# IMPACTS OF GASOHOL E5 AND E10 ON PERFORMANCE AND EXHAUST EMISSIONS OF IN-USED MOTORCYCLE AND CAR: A CASE STUDY IN VIETNAM

NGHIÊN CỨU ẢNH HƯỞNG CỦA NHIÊN LIỆU XĂNG PHA ETANOL E5 VÀ E10 ĐẾN TÍNH NĂNG VÀ PHÁT THẢI ĐỘC HẠI CỦA XE MÁY VÀ XE CON ĐANG LƯU HÀNH Ở VIỆT NAM

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## ABSTRACT

*This paper presents results of utilization of bioethanol E5 and E10 fuels on in-used motorcycle and car regarding performance and exhaust emissions of the engines. It is a collaborative research between Green Field Joint Stock, a bioethanol production company and Laboratory of Internal Combustion Engine, Hanoi University of Technology.*

*Findings of the research on the testing motorcycle and car showed that, using E5 and E10 fuels the air-fuel mixing process and the combustion inside the combustion chamber were improved due to better evaporation of ethanol. The stoichiometric air fuel ratio was decreased due to the available oxygen in the fuel. This helped improve engine power, fuel consumption and exhaust emission components such as CO, HC, while $NO_x$ emission increased significantly because of the better combustion and high combustion temperature. The findings contributed remarkably to the challenge of wide application of bioethanol on vehicles in Vietnam.*

Key words - Alternative fuels, gasohol E5, E10, exhaust emissions.

## TÓM TẮT

*Bài báo trình bày kết quả nghiên cứu sử dụng nhiên liệu xăng pha etanol E5 và E10 đến tính năng và phát thải độc hại của động cơ xe máy và xe con đang lưu hành. Đây là nghiên cứu phối hợp giữa Phòng thí nghiệm Động cơ đốt trong Đại học Bách khoa Hà Nội với Công ty Đồng Xanh, một công ty sản xuất etanol nhiên liệu.*

*Kết quả nghiên cứu trên xe máy và ôtô sử dụng nhiên liệu E5 và E10 cho thấy, quá trình hình thành hỗn hợp và cháy trong động cơ đốt trong được cải thiện nhờ khả năng bay hơi tốt của etanol. Tỷ lệ không khí/nhiên liệu cần thiết cho quá trình cháy hoàn toàn giảm do có thành phần ôxy trong nhiên liệu. Điều này đã giúp cải thiện công suất, tiêu thụ nhiên liệu và các thành phần phát thải CO, HC của động cơ. Trong khi đó phát thải NOx tăng đáng kể do nhiệt độ cháy cao. Kết quả nghiên cứu này có ý nghĩa quan trọng trong tiến trình sử dụng nhiên liệu sinh học xăng pha etanol ở Việt Nam.*

Từ khóa: Nhiên liệu thay thế, xăng pha etanol E5, E10, phát thải độc hại

## I. INTRODUCTION

ETHANOL ($C_2H_5OH$) is pure substance, which can be dissolved in water in all proportion. Of the combustion characteristics, the auto-ignition temperature and the flash point are higher than those of gasoline, which makes it safer for transportation and storage. The latent heat of evaporation of ethanol is 3 to 5 times higher than that of gasoline, this makes the temperature of the mixture in the intake manifold lower, which helps increase the volumetric efficiency. However, the heating value of ethanol is much lower than that of gasoline, so if the proportion of ethanol is high the engine power may decrease.

Nowadays, ethanol has been widely used in many countries either as a gasoline additive or as a substitution for gasoline. In 2007, the world market for ethanol fuel totaled 49.6 billion liters, in which two major producers (Brazil and the US) outputted 19 and 24.6 billion liters respectively, and those took 88% of the worldwide ethanol fuel [6].

Brazil is the most successful country, which has the biggest bio-fuel program all over the world. In 2006, Brazilian ethanol fuel production met 18% fuel consumption demand in transportation area and up to April 2008, ethanol fuel met more than 50% of total required gasoline. The number of 20% on road vehicles using 100% ethanol fuel (including vehicles using only ethanol and flexible fuel vehicles) shows clearly the popularity of the alcohol program in this country.

The US is the biggest ethanol fuel production and consumption country in the world. Almost vehicles can use 10% ethanol in blended gasoline, and the car makers has been releasing models that are able to run in higher ethanol proportions. In 2007, Portland and Oregon became the first cities where gasoline on-sale was required to contain at least 10% ethanol. Then in January 2008, Missouri, Minnesota and Hawaii states applied also this requirement [4].

In Asia, China had taken the third place of ethanol production in the world from 2004 to 2006, then fourth place in 2007. Another country in South East Asia named the seventh place of ethanol fuel production is Thailand, where gasohol E10 has been widely used. Since early 2008 gasohol E20 started to be used and gasohol E85 is released in third quarter of the same year.

In Vietnam, ethanol fuel has been piloted produced, and some ethanol plants using corn and cassava as raw materials are now under construction such as Petrovietnam Biofuels Joint Stock Company (100 mil. liter/year, at Phu Tho province), Green Field Joint Stock Company (100.000 ton/year, at Quang Ngai province) and Sai Gon Biofuels and Petroleum Company (40 mil. liter/year, at Cat Lai HCM city). However due to specific characteristics of vehicles used, weather and climate, research activities on effects of using ethanol fuel on engine performance, exhaust emissions and durability should be conducted upon the published international papers regarding these issues. This was done within a cooperative research between Green Field Joint-Stock Company and Laboratory of Internal Combustion Engine, Institute of Transportation of Engineering, Hanoi University of Technology.

## II. ETHANOL-GASOLINE BLENDED FUELS - AN EFFECTIVE WAY TO REDUCE FUEL CONSUMPTION AND EXHAUST EMISSIONS

Analytic results of gasoline Mogas92, gasohol E5 and E10 conducted in National Key Laboratory of Oil Refinery and Petrochemical Engineering, Institute of Industrial Chemistry showed that the octane number RON of gasohol E5 and E10 are 94.9 and 95.8 respectively, which are higher than that of gasoline mogas92 (RON 92.3). It means that gasohol is better than gasoline mogas92 in anti-knock value.

Density at $20^0$C of pure ethanol (99.5%) is 0.7917, which is not much higher than that of gasoline mogas92 (0.7291), so it assures ethanol to dissolve easily in gasoline.

Moreover, the heating value of pure ethanol is 23.5 MJ/l, much lower than that of conventional gasoline (34.4 MJ/l), thus the heat release is low if ethanol proportion is high. Nevertheless the heating value of gasohol E10 is 33.7 MJ/l. In addition, ethanol contains oxygen and has fast evaporation characteristics, which help promote the combustion process more effectively and by that way the engine power increases, the fuel consumption reduces when using blended fuels with appropriate ethanol proportion.

For environment, many research activities have reported that using gasohol could significantly reduce exhaust emissions from engine, especially carbon monoxide (CO) and hydrocarbon (HC). Some experimental results of gasohol E10 indicated that the octane number increased 5%, the engine power increased 5% while CO concentration reduced up to 30% [1][5]. Besides that, some other studies pointed that using ethanol-gasoline blended fuels increased emissions of formaldehyde, acetaldehyde and acetone than those of using gasoline [4][5]. Although the emissions of aldehyde will increase when ethanol is used as a fuel, the harmfulness to the environment is far less than the poly-nuclear aromatic hydrocarbons emitted from burning gasoline.

In general, using ethanol-gasoline blended fuel in appropriate rate helps improve engine performance, fuel consumption and exhaust emission components such as CO, HC, however, exhaust emissions like $NO_x$, aldehyde must be also paid attention.

## III. Comparative Experiments on Motorcycles and Cars

### 3.1 Methodology

The comparative experiments were done both on cars and motorcycles. The fuels used were gasoline mogas92, bioethenol or gasohol E5 (5% ethanol, 95% gasoline mogas92) and gasohol E10 (10% ethanol, 90% gasoline mogas92).

The measured parameters taken from 5 measured points on the full load curve at gears of 2 to 5 (for cars) and at gears of 2 to 4 (for motorcycles) included engine power, tractive force, fuel consumption, emission components. In addition, the emission concentration at idle speed and the acceleration ability of vehicles were also determined.

A car named Ford Laser Ghia1.8 with mileage of 6.000 (km) and a motorcycle Honda Super Dream 100 (cc) with mileage of 10.000 (km) were chosen for the tests.

### 3.2 Experimental apparatus

The experiments were conducted at Motorcycle Chassis Dynamometer (CD20") and Passenger Car & Light Duty Vehicle Chassis Dynamometer (CD48").

Fuel consumption was measured continuously by Fuel Balancer with the sample rate at 1/sec.

The CO, HC, $NO_x$ and $CO_2$ concentrations of the exhaust flow were instantaneously measured by dedicated analyzers. All of the analyzers were calibrated by calibration gases before each measurement.

## IV. Results and Discussions

### 4.1 Findings from the testing car

*1. Engine power*

Fig.1 shows the measured power output when the testing car was fueled with gasoline mogas92 (G92), gasohol E5 and E10. It can be seen that if ethanol proportion is higher, the engine power increases more. At speed of 65 ($km.h^{-1}$), 3rd gear, E10 fueled, the engine power is 10.2% higher in comparison with that as conventional gasoline mogas92 was fueled.

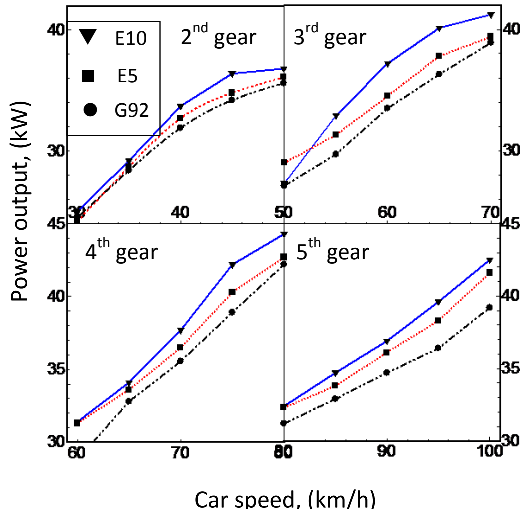


*Fig.1 Power output of the car fueled with different blended fuels (gasohol E5, E10 and gasoline mogas92)*

*2. Fuel consumption*

Fuel consumption in (g/kW.h) of the engine when gasoline mogas92 (G92), gasohol E5 and gasohol E10 fueled versus car speed is shown in Fig.2. At low and normal speeds, the fuel consumption of gasohol is lower than that of gasoline mogas92. But at high speeds, a small difference is recorded.

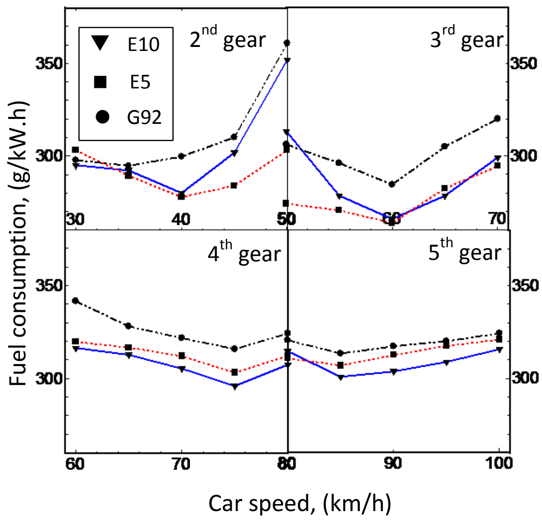


*Fig.2 Fuel consumption of the car fueled with different blended fuels (gasohol E5, E10 and gasoline mogas92)*

*3. Emission components*

Because ethanol contains oxygen so combustion mixture of gasoline-ethanol blended fuel had more oxygen in comparison with gasoline, this helped decrease significantly CO concentration in the exhaust. In addition, the combustion was improved with gasoline-ethanol blended fuel, which led to lower HC concentration. CO and HC concentration of exhaust gas measured when the testing car was fueled with gasoline mogas92, gasohol E5 and gasohol E10 are in turn shown in Fig.3 and Fig.4.

At all speeds, CO concentration was reduced remarkably if gasohol fuels were used. The higher the proportion of ethanol in the fuel mixture, the lower CO concentration was indicated in the exhaust. At speed of 70 (km/h), 4th gear, E10 fueled, the CO concentration was reduced up to 20%.

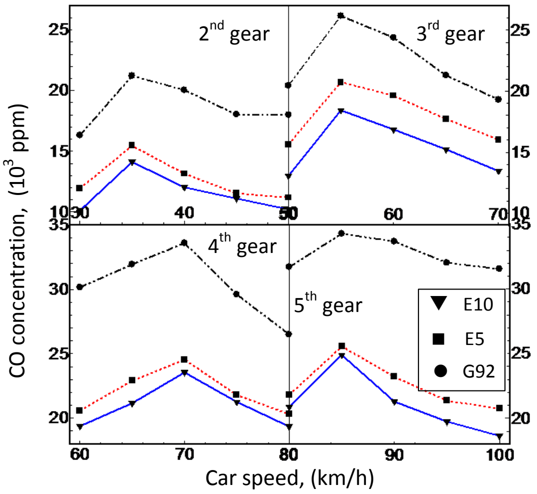


*Fig.3 CO concentration of the car fueled with different blended fuels (gasohol E5, E10 and gasoline mogas92)*

It is depicted in Fig.4 that HC concentration in the exhaust with gasohol fuels is smaller than that of gasoline, especially at high speeds. At speed of 95 (km/h), 5th gear, E10 fueled, HC concentration is 19% lower than that of gasoline mogas92.

Fig.5 shows $NO_x$ concentration of exhaust gas versus car speed when the testing car was fueled with gasoline mogas92, gasohol E5 and gasohol E10. In this figure, the $NO_x$ concentration of exhaust gas increased significantly as gasohol was used as fuel.

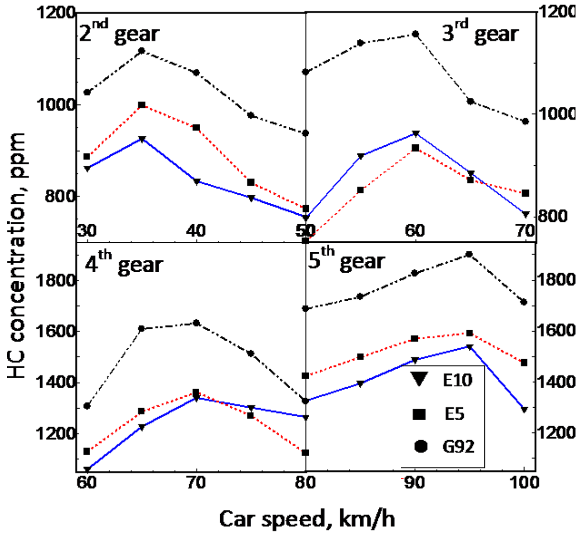


*Fig.4 HC concentration of the car fueled with different blended fuels (gasohol E5, E10 and gasoline mogas92)*

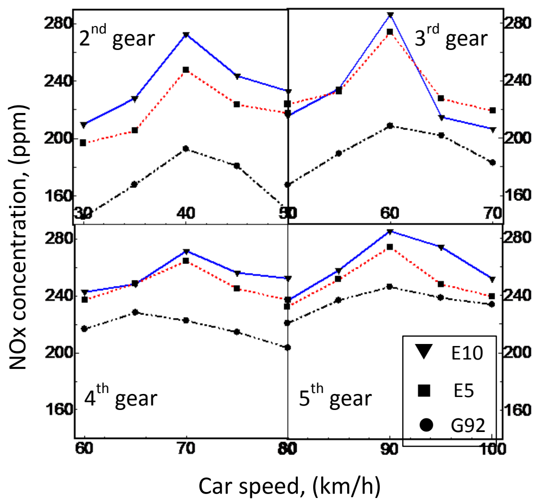


*Fig.5 CO concentration of the car fueled with different blended fuels (gasohol E5, E10 and gasoline mogas92)*

The increase of $NO_x$ concentration was caused by high temperature of the combustion, which was resulted by better mixture formation and efficient combustion process.

Fig.6 indicates $CO_2$ concentration versus car speed. The experimental data pointed that $CO_2$ concentration increased with gasohol fuels, especially at high speeds. It was due to more complete combustion resulted by using gasohol fuels as mentioned above.

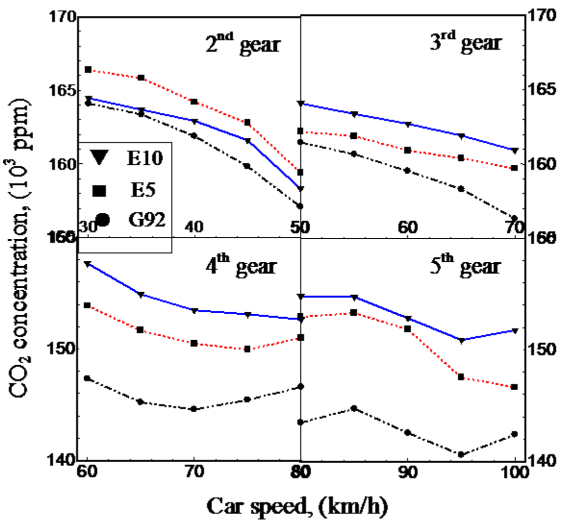


*Fig.6 $CO_2$ concentration of the car fueled with different blended fuels (gasohol E5, E10 and gasoline mogas92)*

Although the $CO_2$ concentration increases with gasohol fuels, the general $CO_2$ concentration which causes green house effect is believed to reduce basing on $CO_2$ close loop created by using bio-fuel sourced plants.

The effects of ethanol-gasoline blended fuels on car's performance and emissions are summarized in average values in Fig. 7.

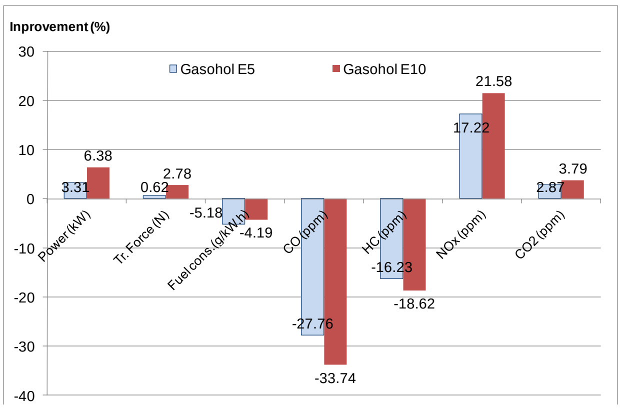


*Fig.7 Improvements achieved with gasohol fuels on a car*

It can be seen that CO and HC concentrations were reduced significantly, up to 33.74% and 18.62% respectively when gasohol E10 was used. However, using gasohol fuels increased $NO_x$ emission up to 21.58% and $CO_2$ emission up to 3.79%. For engine performance, using gasohol improved engine power and traction force up to 6.38% and 2.78% respectively, and fuel consumption up to 5.18%.

*4. Acceleration ability*

The acceleration ability of the testing car is presented in Fig.8, where this criterion was improved clearly with gasohol fuels, especially, with E10 fuel. The accelaration time from 0 km/h to 100 km/h of the car's speed were in turn of 19.1 seconds, 17.2 seconds and 15.7 seconds for the testing car used gasoline mogas92, gasohol E5 and gasohol E10 fuels.

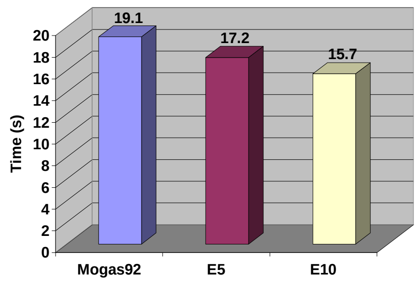


*Fig.8 Acceleration ability from 0 to 100 (km/h) of the testing car*

**4.2 Findings from the testing motorcycle**

Results on the testing motorcycle showed mostly the same rule as that on the testing car. As depicted in Fig.9, the engine power and fuel consumption were improved up to 6.50% and 6.37% respectively, the emission components CO and HC were reduced in turn of 15.05% and 21.65%, while $NO_x$ and $CO_2$ emissions increased 31.67% and 11.64% severally.

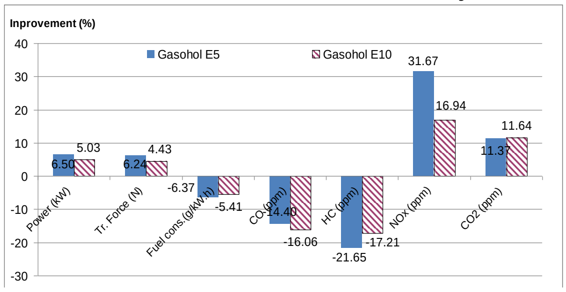


*Fig.9 Improvements achieved with gasohol fuels on a motorcycle*

The acceleration ability of the testing motorcycle is similar with that of the testing car. However, this criterion was improved the most with E5 fuel (Fig.10).

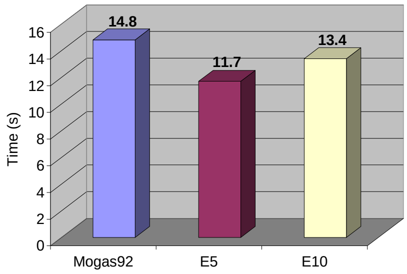


*Fig.10 Acceleration ability from 0 to 70 (km/h) of the testing motorcycle*

Finally, it is easy to see that the rule of improvements in engine performance and exhaust emissions (engine parameters) in case of using E5 and using E10 are different for the testing car and for the testing motorcycle. This matter is pointed in Fig.11, where the correlation between the improvements of engine parameters for the testing car and for the testing motorcycle in case of using E5 fuel and E10 fuel is showed.

It is depicted in Fig.11 that, for the testing car, which equips indirect multi-point injection gasoline engine, when E5 fuel was used, almost all engine parameters were improved less than those when E10 fuel was used. This result combining with acceleration ability showed in Fig.8 proves that as long as the mixture of air with fuel and the combustion are controlled and optimized, the higher proportion of ethanol blended in gasoline can be achieved.

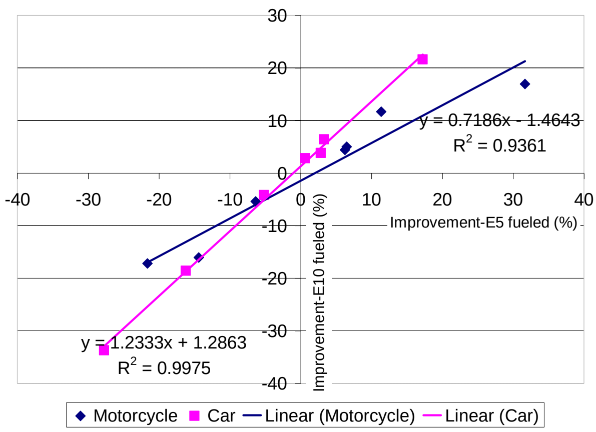


*Fig. 11 Correlation between the improvements of engine parameters in two cases (when E5 was used and when E10 was used) for the testing car and for the testing motorcycle*

For the testing motorcycle, the one has naturally aspirated engine, it is in contrary that almost all engine parameters were better improved with E5 fuel than those with E10 fuel. Together with acceleration ability depicted in Fig.10, for this testing motorcycle the E5 fuel is better for the engine than E10 fuel and fuels with higher ethanol proportion.

However in order to have better performance of the engine as higher proportion of ethanol is used, it is necessary to simply adjust carburetors or electronic control units to have richer mixture to ensure sufficient total energy supplying to the engines. In addition, more tests on different type of vehicles should be conducted to figure out the best proportion of ethanol blended in gasoline fuel for each type of vehicles.

## V. CONCLUSIONS AND OUTLOOK

The durability tests and aldehyde missions were not mentioned within this research due to limited time and budget.

The experiments have shown that it is possible to use gasohol E5 and E10 for in-used motorcycles and cars in Vietnam. The engine power and fuel consumption were improved up to 6.50% and 6.37% respectively for the testing motorcycle, and up to 6.38% and 5.18% severally for the testing car when E5 and E10 fuels were used compared with conventional gasoline mogas92 fuel.

The emission components CO and HC reduced remarkably in turn of 33.74% and 18.62% for the testing car, and 16.06% and 21.65% respectively for the testing motorcycle. While $NO_x$ emission and the green house gas $CO_2$ increased in turn up to 21.58%, 3.79% for the testing car, and up to 31.67%, 11.64% for the testing motorcycle. Although the $CO_2$ concentration increased for the testing vehicles, the total $CO_2$ concentration is believed to reduce due to $CO_2$ close loop created by using bio-fuel sourced plants.

Results of the experiments also shows that, in term of engine performance and emissions, the E5 gasohol fuel is better fitted with naturally aspirated engine of motorcycles than the E10 gasohol fuel, while the E10 is better for multi-indirect injection engine of the testing car.

In the near future, more vehicles should be investigated to find out the common impacts of gasohol fuel on engine's performance and exhaust emissions. In addition, aldehyde emissions and engine durability should also be mentioned.

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