MMSU Hydrous Bio-ethanol IV: Performance of Various Spark Ignition Engines Fueled with MMSU hBE20 under Philippine Conditions

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ABSTRACT

Several performance tests was already conducted in different gasoline engines using various fuels but tested only for a short period of time. The object of this study is to evaluate the performance of various spark ignition engines using MMSU hBE20 for longer periods. The test vehicles used in this study are brand new Kia-Rio (MPI, fuel injected engine), in-use toyota corolla (carbureted), two brand new TMX motorcycles (one unit is the control unit fueled with E10 and the other unit is fed with MMSU 95hBE20). The test machineries referred into are the two brand new 16HP Briggs and Stratton (one is the control unit). Since the test vehicles (Kia Rio and Toyota Corolla) do not have any control unit, a baseline performance was obtained using unleaded E10 fuel before fed with MMSU 95hBE20 fuel. Kia and Toyota test vehicle's power and fuel economy was measured using state of the art facility at UP Diliman'sVehiclesResearch and Testing Laboratory thru their Chassis dynamometer which employs Japanese 10-15 mode cycle procedure while TMX motorcycles were tested at MMSU thru artificial highway. The Briggs and Stratton unit's power and fuel economy were tested at MMSU engine dynamometer using PAES 117 and SAE 1349J procedures as guides.

Of the test vehicle's power and fuel economy, it was found that all engines fuelled with MMSU 95hBE20 appeared to be more economical of about 2.43% for Kia and about 5-12% for TMX (except for TMX at long distance driving), and more powerful of about 2% for both Kia and Toyota while about 20% increase in Powerfor Briggs and Stratton.

However, rust formations were observed in the fuel tank of all test vehicles and test machineries except for Kia which uses an innert material in its fuel system. It is highly recommended that MMSU 95hBE20 can be used as fuel to fuel ignition gasoline engines with rust resistant fuel system because of better performance as regard power and fuel economy (also in carbureted engins). For carbureted engines, the effect of rust formations can be avoided if fuel tank and fuel line system be equipped with rust resistant materials just like the Rusi brand motorcycle that employs already a tank that is made up of a plastic material and or to a Suzuki model motorcycle that install fuel filter to avoid the choking effect of gasoline.Even for commercial E10 fuel, rust formations to fuel tanks had been observed.

Keywords: MMSU hBE20, hydrous ethanol, Spark-ignition engine Performance

INTRODUCTION

Many countries, especially in well-developed countries are facing problems regarding the dwindling supply of petroleum. These problems are due to the abrupt increase of machineries that use fossil fuels as source of energy. As a result of energy crisis in the world, many alternative fuels are being tested to substitute commercial fuels. Petroleum resources are finite and therefore search for alternative fuel is continuing all over the world. Development of bio-fuels as an alternative and renewable source of energy for transportation had become critical in the national effort towards maximum self-reliance.

In the Philippines, we have the Biofuel Act of 2006. This propelled Mariano Marcos State University (MMSU) researches to conduct for the search and production of a promising biofuel that will involve farmers to reduce importation of anhydrous ethanol. Anhydrous ethanol (99.6%) is mandated in the Biofuel's Act that limits the involvement of local producers and farmers because laboratory scale and village scale production can only produce up to 96% alcohol purity.

Since other countries had been using hydrous ethanol blends to run their engines, the fuel blend formulated from the 95% ethanol purity was tested at MMSU and proved to run stationary gasoline engines.

To further test the performance of the hydrous fuel blend (MMSU hBE20) in gasoline engines, a long term testing was aimed using different types of gasoline engines either stationary or mobile engines, either brand new or second hand engines, and either carbureted or electronic fuel injected gasoline engines.

The performance of various spark ignition engines using MMSU hBE20 as compared to commercial E10 fuels as control fuel was madeto determine its effect on its performance: mechanically and physically.

OBJECTIVES

The general objective of the studyevaluates the effect and performance of various spark ignition engines using MMSU hBE20 formulation. Specifically, it aims to:

1. Observe the performance of various spark ignition engines using hBE20 as compared when using commercially available unleaded E10 as regard to:
   1.1 Mileage and or fuel economy,
   1.2 Power, and
   1.3 Recording of any engine related trouble encountered in the entire testing period

2. Conduct physical examination on the vital components of various spark ignition engines that may affect engine's performance particularly in its:
   2.1 Fuel System
   2.2 Combustion System

I. Review of Related Literatures

Hydrous Gasohol Fuel Blends

In the evaluation of a locally fabricated engine test rig for small stationary engines, two treatment blends were compared: 1. 20% hydrous ethanol blend in Unleaded E10 and 2. Unleaded E10. It was found that MMSU hBE20 offers more power and greater but of lower combined fuel economy (Domingo, J.A. et.al. 2012). In this study however, we validated the test using a state of the art facility using a standard procedure of testing in the University of the Philippines-Diliman and in the University of the Philippines-Los Banos. It goes with the findings of having more power output but it contradicts to the fuel economy result as it appears to have a better fuel economy.

Hydrous Gasohol Blends (MMSU95hBE) in XCS gasolinefuel has been able to run 5HP Kenbo Gasoline engine without modifications for 20% and 30% hydrous ethanol blends while it needed minor choke adjustments in carburators for blends 40% up to 100% pure hydrous ethanol at 95% alcohol concentration (Borromeo, B.B.et. al. 2011). The procedure in this study is to make long term observation on the effect of fuel blend in the engines of test cars and test machineries without any engine modifications. Aside from carbureted engines, an electronic fuel injection system was also studied to show that there will be no problem in the firing or combustion process using hydrous blends.

The performance of hydrous ethanol is always being compared in gasoline. At low engine speeds, the torque and mean effective pressure (BMEP) were higher when using anhydrous gasohol blends compared when using hydrous blends. However, at high engine speeds, blends higher torque and BMEP areachieved using hydrous ethanol (Costa, C.R. et.al. 2010). The findings of this study is synonymous to this findings. However, instead of higher BMEP the combustion temperature had been observed to be slightly higher. Since temperature is directly proportional to pressure, the observed high combustion temperature consequently gives a higher BMEP.

METHODOLOGY

Testing Facilities and Testing Standards

The study is mainly stationed at the Mariano Marcos State University (MMSU) in the City of Batac, Ilocos Norte, Philippines.(1)The power and Fuel economy were obtained at the facilities of the Mechanical Engineering Department of UP-Diliman particularly at the Vehicles Research and Testing Laboratory (VRTL) using their chassis dynamometer; (2) at the Agricultural Machineries Testing Centerin UP-Los Banos using their engine dynamometer; (3)long term simulation testing of at the Mechanical Engineering Department of MMSU using an engine dynamometer test rig and an artificial mechanical highway; (4) Kia Motors in Taguig Global for the physical examinations of test car Kia-Rio; and (5) MMSU motorpool for the opening of the in-use Toyota test car conducted by Toyota Motors personnel from La Union.

For the fuel economy and power output, the 10-15 Japanese standard Mode Cycle was used to both Kia-Rio and Toyota-Corolla Test Cars in chassis dynamometer at UP-Diliman. The same concept was used to Honda 155 TMX motorcycles in actual and artificial fuel economy run.The Briggs and Stratton Engines utilizes PAES 117 and SAE 1349J at UP-Los Banos using an engine dynamometer and as well as the simulation long term burning hours of the said engines at MMSU-ME department using an engine test rig dynamometer.

Test Vehicles and Test Machineries

In this study, the test vehicles being referred are: 1. the brand new Kia-Rio car which employs a multi-port fuel injection system similar to an electronic fuel injection engine. Kia-Rio was selected as this is the lowest responsive bidder that complies the minimum test requirement of an electronic fuel injection engine; 2. An in-use (or second hand) Toyota Corolla Car. The said car is also the lowest responsive bidder that meets the requirement of the funding agency, the Department of Energy for an in-use test car that employs a carbureted fueling system; 3. Two brand new Honda 155TMX motorcycles. This brand of motorcycle was selected since target fuel blend users will be tricycle drivers where most of them are using Honda 155 TMX. The one unit is fed with MMSU hBE20 while the other unit is the control that is fed with E10.

The test machineries considered in this test are two units of brand new 16 HP Briggs and Stratton. This is considered because it is believed that most this engine is used by our fisherman. If the fuel was used by the fishermen in their boats in will work reliably.

Fuel Formulation for MMSU hBE20

MMSU hBE20 formulation in this endeavor comprises of a blend of 95% ethanol grade and Unleaded E10 gasoline from Petron only. To eliminate other factors we used one fuel supplier that is Petron and because they gave us some support in terms of fuel thru our consultant from UP Diliman. The MMSU hBE20 is simply:

1 lit hydrous + 7.5 lit E10

Total Runs of Test Vehicles and Test Machineries

Before the test car Kia-Rio was subjected to physical examination, removal or disassembly of the cylinder head and inspection of the fuel system the said brand new car had travelled 33,636 km. The in-use Toyota Corolla had travelled 5300 km before the physical test. Both test cars had reached as far as Mulanay, Quezon, traveled in Metro Manila, Nueva Ecija, and in Pamplona, Cagayan.

The two TMX using E10 and hBE20 had travelled 5702 km and 5657 km respectively. These test vehicles had reached as far as Ilocos-Apayao Road to simulate the cold weather similar to Baguio City. Just like the test cars, it experienced all weather driving conditions to include rainy and sunny conditions.

All test vehicles were used for more than a year as service vehicle either for short travel (or service vehicle) or for long distance travels.

The two Briggs and Stratton had at least produced 189 kW-hr simulated in an engine test rig to control tear and wear and other factors.

Treatment Blends in the Long Term Test

There were to types of treatment blend or fuel used. One is the E10 from Petron which serves as the control fuel and the subject for testing, the MMSU hBE20.

RESULTS AND DISCUSSIONS

I. Performance Test of Various Spark Ignition Engines

Kia Rio is a fuel injected gasoline engine employing a multi-port injection system of kia technology. Table one below shows the performance of a brand new Kia Rio car when evaluated using the AVL Systems Technology chassis dynamometer in UP Diliman at the Vehicles Research and Testing Laboratory (VRTL). Initially, the vehicle was fueled with unleaded E10 from Petron until it reaches 500 km odometer reading just as it reaches VRTL for its base line test. After the baseline test, its fuel was shifted to hBE20 also for its initial test using the latter fuel. It appears that a slight increase of power and fuel economy was observed when the test vehicle was fueled with hBE20 after travelling 1200 km of 0.256% and 1.64% respectively.

Table 1. Performance of Test carin Kia Rio (1.2 MPI SI engine)

Fuel Used	**Distance Traveled**	**Fuel Economy, km/lit**	**Power, KW**
Unleaded E10	1- 500km	13.24	46.73
MMSUhBE20	After 500 km (0 km)	13.05	46.75
	After 1200 km using hBE20	13.459	46.85
	After 30,000 km odometer reading	13.03	48.85

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Table two as shown below is the performance comparison of test vehicle, Toyota Corolla when shifted to MMSUhBE20 fuel. The performance of the engine increases by 2.43 % when hBE20 fuel was used. The said vehicle is an in-use car employing a carbureted fuel system.

Table 2. Power output performance of Toyota Corolla

Fuel Used	Power Output, kW	%Difference
E10	39.08	2.43%
hBE20	40.04	

As shown in Table 3, the mileage run for an actual campus cycle drive runs much further for TMX using hBE20 compared to UnE10c fue with a% difference of 12.73%, while for an actual long distance cycle drive the mileage of TMX motorcycle fueled with E10 traveled more at 2.73%.

Table 3.Mileagecomparison TMX Motorcycles

Method	Fuel Used		% Difference
	(SG 7320) Unleaded E10	(SG 7326) hBE 20	
MMSU Campus Cycle Route	33.22 km	37.74 km	12.73%
Long Distance Cycle Route	46.43 km	45.18 km	2.73%
Artificial/Mechanical highway	35.215 km	37.165 km	5.38%

Table 4 below shows the performance of the two 16HP Briggs and Stratton just above the rated 3600 RPM using separate fuels, unleaded E10 and hBE20 for different testing periods. It appears that during the three testing period, the stationary engine fueled with hBE20 appears to be more powerful consistently at about 20% compared to the other unit fueled with unleaded E10. Both of the stationary engines declined in power output after 40 burning hours as they approached the preventive maintenance schedule just in time upon the conduct of physical examination on the spark plugs and cylinder head.

Table 4. Performance of Stationary engine's 16HP Briggs and Stratton

Stationary Engines	Testing Period, burning hours		
	After 20 hours	After 30 hours	After 40 hours
Briggs fueled with E10	7.54 kW	8.54 kW	6.39 kW
Briggs Fueled with hBE20	9.48 kW	10.27 kW	7.76 kW
% Difference	22.8%	18.69%	19.36%

Table five as shown above shows the common problem encountered during the entire testing period. It appears that test vehicles encountered more engine related problems to those engines fueled with MMSUhBE20.

Table 5. Trouble encountered during the conduct of testing

Test Vehicle/Machinery	Trouble Encountered	Findings/Caused
Kia-Rio	1. Discharged battery	1. Non engine related
Toyota Corolla	1. Engine Choking (2X) 2. Engine Choking (1X)	1. Clogged carburetor 2. Defective fuel filter
TMX fueled with E10	1. Oil leak (magneto)	1. Non engine related
TMX fueled with hBE20	1. Oil leak (magneto) 2. Engine choking (3x)	1. Non engine related 2. Clogged carburetor and clogged fuel tank's filter
Briggs and Stratton	1. Both encountered engine choking	1. Air-fuel mixture related

II. Physical Examination of Various Spark Ignition Engines

Kia Rio

Figures 1-4 as shown below are pictures taken during the physical examination conducted at Kia Motors in Global City, Taguig which is witnessed by personnel from Department of Energy, Kia Motors, project consultant from UP Diliman, and a non-partisan personnel from MMSU.

The fuel tank of Kia-Rio is shown in figure 1 while the floater assembly is shown in figure 2. Both pictures of the vehicles component contains no sign of rust or any similar element that may contaminate fuel or that may cause any corrosion to engines' fuel system.

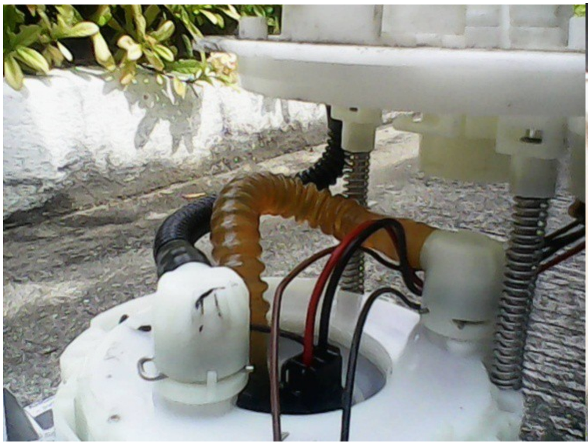

Fig. 1. Rust and corrosion free fuel tank

Fig 2 . Rust and corrosion free floater

Fig 3. Piston head at normal firing condition

Fig 4. Valves and combustion chamber

There shown in figures 3-4 are the conditions of the combustion process showing the valves and piston head. The brownish/grayish tangerine colors of the piston heads and valves signifies a normal combustion activity inside the combustion chamber removing the perceived effect of high combustion temperature due to high octane rating of the MMSUhBE20 of 98.6RON. The result strengthen the initial findings from Kia's GDC software and compression test at 150 psi claiming that the test vehicle is at normal operating condition and at normal tear and wear condition. The physical condition and the GDS results confirmed the non-rusting effect of MMSUhBE and the benefit of oxygenation in the fuel blend.

Toyota Corolla

Figures 5-7shows the fuel system of the test vehicle Toyota Corolla opened last January 28, 2014 at the College of Engineering in preparation for long travel to Mulanay, Quezon. It appeared in figure 5 some brown to black element at the bottom of the tank and at the floater assembly of the said vehicle (figures 6-7). The floater as shown in figure 6 shows some remarkable brown/red color believed to be rust while in figure 7 a whitish precipitates. These elements when pumped to carburetor will possibly clogged the carburetor if not filtered in the fuel filter.

Fig 5.Fuel tank of Toyota

Fig 6. Floater with sign of rust formations

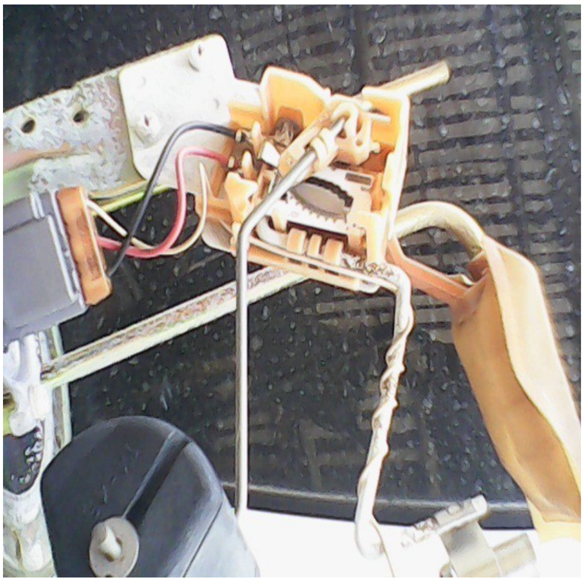

Fig 7. Floater with white precipitate

TMX Motorcycles

Figure 8 shows the fuel tank of the two motorcycles while figures 9-10 show the cylinder head of the said vehicles. The head of the TMX using hBE20 is cleaner.

Fig 8. Rusting in the Fuel tank of TMX using hBE 20

Rusting on the TMX's fuel tank had been observed after four months of using hBE20 on one of the TMX motorcycle. To continue the testing for a longer period and for further obervation, a fuel filter is installed before the carburetor to eliminate the clogging problem in the carburetor.

Fig  9.TMX using E10  head

Fig 10. TMX head using hBE20

Briggs and Stratton

Figures 11-12 shows the cylinder head of both the Briggs and Stratton. It also show that hBE20 fueled briggs has a better performance in terms of combustion.

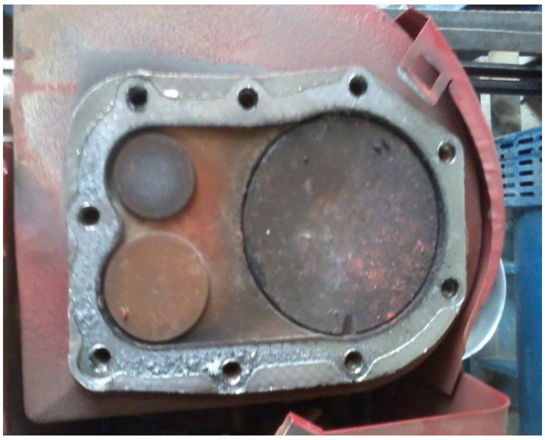

Fig 11. Briggs fuelled with E10

Fig 12. Briggs Fuelled with hBE20

Table 6. Summary of findings in the physical examination

Test Vehicle/Machinery	Result
Kia-Rio	1. Fuel System is very clean without any trace of rust or any similar sediment. 2. Combustion chamber is very clean without any trace of rust and unwanted products of combustion.
Toyota Corolla	1. Rust and white sediments occurs on the floater mechanism which is made up of an ordinary GI wire. 2. There were no phase separation observed in the Fuel tank although a slight rust formation was present which came from the floater mechanism.
TMX fueled with E10	1. Very clean fuel tank
TMX fueled with hBE20	1. Rusting is very obvious in the fuel tank 2. Combustion chamber is cleaner as compared to the combustion chamber of the TMX motorcycle fueled with E10.
Briggs and Stratton	1. Rusting occurs to both engines but more obvious in the engine using hBE20. 2. Combustion chamber is cleaner as compared to the combustion chamber of the Briggs engine fueled with E10

Table six as shown above summarizes the findings from the physicalexamination of the various gasoline engines after the duration of testing.

Rust Test Simulations

Figure 13. Rust Test in GI sheet and copper tube materials

As shown in figure 13 from left to right are pieces of materials submerged in different fuel Blends as follows: (1) E10; (2) MMSU hBE20; (3) MMSU hBE20 with 0.03% lubricant; (4) MMSU hBE20 with 0.04% lubricant; and (5) MMSU hBE20 with 0.05% lubricant. It shows that corrosion appears to all GI sheet materials and some discoloration to copper tube materials after seven days even E10 fuel was used.

CONCLUSIONS

1. Fuel injected engine used in this studyexhibits a more powerful engine and a better fuel economy with MMSU hBE20 as its fuel .
2. Fuel Injected engine used in this study experienced no engine trouble and no rust formation when fueled with MMSUhBE20.
3. Carbureted engines used in this study also exhibit a more powerful engine and a better fuel economy but experienced some engine trouble due to engine choking when MMSUhBE20 fuel was used.
4. Carbureted engines used in this study encountered some rust formation and precipitates when fueled with hBE20.

RECOMMENDATION

The observed whitish precipitates and rust formation in carbureted Spark ignition engines is due to the materials used in the fuel line system this was also found in a rust test even using an E10 fuel. The non-inert material in the fuel lines of the carbureted engines reacts with the gasohol blends.Kia-Rio's fuel system used stainless sheets that is corrosion resistant. The result was presented and consulted with engine experts and pronounced that even engine fueled with pure and E10 gasoline undergo a certain degree of rusting with time.

Considering the cheaper production of hydrous ethanol and the adaptability of the production technology to village level, the following are recommended:

On carbureted spark ignition engines:

1. Improvement of the materials used in the fuel line system, from non-inert to inert materials. A plastic made tank just like Rusi motorcycles is also recommended.
2. Installation of fuel filters to the fuel line just like Zusuki 100 motorcyle did in their product.
3. Addition of lubricant to the gasohol blend should be explored

On Fuel injected spark ignition engines:

1. MMSU hBE20 is highly recommended as fuel to electronic fuel injected engines because it exhibits a more powerful engine and better fuel economy without any observed rust or any similar solid formations.
2. Aggressive information dissemination to stakeholders on the positive effect of hydrous ethanol gasohol blend (MMSUhBE20) and seek support for massive advocacy campaign.
3. DOE to engage KIA and its allied companies –Hyundai and BMW to a tripartite partnership for the advocacy campaign and longer trial test run. Initially, Kia already expressed their interest in this endeavor.
4. To present result to the DOE-Philippine National Standard for possible consideration for the inclusion of hydrous ethanol in addition to anhydrous as biofuel blend.

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