Study on Effects of Oxygenated Additives (Cyclohexanol and Cycloheptanol) to Reduce Coefficient of Variations for Performance and Emission in SI Engine Fuelled by Gasoline and Bioethanol

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Abstract. The final energy consumption of Indonesia's fuel oil continues to increase every year for the past ten years. In general, most of energy consumption is obtained by fossil-fuels such as oil, gas, coal, and geothermal and the rest is renewable energy. This condition indicates that Indonesia is relying on non-renewable energy sources yet, whereas the numbers are running low. To overcome it, other energy needs to be developed to replace oil fuels that are renewable, eco-friendly, and natural. One potential renewable energy source developed in Indonesia instead of fuel is bio-ethanol (C_2H_5OH), which is mixed with gasoline (E5, E10, and E15); further the octane value of fuel can be increased. In addition to the problems in the comparison of the two fuel mixtures, the properties of each different substance are resulted in the difficulty of mixing both types of fuel that can produce a high Coefficient of Variation which results in the performance of the gasoline engine and cause torque fluctuations (vehicle driveability problem) produced. Addition of oxygenated additives (0.5 vol %) is intended, so that an insignificant COV value will be produced (less than 10%) in the two mixtures, whereby it can enhance performance and emissions.

INTRODUCTION

Currently, the use of bioethanol in Indonesia to become fuel is still low. However, it is a different form of bioethanol production as a type of beverage consumed by certain people, both traditional and industrial scale, which are often found in Indonesia. Bioethanol which can be used in mixtures to be engine fuels is usually anhydrous ethanol with a concentration of > 99.5 %. Engine modifications are needed when bioethanol is used entirely as fuel, but when it is mixed with gasoline, engine modifications are not needed. Anhydrous ethanol is used because the water content is atomic and that is to say pure, thus when it is mixed directly with gasoline, you will get a homogeneous mixture and can immediately enter the combustion chamber. While hydrous ethanol with a low concentration and water content in it, it is unmixed directly with gasoline. Normally , for this hydrous ethanol, the water content is around 4.9 % - 5 % while to be used as a mixture with gasoline, the water content is a maximum of 7.4 % [1].

Alirija Kaleli [2] conducted experiments to minimize cyclic variations on SI machines, by controlling the ignition timing for the whole cycle in a row. A stochastic model is carried out between the cylinder ignition timing and maximum pressure using the system identification technique. The maximum cylinder pressure from the next cycle is estimated by this model. Control algorithm is generated from LabView and installed to the chassis Gate Programming (FPGA) Field. For the test results, the maximum cylinder pressure of the next cycle can be predicted properly and the ignition timing can be set to maintain the desired maximum cylinder pressure to reduce cyclic variation. In a constant ignition timing experiment, COVPmax and COVimep were 3.764 and 0.677 %, while the results decreased to 3.208 and 0.533 %, the GMV controller was applied.

A, K. Sen [3] conducted a simulation to examine the cycle release of cycle-to-cycle variations (CCV) on SI engines with a mixture of gasoline-ethanol. The mixture ratio is changed from 0.7 - 0.9 and 1.0 from the thin mixture to the stoichiometric mixture. Ethanol is added proportionally from 5 to 25 %. This simulation was performed to calculate the COV of heat release at each volume increased in ethanol. From the COV value, they found that each addition of ethanol at a fixed ratio of CCV heat release mixtures decreased. They also found it at a fixed ethanol volume mixtures, CCV was increased with a thinner mixture by using continuous wavelet transform (CWT) to analyze heat release. Results based on COV indicate that at a fixed mix ratio, CCV decreases significantly according to an increase in ethanol, when the mixture is thin. When the mixture approaches stoichiometry, a decrease in CCV is insensitive to changes in ethanol levels. Additionally, the COV results indicate that at fixed ethanol levels, the CCV decreases according to the increase at the mixture ratio, and this increase occurs specifically at the thin mixture. The results of the wavelet analysis point out that the CCV heat release on SI engines is very dynamic gasoline-ethanol mixture consisting of high-frequency intermittent fluctuations and low-frequency oscillations. For gasoline engines (without the addition of ethanol), the CCV decreases according to changes in the composition of the mixture from the thin mixture to the stoichiometric mixture. In addition, at a fixed mix ratio, CCV can be reduced by mixing gasoline with ethanol.

Paper [4] 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 power by 15 %. While the torque value was generated at a mixture of E5, E10, and E 15 respectively amounted to 6.92 Nm, 6.64 Nm, and 6.92 Nm, where the value was higher than pure gasoline by 6.1 Nm. The torque value was generated at a mixture of E5, E10, and E 15 with additive oxygenated respectively amounted to 7.5 Nm, 7.6 Nm, and 7.53 Nm [5]. Addition of bioethanol and oxygenated cyclohexanol generally can improve the performance (torque and power) produced by the fuel engine. Torque and brake power increase after engine speed above 5,000 rpm. The highest torque value is obtained from the variation of fuel E10++ of 9.09 Nm at engine speed 6,000 rpm, 2.6 % higher than pure gasoline fuel (E0). The most optimum power (brake power) is produced by the E15 variable of 6.84 kW at 8,000 rpm engine speed which increases 1.94 % from E0 [6].

The use of oxygenated additives has been shown to reduce COV, in this paper we discuss a comparison between the use of cyclohexanol and cycloheptanol additive to COV from SI engines with a mixture of gasoline and ethanol with a mixture of E5, E10, E15, E5 ++, E10 ++, and E15 ++. The additive has the characteristics as a semi-polar solvent; furthermore it can produce a mixture of gasoline and ethanol more mixed homogeneously.

EXPERIMENTAL SET UP

The engine used in this study was the SI Honda type AFX12U21C07 single cylinder 125 cc SOHC with the electronically controlled fuel injection system. General specifications of the test engine as in Table 1.

TABLE 1. Test Engine Specifications

General Spesifications	Parameter
Engine Type	4 stroke, SOHC, single cylinder
Displacement	125 cc
Bore x stroke	52.4 mm x 57.9 mm
Compression ratio	9.3 : 1
Max Output	7.4 kW / 8,000 rpm

Max Torque	9.3 Nm / 4,000 rpm
Fuel System	Fuel Injection (PGM-FI)
Lubricant Capacity	0.7 L at periodic maintenance
Clutch type	Multiple wet Clutch with Coil Spring
Transmission type	4 Speed Manual, Rotary
Starter type	Electrical and Kick Starter

The fuel used is 7 types of the gasoline-bioethanol mixture prepared based on variable mixing ratio form RON 88 to RON 96, ethanol quality by volume, with a mixture of E5, E10, and E15, as well as the addition of cyclohexanol ($C_6H_{12}O$) and cycloheptanol ($C_7H_{14}O$) additives with a composition of 0.5 % vol on each fuel mixture. The mixture is formed in the fuel tank and inlet manifold. So the level premix is high entirely and constant approximately. Therefore, mass flow rates can be measured and controlled at once. Testing the properties of fuel from various gasoline-bioethanol mixtures is carried out.

Cylinder combustion pressure is measured using a Kistler 6617B piezo-electric sensor (maximum pressure up to 200 bar) and recorded by the Lab VIEW acquisition system. The crank position angle (up to 720 crank angles) is acquired with the shaft encoder; the sequence is adjusted to synchronize the cylinder combustion pressure signal with the crankshaft angle. The temperature sensor unit with the K type thermocouple is used to monitor the temperature of the exhaust gas, fuel, lubricant, and spark plug. This machine is connected to the engine dynamometer for power, torque and fuel consumption analysis, and is connected to the QROTECH-401 (4/5 gas analyser) to measure the content in exhaust gases such as Carbon Monoxide (CO), Carbon Dioxide (CO_2), Hydrocarbons (HC), and Nitrogen Oxides (NO_x). Analysis of the air-fuel ratio is operated by installing a lambda sensor (oxygen sensor) in the exhaust manifold.

The following is an experimental set-up chart on a 125 cc SI engine connected to other supporting components (figure 1). One of them is a pressure transducer that is directly attached to the spark plug.

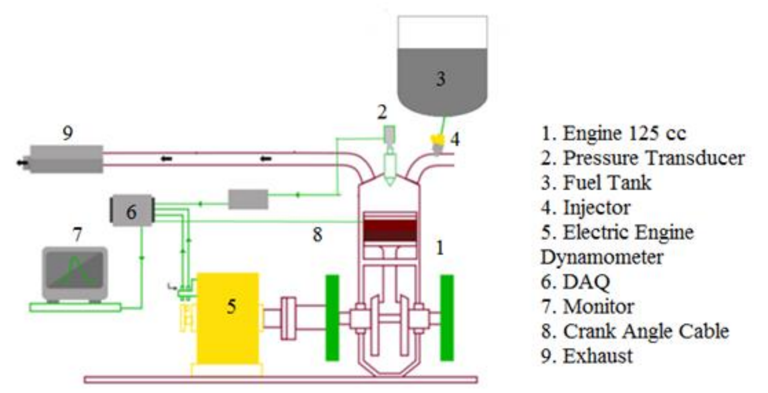

FIGURE 1. Experimental Set up Engine

RESULT AND DISCUSSION

CCV combustion in SI engines is an important subject that has been widely studied because it limits the engine operating range. Many researches have been done to observe the causes of cycle variations in the combustion process, leading to cycle variations in engine output performance. Cycle variations can be observed and characterized by the combustion pressure in the cylinder which is measured experimentally.

Cylinder pressure produced from engine combustion is carried out from 4,000 rpm, 6,000 rpm and 8,500 rpm for each fuel mixture of E0, E5, E10, and E15. Each fuel mixture produces different combustion pressures in each cycle. When viewed from the graph at 8,500 rpm the least variation in combustion pressure occurs in the E5 mixture with a combustion pressure reaching 50 bar.

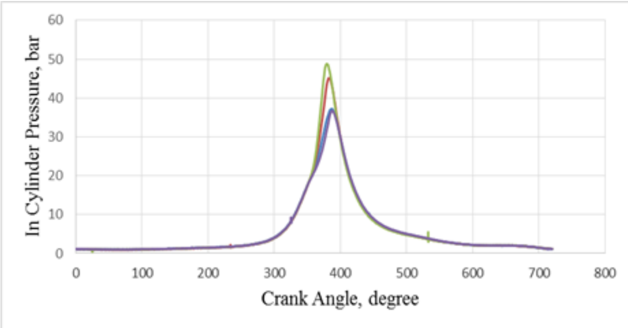

FIGURE 2. In-Cylinder Pressure vs. Crank Angle (E5)

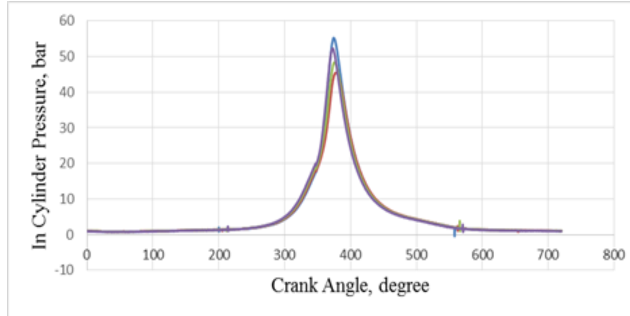

FIGURE 3. In-Cylinder Pressure vs. Crank Angle (E10++)

From the results of the graph above, it was found that the E5 mixture in each engine rotation condition produced the lowest COV when compared to other fuel mixtures including even if compared to E0 mixtures. The lowest COV E5 is by with the least variation of combustion pressure.

Ethanol has a high affinity for water because it composed a certain amount of water in it. This is not a matter if you use entirely ethanol as fuel because it is mixed with water thoroughly, where ethanol has polar properties are water-soluble, but some significant problems can arise when a mixture of gasoline-ethanol is used. Phase separation can occur in this mixture because gasoline and ethanol cannot fully mix homogeneously. This problem can be prevented by using semi-polar solvents (improving solubility).

Oxygenated additives added to each mixture of fuel E5, E10, and E15 are cyclohexanol and cycloheptanol with a volume of 5 vol% / vol. Cyclohexanol ($C_6H_{12}O$) and cycloheptanol ($C_7H_{14}O$) including alcohol group, is a cyclic organic compound with carbon C-6 and C-7 the presence of an OH group (alcohol). By increasing the length of the carbon chain, and with the presence of these OH groups, the influence of the polar hydroxyl group on the molecular nature tends to decrease. Therefore cyclohexanol and cycloheptanol are semi-polar. This becomes a binder between gasoline and ethanol so that the mixture can be more homogeneous.

Each fuel mixture produces different combustion pressures as well in each cycle such as before being mixed with cyclohexanol. When viewed from the graph at 8,500 rpm the least variation in combustion pressure occurs in the E10 ++ mixture (figure 3) with a combustion pressure reaching 50 bar.

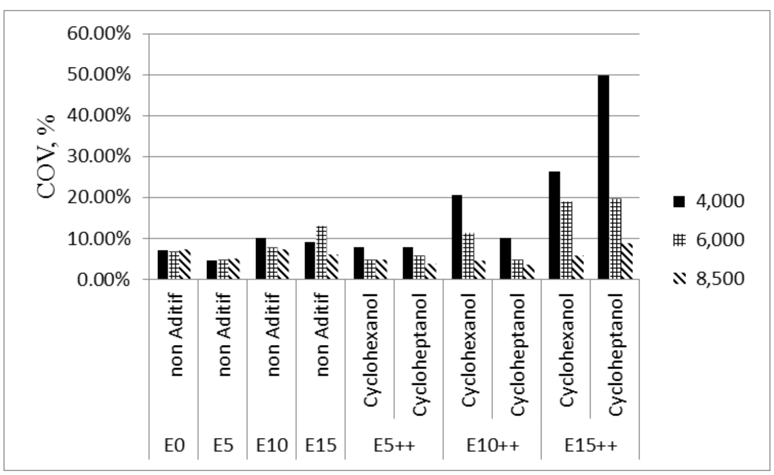

FIGURE 4. COV in Any Variation of Fuel Mixtures with Cyclohexanol and Cycloheptanol

The effect of COV in Torque on each fuel mixture can be seen in the following figure 5. Against torque, COV is very influential especially at 8,500 rpm, this occurs in E10 ++ mixtures with COV of 4.24%, torque increases significantly compared to other mixtures. With the addition of ethanol which has a higher octane value compared to gasoline, it can cause combustion more perfect, coupled with the addition of cyclohexanol, thus making a mixture of gasoline and ethanol is more homogeneous. Because the CCV, the ignition timing and the ratio of air and fuel mixtures must always be conditioned, which will not necessarily produce an optimal combustion process. The varying cylinder pressure has been shown to correlate with the brake torque, which is directly related to engine driveability.

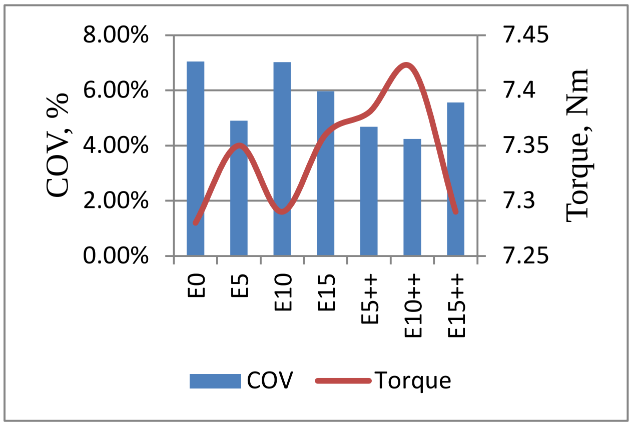

FIGURE 5. COV vs. Torque

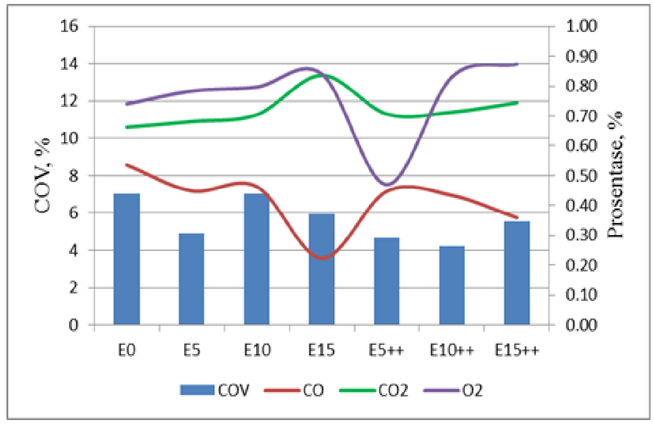

FIGURE 6. COV vs. CO, CO_2, & O_2

Figure 6 above can show the effect of COV from each fuel mixture on the variation of engine speed on CO, CO_2, and O_2 produced. The results of CO gas with the addition of additive resulted in comparison with other fuel variations as shown above. The addition of an additive to variations in fuel with the percentage of ethanol can reduce CO gas emissions produced. The effect of adding ethanol on emissions of additive CO and non-additive CO, this is a product of incomplete combustion because there is inadequate oxygen in the air-fuel mixture or insufficient combustion time in one cycle. The concentration of CO emissions is also very dependent on engine operating conditions and the air-fuel ratio. Some CO always appears on the exhaust even in the thin mixture, but the concentration decreases with decreasing combustion temperature. The O_2 concentration in combustion exhaust gas is inversely proportional to the concentration of CO_2 produced.

CONCLUSION

COV can be put right more effectively, when the mixture of gasoline and ethanol is added with oxygenated substances, when mixed with cyclohexanol (0.5% vol /vol) the lowest COV occurs in E10 ++ mixture at engine speed 8,500 rpm which is 4.24%, there is a decrease of about 36%, and when mixed with cycloheptanol (0.5% vol/vol) the lowest COV also occurs in E10 ++ mixture still at engine speed 8,500 rpm which is 3.42%, there is a decrease of about 48% compared to pure gasoline fuel (E0). The effect of using additives also has an important role in the engine torque, as a result torque fluctuations do not occur and the emission levels results are lower.

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