An effect of different spark plug used and additional ethanol on engine performance and exhaust gas emission

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Abstract. The existence of fossil fuels is increasingly scarce nowadays. Therefore, finding alternative fuels to substitute petroleum fuels, especially gasoline that very huge used for a motor vehicle. One of the alternative fuels as a substitute for gasoline is bioethanol (BE). The aim of the research work was to analyze engine performance and exhaust emission level of vehicle using two different types of spark plug. Further investigation was addressed by varying additional bioethanol fuel made from raw material of cassava. The work was carried out experimentally both in the laboratory and engine test drive. The results show that by using platinum spark plug resulting better performance of engine. The additional bioethanol on fuel, the power, and torque generated from the engine increases with the increase of percent bioethanol in the fuel mixture. The fuel consumption is more efficient by using fuel of 30% BE, compared with engine operation using fuel of 100% pertalite. While the results of the exhaust emission on the vehicle show that by using fuel bioethanol, exhaust emissions decrease as the increase of bioethanol in fuel mixture than exhaust emissions generated when using fuel 100% pertalite. It was proved by statistical data analysis using a one-way ANOVA Varian (F test) for power, torque, and HC emission levels, found of F value less than F table. Therefore hypothesis null (Ho) was accepted. Further result in each variation of fuel there is no significant difference. However, for CO, found that counted F greater than F table, then Ho was rejected; therefore the result of each variation of fuel there is significantly different.

Keywords: Bioethanol, Cassava, Engine Performance, Emission.

1. Introduction

The scarce of fossil fuel is considerable interest to discuss recently. Its effect is really wide in every sector of life. The very close sector and really affected is in the transportation and industrial sector. The fluctuation supply and fuel price should make us aware that the stock of fuel on the earth is getting low day has consisted. Since fossil fuel is nonrenewable energy, then it encourages us to find that alternative. Actually, in Indonesia, there is a lot of renewable sources of energy, such as biodiesel from a plant of Ricinus communis, palm oil, and soy. Another alternative fuel is methanol and ethanol from biomass, sugar cane, corn, etc., which can be used as substitution of gasoline [1].

Other than that, its fossil fuel burning is giving a negative impact on the environment. Air quality that decreases day to day due to the burning smoke from fossil fuel is one of the effects that we can see clearly, the effect of greenhouse generated by gas of CO₂ resulted from the combustion of fossil
fuel. As we can see combustion of un-perfect fossil fuel will produce CO\textsubscript{2} that gradually increases in atmosphere. The radiation of sun spread to the earth should have been reflected back to space, but, the accumulation of its CO\textsubscript{2} will obstruct this reflection. As a result, radiation will be back absorbed by earth that finally increases the temperature of air on the earth [1].

Another CO\textsubscript{2} contributor is fossil combustion. The use of fossil fuel is getting increase significantly since industry revolution in 18\textsuperscript{th} century. In that century, coal became a dominant source of energy than substituted by fossil fuel in the middle of 19\textsuperscript{th} century. The two main sources of CO\textsubscript{2} emission globally were 2 types. Firstly, the electric generator coal-powered. Secondly is the combustion of motor vehicle engine. The emission of greenhouse effect should be reduced so that we should construct industrial systems and transportation that not depend on fossil fuel and coal. Therefore, to overcome this problem requires source of alternative energy which is reduce the use of fossil fuel, whilst it could reduce CO\textsubscript{2} emission. One of the energy sources in conjunction with reducing fossil fuel is fuel from vegetative namely [2].

Alcohol is produced from plants using microorganisms through fermentation process [2]. Introducing its alternative energy is also a struggle in reducing the use of fossil fuel in Indonesia and in the world typically. The form of energy source quite interesting to be developed since the availability in Indonesia and its properties are renewable. There are three categories of ethanol sources, which are liquid sugar cane, jell, and material matrix or lignocelluloses. All that material is relatively easy to be found and to be developed in Indonesia with very huge land area.

Therefore, probably become the most prospective alternative fuel and there are many studies addressed for developing such fuel. It is having some advantages compared with fossil fuel that could be directly mixture in the fuel tank, injected to combustion chamber and burned to reduce emission of exhaust gas. Such material gathered from renewable sources that unlimited in the form of tree that can be grew up perfectly, or biomass that contained sugar inside, jell or cellulose. By mixing and fossil fuel-based gasoline engines could help to enlarge supply of fuel, ensure safety deeply in supply of fuel widely, increase the efficiency of combustion and reduce hydrocarbon (HC) and emission carbon monoxide (CO). Other than that, the higher and gasoline mixing produce of good mixing, and the perfect combustion achieved. Therefore, reduce of environment problems, increase of agricultural economic growth and avoid of dependency to nations of producer of fossil fuel [3].

2. Literature Review

The work on utilization of as mixing of fuel was carried out by Mohsen Ghazikhani et.al. [4], on their research, an experimental study was done in conjunction with gas temperature effect and emission level on exhaust gas for two-stroke gasoline engine using gasoline and mixed with ethanol. The result showed that efficiency of combustion increase along with the increase of ethanol percentage on gasoline, since, properties of ethanol is easy evaporated hence overlapping in combustion chamber better and the dominant result in using ethanol was in reducing pollution significantly emitted from the engine which reduces CO by 35%, and that it the biggest reducing among other pollutants. Also, most of the emission increase with the increase of exhaust gas temperature, yet, hydrocarbon (HCs) on average decrease by 30% on increasing exhaust gas temperature.

Xiaochen Wang et.al. [5], on their work characterization of combustion, was done and exhaust gas emission were tested using fuel of E10W, E10 and pure gasoline (EO) with different load of engine of 20 Nm, 50 Nm, and 100 Nm, as well as in their experiment was done in constant engine revolution of 2000 rpm. The result of the experiment showed that compare with E0, E10W indicates greater than pick pressure on the cylinder at high load, also, the increase of pick released heat investigated for fuel of E10W at all operating conditions. The use of E10W increase of NO\textsubscript{x} at about high load. However, at low load, E10W could reduce HC, CO, and CO\textsubscript{2} significantly. Compared with E10, E10W indicated pick of pressure greater than in the cylinder. Besides that, reducing emission of NO\textsubscript{x} revealed for E10W from 5 Nm to 100 Nm, meanwhile emission of HC, CO, and CO\textsubscript{2} slightly higher than small load and middle load.
Paolo Iodice et al. [6], carried out of a quite simple testing emission on a motorcycle at engine operation that has not reached work temperature by using gasoline fuel with ethanol. In their research, percentage of ethanol used was 10%, 20%, and 30% also, the emission measured was only CO and HC. The result shows that emission of CO and HC on the engine in cool conditions reduce with the use of ethanol-gasoline compared with the used of unleaded fuel, also, factor of emission level on cool engine that quantitatively as a function of ethanol percentage on fuel.

Bambang Sudarmanta et al. [7], undertaken of research experimentally to compare of compression ratio effect and time of ignition to ensure engine performance using fuel of E50. Result of their research showed that the increase of compression ratio increase engine performance by using fuel of E50, for an ignition time increase gradually from 18° before top death centre (BTDC) on engine revolution of 2000 rpm to 26° BTDC at engine revolution of 5000 revolution per minutes (rpm) by using fuel of E50. Then, by adding a compression ratio on the fuel of E50 reduce of specific fuel consumption by 13.42 % and increase thermal efficiency by 14.67 %.

Yanuandri Putrasari et.al [8], carried out of investigation of mixing diesel fuel and ethanol of E2.5%, E5%, E7.5%, E10% and the experiment was done in vary of engine load of 0, 10, 20, 30, 40, 50, 60 Nm to ensure changing of parameter on diesel engine which was fuel consumption, thermal efficiency, exhaust gas temperature and lubricant temperature, meanwhile, characteristic of exhaust gas emission, the measured parameter was CO and HC. The result of the research that engine power indicated an increase in average effective pressure due to the increase of ethanol percentage, for specific fuel consumption reduced with the increase of ethanol percentage, then, reduce exhaust gas temperature and increase oil temperature that suitable with the increase of ethanol percentage on fuel. Also, the result of exhaust gas emission, characteristics of CO, and HC was decreased due to the increase of ethanol percentage.

This ethanol resulted from glucose fermentation followed by the distillation process. Ethanol stands for ethyl alcohol (C2H5OH); often called grain alcohol or alcohol. The feature of ethanol is un-colored fluids, easily evaporated and unique smelted. The density of ethanol is 0.7939 g/mL, and its boiling point of 78.32°C at 766 mmHg. Another characteristic of it is emulated in water and ether, as well as having heating value of 7093.72 kcal. Ethanol is used in vary of industry such as raw material in industry derivative from alcohol, mixing for a soft drink, mixing for sake or gin, pharmacy material and cosmetics, and mixing of vehicle fuel, increasing octane number, and gasoline alcohol (gasohol) [9].

The use of ethanol as an energy source in industry and vehicle will be reduced by CO₂ percentage that affected global warming. Quick or slow, fossil fuel sources (fossil fuel) will be running out as the limited deposits. Fossil fuel as an energy source that is non-renewable, its limitation encourages industrial state glance ethanol (biofuel) as an energy alternative source. Other than that, continuously could be produced by microorganism, ethanol also environmentally friendly [10].

Some of the benefits of using ethanol as fuel are 1.) produced from renewable plants. 2.) Containing oxygen of about 35% therefore perfectly flammable. 3.) The use of gasohol reduces emission greenhouse. 4.) Combustion does not produce lead and benzene which having carcinogenic behavior (stimulate cancer). 5.) Reduce emission fine-particles that dangerous for the health of humans. 6.) Easily solvable in water and not contaminant to water and soil.

The distillation process produced ethanol of 95%, for using as fuel requires much purer and reaching of 99.5% which is often to called Fuel Grade Ethanol (FGE). Considered the use of ethanol which varies, then, ethanol percentage which is utilizing should be different depending on the usage. Ethanol having 90-96.5% could be used in industry, where, ethanol with 96-99.5% can be used for much mixing soft drinks and pharmacy industry. Ethanol is used as fuel mixing for a vehicle that should be really dry and anhydrous in order to a corrosive, hence, ethanol should have percentage of 99.5-100%. The difference in percentage will be influencing to carbohydrate treatment process become glucose dissipated in water [11]. Some references the above were not clearly mentioned, from what the gasohol was made. In this work, investigation was focused in distinguish engine performance operate using two different spark plugs of standard and platinum. Moreover, the most unique of the
used in this work was explicitly made from cassava and also was made by our team, from the beginning till the final process. Further work carried out by forthcoming team as continuation research using biethanol made from durian seeds has been initiated in separate themes.

3. Methodology
The research methodology was constructed consecutively, start from gathering information, collecting tools and materials, followed by biethanol production, performance test of engine, and analysis of data are described as the following section.

3.1. Tools and materials
The tools prepared for this work was; 1.) Four stoke 110 cc gasoline engines 2.) Dynotest/Dynamometer. 3.) Emission Gas Analyzer, 4.) Tachometer 5.) Measurement glass. Whilst, materials used in this research work are; 1.) Pentalite RON 90, 2.) FGE 99.7%, 3.) Standard spark plug and 4.) Platinum spark plug

3.2. Steps of production
The production was done through some steps of; (a) raw material preparation, cassava was destroyed using coconut solvent tools, then added of water 1.5 x weight of raw material to be boiled (b) liquidation process, where structure of powder/jell of cassava was broken chemically become a complex sugar with additional Enzyme Alfa Amylase (c) Next step was scarification process, where complex sugar was broken again to be a simple glucose with lower percentage of (10-12%) with additional Enzyme Gluco Amylase (d) Fermentation, in this step where flour has been changed to be simple glucose for differentiation in order to produce liquid of ethanol/alcohol with percentage of (2-5%) by adding ferment, this process occurred about 5-7 days in closed container (e) Distillation was done to separate alcohol from liquid result of fermentation. In the distillation process, at temperature of 78°C (equivalent with boiling point of alcohol) will be evaporating first than water having boiling point of 100°C. Then, the steam of at distillatory tool will be flowing to condenser then the steam to be condensate to be fluid of alcohol 70-95% (f) Dehydration, in purification ethanol 70-95% with some method, one of the method is chemically using limestone, that physically by absorption process using Zeolite Sintesis. The dehydration result is in the form of ethanol 99.6-99.8 % that is it so-called Fuel Grade Ethanol (FGE) or dry ethanol. Finally, its appropriate to be used as mixing fluid to the fuel.

3.3. Engine performance test
The testing of the engine is aimed to know optimal engine performance from a variety of spark plug both standard and platinum as well as by varying percentage of mixed to the fuel compared with the use of purely pertalite fuel. The parameter measured will cover power, torque, specific fuel consumption and emission of exhaust gas, when fuel was vary mixed with of BE 10%, BE 20% and BE 30% using the optimum spark plug.

3.4. Data analysis
The research work was analyzed using two methods; the first method was using analysis descriptive data. The second one uses statistical data analysis. Where, data logged was made in table, and presented graphically then, compared with statistic data analysis in vary of mixing levels of fuel 10%, 20%, and 30%. The statistical method consisted of t-test (double regression), One-Sample T-Test and Variant test of one way ANOVA (F-test) using SPSS software. Where, data found from the testing process inputted to SPSS program to be processed computerized to ensure the result whether the differences were significant or not for entire parameter investigated.
4. Result and Discussion

4.1. In the first step, the study was focused to investigate engine operation in different types of spark plug.

In this work, two types of spark plug used were the type of standard and type of platinum. The typical parameter was power, torque, and specific fuel consumption operated in vary of engine speed to find the best performance as reference to the continuation investigation, as the following section.

4.1.1. Correlation between power to engine speed using different spark plug and purely 100% pertalite.

It can be seen from Figure 1 that power indicated of increase in power using two different spark plugs when engine was operated using fuel 100% pertalite. The result shows that maximum power has resulted when the engine was operated using platinum spark plug of 7.14 HP at engine speed of 8900 rpm that relatively greater than that maximum power of engine when it is operated using standard spark plug of 6.84 HP at an engine speed of 9000 rpm. Using statistical data analysis proved by t-test (double regression), found that counted-T > table-T or (3.087 > 2.228). That way, Ho was refused. It's indicated that the platinum spark plug was significantly influenced by the power generated. It can be concluded that graphically, optimum power was on engine operated using platinum spark plug.

![Figure 1. Correlation of power to an engine speed of two different types of spark plug](image)

4.1.2. Correlation of torque to engine speed using different spark plug and purely 100% pertalite.

The comparison result of investigation torque to engine speed using different spark plug at engine speed of 4500 rpm resulted in the same torque of 6.20 Nm as shown in Figure 2, therefore, it can be underlined that graphically, torque was slightly increase using platinum spark plug compared with performance using standard spark plug. Further analysis was carried out using t-test (double regression), its resulting counted-T < table-T of (0.110 < 2.228) and counted-T< table-T, of (-0.932 < 2.228), therefore Ho was rejected. Hence, the result both of standard spark plug and platinum was not significantly influenced to the torque resulting. Overall, the result of using purely pertalite using different spark plugs proved that platinum spark plug more optimum than standard spark plug.
particularly on power resulted. Therefore, platinum spark plug was kept for the forthcoming investigation of engine with different percentages of fuel mixing with ethanol.

4.2. The second step study was focused to investigate the engine operation in different percentages of Ethanol added and engine operated using platinum spark plug.

Result of investigation power and torque to engine speed are presented as the following section:

4.2.1. Correlation of power to engine speed using different percent of BE and platinum spark plug.

The investigation result, indicated in Figure 3 showed that maximum power resulted from an engine that is using fuel with 30% BE compared with resulted power using BE 20%, BE 10% and Pertalite 100%. Graphically, the increase of power due to the increase of BE to the fuel. The maximum power was resulted by engine at the use of BE of 30% which is 7.47 HP at the engine revolution of 8700 rpm.
Figure 3. Correlation of power to an engine speed of 3 different % BE using platinum spark plug

From the result presented above, it concludes that graphically, optimal power occurred at fuel with BE of 30% as that optimum power was increased. Investigation results of torque using vary of fuel with platinum spark plug can be seen in the following section.

4.2.2. Correlation of torque to engine speed using different percent of BE and platinum spark plug

It was proved that from Figure 4 the resulting torque test by varying found that maximum torque resulted in fuel with BE of 30% showing from increasing torque compared with torque resulted by fuel with BE of 20% and BE 10%. From the above graph, the torque increase along with the percentage of mixing level. Maximum torque resulted in the use of BE of 30% was 5.51 Nm at engine revolution of 5700 rpm, that graphically, torque result slightly increase compared with the use of pertalite of 100%, yet, maximum torque resulted using fuel with BE of 30%, BE of 20% and BE of 10% slightly lower than maximum torque resulted using fuel pertalite 100% of 6.20 Nm.

Figure 4. Correlation of torque to an engine speed of 3 different % BE using a platinum spark plug

The differences were not significant which is not point both of maximum power and maximum torque resulted from vary of mixing fuel with, and proved by statistical data analysis with one way ANOVA (F-test), resulted counted F-test < table-F or (0.119 < 2.82), which mean that Ho accepted, hence, there is no significant difference of power resulted by varying fuel mixing, meanwhile, for the torque resulting counted-F < table-F or (0.340 < 2.82), then Ho was accepted, and H1 refused, it mean that there is not significantly different on torque resulted by varying fuel mixing. Thus, it can be concluded from statistical data analysis there is no significant difference both of power and torque resulted in varying fuel-mixing.

4.3. Result of specific fuel consumption

The result of the specific fuel consumption test, the investigation was carried out by operating a vehicle at the same condition, and the comparison of test distance to vary of mixing fuel is presented in Figure 5.

Based on a test result that fuel consumption by varying fuel mixture found that the use of fuel variation of BE 30% resulting much saving of fuel in test distance much longer. It is graphically with vary of fuel at difference testing distance (farer) along with compositional fuel mixing of pertalite much higher, yet, fuel consumption using BE 10% and BE 20% the testing distance getting lower
(closer) compared with the use of 100% pertalite. Meanwhile, the use of fuel BE 30%, the testing distance was farer of 33.8 km compared with the use of 100% pertalite of 31.9 km with discrepancy of 1.9 km indicated that using BE 30% much saver by 5.9% compared with using 100% pertalite. However, using analysis data statistics using one-sample t-test, the value of T-test < table-T or (-413.211 < 3.182), therefore, Ho accepted; hence, average value testing distance using vary of fuel are not the same. It can be concluded that statistically, the average testing distance achieved by using vary of fuel is not the same. Thus, the use of BE 30% in testing uses distance farer compared with testing distance using 100% pertalite, BE 10% and BE 20% that indicated that the use of BE 30% are saver.

![Figure 5](image-url)

**Figure 5.** Comparison of the track on the road in vary of fuel mixing

4.4. Result of exhaust gas emission

The result of emission test et exhaust gas for monoxide carbon (CO) in vary of fuel mixing is shown in Figure 6,

![Figure 6](image-url)

**Figure 6.** Comparison of CO emission to rpm using vary of fuel

The test of CO emission that CO found using fuel BE of 30% is lower compared with using 100% pertalite, and it can be seen on the engine revolution of 1500 rpm. The result using 100% Peralite was 4,856% volume, and BE 10% of 4,181% volume, as well as BE 20% of 3,850% volume and BE 30% of 3,238% volume. It was occurred reducing CO of significantly, and proved statistically using one way ANOVA (F-test), of counted-F > table-F or (7,285 > 3,10), therefore, H1 was accepted, hence, there is significant difference emission of CO resulted by varying fuel mixing. It can be concluded that statistically CO resulted by using vary of fuels are not same. Thus, the use of fuel BE 30% the CO was...
less compared with the use of 100% pertalite, BE 10% and BE 20% that indicated that the use of BE 30% reduces CO significantly.

The testing result of the emission of exhaust gas of hydrocarbon (HC) is shown in Figure 7.

![Figure 7. Comparison of HC emission to rpm using vary of fuel](image)

The investigation result of HC found that the use of fuel BE 30%, resulting in emission of HC lower than the use of 100% pertalite at engine revolution of 1500 rpm. The result using 100% Pentalite 100% is 858 ppm, BE 10% of 684 ppm, BE 20% of 563 ppm and BE 30% of 472 ppm, occurred at significantly reduce of HC, however, along with increasing rpm particularly at rpm of 2500 and more, the graph shows that changing not significantly, it almost say as same though using of fuel, such as engine revolution 3000 rpm resulting using 100% Pentalite of 153 ppm, BE 10% of 152 ppm, BE 20% of 136 ppm and BE 30% of 132 ppm consecutively, and there is no significantly different, and it proved that statistically using one way ANOVA (F-test), the counted-F < table F, (0,275 < 3,10), therefore, Ho was accepted, and there is no significantly different on HC emission resulted by varying fuel. Thus, it can be concluded that statistically, HC using vary of fuel was not giving changing on the graph significantly, especially at the engine revolution of above 2500 rpm.

5. Conclusions
The experimental test of gasoline engine was carried out in investigating the effect on different spark plugs used and the use of platinum spark plug type was found to be the optimum performance of the engine. Further testing was focused on distinguishing a vary of mixing levels of fuel. The investigation was followed by identifying exhaust gas emission of CO, CO₂ and HC. Moreover, the conclusion of the experimental result was done analytically and statistically.

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