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Performance analysis (WHP and torque) on SI engine fueled with low-grade bioethanol and oxygenated fuel additive

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Abstract. Utilization of renewable energy in Indonesia is still relatively low compared to the non-renewable energy source of petroleum, coal, and natural gas. The limited amount of the non-renewable energy encourages the development of alternative fuels. Currently, low-grade bioethanol is one of the alternative fuel being developed. Bioethanol has a higher octane number compared to gasoline. Mixing of bioethanol requires a certain comparison, the mixing is intended to increase the octane number of a fuel mixture. The use of low-grade bioethanol (C2H5OH) as a substitute or mixture of fuels has an impact on engine performance. To get a more optimal effect on the fuel mixture, oxygenated cycloheptanol as an additive can be added to the fuel. This study examined the effect of fuel mixture with the addition of oxygenated cycloheptanol to single cylinder SI engine, 150 cc premix type at 100% throttle position. The tests was carried out on E5, E10, E15 and the addition of 0.5% oxygenated cycloheptanol at each fuel mixture with engine speed variation above 4000 rpm. Performance test will be performed with connecting the machine to a dynamometer. This study aims to obtain efficient performance on the engine with the addition of additives, there is an average increase of 9% in horsepower and 6% in torque.

1. Introduction

Utilization of renewable energy as an alternative fuel continues and becomes an object of interest to be developed. The use of alternative fuels cannot be separated from the two global issues about the availability of crude oil and the issue of exhaust emission are increasingly worrying [1]. Indonesia is a tropical country with the highest potential to develop alternative energy.

Bioethanol (C2H5OH) is a renewable fuel source derived from biomass derivative product from the plant's fermentation containing starch. Bioethanol has a simple molecular structure with easily defined chemical and physical properties. Bioethanol is able to use as fuel either directly or as a mixture of other fuel, such as gasoline. To apply bioethanol as a replacement or mixture fuel for the engine, bioethanol must have a high content at least 85%.

The use of bioethanol as a fuel for Spark Ignition machine has some several advantages compared to gasoline. Bioethanol has better anti-knock characteristic and the improved thermal efficiency of the engine on the compression ratio [2]. A mixture of bioethanol and gasoline at the condition of stoichiometry can reduce knocking effect [3].

Bioethanol burns at lower fire temperatures and luminosity due to a decreasing peak temperature in the cylinder, thereby resulting in wasted heat and decrease NOx emission. Bioethanol has a high latent heat of vaporization. Latent heat cools the air inlet for increased density and volumetric efficiency.

However, the oxygen content in bioethanol reduced caloric value more than gasoline. Therefore, bioethanol can be used as fuel in SI engine [4, 5].

Rodrigo C.Costa et al [6] conducted an experiment on the 1000cc engine, 4 cylinders. Fuel mixture of 78% gasoline and 22% ethanol. And hydrous ethanol (E100). On the variation of 1.500 rpm till 6.500 rpm. The measured ratio compression is 10:1, 11:1, and 12:1. The performance evaluated were torque, brake mean effective pressure, power, specific fuel consumption, thermal efficiency, exhaust gas temperature and volumetric efficiency. The result obtained was on a higher ratio compression that could improve the engine performance to both of fuels in engine rotation.

Gholamhassan Najafi et al [7] tested to the engine in speed variation, besides this study was conducted by using RSM and its tool was DoE to optimize parameter perform and bioethanol – gasoline 5%, 7,5%, 10%, 12,5% and 15%. The obtained result from fuel ethanol mixture was increased compared with the gasoline, brake power, and engine torque, while brake specific fuel consumption declined. In addition, the concentration of CO and NOx decreased, but on CO_2 and NOx increased [8].

Setia abikusna et al [9] conducted the test by using distilled bioethanol low-grade autonomously that utilized the exhaust heat on compact destilator to produce high-grade bioethanol which was ready to use as fuel mixture. From the test was obtained that wheel power and wheel torque generated from a mixture of gasoline and bioethanol had a higher value than pure gasoline as fuel. A mixture of gasoline and bioethanol was able to increase the power by 15%. While the torque value was generated at a mixture of E5, E10, and E 15 respectively amounted to 6.92Nm, 6.64Nm, and 6.92Nm, where the value was higher than pure gasoline by 6.1Nm.

C. Ananda Srinivisan [10] examined the effect of ethanol gasoline which was mixed with oxygen additives on SI engine. The experiment result addressed that there was an increased efficiency thermal brake. On the emission test was found that CO decreased slightly, while HC and O_2 increased enough and CO_2 and NOx decreased. In addition, the analysis of burning was done where the cylinder pressure and heat release rate were analyzed. Combustion analysis in this research was produced with maximum load 40N at 3.000 rpm. If cylinder pressure increased, heat release rate was also increased. For alcohol fuel, if cylinder dropped, heat release rate also declined.

This research was conducted on SI machine with 7 variations of the gasoline-bioethanol fuel mixture and oxygenated cycloheptanol additive. The purpose of this research is for finding out the influence of additive to performance machine based on wheel horsepower and torque, besides the comparison of performance with additive and without additive will be discussed in detail in this paper. Based on the author’s knowledge, performance testing on the SI engine using oxygenated cycloheptanol is new research.

2. Experimental Set Up

The engine was tested in this study as a form of SI engine single cylinder 150cc with fuel injection. Fuel system modification was done on fuel tank system with a pre-mixed fuel mixture of gasoline and bioethanol using a mixer on the fuel tank. There were seven variations of mixed fuel used, i.e. E0, E5, E15 without additives and E5, E10, E15 with the addition of additives (Table 1). The test was done by placing the engine on the dynamometer chassis to analyzed the power and torque that were generated on some variation of the fuel mixture. Timing and injection duration were regulated by the ECU. Here is set-up experimental in 150 cc SI engine that was supported to others component.

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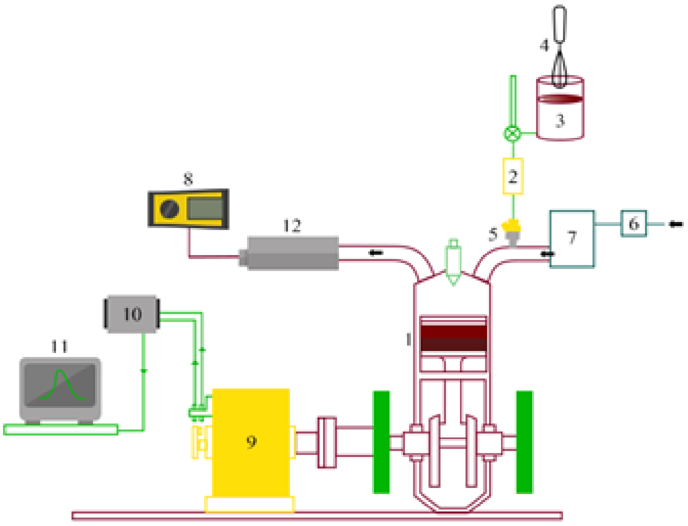

Figure 1. Experimental Set up Engine

Testing was done on the SI 150cc single cylinder engine that was mounted on a dynamometer chassis, where rear wheel of the vehicle served as a driving force that was linked on a roller dynamometer. Dynamometer Calibration process was done by adjusting the rotation of the wheels of the vehicle with the round roller drum to obtain corresponding values between rpm engine and the results of the readings on a dynamometer. Further, testing was done at 100% throttle position variation rounds of 4000 rpm to 10000 rpm. The results of the power and torque testing were issued in the form of a graph and its value on the monitor that were connected to the dynamometer. The test was performed four times for each variation of the fuel mixture. That was intended to get more accurate data.

Table 1. Sample volumetric composition

Sample name	Gasoline	Bioethanol	Oxygenated cycloheptanol
E0	100.00	----	----
E5	95.00	5.00	----
E10	90.00	10.00	----
E15	85.00	15.00	----
E5 +additive	95.00	4.5	0.5
E10 +additive	90.00	9.5	0.5
E15 +additive	85.00	14.50	0.5

3. Fuel Mixing

The method was used in mixing the fuel namely premixture by placing the mixer on the fuel tank which had been modified. The next, gasoline, bioethanol and oxygenated additives cycloheptanol were put into the tank with the appropriate comparison to the types of variables that had been set.

Then the mixer was turned on by pressing the on/off valve on the mixer. By using this method, there was no fuel mixture settles, because, during the process of testing, the fuel continued to stir until well mixed perfect before streamed to the injectors for atomizing towards to the combustion chamber.

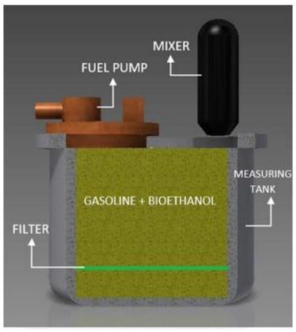

Figure 2. Modification of Fuel Tank

4. Result and Discussion

Overall, the analysis of the engine performance on this test included two things, namely power, and torque. Engine performance testing was conducted by using a chassis dynamometer Dyno Mainline. Based on the study, illustrated that the test results in the form of a comparison between the power and torque of the engines rotation variations for each variation of the fuel that was tested and presented in the form of tables and charts that aimed to make it easier to analyze data.

4.1. The Results of the Testing Power (Wheel Horse Power)

Testing gains value from the round wheel which is measured on the chassis dynamometer. Wheel horsepower is the actual value of the resources obtained through several components such as couplings, transmission and more. While its value is obtained from the measurements at the crankshaft or commonly referred to as Brake Horse Power will produce a comparison of 20%-30% that is larger than the measurements on the wheel (WHP).

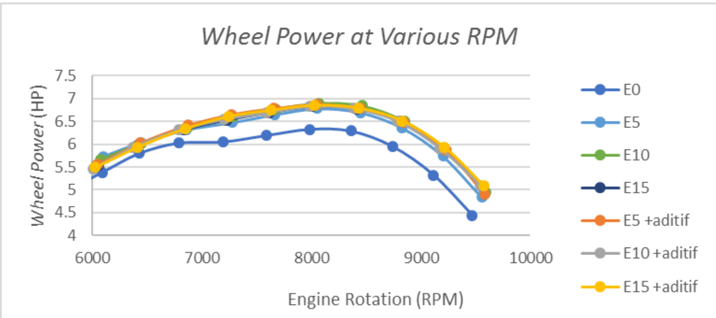

Figure 3. Wheel Power at Various RPM

Further, figure 3 is the result obtained in the test wheel power variation rounds until 10.000 rpm for a wide variety of fuel tested. On the graph to see that power is generated by the gasoline on some variation of the machine rotation lower than that is produced by the fuel mixture. The higher the spin machine, then the higher the delta power which is generated between the E5 to E15 + additive compared to E0. The maximum power is capable to result of E0 equal to 6.33 HP at 8000 rpm with an average difference between E0 – and the variation of fuel mixture of 9%. The difference is caused by the difference in air-fuel ratio (AFR), large or small values of AFR affected the amount of fuel entering the combustion chamber. In addition to the AFR, other things that affected to the power generated by the engine, namely a heat value of fuel, fuel efficiency, volumetrics and conversion of energy. The efficiency of volumetrics on some variation of fuel will be different, besides the round value also affects the efficiency of the machine volumetric.

The addition of additives on mixed gasoline with bioethanol also affects the resulting peak power. The peak power is generated on every variation of fuel at 8.000 rpm. Maximum power is generated on E5(5% bioethanol) equal to 6.78 HP while on E5+ additive (5% bioethanol with additives) is generated power equal to HP 6.78. On E10 (10% bioethanol) produces power equal to 6.90 HP and maximum power on E10+additive equal to 6.93 HP. The variation of fuel E15(15% bioethanol) generates the power equal to 6.83HP and E15+additive equal to 6.8HP. The additive is mixed in fuel variations (E5, E10, and E15) raises the value of the AFR, so the power is produced by adding additives larger than the mixture variation without additives. Figure 4 Shows a power comparison of 7 fuel variations tested at 8.000 rpm.

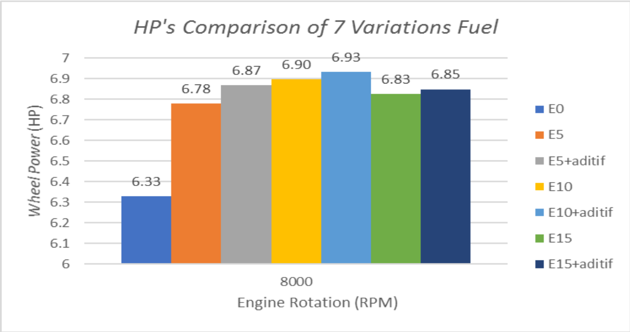

Figure 4. HP's Comparison 0f 7 Fuel Variations

Based on the test results, obtained that the variation of the fuel mixtures was the most effective on E5 (5% bioethanol). The value of the AFR on E5 is richer with the resulting power of 6.78HP. Besides the addition of oxygenated additives, cycloheptanol was conducted on the most optimal variation of fuel mixture E5 which generated a power of 6.78HP. In addition, to produce high-performance value, the detonation effect on the E5+additive variation was also relatively minor so the generated power more optimum.

4.2. The Results of the Testing Torque (Wheel Torque)

This test yielded a value of Wheel Torque (WT) of the wheel rotation that was connected on the chassis dynamometer.

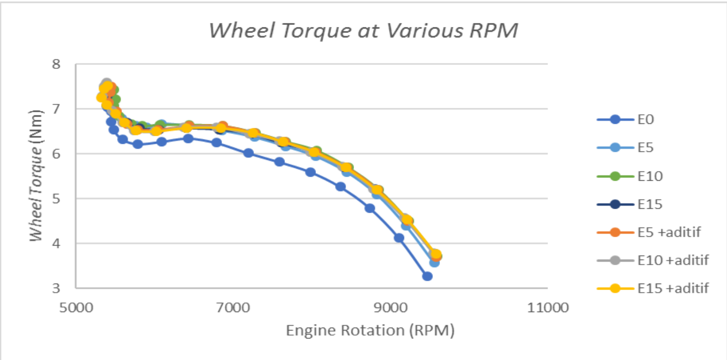

Figure 5. Graph of Torque at Various RPM

In figure 5 shows that torque results on the variation of fuel mixture gasoline with bioethanol has a higher value than gasoline (E0). The maximum torque value occurs at 5.000-6.000 rpm engine. The maximum torque value that can be generated by E0 fuel variation equal to 7.08 Nm at 5.400 rpm. Its value is lower 6% of the mean difference-maximum torque between fuel gasoline and gasoline-bioethanol mixture at rotation about 5.400 rpm. The torque resulted in each fuel variations in sequence on E5, E5+additive, E10, E10+additive, E15, and E15+additive is 7.48 Nm, 7,5Nm, 7.43 Nm, 7,6Nm, 7.45Nm, and 7.53Nm.

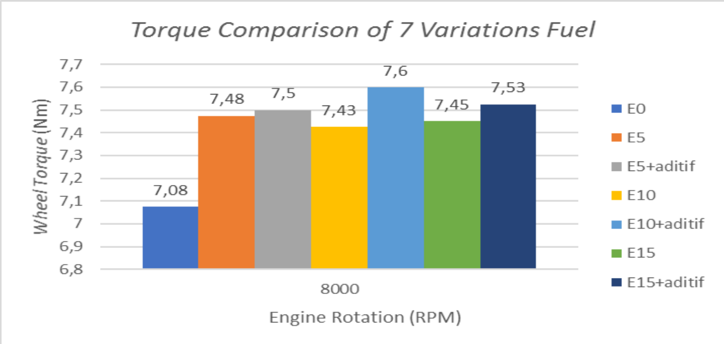

Figure 6. Torque's Comparison of 7 Fuel Variations

Figure 6 shows that fuel variations with additive additions result in greater torque compared to fuel variations with the same amount of ethanol without additives. The largest increase in torque occurs at about 5.400 rpm with a variation of E10and E10 +additives. With the addition of an additive, the torque increased by 2.4%. This is because the AFR at 5.400 rpm round approaches stoichiometry, with the additives the AFR becomes rich and it would decrease engine rotation. The engine rotation affected to torque, low engine rotation would be increasing torque.

Mustafa koc et al [11] tested the performance and emission on the engine with gasoline-ethanol fuel mixture (E50 and E85), maximum torque was obtained on E85 mixture variation at 3500 rpm with a value of 33 Nm higher than E50 and E0. Ethanol mixture in the fuel increased the oxygen content so that the combustion had completed and the torque increased. While based on the test results, the variation of fuel (E5, E10, and E15) with the addition of oxygenated additive cycloheptanol could increase the generated maximum torque of additives on a fuel mixture

5. Conclusions

This research aims to maximize the performance that is obtained in the engine by adding additives to the fuel mixture of gasoline and bioethanol. Through this paper, we demonstrated the results, namely the method of mixing fuel that modified tank and fuel mixer tool rated effective. The mixture of gasoline with bioethanol and oxygenated additives cycloheptanol approached homogenously. Due to the fuel mixture was stirred during the testing process, so the fuel entered the combustion process which had not occurred precipitation. The power value generated on the variation of the fuel mixture is higher than gasoline (E0). The addition of oxygenated additives cycloheptanol is the most optimal variation to E5 fuel variation that generated power equal to 6.78HP, increase equal to 1.3% of the E5 mixture without additives. The torque resulted on the fuel mixture of E5, E10, E15, E5+additive and E15 +additive is greater than gasoline (E0). The maximum torque is obtained at 5.400 rpm engine. The addition of additives enhances the value of the torque n each variation of the fuel (E5, E10, and E15) equal to 0.33%, 2.4%, and 1,1%.

6. Acknowledgement

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