine at rotational engine speeds of 3500, 5000, 6500, and 8000 RPM. The test-bench rig is illustrated in Figure 1.

3. Results and Discussion

3.1. Research Octane Number and Density

The results showed that the tested fuel blends with E40, E50, E60 blends of RON 92 commercial gasoline increased the RON value, density, and the RON value of the base gasoline (RON 91) (Tangka et al., 2011) in Table 2.

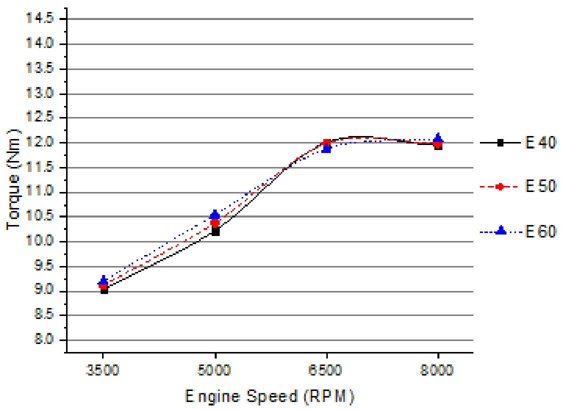
Table 2 Characteristics of fuel tests

Parameter	Unit	RON 92 Gasoline (tested)			RON 91 Gasoline (Tangka et al., 2011)		
		E40	E50	E60	E40	E50	E60
Research Octane Number		104.6	106.62	108.62	97	99	100
Density 15°C	Kg/m³	760.9	768.26	775.396	779.2	780.5	781.2

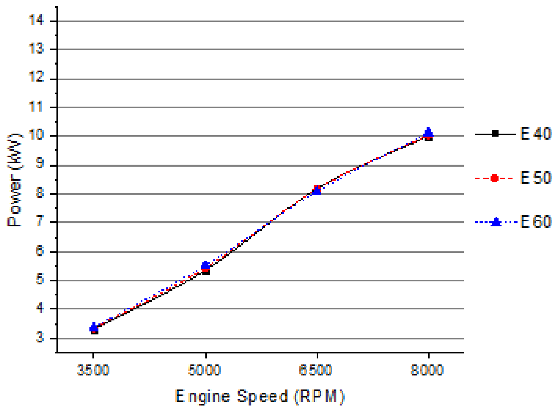
The characteristic of gasoline blends ethanol such as density increased linearly ad the value of Research Octane Number (RON) increased with increasing blends percentage volume ethanol (Kheiralla et al., 2012). The addition of a certain percentage volume ethanol and a certain base Gasoline could use a predictive calculation to the value Research Octane Number (RON) of fuels blends (Wang et al., 2017). The oxygenate content on ethanol blends to gasoline could improve the characteristics of cold-flow properties of fuel blend (Al-Mashhadani and Fernando, 2017).

3.2. Torque and Power

The parameters evaluated for this research project were torque, power, and specific fuel consumption (Sugiarto et al., 2020). Each parameter was analyzed by comparing the results of those from previous research (Wibowo et al., 2019). In Figure 2, the results show the highest amount of torque was achieved by the E60 mixture at 8000 RPM, which is considered the optimal torque output as it exceeds the E40 blend by 1%. While the fuel test of E40 in the present study shows nearly the same trendline as E60, a key difference occurs at 6500 RPM.



(a)



(b)

Figure 2 Torque with varying bioethanol percentages (a) and Power (b)

A higher bioethanol percentage results in higher torque, which concurs with the present study's results, as shown in Figure 2a. In summary, the results show the bioethanol percentage volume has a positive impact on torque, as seen in Table 1.

As shown in Figure 2b, the highest amount of power was achieved using an E60 mixture at 8000 RPM, which is also considered to represent the optimal power output as it exceeds that of E40 by 1% at the same RPM. Therefore, this represents the optimal blend to maximize power output. The blending percentage of local ethanol-gasoline increases torque with an open 100% throttle engine (Efemwenkiekie et al., 2019). This result corresponds with the torque parameter, where the varying bioethanol percentages affected the generated power.

3.3. *Specific Fuel Consumption*

Specific fuel consumption is the amount of mass rate flow of a fuel needed to produce each power output unit. As shown in Figure 3, each bioethanol percentage volume achieved a different specific fuel consumption. Value density is an important factor for calculating fuel consumption (Al-Mashhadani and Fernando, 2017).

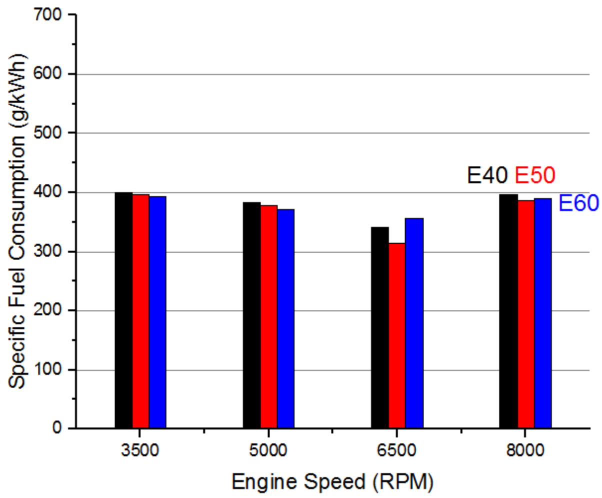


Figure 3 Specific Fuel Consumption with Varying Bioethanol Percentages

The lowest specific fuel consumption was achieved by using the E50 mixture at 6500 RPM, as it achieved an 8% lower fuel consumption than the E40 mixture. The test used a single-cylinder engine with gasoline blend ethanol 10–60% volume to obtained optimum specific fuel consumption as E40 fuel (Thakur et al., 2017). In summary, the higher the bioethanol percentage, the lower the specific fuel consumption.

3.4. *Hydrocarbon (HC) Emission Aspect*

Hydrocarbon emissions are caused by a non-stoichiometric air-fuel ratio (Pulkrabek, 2004). As shown in Figure 4, the lowest hydrocarbon emissions were achieved using the E40 mixture at 5000 RPM, as this was 32.1% lower than that of E60, and at 8000 RPM, E60 achieved a lower fuel consumption than E40. Therefore, hydrocarbon emissions are reduced with the use of ethanol blends due to the higher oxygen content enhancing combustion (Chansauria and Mandloi, 2018).

3.5. *Carbon Monoxide (CO) Emissions*

Carbon monoxide emissions are caused by a non-stoichiometric air-fuel ratio (Pulkrabek, 2004). As shown in Figure 5, the lowest hydrocarbon emissions were achieved using the E60 mixture at 6500 RPM, as it lowered hydrocarbon emissions by 67.7%

compared to E40; the latter being the optimal blend for the reduction of carbon monoxide emissions in previous research.

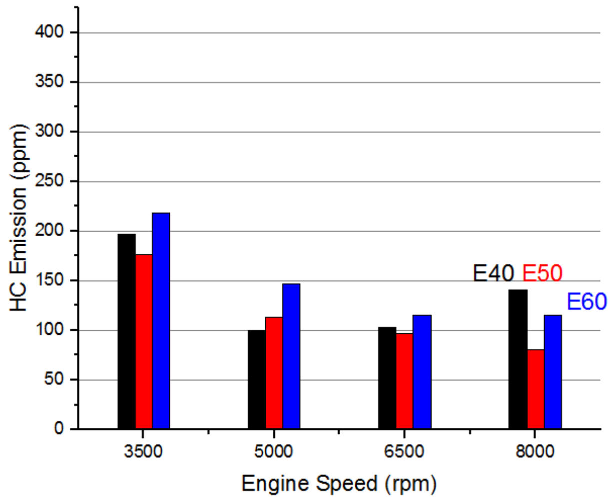


Figure 4 Hydrocarbon emissions with varying bioethanol percentages

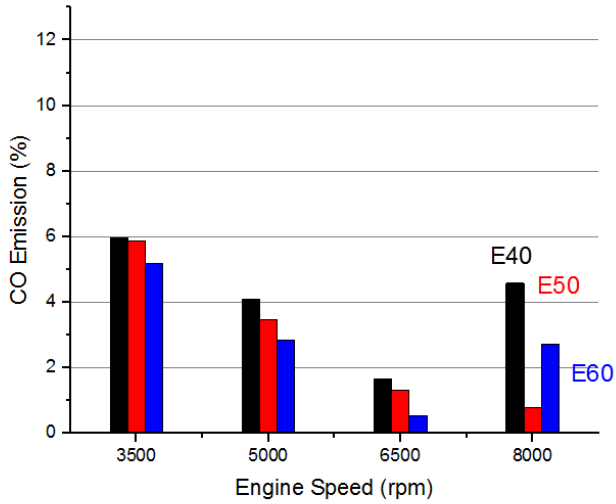


Figure 5 Carbon monoxide emission with varying bioethanol percentage

The trendlines for both blends (E40 and E60) in the previous research are comparable with the trendlines for E40 and E60, where the differences also occur at 5000 RPM and 6500 RPM, respectively. The fuel with blend ethanol of engine carburated system could effect decreasing CO emissions to high-level emission standard (Tibaquirá et al., 2018). In summary, increasing the percentage of ethanol decreases CO emissions (Samuel Raja et al., 2015).

3.6. Carbon Dioxide (CO_2) Emission Aspect

As shown in Figure 6, the highest carbon dioxide emissions were achieved by the E60 blend at 8000 RPM, which is considered the optimal result as it exceeds that of E40 (11.5%). Critically, higher blends of ethanol in gasoline cause higher CO_2 emissions than gasoline alone (Singh et al., 2016). The fuel gasoline blend bioethanol used alternative fossil fuel to reducing CO2 emissions SI engine combustion (Turner et al., 2011).

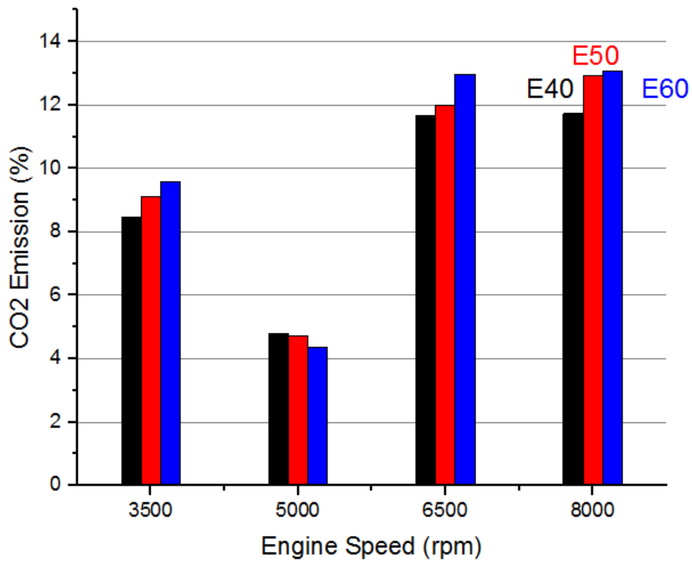


Figure 6 Carbon dioxide emissions with varied bioethanol percentage volumes in previous research (Left) compared with the present research (Right)

4. Conclusions

The results show the outcomes of using varying blends of bioethanol in RON 92 gasoline together with their effects on performance and emissions. In terms of performance, optimal torque and power were achieved using the E60 blend, which suggests that both torque and power benefit from the use of a higher percentage of bioethanol in the fuel mixture. For specific fuel consumption, the optimal value was obtained using the E50 blend. In terms of emissions, optimal hydrocarbon emissions were achieved using the E50 mixture while carbon monoxide and carbon dioxide emissions were optimized using the E60 mixture.

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