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Performances and Emissions Characteristics of Three Main Types Composition of Gasoline-Ethanol Blended in Spark Ignition Engines

Marth E. N. Paloboran[1], I. Nyoman Sutantra[2], Bambang Sudarmanta[3]

Abstract – *Ethanol as an alternative fuel will become the prime feed of vehicles for replacing the fossil fuel in the future. It is due to the combustion of ethanol producing the lowest particulate and it could be renewed, respect to gasoline. Some properties of ethanol have several advantages when applied in engine spark ignition. It has high octane number, allowing to improve the compression ratio to minimize knocking and increasing torque and power as well. Furthermore, the high heat of vaporization reduces the peak of cylinder temperature so NOx radiation is overcast. Moreover, the oxygen content of ethanol helps to the stoichiometric combustion therefore CO and HC emissions are lower if compared to gasoline. This paper will explain the combustion characteristic of ethanol in spark ignition engine with port and direct injection system, even in carburettor system. The characteristic will describe when being run with three main composition of gasoline-ethanol blends; those are 0–20, 25–40 and 50–100% respectively. The result shows that ethanol will act as an octane booster when it is added in gasoline up to 20% (E20). The blends have some impact on improving engine performances and to reduce emissions without any adjustment on the engine. In concentration, 25 to 40% of ethanol needs to adjust a suitable compression ratio as an increasing of ethanol percentage. Finally, in high concentration setting simultaneously of CRs, ignition timing and excess air will be applied to produce high performances and low emissions.*

***Keywords**: Gasoline, Ethanol, Blended, Alternative Energy, Concentration*

I. Introduction

Nowadays, the increases of production of greenhouse house gas (GHG) and the global warming problem has become the major environmental issue in the world. It is caused by the fact that the production of CO_2 from fossil fuel combustion is very high. The current situation forced all the countries in the world to change their energy consumption in favour of renewable energy [1]-[42].

According to the Board of National Energy of Indonesia 2014 (DEN), the world oil reserve should be ready to cover the demands of the world community only in 300 years. Meanwhile, ASEAN and Indonesia region will serve for 80 and 13 years respectively [1].

At the same time, greenhouse gas has been increased continuously by human activities. Transportation sector has produced about 65% of CO_2 emissions overall, and its rest from industries, households and commercial sector and others [2], [3]. Combustion of fossil fuel does not only produce carbon dioxide, but also CO, HC and NO_x emissions. The pollutants are endangering of humans survival and all the ecosystems on the Earth.

Bioethanol as a vegetable fuel has been developed since 1897 and it has been used in Ford engine since 1908 firstly [3]-[5]. Some properties of ethanol have been used as a solution on environmental issue and lack of vehicle fuels problem [36]-[38].

The high heat latent of vaporization of ethanol can reduce the peak temperature in cylinder increasing the density of charge. In this condition, brake mean effective pressure (BMEP), brake torque and volumetric efficiency are increased as well as low NO_x emission [6].

As an oxygenated compound, it helps to get the complete combustion so the percentage of CO and HC emissions decreases in the exhaust air [7]. The high octane rating of ethanol may increase the compression ratio to make a better power, torque and specific fuel consumption [6].

On the contrary, there are some drawbacks of ethanol when applied in spark ignition engine [39]-[42]. The lowest energy content of ethanol will impact on higher fuel consumption instead of gasoline. High solubility of ethanol in the water has made faster the corrosion process on equipment engine. Moreover, the components of engine that are made by rubber are more elastic.

Besides that, the engine is difficult to start in cold condition due to a lower vapour pressure respect to gasoline [8], [9].

Ethanol as a blend of fuel with gasoline has the potentiality to experience the separation at certain pressure and temperature, and it is called demixing process. This is due to the different boiling point of ethanol and gasoline because ethanol is a single compound whereas gasoline is constructed by some carbon elements.

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Blending gasoline and ethanol lead to azeatropica effect, which is a lower vapour pressure of mixture than their constituents [8]. Both the problems have been the backgrounds to adjust all the engine parameters based on the percentage of ethanol in the blends.

The authors have investigated some studies related to the topic. Adjustments on engine parameters such as ignition timing, injection duration, excess air and compression ratio are based on the ethanol concentration in gasoline. According to the result of the review, the authors found three main composition gasoline-ethanol blends needing the same parameters setting. They were 0–20% or E0-E20 called "low composition", then "medium composition" consisting of ethanol from 25% to 40%, and "high composition" where the content of ethanol is above 50 per cent. The aims of this study are revealing and discussing the combustion characteristics of three main composition gasoline-ethanol blends in spark ignition engine. As known, the firing process of internal combustion engine (ICE) was mostly influenced by the engine design, the injection of fuel and the instrumentation system as well as by the emissions handling [10]. But in this session, the authors only will discuss about the fuel injection system comparing their result with other research results.

II. Comparison of Gasoline-Ethanol Properties and Their Effect on Combustions Process

Properties of fuel have an important role in the combustion process. Optimizing the properties will be getting a high engine power and avoiding to produce toxic matters. There are many differences of properties of gasoline and ethanol (Table I), such as heating value, air-fuel ratio, heat of vaporization etc.

Gasoline as a hydrocarbon fuel is formed by about 90% of carbon elements while ethanol by only 52.2%.

This is an indicator that the energy content of gasoline is higher than ethanol. Therefore, potential energy of gasoline is 35% higher than ethanol in the equal mass flow rate. Furthermore, the injection of ethanol needs 1.5 to 1.8 times rather than gasoline [8], [11].

The differences of energy content of gasoline and ethanol also reveal on specific fuel consumption where gasoline is lower than ethanol. The oxygen fraction in ethanol by 35% produces an air fuel ratio of ethanol lower than gasoline, 9:1 and 14.7:1, respectively.

Many studies have found that oxygen in ethanol is more effective to carry out the blend of fuels to stoichiometric combustion than the one inducted in combustion chamber. The densities both of gasoline and of ethanol are equivalent, so their mass flow rate will be equal on the certain unit. In contrast, kinematic viscosity of ethanol is bigger than gasoline, so injection pressure of ethanol should be higher than gasoline. Reid vapours pressure of ethanol is lower than gasoline, so ethanol is difficult to evaporate on low temperature. Therefore, the engine does not run in cold temperature when ethanol is applied. This situation also describes the flash point value in which ethanol needs hotter temperature than gasoline to run the engine.

Auto ignitions of ethanol and gasoline are 425^{o}C and 257^{o}C respectively. By this point, a high self-ignition can reduce the engine knocking due to the self-ignition of fuels. It is a reason to improve the compression ratio on gasoline engine when ethanol is used.

The heat of ethanol vaporization is superior to gasoline, therefore it bring out to cold effect on air intake manifold and combustion chamber. The air temperature flows along the intake valve which will be absorbed by ethanol, therefore the temperature is cool. Furthermore, the density of charge increases together with mass flow rate of air. Finally, volumetric efficiency will increase while NO_x emission will decrease.

The laminar flame speeds of ethanol are shorter than gasoline, therefore the combustion duration of ethanol needs a little time to complete the combustion. Hence, the variety of cycle is slight so that the heat loss and pressure loss are reduced. At the end of the process, the conversion of heat energy in useful energy is increased.

III. Combustion Characteristics of Gasoline-Ethanol Blends in Low Composition

The main objectives of designing internal combustion engine are to improve high power, with low emissions and small fuel consumption in the combustion process.

As a vehicle fuel, ethanol is used mostly in spark engine than in the compression engine.

The reason is that the properties of ethanol are closer to gasoline than to solar fuel. Some studies revealed that the addition of ethanol up to 20% within gasoline would increase the performance with low emissions, without any adjustments on engine. Moreover, ethanol as an octane booster will impact on combustion stability, so the combustion is spared by detonation. This result has been supported by many researchers who have studied this composition.

III.1. Characteristic of CO and HC Emissions in Low Composition

Adding ethanol to gasoline up to 5% would be reducing CO and HC emissions by 20% and 5.2% respectively, compared with pure gasoline. Furthermore, the emissions fall down by 45% and 73% when 5 to 10% of ethanol is found in gasoline blends [13]-[15].

The HC emission is stagnant at 73% if the concentration of ethanol is increased up to 20% and the radiation of CO decreases by 67% slightly [10].

The above result evidences that ethanol content 35% oxygen are reducing CO and HC toxic effectively. This is due to the addition of 5–20% of ethanol in gasoline increasing lambda value by 0.7–8.4%. The results show that the air fuel ratio is into stoichiometric condition to complete combustion [10].

TABLE I
COMPARISONS OF PROPERTIES OF GASOLINE AND ETHANOL

Properties	Units	Gasoline	Ethanol	Reference
Chemical formula	-	$C_5 - C_{12}$	C_2H_5OH	16
Molecular weight	kg/kmol	114,15	46.07	16
C-fraction	% mass	85 – 88	50,59 – 52,20	16, 26, 35
O-fraction	% mass	0	34,73 – 36,42	16, 25, 26, 35
H-fraction	% massa	12,6 – 13	12 – 15	16, 26, 35
C/H	Ratio atom	0.44 – 0.50	0.33	25
O/C	Ratio atom	0	0,5	16
Specific gravity	-	0,7 – 0,78	0,794	16
Density (at 20°C)	kg/m^3	718.33 – 760	789.67 – 810	25, 26, 35
Stoichiometric air-fuel ratio	w/w	14,2 – 15,1	8,70 – 9.0	16, 25, 26
Kinematic viscosity(at 20°C)	mm^2/s	0,5 – 0,84	1.2 – 1,57	16, 34, 35
Reid vapour pressure	kPa	53 – 102.4	15.8 – 17	16, 35
Research Octane Number	-	86 – 100	98.0 – 110	16, 25, 35
Motor Octane Number	-	82 – 92	87 – 92	16, 25, 26
Cetane number	-	8	5 – 20	16
Enthalpy of formation				
a) Liquid	kJ/kmol	-259,28	-224,1	16
b) Gas	kJ/kmol	-277	-234,6	16
Higher Heating Value (HHV)	MJ/kg	47,3	29,7	16
Lower Heating Value (LHV)	MJ/kg	41,4 – 44.3	25,0 – 26,9	16, 25, 26, 34, 35
LHV at stoichiometric mixture	MJ/kg	2,77	2,70	16
Heat of Latent Vaporization	kJ/kg	349 – 400	900 – 992.1	16, 25, 26
Specific Heat				
a) Liquid	kJ/kgK	2,4	1,7	16
b) Gas	kJ/kgK	2,5	1,93	16
Freezing point	°C	-40	-114	16
Boiling point	°C	27 – 225	78	16
Flash point	°C	-45 s/d -13	12 – 20	16
Auto ignition temperature	°C	228 – 470	363 – 425	16, 25, 26
Boiling point	°C	27 – 225	78 – 79	16, 25, 34
Adiabatic flame temperature	°C	2002	1920	25
Vapour Flammability Limits	% vol	0,6 – 8	3,5 – 15	16, 25
Laminar flame speed at 100kPa, 325K	cm/s	33 – 34	39 – 42	16, 25, 26
Water solubility	%	0	100	16
Aromatics volume	%	27,6	0	16
Vapour toxicity	-	Moderate irritant	Toxic (large doses)	16
Smoke character	-	Black	Slight to none	16
Conductivity	-	None	Yes	16
Surface tension (at 20°C)	N/m	0.024	0.027	35

According to the above data, HC emissions go down slightly when ethanol by 5% is used in blend.

On the other hand, the emission tends to steady on concentration of 10–20%. HC emission is not only influenced by the percentage of ethanol, but it is affected by homogenates of charge and spark timing of fuels.

The results of the investigation found that there is not any adjustments on engine. Hence, ethanol concentration up to 20% in gasoline is effective as an additive matter.

III.2. Characteristic of NOx and CO_2 Emissions in Low Composition

In general, the emission of NO_x and CO_2 will rise gradually when ethanol up to 20% is applied in combustion. Nevertheless, it remains stable if ethanol by 3% is added in gasoline-ethanol blend [12].

The existence of oxygen in ethanol will impact on the increase of temperature of cylinder then as a result NO_x emission is formed. This situation will happen when the compositions are applied in a higher compression ratio.

As addition, the emission of CO_2 will increase due to the condition in stoichiometric combustion. Yao et al. [17] examined the emissions of gaseous pollutant from motorcycle powered by ethanol–gasoline blend by using 15% of ethanol (E15) and commercial unleaded gasoline (G95) on both injection and carburettor systems. To be more precise, the emission of NO_x by 76% on carburettor system was lower than injection system. In this experiment the ranges of NO_x emission were wide when the percentage of ethanol increased to 20% [15], [17].

Rate of NO_x production could be broken into this composition with double injection system. But, it brought negative impact on brake power and indicative mean of effective pressure (IMEP) [14].

III.3. Characteristic of Engine Performances in Low Composition

The performances of spark ignition engine are high when E0–E20 is used. Engine performance is characterized by power, torque and fuel consumption. Najafi et al. [6] studied the characteristic of gasoline – ethanol blends using ethanol up to 15%.

The result showed that the brake power increased by 4.78% of each addition of 2.5% gasoline. Furthermore, the trend line increased steadily while increasing the engine speed at 2500–4000 rpm. Forward, torque increased slowly by 2.8 when 5 to 15% of ethanol was added within gasoline.

Then, the specific fuel consumption was decreased slightly by 1.9%. The experiment of Kumar et al. [18] found similar results by using 5-20% of ethanol on 2000-5000 of engine speed. In contrast, SFC of Najafi experiment increased dramatically at engine speed of 4000 rpm, while Kumar research found that the SFC value was decreased continuously until the maximum engine speed.

The reason is that the ignition timing could be determined by using methodology response surface on Najafi study whereas Kumar study was still on original condition. But, both studies showed that SFC was declining when ethanol was applied up to 20.

IV. Combustion Characteristics of Gasoline-Ethanol Blends in Medium Composition

There are not many investigations about the topic, since only few researchers have dedicated their studies on this issue. The reason could be found on the fact that the vehicles existing today are using ethanol only by maximum 20% in gasoline.

IV.1. Characteristic of CO and HC Emissions

Fintas et al [19] carried out some investigations on Yamaha Vega engine, R-110 3SO/4D7 regarding the use of E0, E5, E15 and E25 on the original setting of engine.

The result is that the concentration of CO and HC emissions decreased consistently while increasing ethanol in percentage. The trend line occurred continuously when the addition of ethanol was until 40% and intake temperature was fixed at 20°C [20].

They have also observed that CO decreased and HC increased when the engine speed was on the idle. The reason was a not homogenates of charge during low engine speed so the combustion was not completed and then radiation of HC increased. The effects of various compression ratio on carbon dioxide and unburnt hydrocarbon have been reviewed by Anderson et al. [21].

On their investigation, it was demonstrated that the increases of CO and HC matters at 25–40 per cent of ethanol were higher than the composition before.

The addition of ethanol to gasoline by 25 to 40 would increase about 97 to 101 of compression ratio [21], because the compression ratio should improve of one point if the octane number of fuel was increased by five point [22]. Sayin et al [23] studied the alcohol-gasoline blend on various compression ratio.

The percentage of alcohol was on 10, 30 and 50 respectively, within gasoline. The results showed that CO and HC were slightly decreasing at 9 of CR, even though the emissions of CO and HC dramatically decreased when 11 of CR was applied. On this point, it was decreasing by 0.07, 0.17 and 0.31g/kWh of CO as well as 0.045, 0.142 and 0.149g/kWh of HC when there was an addition of alcohol fuel by 10, 30 and 50% respectively to gasoline.

The review showed that a setting of compression ratio would be needed when blend of ethanol by 25 to 40% to gasoline was used in spark ignition engine.

IV.2. Characteristic of NOx and CO_2 Emission

Theoretically, the increase of compression ratio will increase the temperature and the pressure of cylinder.

An uncontrolled increase of the cylinder temperature will potentially produce a radiation of NO_x at the end of the process, particularly in low composition. However, the phenomenon could be avoided using gasoline-ethanol blend of above 25% of ethanol. The reason is that a high heat of vaporization of ethanol will absorb some heat due to the increasing compression ratio [24]. Some studies have been conducted on the usage of gasoline–ethanol blends with percentage of ethanol by 25-40.

The results of the test showed that NO_x emission in this composition was lower than in low composition when there was an increase of CRs. On the other hand the emissions of NO_x increased dramatically while increasing the engine speed when the medium level using compression ratio was lower than 9.8 [20]. The reduction of NO_x emission shown on this study is not only caused by the heat of vaporization effect, but also by the homogenates of charge. The exhaust emission of CO and NOx would be low when AFR in rich condition (λ = 0,9) and ahigh compression ratio are applied in spark ignition engine [23], [24]. Moreover, Sayin study found that CO_2 emission increased with the increase of compression ratio. The values of CO_2 at 10% of alcohol in gasoline were 20.5, 21 and 21.5g/kWh with a compression ratio 9, 10 and 11 respectively. The emission was stable at 9 to 10 of CRs when 20% of alcohol was added to gasoline.

However, the values were rebound started from 21.5 to 24.g/5kWh while increasing by 10 to 11 of compression ratio. A significative increase was gained at 50 per cent of alcohol in the blends.

The maximum value of CO_2 on the maximum compression ratio was 26.5g/kWh.

IV.3. Characteristic of Engine Performance

The engine performance was decreased when medium grades of gasoline ethanol blend were used in spark ignition engine. Fintas demonstrated that the brake power and engine power increased slightly when using 5-15 per cent of ethanol in the blends with both engine speeds of 2000 and 3000 rpm. In contrast, brake power and engine power were decreased from 8.73 to 7.53kW and 6.64 to 4.55 at 2000 rpm if added 15–25 ethanol to gasoline.

Furthermore, the power still fell down at 3000 rpm of speed by 0.74 and 1.71kW, respectively.

Sayin explained that the highest engine performance would be gained when the increase of compression ratio was proportional to grade of ethanol in gasoline. The BTE tended to steady from 9 to 10 of CRs for all fuel.

But, the BTE increased by 2.8% from10 to 11 of CR using 50% of alcohol.

The SFC of medium level was higher than low level of ethanol if it was running on gasoline engine standard.

It was recorded by 0.05 and 0.07kg/kWh with2000 and 3000 rpm of speed and increased by 15 to 25of ethanol, respectively. It was also caused by reducing23.73 and 37.22% of thermal efficiency at 2000 and 3000 rpm of engine speed [19]. A similar result was also revealed by Sayin.

V. Combustion Characteristics of Gasoline-Ethanol Blends in High Composition

Several researchers have been investigated the effect of the addition of 50–100% of ethanol to gasoline in spark ignition engine. The results of the studies have given a recommendation to re-adjust all the engine parameters, especially compression ratio, ignition timing, injection duration and lambda, when E50-E100 is applied.

V.1. Effect of CR on Performance and Emission in High Composition

With a high octane number of ethanol then the engine compression ratio can be improved, so the efficiency will increase as indicated in the formula $\eta = 1 - 1/\varepsilon^{k-1}$, where ε is the compression ratio and k is specific heat of ratio. Nowadays, vehicle's fuel in Indonesia are already in RON≈88–95. It is set on CR 9–11. Meanwhile, RON of ethanol average is 106 -108, so the CR of engine should be higher than 11 [21].

V.1.1. Effect of Compression Ratio on Engine Performance

Balki et al. [25] conducted some assessments of the various compression ratio on the performance and the emissions of SI engine by using pure gasoline, ethanol and methanol. In general, it could be observed that BTE and BMEP increased with an increase of CR of the ethanol and methanol. However, the BTE and BMEP decreased after reaching the maximum point along with the increase of the CRs in pure unleaded gasoline.

The maximum values of BMEP were 725.94, 749.07 and 786.44kPa with unleaded gasoline, ethanol and methanol respectively. When all the CRs were investigated, the average increases in the BMEP for ethanol and methanol were 10.07% and 15.84%.

This increase was thought to be caused by a higher oxygen and heat of vaporization level of methanol than those of unleaded gasoline and ethanol. This result was supported by Rodrigo [26] for E0, E22 and E100 fuels. It was observed that the highest torque and BMEP were achieved at 12 of CR and the lowest at 10 of CR for all the fuels. Furthermore CR 12 ethanol produced higher torque than those E22 and gasoline, especially at high speed. The effect of CR on SFC was discussed by Celik [11]. His experiment indicated that a higher compression ratio produced low SFC at 10 of CR, even slightly lower than gasoline at 6 of CR. The minimum value of SFC with E0 fuel was 411 g/kWh at the compression ratio of 6 and 2500 rpm. At the same CR and engine speed, the SFC increased by 19% when running with E50 fuel. When the engine run with E50 fuel at the compression ratio of 10, the SFC was lower by 3% than E0 fuel. A similar measurement was recorded in the researches of Farha et al (27), Krishna et al [28], Mustafa, Rodrigo and Sudarmanta [29].

V.1.2. Effect of Compression Ratio on CO and HC Emission

Farha observed the effect of compression ratio on CO and HC emission. It was doing at compression ratio of 8, 9 and 10 as well as E0–E100 fuels with 20% of intervals. The results showed that the emissions of CO and HC were decreased if the compression ratio and ethanol concentration increased. Farha noted that the emissions decreased by 6.5, 5.9 and 5.2% of CO and 1350, 1050 and 950ppm of HC if increasing the compression ratio of 8, 9 and 10 at maximum loads when using E100 fuels.

If compared with E0, the emission declined dramatically when it was applied with E100 fuel for all the speeds and CR. There was a slight difference with Balki study. The emissions of CO and HC showed to decrease from 8 to 8.5 of compression ratio, but they increased when applying a compression ratio higher than 8.5. The reason was that the increase of CR needs a high supply of air as a consequence. Meanwhile, mechanism of engine inducted the air into the manifold naturally, so the mass flow rate of air is insufficient for the complete combustion.

V.1.3. Effect of Compression Ratio on CO_2 and NO_x Emission

The effect of compression ratio on NOx and CO_2 emissions was investigated also by researcher before.

The NO_x toxics were reduced significantly when they used high composition in the spark ignition engine.

High heat of vaporization was superior destroying the NO_x emissions. In contrast, the CO_2 emissions were increased as an indication that the quality of combustion is better.

V.2. Ignition Timing

The ignition timing holds an important role in combustion process, particularly in gasoline engine.

The ignition timing when is too advanced will cause the cylinder pressure increasing faster before the end of compression stroke. This situation will impact on power degradation throughout the compression process, so the output power is decreased. On the other hand, with a too late spark timing, a low pressure is gained and the expansion process is slow down.

V.2.1. Effect of Ignition Timing on Engine Performance

Sudarmanta et al [29] and Phuangwongtrakul et al [30]observed the influence of ignition timing on engine performance. The best ignition timing on their experiments was gained on the method of the minimum advanced for maximum brake torque (MBT) for all the tests on fuel and compression ratio. According to the Sudarmanta research, the brake torque was increasing slightly to the maximum value at 3500 rpm, after that it was decreasing significantly. Otherwise, the brake power was climbing steeply for reaching the maximum value at the 3500 rpm, and then it was steadily decreased to maximum speed. With this method, brake torque, power and BMEP increased by 3.68, 4.58 and 3.68% respectively when using E50 at CR of 11.6 as a comparison to using pure gasoline at CR of 9.6.

The SFC decreased by 13.42% from the E0 fuel and at the CR of 9.6 when the engine was run with E50 fuel and at the CR of 11.6. Nanlohy et al. [31] found an ignition timing suitable with E50 fuel, at CR of 9 as well as on engine 125cc. The result was on 12^o of BTDC production of power and torque higher and SFC is lower than pure gasoline. A similar methodology has been conducted by Turkoz et al. [32] when using E85 fuel.

Then, the optimum point was 4^o before the original ignition timing of engine. From the above results, it is demonstrated that the increase of compression ratio needs to re-adjust the ignition timing when concentration of ethanol is more than fifty per cent.

V.2.2. Effect of Ignition Timing on Emissions

The effect of the ignition timing on emission when using ethanol more than 50% was investigated in detail by Turkoz et al. [32]. In general, they demonstrated that the emissions of CO, HC and CO2 would decrease if the spark timing advanced to 4^o for all the engine speeds.

The oxygen content in ethanol by 35% was dominant in gasoline so to help in completing the combustion to reduce the emissions. When the ignition timing advanced, the ignition lag would be longer. Then, heat latent of vaporization would increase the mass flow rate of air into the manifold and combustion chamber.

The drawback of this method is that the emission of NO_x would still remain increased when the ignition timing advanced even if using E85 fuel. In theory, the NO_x emission decreases by using E85 fuel, even if the ignition timing is advanced. To answer the phenomenon, it should be confirmed by the methodology of experiment that will be equal when the use of ethanol is higher than E85 fuel.

V.3. Lambda

The air fuel ratio of gasoline-ethanol blends are determined by the percentage of ethanol in the mixture.

The AFR decreases if the ethanol concentration increases to go to the stoichiometric process, due to 35% compound of oxygen included in pure ethanol. Lambda influence on performance and emission of spark ignition engine using E0, E20 and E85 fuels was observed by Radu et al. [33].

The study was explaining that the maximum of effective power and cylinder pressure was reached when the excess air increased by 0.90 to 0.95. The combustion duration on the lean of equivalent ratio was short. They also monitored that the minimum of specific fuel consumption for ethanol and gasoline fuels were$\lambda \approx 1.05$–1.1 and $\lambda=1$, respectively.

In their research they revealed that the level of CO emission of ethanol was lower than gasoline when running with 0.8 – 1.4 of lambda. The trend line of CO emissions decreased up to an excess air of $\lambda=1.23$, after that it began to grow slowly. For all the engine speeds, HC emissions also decreased from 20% and up to 75% when fuelled with E20 and E85, respectively compared with gasoline. The decrease was emphasized when the engine speed increased.

This reduction in CO and HC emissions was due to the oxygen content of ethanol, which leaded to an improvement of combustion when the concentration of ethanol in gasoline increased. Meanwhile, the level of NO_x emissions for E20 and E85 were higher than gasoline for all the engine speeds. The average of the increase of NO_x emissions at 3200 and 3500 rpm of engine speed when running with E20 and E85 were 12% and 50% as well as 25 and 50%, respectively. The oxygen content of ethanol has been a trigger on increasing of NO_x emissions.

VI. Conclusion

Blends of gasoline and ethanol as a fuel in spark ignition engine produce lower emission than pure gasoline. On the other hand, the blends of fuels will also increase the power and engine efficiency.

The consistency reduces emissions and it increases the engine performance on setting of standard engine obtained if the concentration of ethanol in gasoline is up to 20%. In these conditions the existence of ethanol in gasoline acts as an octane booster so that the power, torque and efficiency are increased and fuel consumption is decreased even minimizing the detonation that occurs for each cycle.

The combustion of ethanol 25% - 40% as a blend fuel in spark ignition engines will reduce the engine performance and it will increase the emissions if using a conventional engine with a standard setting, with a range of compression ratio by 6/1 to 10/1. To overcome this matter, it is necessary to adjust the compression ratio based on the octane number value of the mixture, in which every increase of 5 octane numbers needs an increase of 1 of compression ratio. On the medium level of composition, the adjustment of the compression ratio leads to the influence on excess air and a better ignition timing, so that in this condition the settings of two parameters, lambda and ignition timing are not needed.

The combustion of gasoline and ethanol blends at high composition in the spark ignition engine requires the adjustment on three main parameters simultaneously, namely compression ratio, ignition timing and lambda. It does not only depend on the octane rating, but also on the types of engine and condition of operating of engine, particularly injection system of engine, which is taken into consideration in order to produce a higher engine performance.

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Authors' information

[1]Automotive Engineering Department, Faculty of Engineering Makassaar State University, Indonesia.

[2]Automotive Laboratory in Mechanical Engineering Department ITS Surabaya Indonesia.

[3]Fuels and Combustions Engineering Laboratory in Mechanical Engineering Department ITS Surabaya Indonesia.

Marth End Paloboran was born on November 29, 1971 in Pare-Pare-Pare, South Sulawesi, Indonesia. Nowdays, he is a PhD student in Mechanical Engineering at Sepuluh Nopember Technology of Institute (ITS) Surabaya, Indonesia since 2014. He received his Bachelor and Master Degree at the same major and institution in Mechanical Engineering of Hasanuddin University, Makassar, Indonesia on 2004 and 2009 respectively. He worked as a lecturer at Automotive Engineering, Makassar State University (UNM) Indonesia. He focused and interested to conduct some researches on internal combustion engine field, especially on the optimization of Bio-fuel combustion. Prof. Sutantra and Dr. Sudarmanta are the supervisor and co-supervisor for author's dissertation. They are also lecturer at ITS Surabaya, Indonesia

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