The Effect of Engine Performance of Single Cylinder SI Engine Using Alternative Fuels Due to Various Compression Ratios

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Abstract- This paper is concerned with the ethanol using as the alternative fuel in Myanmar. The sugarcane is the main feedstock of ethanol production among the maize, cassava, potato, sweet potato, yam, broken rice, and sweet sorghum meanwhile the alcohol distillation technology has been well established in Myanmar. According to the FAO's project in fiscal year 2008, the sugar production was much more exceeded 117363 million tons in Myanmar stock. The resultant surplus sugar output was diverted to bioethanol production to utilize as the alternative fuel. However, the ethanol is expensive to dehydrate the dissolving water in Myanmar Market. Therefore, 95 percent of ethanol product is available in local market. The main purpose of the experiment is to test the engine performance compared with the gasoline and ethanol usage in rural areas. In this paper is intended to how to upgrade the engine performance when using the gasoline engine with ethanol, E10 and E20. According to the test, the result of using E10 and E20 is saved around 8.6 % fuel consumption more than the usage of gasoline and locally produced pure ethanol.

Indexed Terms- 95 percent Ethanol, E10, E20, Engine performance, Fuel Consumption.

I. INTRODUCTION

Fossil Fuels usage in Internal Combustion Engine is generally basic concept in the world. On the other side, the fossil fuels are rare to produce and the environmental impact enlarges with the increase of air pollution and global warming. As People suffers from the climate changes, the scientists wanted to replace the alternating fuel such as ethanol and methanol which is the renewable recourses instead of using of fossil fuels. In Myanmar, as the developing country, the usage of alternating fuels is much more expansive compared with the fossil fuels nowadays. In future, the using of alternative fuels might be much more popular for the internal combustion engine. Ethanol which is a renewable energy source that can be easily obtained from agricultural biomass products like corn and sugarcane can be used in spark ignition engines on its own or blended with gasoline.

The ethanol's physical and thermal properties show similarities with those of gasoline. Its low greenhouse effect, lower harmful exhaust emission into the atmosphere, ability to blend with the gasoline homogenously, and the high-octane rating have been popularizing ethanol usage in recent years. On the other hand, its lower heat of the combustion compared to gasoline, a need for modifications on internal combustion engines to be able to use it as fuel, and its being obtained from products requiring large fertile agricultural lands are the disadvantages of ethanol.

Developing alternative fuels for internal combustion engines is one of most attractive research topics for scientist and engineers. The use of alcohol and their blends as fuels has been a popular subject of research since the 1970s. Currently, alcohols are the most popular additives as octane boosters and as a partially oxidized fuel in gasoline fuel. In literature, there are several recent studies on the usage of ethanol blending with gasoline in SI engines [1-4].

In other some studies, the effects of ethanol blends with gasoline on engine performance and exhaust emissions were investigated. Koc et al. stated that the engine torque, power, and BSFC increases, while the emissions of CO, NOx and HC decreases with the higher ethanol concentration in the blends compared with the gasoline. Schifter et al. [5] investigated the effect of ethanol-gasoline blends containing up to 20vol% ethanol on engine performance and exhaust emissions. They found that ethanol in the blends of 20 vol% was slowed down the rate of burning and the cyclic variation was increased. Another study reported that the use of hydrous ethanol causes higher BSFC and higher thermal efficiency than the gasoline-ethanol blend for the range of all operating speeds [5]. In a limited number of studies, the effect of ethanol blends with gasoline on the combustion characteristics of SI engines have investigated [5,6]. The effects of adding at the low ratios of ethanol to gasoline on the combustion characteristics, the engine performance and exhaust-gas emissions were experimentally investigated [7]. Their results showed that the ethanol-gasoline blends have higher BSFC compared with pure gasoline. They also found that the combustion pressure rise was noted to occur later than gasoline fuel, and the lowest peak heat release rate was obtained in the gasoline study. Balki et al. [7] revealed that the engine torque, BSFC, BTE and combustion efficiency increased, the emissions in CO, HC, and NOx also decreased when using alcohol blended gasoline instead of pure gasoline. Moreover, the cylinder pressure and heat release rate (HRR) occurred earlier. Turner et al. [8] investigated the effect of ethanol-methanol-gasoline blends on NOx and CO2 emissions. They found that dual fuel blends can reduce the CO2 and NOx emissions than pure gasoline. Elfasakhany [8] investigated experimentally the effects of different ternary blends on the performance and pollutant emissions of an SI engine. He found that the torque, brake power, and volumetric efficiency was increased, while exhaust emissions of HC and CO were decreased at using ethanol-methanol-gasoline fuel blends, compared to other blended fuels.

It can be realized from the literature that several studies were conducted on the use of gasoline and their blends with gasoline as fuel in SI engines. However, there are very few studies on the usage of ethanol-gasoline blends in SI engines. Therefore, this paper is intended to investigate the engine performance parameters using the locally produced ethanol in single cylinder SI engine. In addition, the various ethanol-gasoline blends such as E10 and E 20 are compared with the pure ethanol and gasoline in different compression ratios of 8 and 9.

II. EXPERIMENTAL METHOD

The ethanol is produced from the maize, cassava, potato, sweet potato, yam, broken rice, and sweet sorghum in Myanmar. Most of the ethanol from the urban area is produced from the broken rice to alternate the alcohol meanwhile it can be obtained from the sugar cane in the rural areas. The normal ethanol formula is CH_3CH_2O and the gasoline formula is C_8H_{18}. The amount of oxygen is exceeded in ethanol so that the complete combustion happens in combustion chamber of SI engine meanwhile the stoichiometric air fuel ratio of ethanol is 9. On the other side, that of gasoline is 14.7 for SI engine and the amount of fuels are much more needed when using the ethanol. The calorific value of ethanol is 22890 kJ/kg and that of gasoline is 48290 kJ/kg and that of E10 is 46300 kJ/kg and that of E20 is 45903 kJ/kg [10]. Therefore, the modification of engine is required to use the pure ethanol for the fuel input system to the combustion chamber. The need of modification is to amplify the main jet of the carburettor of the SI engine for using the locally produced 95% ethanol. For another blended gasohol such as E10 and E20, there is no more engine modification. As the side effects, the local produced ethanol is involved the ethanol 95 percent and water 5 percent. It is obviously seen that to occur the corrosion in the fuel line system.

A. Experimental Engine Set up

CL 3900 Corolla Inclined Single Cylinder SI Engine are used for this experiment. The following engine specifications are described in table 1.

Table 1. Engine Specifications

No.	Items	Engine type and Properties
1	Model	CL-3900
2	Engine-type	Inclined Single Cylinder 4stroke (OHV), air cooled
3	Max: Output	2.5 hp
4	Bore x Stroke	54 x 38 mm
5	Speed	3000 rpm
6	Oli Capacity	0.6L
7	Fuel Tank Capacity	5.5L
8	Ignition System	Transistorized Ignition
9	Compression Ratio	8:1
10	Voltage	220 VAC
11	Frequency	50Hz
12	Over Current Breaker	10A
13	Dimension	460x370x410 mm
14	Weight	23 kg

Firstly, the engine is assembled with the fuel tank which is separated for gasoline, ethanol and ethanol blends such as E10 and E20. Before mixing the fuel and air in the carburettor, the fuel gauge meter to measure the fuel volume flow rate is connected with two lines which has the valves to open or close the fuel passing from the fuel tanks. At the entrance of the intake air system before the carburettor, the air box is connected to passage of the inlet manifold. The exhaust gas temperature sensor (thermocouple K type) which linked with the display unit box is located at the muffler. The clamp meter or multi-meter to measure ampere and volt meter to measure voltage are installed obtaining the power consumption from switching on or off electric bulbs. Another necessary instruments such as ambient temperature sensor and pressure sensor is installed in display unit box.

B. Theories and Equations

The Brake Mean Effective Pressure (BMEP) is a theoretical parameter used to measure the performance of an internal combustion engine (ICE). Even if it contains the pressure, it's not an actual pressure measurement within the engine cylinder. The brake mean effective pressure can be regarded as an average pressure in the cylinder for a complete engine cycle. By definition, brake mean effective pressure is the ratio between the brake power and engine displacement.

$$\text{BMEP} = \frac{60 \times \text{B.P} \times n}{0.1 \times N \times v_d}$$

Where, BMEP = brake mean effective pressure in bars

B.P = brake power in watts

N = engine speed in rpm

v_d = engine capacity in cm^3

The brake power (briefly written as B.P.) of an IC Engine is the power available at the crankshaft. The brake power of an I.C. engine is usually measured by means of a brake mechanism (Prony Brake or Rope Brake) and the hydraulic dynamometer and the electrodynamometer (voltage and current). Among them, electrodynamometer is introduced to this paper to measure the brake power. In the measurement of brake power, the loads of power consumption used by bulbs can be counted with the voltage meter and ampere meter. There are some factors to be considered for the generator efficiency and power loss due to voltage and current. When voltage and current are out-of-phase, the cosine of the angular displacement is called power factor. The power factor of the generator using in this experiment is r cos Ø = 1. Meanwhile, although the generator efficiency is the ratio of energy output to energy input expressed as the percentage, assume that the generator efficiency is 90%.

$$\text{B.P} = \frac{2 \times \pi \times N \times T}{60}$$

$$\text{B.P} = \frac{V \times I}{\text{generator efficiency x power factor}}$$

Where, B.P = brake power in watts

N = engine speed in rpm

T = Torque in N.m

V = voltage in Volt

I = current in Amp

Brake specific fuel consumption (Bsfc) is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft power. It is typically used for comparing the efficiency of internal combustion engines with a shaft output. It is the rate of fuel consumption divided by the power produced. It may also be thought of as power specific fuel consumption, for this reason. Bsfc allows the fuel efficiency of different engines to be directly compared.

$$Bsfc = \frac{3600 \times 1000 \times \dot{m}_f}{B.P}$$

Where, Bsfc = brake specific fuel consumption in kg/kW.hr

$\dot{m}_f$ = fuel mass flow rate in kg/s

The mass of fuel flow rate is obtained from the volume flow rate which is measured from the fuel gauge by multiplying the fuel density. The measure of fuel density of ethanol and gasoline are demonstrated in fig. 1. The equation of fuel mass flow rate is

$$\dot{m}_f = \rho \times \dot{v}_f = \rho \times \frac{\pi}{4} \times D^2 \times \frac{L}{t}$$

Where, ρ = density of fuel in kg/m^3

$\dot{v}_f$ = fuel volume flow rate in m^3/s

D = diameter of glass tube to measure fuel passing through it in meter

L = Length of glass tube to measure fuel passing through it in meter

T = time taken in second

The brake thermal efficiency is defined as the brake power of a heat engine as the function input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical efficiency. The equation of brake thermal efficiency is

$$\eta_{bth} = \frac{B.P}{\dot{m}_f \times C.V}$$

Where, η_{bth} = brake thermal efficiency

$\dot{m}_f$ = fuel mass flow rate in kg/s

C.V = Calorific Value of fuel

Fig 1. Fuel Density Measurement

There are 2 steps to measure the density of the fuels such as E10, E20, ethanol and gasoline. Firstly, the fuel is putted into the 1liter volume of plastic bottle. After that, the weight of the fuel is obtained from the weight scale. The density of the pure ethanol is 789 kg/m^3. Meanwhile, the gasoline's density is 720 kg/m^3. The densities of E10 and E20 are approximately near to that of gasoline and the values are 727 kg/m^3 and 734 kg/m^3.

C. Measuring Parameters

The SI engine performance is investigated by using of these instruments shown in fig 2. There are two types of measuring methods for IC engine, various speed measurement and constant speed measurement with wide open throttle (WOT).

This paper is used the constant speed measurement at 3000 rpm with WOT. Fuel glass tube has 13.2mm diameter and 50.8mm length by means of recording time with the stop watch when the fuel is passing through it. The tachometer is used to measure the speed of the engine. By loading the switching on the electric bulbs one by one, the power consumption is read on the volt meter and clamp meter. The power output can be obtained as watt unit by multiplying with ampere and voltage and power factor.

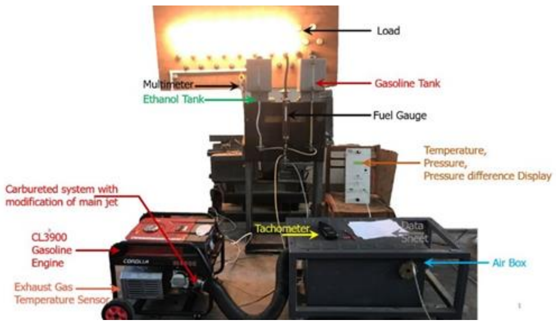

Fig 2. SI Engine with Measurement Instruments

III. RESULTS AND DISCUSSION

There are two aspects measurements with gasoline, ethanol-gasoline blends (E10, E20) and ethanol for different compression ratios 8 and 9.

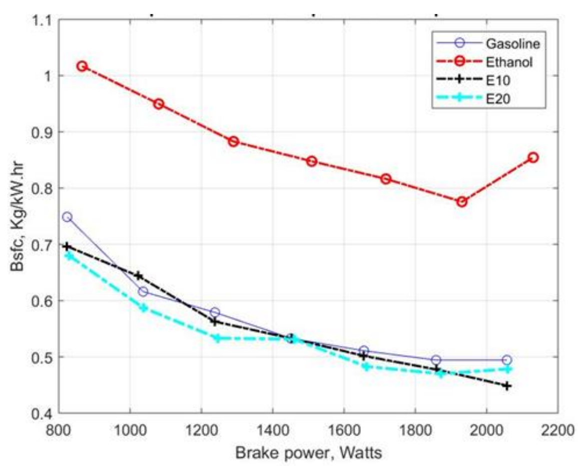

Fig 3. Brake Specific Fuel Consumption Vs Brake Power for compression ratio 8

The Fig 3 is illustrated that the fuel consumption is equal at over 1400 watts for gasoline, E10 and E20 meanwhile the ethanol is much more than that of gasoline because the stoichiometric air-fuel ratio of ethanol is 9 and that of gasoline is 14.7. looking at the below of the 1400 watts, the E20 is quite better fuel consumption compared with other fuels including gasoline.

The more the torque, the less fuel consumption at the constant speed of 3000 rpms. However, 4.5 Nm of Torque is optimum for gasoline and E10 and E20. The dynamometer is limited with the maximum 1200 watts and E20 is better before 4.5 Nm as shown in fig. 4.

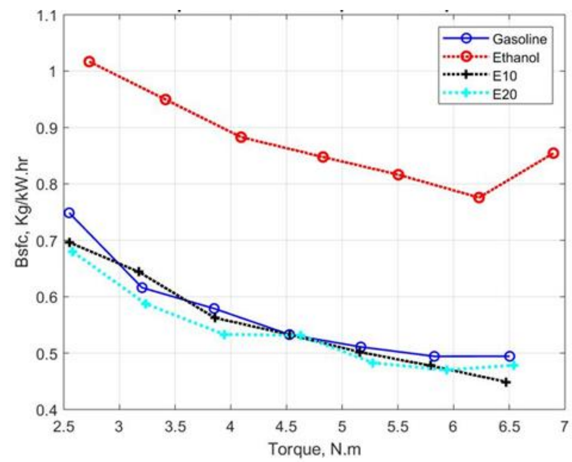

Fig 4. Brake Specific Fuel Consumption Vs Torque for compression ratio 8

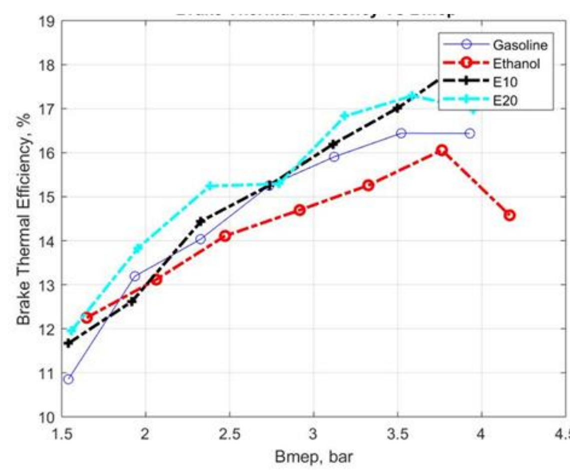

Fig 5. Brake Thermal Efficiency Vs Brake Mean Effective Pressure for compression ratio 8

Brake thermal efficiency is the product of indicated thermal efficiency and mechanical efficiency. Mechanical efficiency decreased as the compression ratio is increased due to the higher loads on the pistons, rings and bearings of the engine. The brake thermal efficiency is increased gradually for E10, E20 and gasoline except of ethanol. This is due to the increase in brake thermal efficiency and decreases in equivalence air fuel ratio (φ). The fig. 5 illustrated that the maximum brake thermal efficiency is around the 17% at 3.75 bars.

To be compared with the fuel flow rate in fig. 6, E20 is the lowest level with the value of $2.5x10^{-7}$ m^3/s at the reach of maximum power output of 1200 watts. The optimum point for all fuels is around 1400 watts although the maximum is specified for this engine.

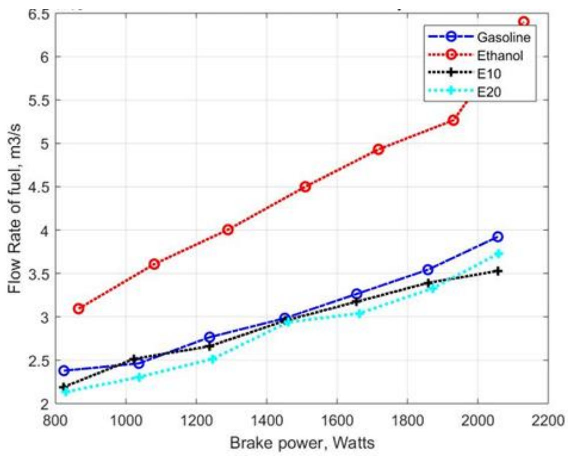

Fig 6. Flow Rate of Fuel Vs Brake Power for compression ratio 8

When looking at the exhaust gas temperature in fig. 7, the ethanol is leaded compared with the E10, E20 and gasoline. the starting point of ethanol is around 320°C meanwhile E10 is reached 260°C at 800 watts. The obvious point of exhaust gas temperature is that E20 is starting from the 290°C at the same watts.

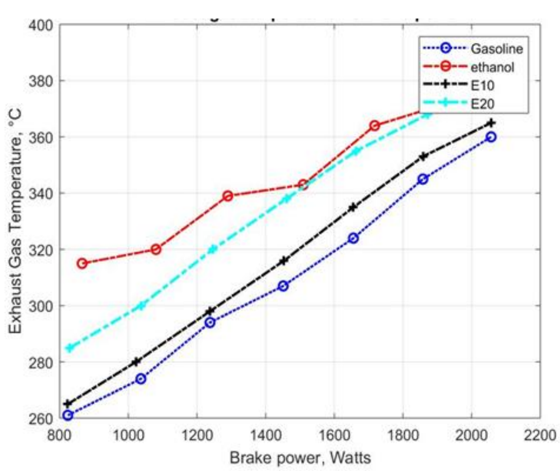

Fig 7. Exhaust Gas Temperature Vs Brake Power for compression ratio 8

For the compression ratio 9, it can be seen in fig. 8 and fig. 9 that the ethanol brake specific fuel consumption is quite differed from the use of gasoline. However, to be compared with the compression 8, the fuel consumption can be reduced by 1.2 kg/kW.hr at the compression ratio 9 because the higher-octane number can be reduced the detonation and the ethanol has the 104-octane number.

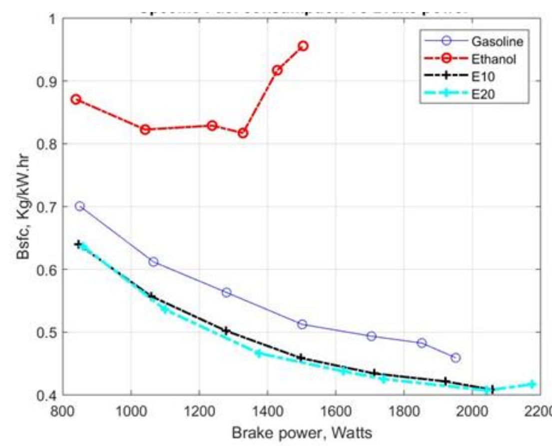

Fig 8. Brake Specific Fuel Consumption Vs Brake Power for compression ratio 9

As the same as the brake power, E20 is obtained the maximum torque with the minimum brake specific fuel consumption of 0.42 kg/kW.hr.

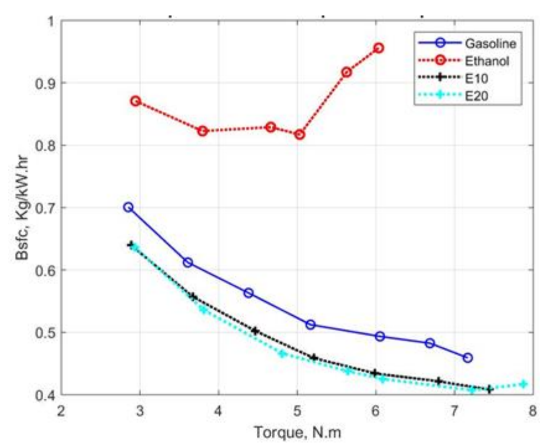

Fig 9. Brake Specific Fuel Consumption Vs Torque for compression ratio 9

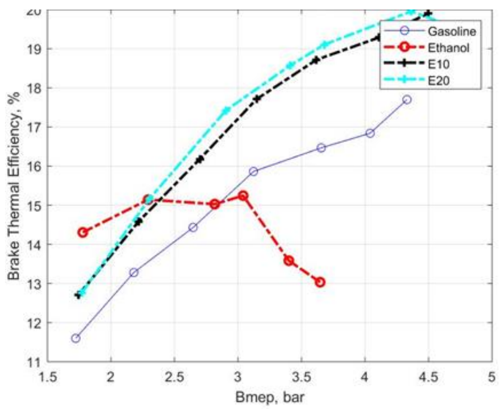

Fig 10. Brake Thermal Efficiency Vs Brake Mean Effective Pressure for compression ratio 9

The brake thermal efficiencies of E20 and E10 in fig.10 are gradually increase with the brake mean effective pressure. Even the ethanol characteristic of brake thermal efficiency is totally different at the compression ratio 9. At bmep of 3 bars, the sudden drop of brake thermal efficiency occurs up to 13%.

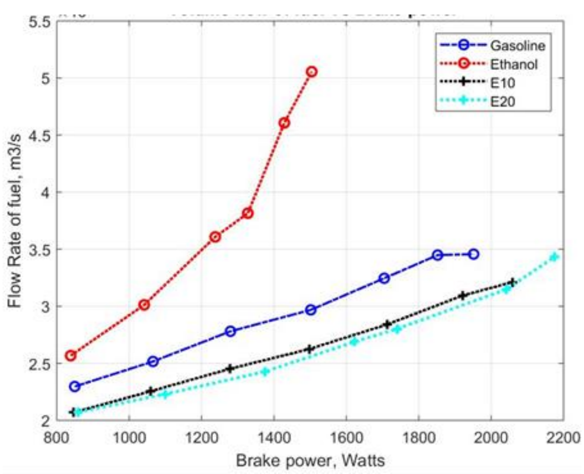

Fig 11. Flow Rate of Fuel Vs Brake Power for compression ratio 9

The flow rate of ethanol is raised up to $5.3x10^{-7}m^3/s$ at 1500 watts of compression ratio 9. Compared with compression ratio 8, the flow rate is $4.2x10^{-7}m^3/s$. At the same time, the flow rate of E10 and E20 are $3.2x10^{-7}m^3/s$ at 1900 watts and the gasoline is at $3.5x10^{-7}m^3/s$ in fig. 11.

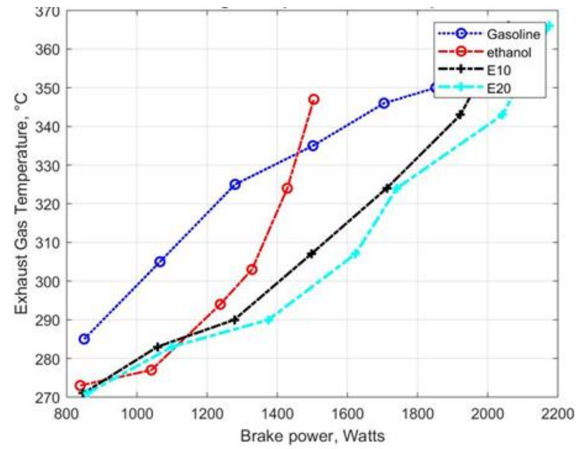

Fig 12. Exhaust Gas Temperature Vs Brake Power for compression ratio 9

The exhaust gas temperature of E20 is lowest level in compression ratio 9. It is seen that the gasoline exhaust gas temperature is higher than any other fuel in fig. 12. Therefore, the higher compression ratio, the more suitable to use high octane fuel to reduce No_x production in SI engine.

CONCLUSION

As a conclusion, the ethanol is not obtained the power as same as use of gasoline because the ethanol calorific value is lower than that of gasoline even the high of octane. However, the ethanol-gasoline blends are more effective in fuel consumption than using gasoline. E20 can be saved 8.6 % of fuel consumption compared with the gasoline at 3000 rpms, the maximum output of 1200 watts and compression ratio 8. E20 is also reduced fuel consumption 11.3% with the compression ratio 9 meanwhile the exhaust gas temperature is raised around 3 % with the change of pressure and temperature rise in combustion chamber. As the side effect, the local produced ethanol is 95 percent available and water 5 percent is dissolved in this. This caused the corrosion at the fuel pipe line system to occur leakage.

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