# EFFECT OF HYDRATED AND ANHYDROUS ETHANOL-GASOLINE BLENDS ON ENGINE PERFORMANCE

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## *ABSTRACT*

*Renewable energy sources for the gasoline engines such as alcohols gain importance recently. This paper focuses on the performance and emissions tests conducted on a 1.3L engine running on several composition of hydrated or anhydrous ethanol blended with unleaded RON97 gasoline. Several property tests were also conducted for each blend. It was found that adding ethanol to the unleaded gasoline increases the blend density, viscosity and surface tension but decreases its calorific value. Engine performance characteristics such as torque, brake power and brake specific fuel consumption were measured to determine the best blend for automotive applications. It was found that, ethanol-gasoline blend produces relatively poorer engine performance due to its lower calorific value compared to pure gasoline. As for the exhaust emission of ethanolgasoline blend, lower value of hydrocarbons and carbon dioxide were obtained with a tremendous reduction in carbon monoxide. With the same gasoline blend percentage, anhydrous ethanol gave better engine performance than hydrated ethanol but the result was other way around for exhaust emission.*

***Keywords****: hydrated ethanol, anhydrous ethanol, engine performance, emission*

## INTRODUCTION

One of the fundamental needs of mankind is energy. For centuries, man has been depending heavily on fossil fuel, especially petroleum since its discovery. Petroleum is used mostly, by volume, for producing fuel oil, as the most important primary energy source. 84% by volume of the hydrocarbons present in petroleum is converted into energy-rich fuels (petroleum-based fuels), including gasoline, diesel, heating, and other fuel oils and liquefied petroleum gas. Last year's fuel price hike which led to the severe energy crisis to the world is just an example on how imperative is the fuel in our daily life. Therefore, the world is seriously looking towards sustainable energy resources besides good energy management.

Ethanol, one of the renewable energy sources, has been widely used in countries like as Brazil and the US as automotive fuel. Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing automobile petrol engines can run on blends of up to 15% bioethanol with petroleum/gasoline. Gasoline with ethanol added has higher octane, which means that your engine can typically burn hotter and more efficiently.

In Malaysia, utilization of ethanol as automotive fuel is yet to be realized. The reasons are that Malaysia is still net exporter of fuel and the current demand can still be met. The potentials though, for ethanol to become automotive fuel, is still very high. The recent government rule which requires industries to use 5% methyl-ester produced from palm oil is a good example that the government are serious towards exploring bio-fuel potentials for domestic uses.

As such, the current work reports the findings from experiments conducted on various gasoline-ethanol blends, which can also be termed as gasohol. Two types of ethanol are used to produce the gasohol here, the hydrated ethanol and the anhydrous ethanol. Several compositions of both gasohols are studied in terms of property tests, followed by the performance and emission tests on 1.3 litre engine. The study is significant to understand the fundamental aspects of fuel blending and the possibility to adopt gasohol as automotive fuel, particularly in Malaysia, and ultimately towards reducing the dependence on fossil fuel as per today. Apart from that, local automotive engine manufacturers may also benefit towards manufacturing engines that may run solely on gasohol.

Fuel blending, especially ethanol-gasoline is not new. In Brazil for example, the usage of fuel blend started since 1970's as a government response to fuel crisis at that time. Since then, ethanol-gasoline fuel blend or better known as E25 (25 volume % of anhydrous ethanol blended with 75 volume % of gasoline) has become common in Brazil. Properties of both gasoline and ethanol are given in Table 1 below:

*Table 1: Fuel properties*[1]

| Properties | Value | |
|---|---|---|
| | Gasoline (RON 97) | Ethanol |
| 1. Chemical formula | C 4 to C12 | C2H5OH |
| 2. Molecular Weight % | 100-105 | 46.07 |
| 3. Composition Weight %<br>- Carbon<br>- Hydrogen<br>- Oxygen | 85-88<br>12-15<br>0 | 52.2<br>13.1<br>34.7 |
| 4. Specific gravity (15.55ºC) | 0.72-0.78 | 0.796 |
| 5. Density, kg/m3 | 718.092-777.933 | 792.285 |
| 6. Surface tension | $2 \times 10^{-3}$ *N/M* | |
| 7. Calorific value | 42-44 MJ/kg | |

The effects of ethanol and gasoline blends on spark ignition engine emissions were investigated by Hseih et al. [2]. In their study, test fuels were prepared using 99.9% pure ethanol and gasoline blended with the volumetric ratios of 0–30% (E0, E5, E10, E20 and E30). In the experiments performed at different throttle openings and engine speeds, nearly the same torque values were obtained when used different ratios of ethanol–gasoline blends compared with pure gasoline. Only the torque values obtained using E5 and E30 blends were lower than that of pure gasoline (E0) especially at high engine speeds (after 4000 rpm) and partly open throttle in 20%. Guerrieri et al. [3] reported their studies on engine emissions. Nine different volumetric percentages of ethanol–gasoline blends, ranging from 10% to 40%, on engine emissions were tested at six different cars which were produced between 1990 and 1992. In the experiments, linear variations of emissions were observed with respect to ethanol percentage. In the highest ethanol percentage which is 42%, the HC and CO emissions decreased about 30% and 50%, respectively, and the fuel consumption increased approximately 15%.

Effect of ethanol (99% pure) and unleaded gasoline blends on engine performance was also investigated by Al-Hasan [4]. Ten different ethanol–gasoline blends were prepared for the experiments, ranging from 0–25%. The results obtained from the experimental studies showed that the engine emissions and performance were improved. The engine power, brake thermal efficiency and volumetric efficiency were increased by 8.3%, 9% and 7% mean average values, respectively when the ethanol blended fuels were used.

Studies on various gasoline-ethanol blends and compression ratio on engine performance were investigated by [5]. In the experiment 10%, 20% and 30% ethanol–gasoline blends were used as fuel. Optimum compression ratio which obtained maximum indicated power was determined for each blend. For the 10%, 20% and 30% ethanol–gasoline blends, the optimum compression ratios of 8, 10 and 12 were obtained.

Yusecu et. al. [6] experimented various ethanol-gasoline blends on the effect of compression ratio on engine performance and exhaust emissions at stoichiometric air/fuel ratio, full load and minimum advanced timing for the best torque MBT in a single cylinder, four stroke, with variable compression ratio and spark ignition engine. The authors found that increasing compression ratio actually improves engine performance for all fuel blend composition but on the other hand did not reduce emissions compared to gasoline.

It can be summarized here from previous studies that in general, ethanol-gasoline fuel blending produces less torque and horsepower compared to engine running on gasoline alone, but significantly reduces emission. Other operating parameters such as compression ratio and engine speed should also be given attention as they also may affect the findings.

## EXPERIMENTAL SET-UP

Ethanol-gasoline blends are known to work well in unmodified gasoline engine. In the current work, petroleumbased ethanol was blended in gasoline by volume percentage. Two types of ethanol studied here, namely the hydrated and anhydrous ethanol. Hydrated petroleum-based ethanol (HE) contains about 95% ethanol and 5% water, while petroleum-based anhydrous ethanol (AE) contains more than 99% ethanol. The fuel blends, now can be designated as gasohol was prepared with the volumetric ratios of 0–100% (E0, E20, E40, E55, 70, E85 and E100).
Experiments were conducted in two stages. The first stage is the study on the fuel and fuel blend properties such

as surface tension, density and calorific value and the second stage consists on evaluation of performance of the engine in terms of power, torque and emission. Taking gasoline as the base for comparison in this study, all fuel blend compositions were tested on locally manufactured sedan, Proton Saga 1.3L 4G13 in the state-of-art chassis dynamometer - *Dynapack*. The engine comprises a 12 valve, Single Over Head Cam (SOHC) system with downdraught carburetor and a compression ratio of 9.5:1. As for the fuel properties, calorific values are obtained using bomb calorimeter model LECO AC 350 while surface tension are determined using viscometer, model Viscolite 700. Emissions were recorded using exhaust gas analyzer model KOEN KEG 500. All tests are conducted in accordance to ASTM standards, particularly ASTM D4806 [7].

## RESULTS AND DISCUSSIONS

This section presents all experimental results of the gasohol studied, both using hydrated and anhydrous ethanol. The data obtained from all those experiments are presented in the form graphs. The results are divided into property tests and performance tests, which are as follows.

Gasohol Properties Tests

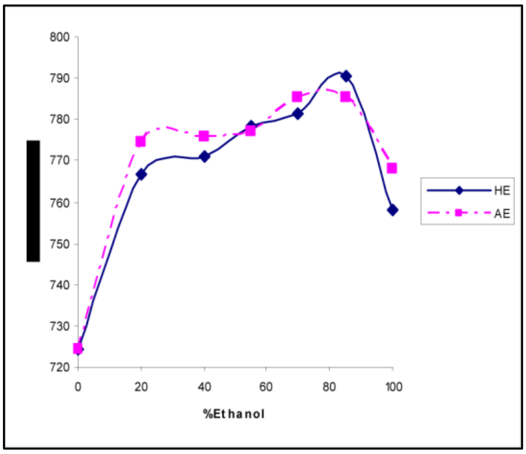


*Figure 1:Density vs percentages of ethanol per-litre gasoline*

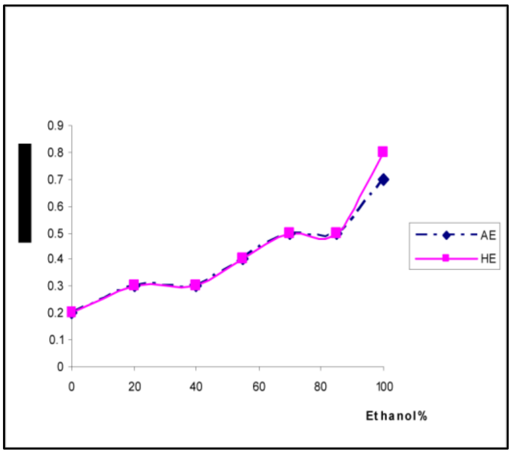


*Figure 2:Viscosity vs percentages of ethanol per-litre gasoline*

Figure 1 shows that the density of both gasohol increases with the percentage of ethanol, with AE experiencing quicker density change. Density values became comparable beyond 60% of ethanol volume in gasohol. Similarly, both gasohol exhibits viscosity increase with increase of percentage ethanol, and the values of AE and HE are almost identical, as shown in Figure 2. In general, it can be said here that both properties above may affect the performance of engine in terms of power output as the fuel becomes heavier and more viscous, thus harder to atomize for combustion, apart from the fact that the calorific values of gasohol are lower than pure gasoline.

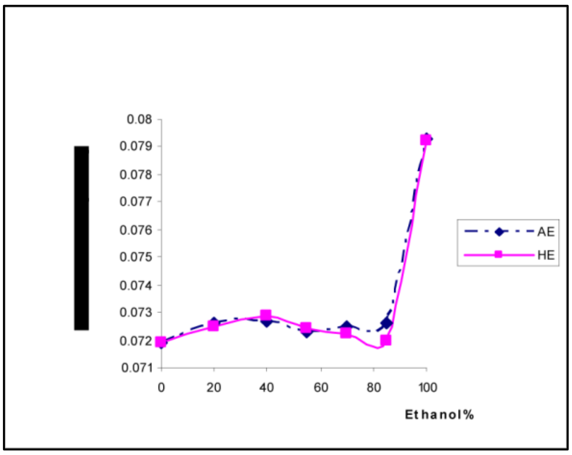


*Figure 3: Surface tension versus percentage ethanol per-litre gasoline*

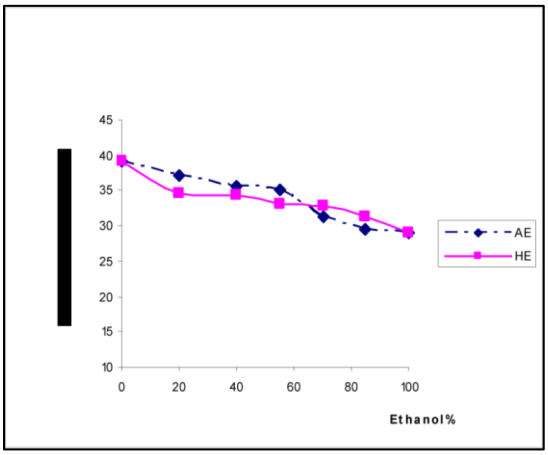


*Figure 4: Calorific value versus ethanol per-litre gasoline*

Figure 3 shows the increment of surface tension of gasoline when added with ethanol. The surface tension of pure ethanol is naturally higher than gasoline, thus fuel blends for both AE and HE exhibits slight increment of surface tension values. A higher value of surface tension is not desirable for combustion because larger Sauter Mean Diameter (SMD) of fuel droplets will be produced during fuel injection. It will cause evaporation problem, thus inhibit complete combustion in the chamber as mentioned earlier. The calorific values of AE and HE gasohol are shown in Figure 4. Calorific values for both fuel blends decrease with the increase of ethanol volume %, with AE having higher calorific values for blends less than 60%. The findings are in agreement with other researches [2], [5], [6]. Lower fuel calorific value of fuels will eventually reduce engine power and overall performance of engine.

## Gasohol Performance Tests

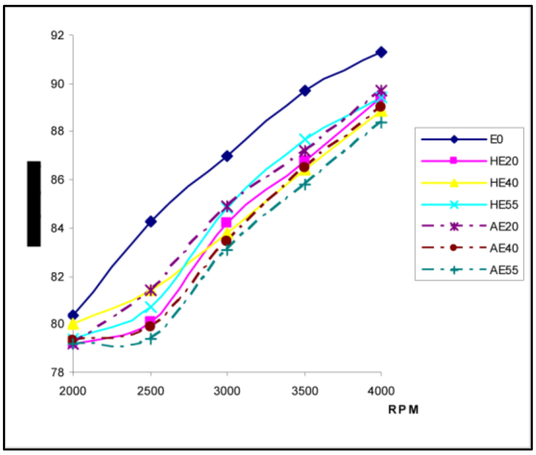


*Figure 5: Torque vs engine speed*

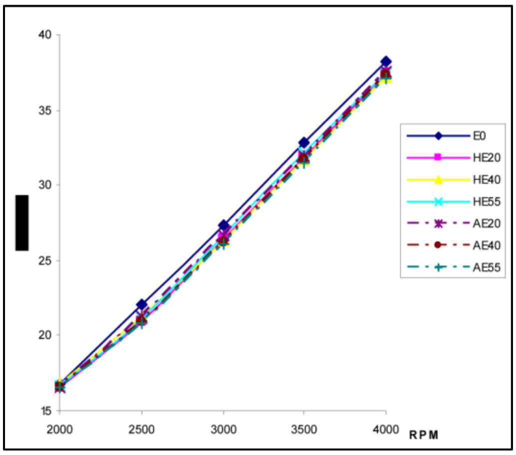


*Figure 6: Brake power vs engine speed*

Figure 5 and 6 shows the performance of the 1.3 litre engine tested on the chassis dynamometer. Generally, both AE and HE gasohol exhibits increase in torque with increasing engine speed for all compositions. However, these values are about 5 to 10% lower than that of pure gasoline, owing to the lower calorific values of both gasohol compared to pure gasoline. Surprisingly, AE40 and AE55 produced less torque compared to HE55. On Brake power for pure gasoline is only about 3% superior to gasohol. Overall, the anhydrous ethanol E20% blend provided the highest brake power in comparison with other blends.

Figure 7 shows the value of Brake Specific Fuel Consumption (BSFC) at different engine running speed. The graph shows the reduction of BSFC of gasoline and mixture of hydrated and anhydrous ethanol blend.

Theoretically, higher calorific values give better BSFC due to higher energy content. Thus, slight reduction of BSFC observed when hydrated E55% at high engine speed (3500 rpm).

## Gasohol Emission Tests

Figure 8 shows the reduction of hydrocarbon (HC) concentration at low running engine speed (2000 rpm). From the graph, the hydrated HE55% shows the highest emission of HC. While the HE20% shows a best performance at the low engine speed (2000 rpm). The result suggests that the reduction of HC occurred at high engine speed. Figure 9 shows the percentage of Carbon Monoxide (CO) from the emission test. It can be seen that for any percentage of ethanol blends, the amount of CO emission is highly reduced as expected because ethanol has been used as oxygenate (oxygen containing organic compound) mix with pure gasoline to reduce CO produced during burning of the fuel. Figure 10 shows that carbon dioxide CO2 concentration increases as engine speed increased. From the graph, the anhydrous ethanol has higher CO2 concentration other than pure gasoline and both hydrated and anhydrous ethanol. A higher percentage CO2 indicates a better combustion process of the engine.

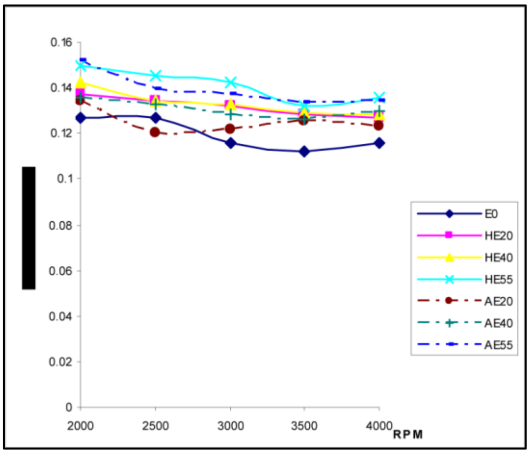


*Figure 7: Brake specific consumption (BSFC) versus engine speed*

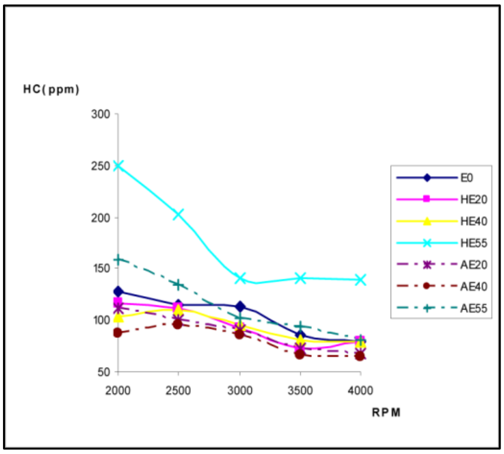


*Figure 8: Hydrocarbon (HC) versus engine speed speed*

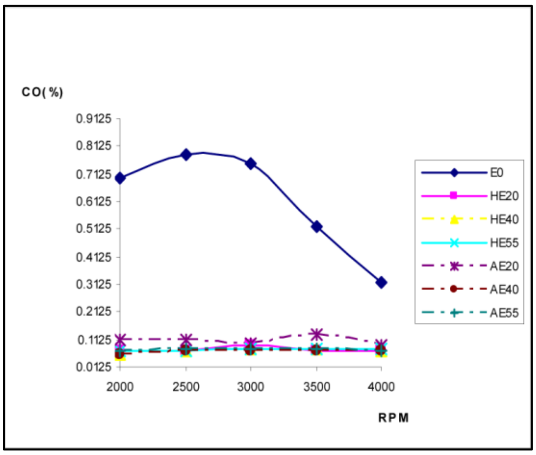


*Figure 9:Carbon Monoxide (CO) versus engine speed*

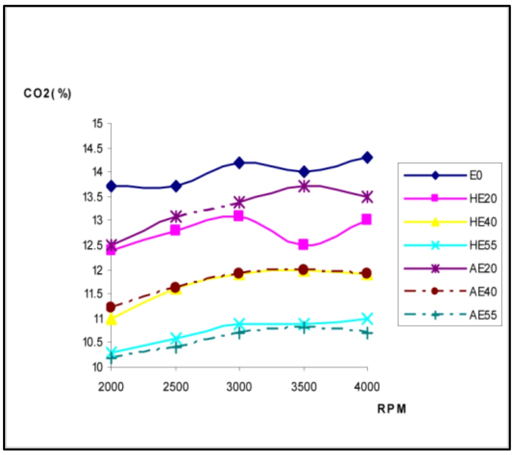


*Figure 10: carbon dioxide (CO2) versus engine speed*

Comparison of similar volume percentile (HE20% and AE20%) of ethanol blends are shown in Figure 11 to 16. Figure 11 and Figure 12 shows the torque and BP 20% gasohol hydrated and anhydrous ethanol blend respectively. Both torque and BP 20% hydrated and anhydrous mixture are slightly lower than a pure gasoline. It can be that AE20% shows better performance than HE20%. Figure 13 shows that BSFC on 20% gasohol ethanol hydrated and anhydrous blend is increase proportional to the engine running speed. It shows a fluctuation data obtained which is E0% in the low running speed (2000 rpm). Overall, AE20% shows a better BSFC than HE20%.

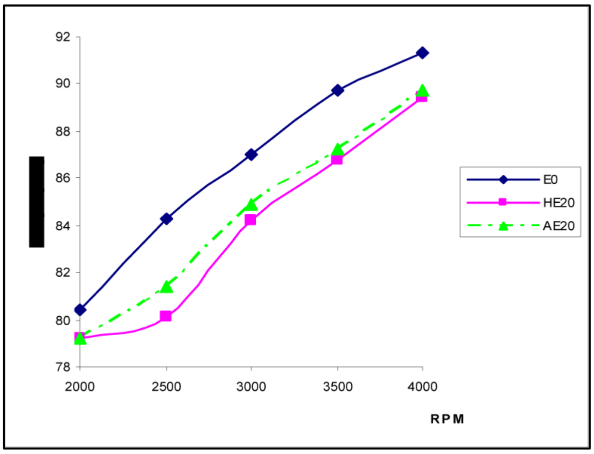


*Figure 11: Torque versus engine speed running on HE20% and AE20%*

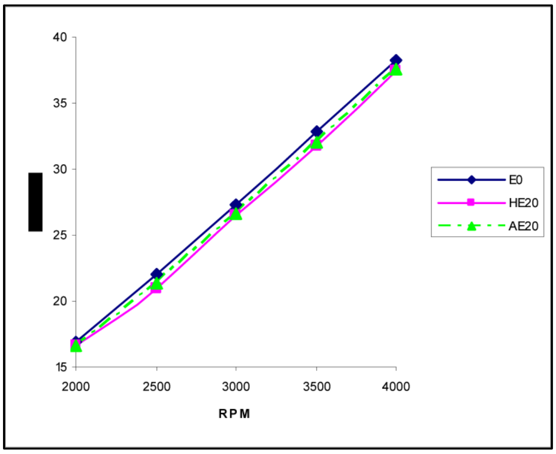


*Figure 12: Brake power versus engine speed running on HE20% and AE20%*

Figure 14 shows the reduction of hydrocarbon (HC) concentration started at low running engine speed (2000 rpm). It shows HC emission of pure gasoline E0% is higher than 20% hydrated and anhydrous ethanol mixture. AE20% shows lower HC emission than HE20% when engine speed is running. Figure 15 and Figure 16 shows the percentage of Carbon Monoxide (CO) and carbon dioxide (CO2) emission of E0%, HE20% and AE20% respectively. By comparing similar volume percentile of ethanol blend, HE20% shows the lowest CO and CO2 emission throughout the speed range. This is due to high oxygen content in the ethanol. May be, the water in the HE promotes better combustion.

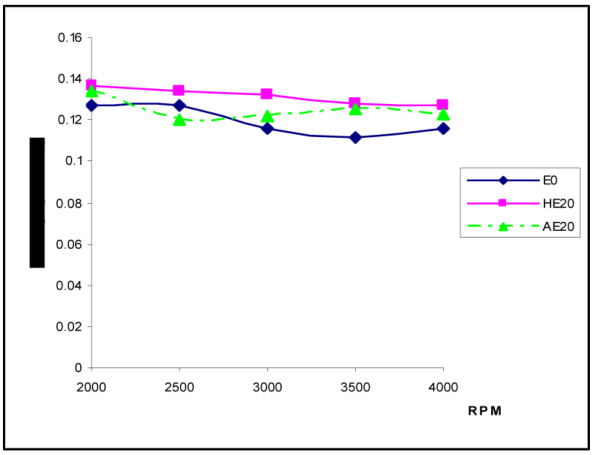


*Figure 13: Brake specific consumption (BSFC) versus engine speed running on HE20% and AE20%*

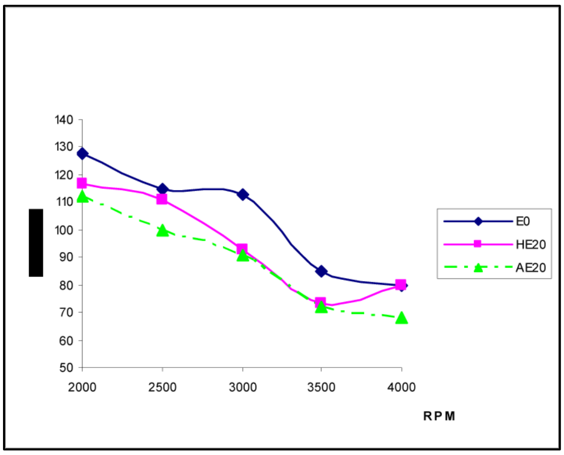


*Figure 14: Hydrocarbon (HC) versus engine speed running on HE20% and AE20%*

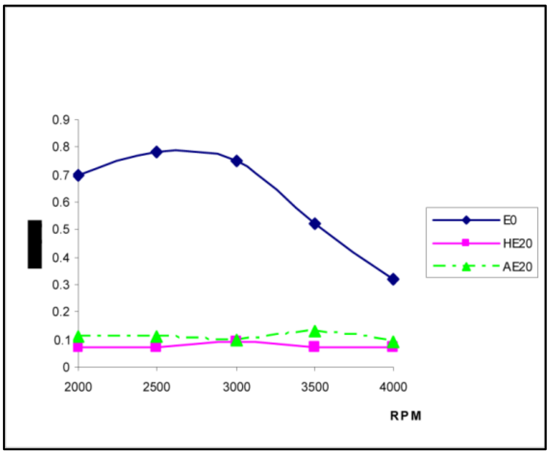


*Figure 15: Carbon Monoxide (CO) vs engine speed running on HE20% and AE20%*

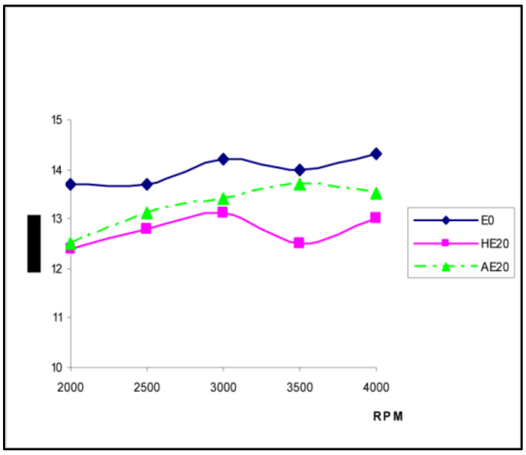


*Figure 16: Carbon dioxide (CO2) vs engine speed running on HE20% and AE20%*

## CONCLUSIONS

The effect of hydrated and anhydrous ethanol-gasoline blend on the performance and the emission of a 1.3L engine have been studied and the following conclusion can be made:

- Adding of ethanol will change the physical property of the gasohol.
- Comparing with pure gasoline, gasohol will lower the engine power and torque due to its lower calorific value. Therefore, BSFC for gasohol blend is higher than E0%.
- In terms of HC, CO and $CO_2$ emission gasohol fuel gave a better result throughout the speed range. Acting as oxygenates, addition of ethanol to gasoline reduces the amount of CO emission remarkably.
- Between AE and HE with the same blend percentage, AE gave a better engine performance in terms of torque, power and BSFC while HE out performed AE in terms of exhaust emissions.

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