Jan 2014. Vol. 4, No. 7 ISSN2305-8269
International Journal of Engineering and Applied Sciences

www.eaas-journal.org

PEFORMANCE AND EMISSION ANALYSIS OF ETHANOL-GASOLINE BLENDED FUEL

Lim Soo King[1], Low Chong Yu[2], Chan Jiun Khin[3]

Department of Electrical and Electronic Engineering, Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Malaysia[1].
Department of Petrochemical Engineering, Faculty of Engineering and Green Technology, Universiti Tunku Abdul Rahman, Malaysia[2].
Department of HSE, Sembawang Shipyard Pte Ltd (a subsidiary of Sembcorp Marine Ltd)[3].
email: limsk@utar.edu.my, cylow@utar.edu.my, jkchan_thomas@hotmail.com

ABSTRACT

Majority of world energy consumption is generated from fossil fuel beside a small percentage from solar, nuclear sources etc. It has been predicted that by year 2030, there will be an increase of 50% of the current consumption. Ethanol is considered as an alternative fuel to replace depleting fossil fuel due to less release of environmental harmful gas and having near complete combustion.

The experiment was carried out with a Mitsubishi 4G1 series engine run with various proportion of ethanol (5%, 10%, 15%, and 20%) by volume blended with Research Octane Number 95 (RON95) unleaded gasoline. The amount of harmful gas emission, carbon monoxide (CO) and total hydrocarbon (THC) are analyzed with CG200 emission analyzer and its performance is measured by the amount of gasoline consumption.

The study shows that the CO and THC emission have been reduced from 20.6% to 72.1% and from 17.5% to 58.1 % respectively for blended proportion of 5%, 10%, 15%, and 20% of ethanol. The fuel consumption has been reduced from 1.05% to 6.5% for RON95 to 20% ethanol blended RON95 gasoline for every one kilometer distance travelled.

It is viable alternative for reducing the rate of fossil fuel depletion and reducing harm green house gases.

Key words — RON95, ethanol, hydrocarbon, Mitsubishi 4G1 series engine, and CG200 analyzer.

1 Objectives

The main objective of this experimental study is to analyze the performance and harmful gas emission from a 4-stroke Mitsubishi 4G1 series engine that uses various proportion of ethanol (5%, 10%, 15%, and 20%) by volume blended with Research Octane Number 95 (RON95) unleaded gasoline as fuel. The amount of harmful gas emission, carbon monoxide (CO) and total hydrocarbon (THC) are analyzed with CG200 emission analyzer and its performance is measured by the amount of gasoline consumption per kilometer distance traveled.

2 Introduction

Global climatic change has been a hot topic of discussion and research. Primary cause is due to excessive emission of harmful gas such carbon monoxide (CO) and total hydrocarbon (THC) gases that cause global warming and green house effect (Huang & Wu, 2008).

Huge amount of fossil fuel consumption has been profound as a main source of these pollutants. Burning of fossil fuel emits harmful gases such as carbon monoxide (CO), nitrogen oxides, and un-burned hydrocarbon (HC) (James & Glen, 1993).

Heavy dependency on fossil fuel has lead to drastic decrease of fossil fuel reserve. It also leads to price increase of cruel oil.

The use of ethanol as an alternative to replace fossil fuel has been one of the ways to reduce the amount of pollution and the use of ethanol improves the efficiency of engine because it has near complete combustion leaving no un-burned fuel to be released (Anderson et al., 2012).

Ethanol can be produced from agricultural crop like corn in USA, sugar cane in Brazil (Luo et al., 2007). In Malaysia, the climate is suitable to plant cassava (Manihot, Es-

Jan 2014. Vol. 4, No. 7 ISSN2305-8269
International Journal of Engineering and Applied Sciences

www.eaas-journal.org

culenta, Crantz) easily that can be used as the raw material for fermentation to produce ethanol. In regards to this, bio-ethanol has the great potential as a form of renewable green energy source in Malaysia.

3 Background Studies

The world's oil reserves available are estimated to be approximately 1,238 billion barrels. With the current consumption rate, it is estimated to last for another 37 years (Lai, 2011). The use of alternative fuel has received considerable attention due to reduce in oil reserves as well as stringent emission restrictions. Alternative fuel as defined by the US Energy Policy Act of 1992, include ethanol, methanol, natural gas, hydrogen, biodiesel, and electricity. Among these alternative fuels, ethanol is employed most widely (Niven, 2005). Thus, ethanol has been considered as an attractive fuel not only for road transport vehicle but also applicable to air transport and maritime transport due to its renewable nature.

Ethanol or ethyl alcohol (C_2H_5OH) is a clear colourless liquid which is bio-degradable and has low toxicity. Ethanol burns to produce carbon dioxide and water. Ethanol is also a high octane fuel and has been used to replace lead as an octane enhancer in gasoline (Strathclyde, 2011). By blending ethanol with gasoline, the fuel mixture is oxygenated and burned here complete. Thus, it reduces polluting emissions such as carbon monoxide (CO) and hydrocarbon (THC) gases.

Carbon monoxide emitted from vehicles not only causes air pollution but also triggers serious respiratory problems. When CO enters the bloodstream of human body, it reduces the delivery of oxygen to body's organ and tissues. Exposure to high CO level can cause impairment of visual perception, manual dexterity, learning ability and performance of complex tasks.

Carbonyl compound is an important class of total hydrocarbon. In urban, atmospheric carbonyl compound is mainly emitted from vehicle (Grosjean et al., 2001). It is a precursor to free radicals, ozone, and peroxyacylnitrates and plays a critical role on the tropospheric chemistry (Carter, 1995; Gaffney et al., 1997). Some carbonyl compounds are toxic, mutagenic, and even carcinogenic to human body (Carlier et al., 1986).

Composition of gasoline used in the combustion engine would determine the emission of green house gas like CO, CO_2, and total (THC). Such effect has been investigated since the early 1990s. Since the establishment of the United States automobile and oil companies determined the Air Quality Improvement Research Program in 1989 and the European Commission introduced the European Programme on Emission, Fuels, and Engine Technologies in 1992, these two research establishments have conducted studies to evaluate the impacts of gasoline composition on exhaust emission and air quality. In general, the studies have indicated that if there is a decrease of sulfur and aromatic contents in gasoline, there is a reduction of CO, CO_2, THC, and other toxic gas emissions.

As the results, many studies have been done focusing on the studies of ethanol-gasoline blended fuels for 3 to 30% volume of ethanol versus its pollutant gas emission.

3.1 Characteristic of Ethanol in Fuel System

Gasoline is composed of C_4–C_{12} hydrocarbons and it has wide transitional properties. On the other hand, alcohol such as ethanol contains OH group that has oxygen atom and it is viewed as a partially oxidized hydrocarbon that would undergo complete combustion.

As for the combustion characteristics, the auto-ignition temperature and flashpoint of alcohol are higher than gasoline, which makes it safer for transportation and storage. The latent heat of evaporation of alcohol is 3–5 times higher than gasoline. Thus, it lowers the temperature of the intake manifold and increases the volumetric efficiency.

The Enthalpy of alcohol is lower than gasoline. Therefore, more alcohol fuel is required to achieve the same energy output, which is an approximately1.5–1.8 times of gasoline fuel. The stoichiometric air to fuel ratio (AFR) of alcohol is about 1/2–2/3 of the gasoline, so the amount of air required for complete combustion is lesser for alcohol.

Alcohol is completely miscible with water, while the gasoline and water are immiscible (Furey, 1991). Therefore, adding ethanol causes the blended fuel to contain water, and result in the corrosion problems on the mechanical components especially for components made of copper, brass or aluminum. To reduce this problem on fuel delivery system, such materials mentioned above should be avoided. Besides, alcohol can react with most rubber and create jam in the fuel pipe. Therefore, it is advisable to use fluorocarbon rubber as a replacement for rubber (Naegeli et al., 1997).

3.2 Ethanol-Research Octane Number (RON) Gasoline Blended Fuel

RON is an important parameter for vehicle combustion. According to the past studies, the research octane number (RON) of the gasoline has been changed due to the addition of ethanol. The more ethanol is added, the higher is the RON. Increasing octane number of the fuel leads to decreases in CO and THC emissions but higher NO_x emission.

The combustion duration also becomes prolong with increasing octane number. Longer combustion duration may result in lower thermal efficiency and increased fuel consumption. Moreover, gasoline with a high octane number is suitable for vehicles with a high compression ratio. The compression ratios of motorcycles (8–10:1) are less than gasoline cars (9–12:1). Thus, high ethanol content gasoline (>15%) may not be suitable for motorcycles due to high octane number (Chen, 2005).

3.3 Emissions of Ethanol Blended Gasoline

Bata et al. (1989) studied different blend rates of ethanol gasoline fuel for combustion in the engine and found that adding ethanol had reduced the CO and THC emissions to some degree. The reduction of CO emission is attributed by the wide flammability and oxygenated characteristic of ethanol. The study done by Palmer (1986) indicated that addition of 10% ethanol to gasoline could reduce the concentration of CO emission up to 30%. Alexandrian and Schwalm (1992) showed that the air fuel ratio (AFR) has great influence on the CO emission.

Using ethanol-gasoline blended fuel instead of gasoline alone, especially under fuel-rich conditions, it has lower CO and NO_x emissions. However, studies by Chao et al. (2000) has pointed out that using ethanol-gasoline blended fuel, it increases the emission of formaldehyde, acetaldehyde and acetone, 5–14 times higher than from gasoline. Even though the emission of aldehyde will be increased when ethanol blended gasoline is used as a fuel, the damage to the environment by the emitted aldehyde is far less than by the polynuclear aromatics emitted from burning gasoline. Therefore, using higher percentage of alcohol in blended fuel can make the air quality better in comparison with burning of gasoline.

Pang et al. (2007) found that CO emission was slightly reduced (1.5–6%) from 10% (E10) ethanol blended gasoline in comparison with gasoline (RN95 -E0). The oxygenated agents (ethanol) blended with gasoline can effectively deliver oxygen to the pyrolysis zone of the burning gasoline resulting in less CO generation. In engine-out exhaust, THC emission from E10 was lower than E0 at the torque of 3 Nm, but higher than from E0 by 2–17% under other operating conditions.

3.4 Performance of Car Engine using Ethanol Blended Gasoline

In 1986, Palmer investigated the effect of various blend percent by volume for ethanol-gasoline fuels in engine tests. Results indicated that adding 10% ethanol increases the engine power output by 5% and the octane number can be increased by 5% for each 10% ethanol added.

Abdel-Rahman and Osman (1997) had tested 10%, 20%, 30% and 40% ethanol of blended fuels in a variable-compression-ratio engine. They found that the increase in ethanol content increases the octane number, but decreases the heating value. The 10% addition of ethanol had the most observable effect in increasing the octane number. Under various compression ratios of engine, the optimum blend rate was found to be 10% ethanol with 90% gasoline.

Hsieh et al. (2002) determined the brake specific fuel consumption (bsfc) to demonstrate the variations of fuel consumption in the test engine using different ethanol gasoline blended fuels. The theoretical air-fuel ratio (AFR) of gasoline is 1.6 times of ethanol. Therefore the bsfc should be increasing with increase of ethanol content.

However, the fuel injection strategy tends to operate the engine at fuel-rich condition. Thus, the ethanol addition produces leaning effect to enhance the combustion of fuel. Therefore, this factor makes no difference on the bsfc between using pure gasoline and using ethanol-gasoline blended fuels.

The influence of different ethanol-gasoline blended fuels on the torque output has also been investigated by performing engine test at 3,000 rpm with throttle valve opening of 40%, 60%, 80%, and 100%. It was observed that at lower throttle valve opening, the torque output is either increased or decreased by adding ethanol. However, at higher throttle valve openings (60%, 80%, 100%), the torque output increases with the ethanol content, which range from 2% to 4%.

4 Experimental Set-ups

A properly warmed-up and calibrated CG200 Automotive Emission Analyzer that utilizing non dispersive infrared (NDIR) technique is used to analyze the CO and THC contents for the experiment. The fuel transport route of the Mitsubishi 4G1 series car that has compression ratio of 9.5:1, is modified to add in a spare tank that can be switched alternatively via valve to supply either RON95 gasoline stored in the origin fuel tank of the car or different composition ethanol-gasoline blended fuel from the spare tank.

The ethanol-gasoline blended compositions that are used to carry out the experimental tests are 0% (pure RON95), 5% (E5), 10% (E10), 15% (E15), and 20% by volume of ethanol mixed with RON95 gasoline. Eight sets of data for the CO content in % and THC in part per million (ppm) emissions were measured and tabulated.

The Performance analysis is carried out to obtain the fuel consumption by calculating the fuel consumed for each kilometer of distance traveled for gasoline (E0) and ethanol-gasoline blended fuel of various compositions of ethanol content by volume (E5, E10, E15, and E20). The experimental tests were carried out by driving the car with one liter fuel at the speed of 40km/h for 4.5km distance and measured the left over fuel after ten rounds of test.

5 Results and Discussion

The results of experimental study are shown graphically. The average values for CO emission using gasoline and different ethanol-gasoline blended fuel were calculated and shown in Fig. 1.

The percentages of CO reduction for each types of ethanol-gasoline blended fuel are calculated and shown in Fig. 2. The average values for THC emission using gasoline and different ethanol-gasoline blended fuel are shown in Fig. 3.

The percentages of THC reduction for each types of ethanol-gasoline blended fuel are calculated and shown in Fig. 4.

The average value for fuel consumed per kilometer distance traveled gasoline (E0) and different ethanol-gasoline blended fuel are shown in Fig. 5.

The percentage reduction of fuel consumption for each types of ethanol blended gasoline was calculated and shown in Fig. 6.

Data Set	**Type of Fuel**				
	RON95	**E5**	**E10**	**E15**	**E20**
1	3.5950	2.6520	2.1005	1.5025	0.9850
2	3.5500	2.7325	1.9595	1.7180	0.9410
3	3.2340	2.6230	1.8950	1.8270	0.9310
4	3.2380	2.5115	2.1280	1.7736	0.9495
5	3.2935	2.5025	2.1290	1.4865	0.7935
6	3.2630	2.7755	1.9250	1.4810	0.9525
7	3.2560	2.6510	2.1265	1.4445	0.9500
8	3.2610	2.7475	2.0500	1.4280	0.9445
Average	3.3363	2.6494	2.0392	1.5826	0.9309

Figure 1: CO emission % for various fuel types

Type of Fuel	**Percentage of CO Reduction**
E5	20.59
E10	38.88
E15	52.56
E20	72.10

Figure 2: Percentage reduction of CO emission for various fuel types using E0 as baseline

Data Set	**Type of Fuel**				
	RON95	**E5**	**E10**	**E15**	**E20**
1	266.40	214.20	180.05	119.15	131.60
2	260.70	211.30	212.90	124.00	109.60
3	258.30	104.60	207.05	125.15	103.50
4	240.40	186.30	200.35	111.55	98.55
5	236.65	233.35	206.05	107.50	103.85
6	250.80	213.00	233.20	117.40	107.50
7	239.40	203.90	198.20	107.05	91.95
8	240.00	198.40	175.05	105.40	89.30
Average	249.09	205.63	201.61	114.65	104.44

Figure 3: THC emission (ppm) for various fuel types

Type of Fuel	**Percentage of THC Reduction**
E5	17.45
E10	19.06
E15	53.97
E20	58.07

Figure 4: Percentage of THC reduction for various fuel types using E0 as baseline

Type of Fuel	**Fuel Consumption liter per km**
E0	0.1153
E5	0.1141
E10	0.1121

International Journal of Engineering and Applied Sciences

www.eaas-journal.org

E15	0.1096
E20	0.1078

Figure 5: Fuel consumption per km for various fuel types

Type of Fuel	Percentage of Consumption Reduction
E5	1.05
E10	2.75
E15	4.94
E20	6.50

Figure 6: Percentage of fuel consumption reduction for various types of fuel using E0 as baseline

As the percentage of ethanol increases, there was a reduction in CO and THC emissions. The overall consumption of ethanol-gasoline blended fuel (E5, E10, E15, and E20) was lesser as compared with gasoline (RON 95).

CO and THC are emitted from exhaust system due to the incomplete combustion in the combustion chamber. Therefore, lower CO and THC emissions indicate that higher degree of combustion is achieved. By using ethanol-gasoline blended fuel, there is significant reduction in CO and THC emissions as compared with gasoline (RON 95).

It can be observed that the reduction of CO and THC emissions become more significant as the ethanol content increased. Ethanol which contains OH group is used as an oxygenate compound to raise the oxygen content of gasoline.

With additional oxygen molecule, the current air to fuel (A/F) ratio is increased and allowed the combustion occur at stoichiometric burning. In this case, the engine tends to operate in leaner conditions where combustion process of fuel is more complete. Therefore, the concentration of CO and THC emissions decreases as the fuel burning is more efficient (Wei-Dong et al., 2001). Decrease of CO and THC concentration is also due to the lower carbon content of ethanol in comparison with gasoline.

Based on the research by Zervas et al. (2003), addition of ethanol dilutes the fuel. Hence, it enhances the combustion of CO and hydrocarbon in the cylinder. Ethanol reduces the high boiling point hydrocarbon chain by increasing the number of methyl branches. This results in more completely fuel combustion in the cylinders without generated accumulation of un-burned hydrocarbon in combustion chamber emitting into the environment through the exhaust system.

American Petroleum Institute (2010) stated that octane number of unleaded gasoline like RON 95 will increase up to certain degree by adding in ethanol as an octane booster. Thus, ethanol blended with RON 95 will increase the octane number of the fuel to that of RON 97 or even higher as the content of ethanol increases. It is observed that the fuel consumption per kilometer is reduced up to 6.5% for E20.

Octane booster increasing the number of methyl branches in the hydrocarbon. The higher the octane number, the more compression the fuel can withstand before detonating. This prevents the air/fuel mixture in the cylinder ignites before the spark plug fires, which known as an anti-knocking. Burning fuel with a higher octane rating will truly result in an improvement of power output and efficiency of combustion.

6 Conclusion

Ethanol-gasoline blended fuel (E5, E10, E15, and E20) has reduced CO and THC emission up to 72.1 % and 58.1% respectively as compared to gasoline (RON 95). There is also a reduction of fuel consumption up to 6.5%. Lesser emissions of green house effect gases into environment can be achieved by burning ethanol blended gasoline. It is viable alternative for reducing the rate of depletion of fossil fuel and a better fuel to reduce harmful gases emission into atmosphere. The results of this study can be used as the basis to determine the optimum blending proportion in future study.

References

1. Lai, S. C. (2011). Engineer in Society. *Non Renewable Energy*, 1-2.

2. Niven, R. K. (2005). Ethanol in gasoline: environmental impacts and sustainability review article. *Renew Sustain Energy Rev*, 35–55.

3. University of Strathclyde. (2011). Energy Systems Research Unit. *What is Ethanol?* Scotland, DC: Author.

4. Huang Y. H & Wu J. H (2008). Analysis of biodiesel promotion in Taiwan. *Review Sustainable Energy*, 12, 76-86.

5. James Y. H & Glen E. H (1993). Petrolium Refining: Technology and Economics, New York.

6. Anderson J. E, DiCicco D. M, Glinder J. M, Kramer U, Leone T G, Raneyprblo H. E & Wallington T J(2012). High octane number ethanol-gasoline blends: quantifying the potential benefits in the United States. *Fuel*.

7. Luo L, Voet E v D & Huppes G (2007). Life cycle of bioethanol sugarcane in Brazil.

8. Furey, R.L., Perry, K.L. (1991). *Composition and reactivity of fuel vapour emissions from gasoline-oxygenate blends.* SAE Paper 912429.

9. Naegeli, D. W., Lacey, P. I., Alger, M. J., & Endicott, D. L. (1997). *Surface corrosion in ethanol fuel pumps.* SAE Paper 971648.

10. Chen, H. L. (2005). *Effect of an alternative fuel–gasohol on the characteristics of emission using a motorcycle engine.* National Pingtung University of Science and Technology.

11. Bata, R. M., Elord, A. C., & Rice, R. W. (1989). *Emissions from IC engines fueled with alcohol–gasoline blends: a literature review.* Transactions of the ASME 111, 424–431.

12. Palmer, F. H. (1986). Vehicle performance of gasoline containing oxygenates. International conference on petroleum based and automotive applications. *Institution of Mechanical Engineers Conference Publications*, 33–46.

13. Alexandrian, M., & Schwalm, M. (1992). *Comparison of ethanol and gasoline as automotive fuels.* ASME papers 92-WA/DE-15.

14. Chao, H. R., Lin, T. C., Chao, M. R., Chang, F. H., & Huang, C. I. (2000). Effect of methanol-containing additive on the emission of carbonyl compounds from a heavy-duty diesel engine. *Journal of Hazardous Materials,* 13 (1), 39–54.

15. Pang, S. B., Mu, Y., Yuan, J., & He, H. (2007). Carbonyls emission from ethanol-blended gasoline and bio-ethanol diesel used in engines. *Journal of Atmospheric Environment*, 42, 1349–1358.

16. Abdel-Rahman, A. A., & Osman, M. M. (1997). Experimental investigation on varying the compression ratio of SI engine working under different ethanol–gasoline fuel blends. *International Journal of Energy Research*, 21 (1), 31–40.

17. Hsieh, W., Chen, R., Wu, T., & Lin, T. (2002). Engine performance and pollutant emission of an SI engine using ethanol-gasoline blended fuels. *Atmospheric Environment*, 36 (3), 403–410.

18. Wei-Dong, H., Rong-Hong, C., Tsung-Lin, W., & Ta-Hui, L. (2001). Engine performance and pollutant emission of an SI engine using ethanol – gasoline blended fuels. *Atmospheric Environment*, 36 (3), 403–410.

19. Zervas, E., Montagne, X., & Lahaye, J. (2003). Emission of regulated pollutants from a spark ignition engine. Influence of fuel and air/fuel equivalence ratio. *Environ SciTechnol*, 37 (14), 3232–3238.

20. American Petroleum Institute. (2010). *Determination of the Potential Property Ranges of Mid-Level Ethanol Blends.*