INFLUENCE OF E10, E15 AND E20 FUELS ON PERFORMANCE AND EMISSIONS OF IN-USE GASOLINE PASSENGER CARS

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Abstract

The use of ethanol/gasoline blends on gasoline engines is not only a potential solution for satisfying the fuel demand but also for reducing emissions from vehicles which cause environmental pollution and adverse health effect. In Vietnam, the blend with 5% of ethanol (E5) has been widely used. However, blends with higher than 5% of ethanol should be studied and applied in order to improve the ability to substitute for gasoline. This paper presents the experimental results of in-use carbureted and fuel injected passenger cars fueled by gasoline RON92, E10, E15 and E20. These cars were tested at the steady state as well as following the ECE15+EUDC driving cycle. Results indicated the different influence of these ethanol/gasoline blends on power, fuel consumption and emissions of the cars.

Keywords: Alternative fuel, Biofuel, Ethanol, Gasohol

Introduction

Because of the depletion of fossil fuel, it is necessary to find out other alternative fuels which are possible to substitute for diesel and gasoline fuel. Some of them are liquefied petroleum gas (LPG), natural gas (CNG, LNG), biodiesel, alcohol fuels (methanol, ethanol, butanol), hydrogen, dimethyl ether (DME), synthesis gas. In recent years, blends of ethanol/gasoline used as fuels for gasoline engine have been studied and widely utilized in many countries around the world such as the U.S. (E10), Brazil (E20), Thailand (E10)... The use of these fuels is not only a potential solution for satisfying the fuel demand but also for reducing emissions from vehicles. Many studies showed that fuelling ethanol/gasoline blends for gasoline engine can improve engine performance, reduce HC and CO, but the trend of NO_x may vary depending on specific situations. Testing E10 on a carbureted motorcycle and a fuel injected car at steady states [1] showed that the engine power and fuel consumption were improved up to 5.03% and 5.41%, CO and HC emissions reduced by 16.06 and 17.21 respectively for the motorcycle, and these values were 6.38%, 4.19% and 33.74%, 18.62% for the car as compared to conventional gasoline fuelling. However, NO_x emissions increased by 16.94% for the motorcycle and by 21.58% for the car. Other studies on performance and emissions of fuel injected engines fuelled by E0 to E30 were also carried out [2,3,4]. The results indicated that using ethanol/gasoline blended fuels, the torque output and fuel consumption nearly unchanged or slightly increased, while CO and HC emissions decreased dramatically by 10–90% and 20–80%, respectively. It was noted that the change in NO_x emissions depended on the engine operating condition rather than the ethanol content. The effects of E50 and E85 on an injected SI engine at wide open throttle were also investigated and the similar trends could be observed except for the decrease in NO_x emissions with E50 and E85 compared to conventional gasoline fuelling [5]. For carbureted SI engine, blending unleaded gasoline with ethanol increased the torque, brake thermal efficiencies, CO_2 emission while it decreased the brake specific fuel consumption, CO and HC emissions, and the 20 vol.%

ethanol in fuel blend gave the best results for all measured parameters at all engine speeds [6]. The blends containing high concentration of ethanol, E40 and E60, could help to increase compression ratio, and the high improvement of engine torque, fuel consumption, HC and CO emissions were observed [7]. In Vietnam, the government approved the scheme on development of biofuels up to 2015, with a vision to 2025 [8] and E5 has been widely used since 2010. According to the decision, biofuels will meet 1% of national petroleum demand in 2015 and it will be 5% in 2025. To meet that target, it needs to increase ethanol concentration in blend. For that purpose, a project supported by Vietnamese government has been conducted which assesses the ability to fuel higher than 5% of ethanol in blend for in-use gasoline vehicles. Within the project, this paper studies the influences of RON92, E10, E15 and E20 on performance and emissions of a carbureted and a fuel injected passenger cars. The experimental works were carried out in Laboratory of Internal Combustion Engines, School of Transportation Engineering, Hanoi University of Science and Technology.

Experimental

Experimental Apparatus

Testing equipments include a chassis dynamometer 48” (CD 48”), a constant volume sampling (CVS) system, a combustion emission bench (CEBII) and a fuel balance (*Figure 1*). Each section has its own computer controlled by dedicated software and connected to common local network (LAN). The chassis dynamometer 48” is an asynchronous machine placed between two rollers which have diameter of 48 inches. By this dyno, vehicle speed and power at wheel can be controlled and measured. In the CVS system, exhaust gas is mixed with clean ambient air in order to simulate the real on road condition. The total flow rate in the system remains constant which can be used to calculate the mass of emissions. The CEB II comprises all analyzers for HC, CO and NO_x measurement. CO emission is analyzed by using Non Dispersive Infrared (NDIR) method. HC emission is analysed by a Flame Ionization Detector (FID) and NO_x by a Chemiluminescence detector (CLD). Each analyzer has 4 measurement ranges that can be adjusted automatically to consist with measured values in order to increase the accuracy. For determine the fuel mass supplying for vehicle, a Fuel Balance AVL 733S which is based on the gravimetrical method can be used.

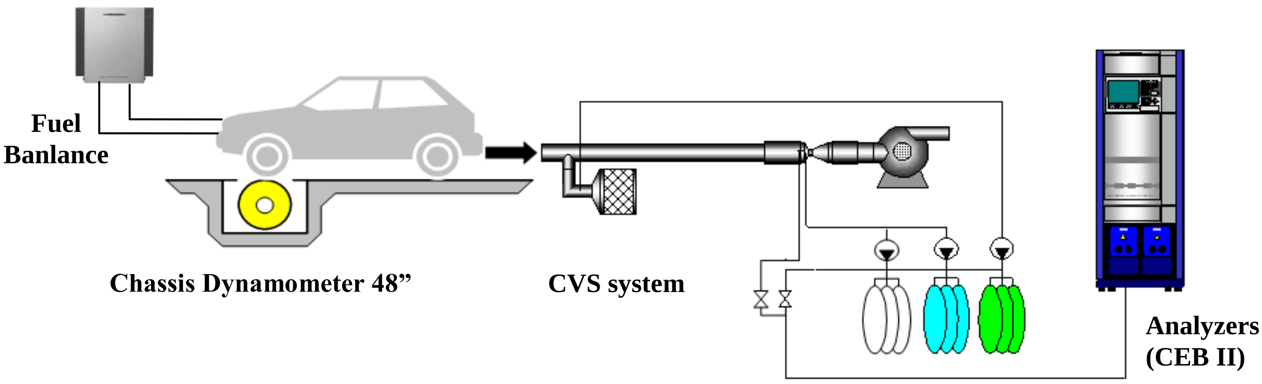

Figure 1. Experimental setup

Test Cars

In order to assess the effect of ethanol/gasoline blends on in-use vehicles, a carbureted and a fuel injected passenger cars were selected. Information of these cars is described in Table 1.

Table 1. Information of Test Cars

	Carbureted Car	Fuel Injected Car
Model year	1989	2001
Fuel system	Carbureted	MPI
Displacement (cc)	1498	1498
Mileage (km)	232455	87478
After-treatment	no	no

Test Fuels

In this study, the ethanol/gasoline blends were mixed from commercial gasoline RON92 and ethanol 99.5%. The percentage in volume of ethanol in blends was 10%, 15% and 20% corresponding to E10, E15 and E20. The properties of these fuels are presented in Table 2.

Table 2. Properties of Test Fuels

Property		RON 92	E10	E15	E20
Distillation temperature (^oC)	IBP	38.9	39.1	40.5	39.3
	t_{10}	53.6	51	51.0	51
	t_{50}	93.6	73.8	72.5	71
	t_{90}	158.6	161.6	160.4	159.5
	EBP	180	185.5	182.7	178.5
Octane number		92.4	94.4	95.4	96.6
RVP (kPa)		60.46	70.46	68.41	67.09
S content (wt ppm)		215	215	203	190
Aromatic hydrocarbons (vol%)		31.6	27.8	26.5	25.1
O content (wt%)		0	3.93	5.12	8.03
Density (kg/liter)		0.730	0.740	0.746	0.754

Test Procedure

Firstly, the cars were tested at steady state at which the throttle was pressed fully (full load condition) and gear position at number 3, 4 and 5, and vehicle speed varied in corresponding ranges. Power at wheel and fuel consumption were recorded with each fuel. Secondly, the cars ran following the ECE15+EUDC driving cycle (Figure 2) which normally applied for Euro 2 emission standard, and exhaust emissions were analyzed continuously as well as averaged over cycle.

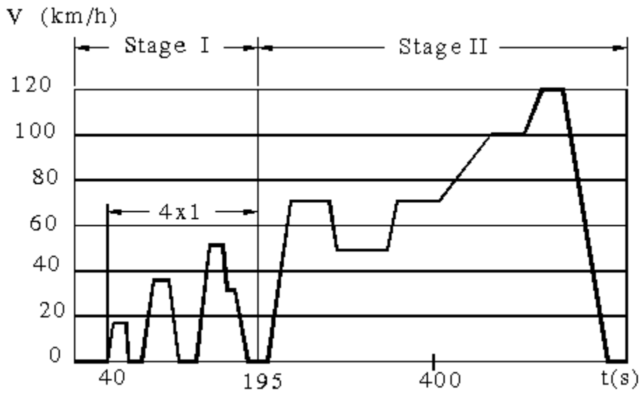

Figure 2. European test cycle ECE15 +EUDC

Results and Discussions

The Comparison of Performance and Emissions between of these Test Cars when Fueling with E10, E15 and E20 and with base Gasoline RON92 was Performed

Effect of the Ethanol/Gasoline Blends on Power, Fuel Consumption and Emissions of the Carbureted Car

Power and Fuel Consumption at Steady State

Results show that power at wheel and fuel consumption at three gear numbers have similar trend. Below displays these values at gear number 4 with the test fuels (Figure 3,4).

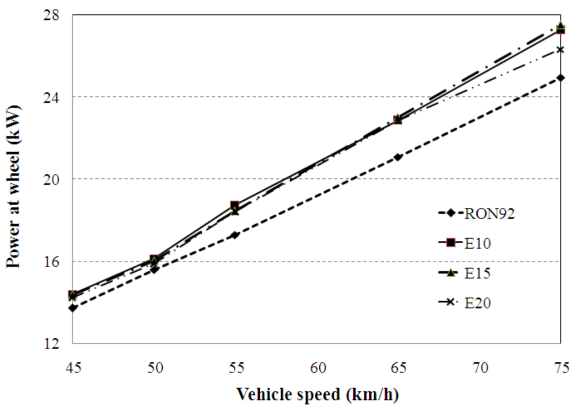

Figure 3. Power at wheel at gear number 4

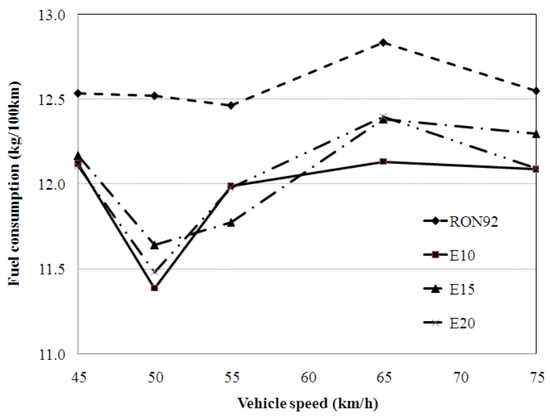

Figure 4. Fuel consumption at gear number 4

There was not much difference in power and fuel consumption between the blends. However, power with blends was about 6% in average higher than that of base gasoline in the speed range, although the ethanol addition to the gasoline decreased its heating value. That can be explained by some reasons. Ethanol plays as an oxygenated additive which is a possible reason for more complete combustion, especially at full load condition where the mixture is a little rich, thereby increasing the power. In carbureted fuel system, fuel comes into intake manifold due to the vacuum pressure at venturi, and then mixes with intake air to form the mixture. Therefore, volatility and latent heat of evaporation of fuel are important properties. For the ethanol/gasoline blends, the Reid vapour pressure and latent heat of evaporation were higher than that of base gasoline which could provide a better mixture, lower temperature intake manifold and increase volumetric efficiency. The improvement in power with the blends led to the reduction in fuel consumption. Compared to gasoline RON92, fuel consumption (in kg/100km) reduced by 4.6% for the blends and there was not much difference between the blends.

Emissions Over ECE15+EUDC Driving Cycle

The regulated gaseous emissions over the cycle were measured and evaluated in g/km (Figure 5,6,7).

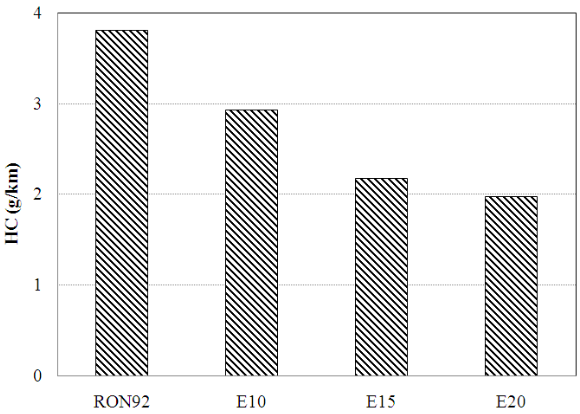

Figure 5. HC emission

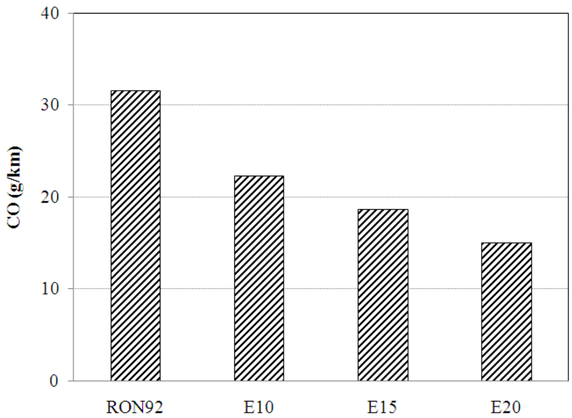

Figure 6. CO emission

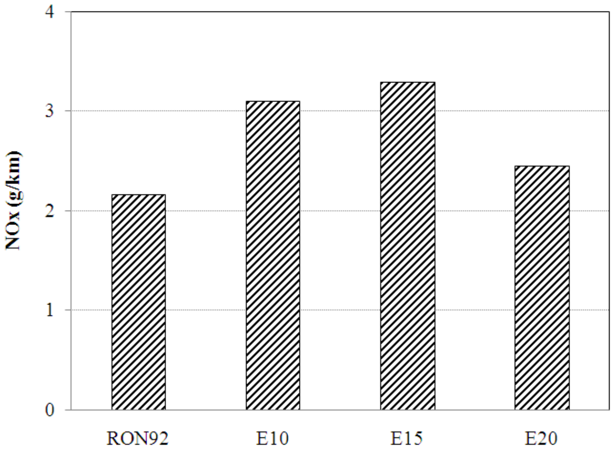

Figure 7. NO_x emissions

It is can be seen that HC and CO emissions for the blends were lower than that for gasoline RON92. The higher portion of ethanol in blends, the lower HC and CO emissions in exhaust gas. Compared to gasoline RON92, fuelling the car with E10, E15 and E20 reduced about 25.0%, 42.3% and 48.2% for HC, and 29.6%, 40.8% and 52.4% for CO, respectively. The decrease may be due to the improvement of combustion process as a result of the oxygen content in blends. However for NO_x emissions, the opposite trend was obtained. The NO_x increased and the highest value appeared with E15. The increase in NO_x was 43.7%, 52.7% and 13.3% with E10, E15 and E20.

For CO_2 emission, it increased slightly by 2.2%, 4.7% and 2.5% with E10, E15 and E20 (Figure 8). As a result, fuel consumption over cycle decreased a little by 1.8%, 3.8% and 5.1% with E10, E15 and E20 (Figure 9).

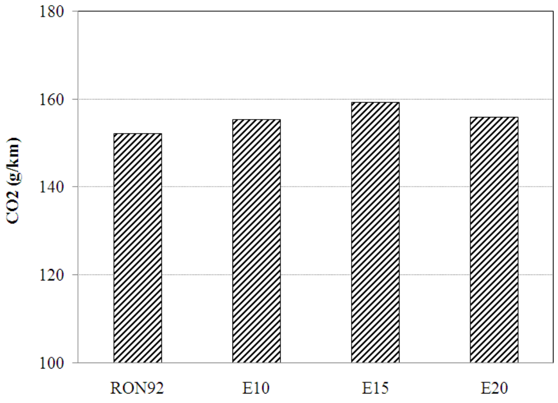

Figure 8. CO_2 emission

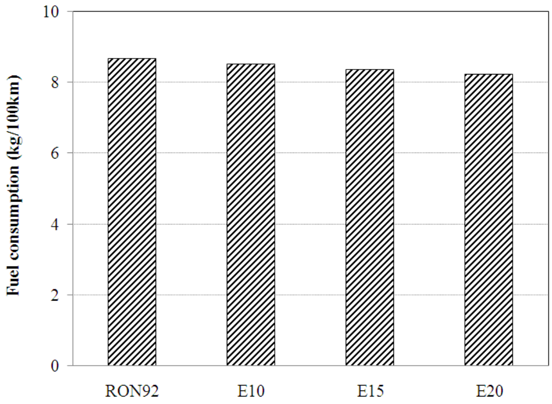

Figure 9. Fuel consumption over the cycle

Effect of the Ethanol/Gasoline Blends on Power, Fuel Consumption and Emissions of the Fuel Injected Car

Power and Fuel Consumption at Steady State

Here also presents power at wheel and fuel consumption at gear number 4 (Figure 10,11). Not like the carbureted car, in this case there was not much difference in power and fuel consumption between these test fuels that is due to the equal amount of injected fuel. For the injected system, fuel was injected into the intake port and volume of injected fuel was preconsidered which basically based on intake air flow rate and engine speed. These parameters were similar for all test fuels at full load point. A little improvement could be seen with E10. The highest change occurred for E20 which reduced averagely in power by 2.75% and increased in fuel consumption by 4.38% because of its lowest heating value.

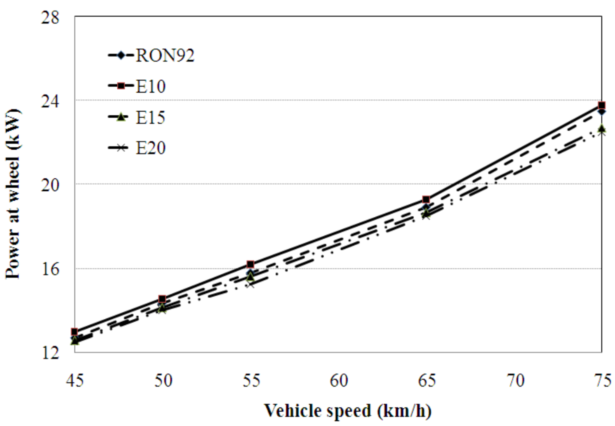

Figure 10. Power at wheel at gear number 4

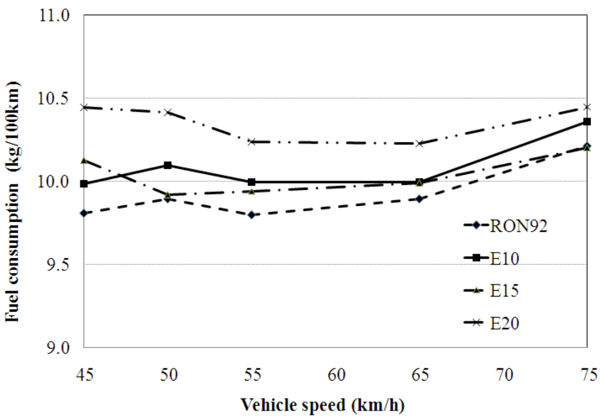

Figure 11. Fuel consumption at gear number 4

Emissions Over ECE15+EUDC Driving Cycle

HC and CO emissions in exhaust gas of the fuel injected car are also different from that of the carbureted car. Here, the lowest HC and CO emissions were obtained with E10, reduced HC by 3.88% and CO by 7.76%, whereas E15 and E20 resulted higher these emissions, namely increased HC and CO by 1.06% and 16.03% for E15, 3.09% and 22.3% for E20, respectively (Figure 12,13). That can be explained by a little improvement in combustion process for E10 as mentioned above. For E15 and E20, the combustion temperature decreased due to the higher latent heat of evaporation that may lead to the increase in HC and CO. These are consistent with results of some previous study in which HC and CO emissions when using E20 were higher than E0 at some measured points [6] or the emissions started to increase if the ethanol concentration in blends exceeded the certain value [7].

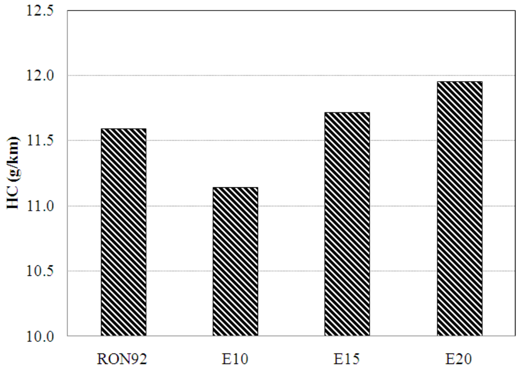

Figure 12. HC emission

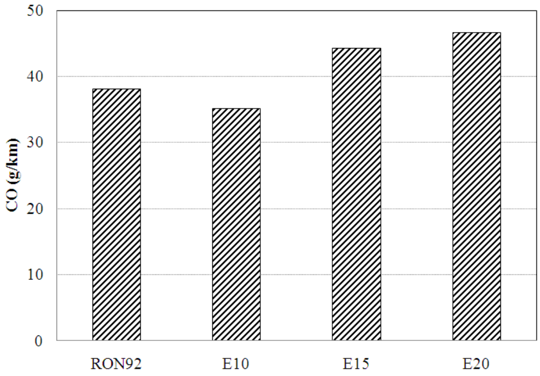

Figure 13. CO emission

The trend of NO_x emissions with E10 and E15 for the injected car was similar to that of the carbureted car (Figure 14) in which NO_x emissions increased by 10.70% and 21.63%, respectively. However, NO_x emissions reduced by 10.58% with E20 blend, that might be caused by lower combustion temperature as compared to the RON92.

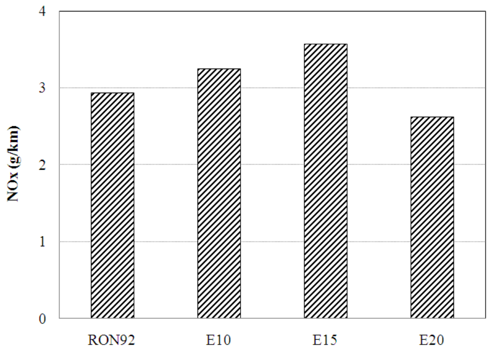

Figure 14. NO_x emissions

For CO_2 emissions and fuel consumption, there was not much difference between these test fuels (Figure 15,16). CO_2 emission increased by 3.41%, 3.90% and 1.29% for E10, E15 and E20. Fuel consumption with E10 was slightly lower with value of 0.8%, whereas it increased a little by 0.92% and 2.34% with E15 and E20.

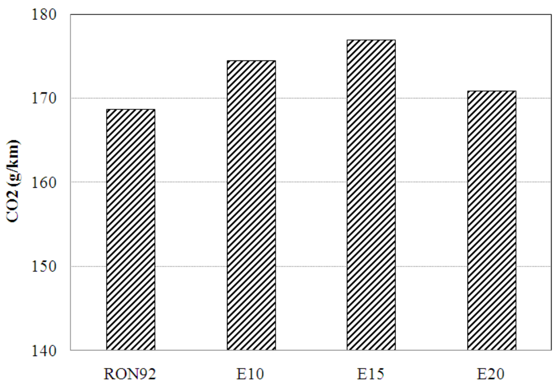

Figure 15. CO_2 emission

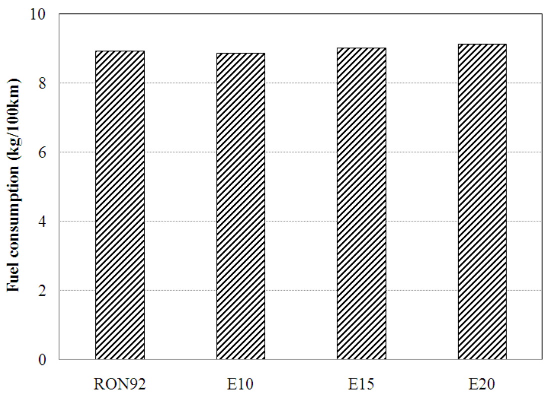

Figure 16. Fuel consumption over the cycle

Conclusions

The performance and pollutant emission of the in-use carbureted and fuel injected cars fueled by ethanol/gasoline blends were studied. The results indicated that effects of the ethanol/gasoline fuels on cars were not the same if the cars equipped with different fuel systems. For the carbureted car, using E10, E15 and E20 could increase power, reduce fuel consumption, and decrease significantly HC and CO emissions, whereas increase NO_x emissions. For the fuel injected car, these blends nearly did not affect power and fuel consumption. HC and CO emissions were reduced for E10 but increased for E15 and E20, while NO_x was higher for E10 and E15 but lower for E20 as compared to base gasoline RON92. In this study, it found that utilization of E10 possibly gave benefit for both of the cars.

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