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Original Research Article

Performance and exhaust emissions of a spark ignition engine using G-Series and E20 fuels

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Abstract

In this research paper, performance and exhaust emissions of a spark ignition (SI) engine (XU7JP/L3) is presented. A gasoline-ethanol blend (E20) and G-Series fuel, of GS1 and GS2, which is a mixture of gasoline, ethanol, biodiesel and diesel, is used. The tests results revealed that the power and torque of XU7JP/L3 engine decreases (not significantly) 6.5% and 1.2% for the mixtures of fossil fuel and biofuel blends respectively. In these circumstances, the rate of fuel consumption increases by 36%. The tests results also show that the rate of both UHC and CO faces 8% and 47% reduction but CO_2 emission is increased. As a conclusion, it is found that the XU7JP/L3 engine performance is most suitable when it runs on E20 (80% gasoline + 20 % ethanol) and GS1 (10 v% ethanol, 2.5 v% biodiesel, 2.5 v% diesel and 85 v% gasoline).

Keywords: Spark ignition engine, Performance, Emission, Fossil fuel, Biofuel, G-Series.

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1. INTRODUCTION

Fossil fuels are the most important sources of power production in engines and thermal machines. On the other hands, produced gases such as NO_x, SO_2 and CO_2 are the main reasons for environmental pollution. The reason for extensive researches carried out in the world to find proper alternative fuels and renewable energies. Biofuels can bring many benefits such as stability and immortality, greenhouse gases reduction, regional development, social and agriculture structure stability and security of supplying raw materials [1]. Also, these fuel types are very important as fuel dissolubility, raw materials quick availability and environmental compatibility is required. The most significant advantage of these fuels compared to conventional ones is higher cetane number, pollution reduction due to non sulfur content and oxygen content [2, 3, 4, 5]. Therefore, the most important reasons of choosing these fuels are their renewability and environmental friendly. The major consumption of fossil fuels take place in internal combustion engines. The spark ignition engines that run on gasoline, consume these fuels. The automobiles that run on these engines are one of the important causers of environmental air pollution. The pollution caused by automobiles is known to be of the most important source of air toxic in many urban centers of the entire world [6, 7, 8, 9, 10, 11 and 12]. Based on the researches, using biofuels in these engines have a vital role to reduce the fossil fuel consumption and then reduce air pollution. Therefore, the purpose of this research work is to investigate the performance and exhaust emissions of an SI engine using fossil fuels and biofuel blends. G-Series fuel which is a mixture of fossil fuels and liquid biofuels has been used in 405GLX-XU7JP/L3 engine and its effect on performance exhaust emission of this engine has been investigated. Many methods have been used to reduce environmental pollutants from engine exhaust emissions. Adding oxygenate components to fossil fuels is one of the most important methods. Types of alcohol and biodiesel have high ability to reduce exhaust emissions. In case of SI engines, this is achieved by blending alcohol with gasoline. Using ethanol and gasoline blends in SI engines has been studied by many researchers [19-28]. High purity ethanol (> 95%) is required to be blended with gasoline and is exploded in engine [13]. In a study, the effect of compression ratio on performance of an SI engine using 78% gasoline and 22% ethanol blend (E22) and aqueous ethanol (E100) was investigated. The results showed that engine performance was improved in high compression ratios with both fuels compared to gasoline [14]. The effect of ethanol- gasoline (E5, E10) and methanol-gasoline (M5, M10) on performance and combustion characteristics of an SI engine was first investigated and then compared with gasoline fuel. The results showed that the brake specific fuel consumption (BSFC) was increased. The lowest peak of heat release rate was obtained when gasoline fuel was used [15]. Also in an investigation, the effect of hydrous ethanol (6.8% water content in ethanol) on performance and exhaust emissions of a gasoline engine were compared with those of 78% gasoline- 22% ethanol blend. The results showed that torque, brake mean effective pressure (BMEP), brake power, thermal efficiency and specific fuel consumption (SFC) were higher when the hydrous ethanol was used as fuel for high engine speeds. Also, CO, HC decreased and CO_2, NO_x increased using hydrous ethanol [16]. The effect of unleaded gasoline and ethanol- unleaded gasoline blends (E50, E85) on performance and exhaust emissions of an SI engine was investigated. The results suggested that ethanol addition to unleaded gasoline increased the engine torque, power and fuel consumption and reduced CO, NO_x and HC emissions [17]. As the history of previous studies show, only mixtures of two or three fuels were used to evaluate SI engines performance so far. However, there are no accurate information about using mixture of two types of fossil fuels (gasoline, diesel) and two types of biofuels (biodiesel, ethanol) in internal combustion engines. In this regard, the newly developed fuel called "G-Series fuel" was used in the present research work to evaluate the possibility of fossil fuels and biofuels mixture to improve economical and environmental performance of the engine. Hence, unleaded gasoline was used as the base fuel and ethanol, biodiesel and diesel fuel were added to it by different volume percentages as additives. After preparing the mixtures, some significant properties of blends were measured and compared with gasoline fuel standard. Then, performance and exhaust emissions of XU7JP/L3 engine were compared with those of gasoline fuel using G-Series fuel.

2. MATERIALS and METHODS

2.1. Fuel preparation

As mentioned earlier, the G-Series fuel is a mixture of unleaded gasoline, ethanol, biodiesel, and diesel fuels. The G-Series fuel was used in an SI engine (Fig. 1). To carry out the engine performance and exhaust emission test, the volume percentage of testing fuel blends are presented in Table 1. The results of G-Series fuel on engine performance and emissions were then compared with those of the other fuel blends.

The various fuel properties of gasoline, diesel, ethanol and biodiesel produced from cooking waste oil and their blends were determined based on the ASTM standards.

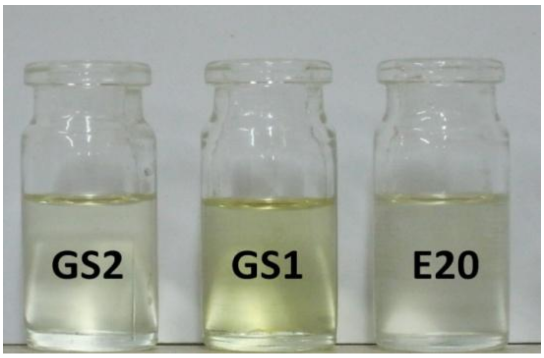


Fig. 1. The G-Series fuel blends under test and E20.

Table 1. Volume percentages of testing fuel blends.

	Fuel	Ethanol	Biodiesel	Diesel	Gasoline
1	G100	-	-	-	100
2	GS1	10	2.5	2.5	85
3	GS2	18.1	4.31	4.31	73.28
4	E20	20	-	-	80

2.2. Experimental apparatus

The experimental set up consists of a spark ignition engine, engine test bed with a MPA eddy- current dynamometer, and a gas analyzer. A view of the experimental set up is shown in Fig. 2. A LFZ type, four cylinder four stroke spark ignition engine was used in the experiments. The general specifications of the test engine are given in Table 2. An AVL gas analyzer model DIGAS 4000 Light was used for measuring CO, CO_2 and HC emissions. Technical properties of gas analyzer have been indicated at Table 3. The engine was run at several speeds and full load. Torque, power, fuel consumption and emission gases were measured. The fuel tank was placed in maximum fuel injection position at full load condition. Then the engine was gradually loaded, and the speed was naturally reduced as the load was increased. Schematic diagram of experimental setup is shown at figure 3.

Table 2. The test engine characteristics

Type	LFZ
Number of cylinder	4
Bore ×stroke	81/4×83 mm
volume	1761 cm^3
Compression ratio	9.25:1
Number of valve	8
Maximum power at 6000 rpm	100 hp
Maximum torque at 3500 rpm	153 N.m

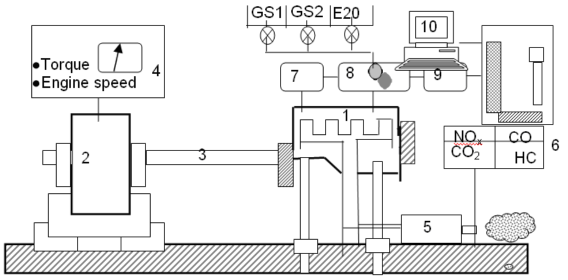
a

b

Fig. 2. A view of (a) gas analyzer and (b) the engine test bed.

Table 3. Technical properties of gas analyzer

AVL DİgAS 4000/avl	Measurement range	Resolution
CO	0-10 % Vol.	0,01 % Vol.
CO_2	0-20 % Vol.	0,1 % Vol.
HC	0-20.000 ppm Vol.	1 ppm
NO_X	0-5.000 ppm Vol.	1 ppm
O_2	0-25 % Vol.	0,01 % Vol.
λ-calculation	0-9.999	0,001
λ-sensor voltage*	0-5,0 V	0,04 V
Engine Speed	250-9.990 rpm/min	10 rpm
Oil Temp.	0-150 °C	1 °C
Ignition angle TDC sensor	- 60-100 °c.a.	0,1 °c.a.
Ignition angle stroboscope	0-60 °c.a.	0,1 °c.a.
Dwell angle*	0-100%	1,0 %



1. Engine; 2.Dynamometer; 3.Drive shaft; 4.Dynamometer control unit, load & speed indicator; 5.Exhaust; 6.Gas analyzer; 7. Air flow meter; 8.Fuel measurement system; 9.Measuring boom; 10.Computer

Fig. 3. Schematic diagram of experimental setup.

3. RESULTS and DISCUSSION

3.1. Fuel properties

Initially several fuel blends were prepared and tested; two of these fuel mixture are G-Series, GS1 and GS2. E20 is a mixture of 20 v% of ethanol and 80 v% of unleaded gasoline. Some of the important fuel blend properties were measured which are summarized in Table 4.

Table 4. Properties of testing fuel blends.

	Fuel	Density (g/cm^3)	Dynamic viscosity (MPa.s)	Kinematic viscosity (mm^2/s)	Water and sediment (%)	Flash point (°C)
1	Diesel	0.8216	2.5605	3.1167	0.06	75
2	Biodiesel	0.8621	3.8445	4.4596	0.19	158
3	Gasoline	0.7221	0.3213	0.4449	0.17	-
4	Ethanol	0.7748	0.8675	1.1196	3.25	-
5	E20	0.7443	0.4401	0.5913	-	-
6	GS1	0.7393	0.3699	0.5003	-	-
7	GS2	0.7478	0.4438	0.5935	-	-

3.2. Engine performance

The engine was started using gasoline fuel and it was operated until it reached the steady state condition. After the engine reached the stable working condition, the engine performance parameters (power, torque, fuel consumption) and engine emission parameters (UHC, CO, CO_2 and exhaust temperature) were measured by using of E20, GS1 and GS2 blended fuels. The variations of these parameters with respect to speed are presented in Figs. (4a-d and 5a-d).

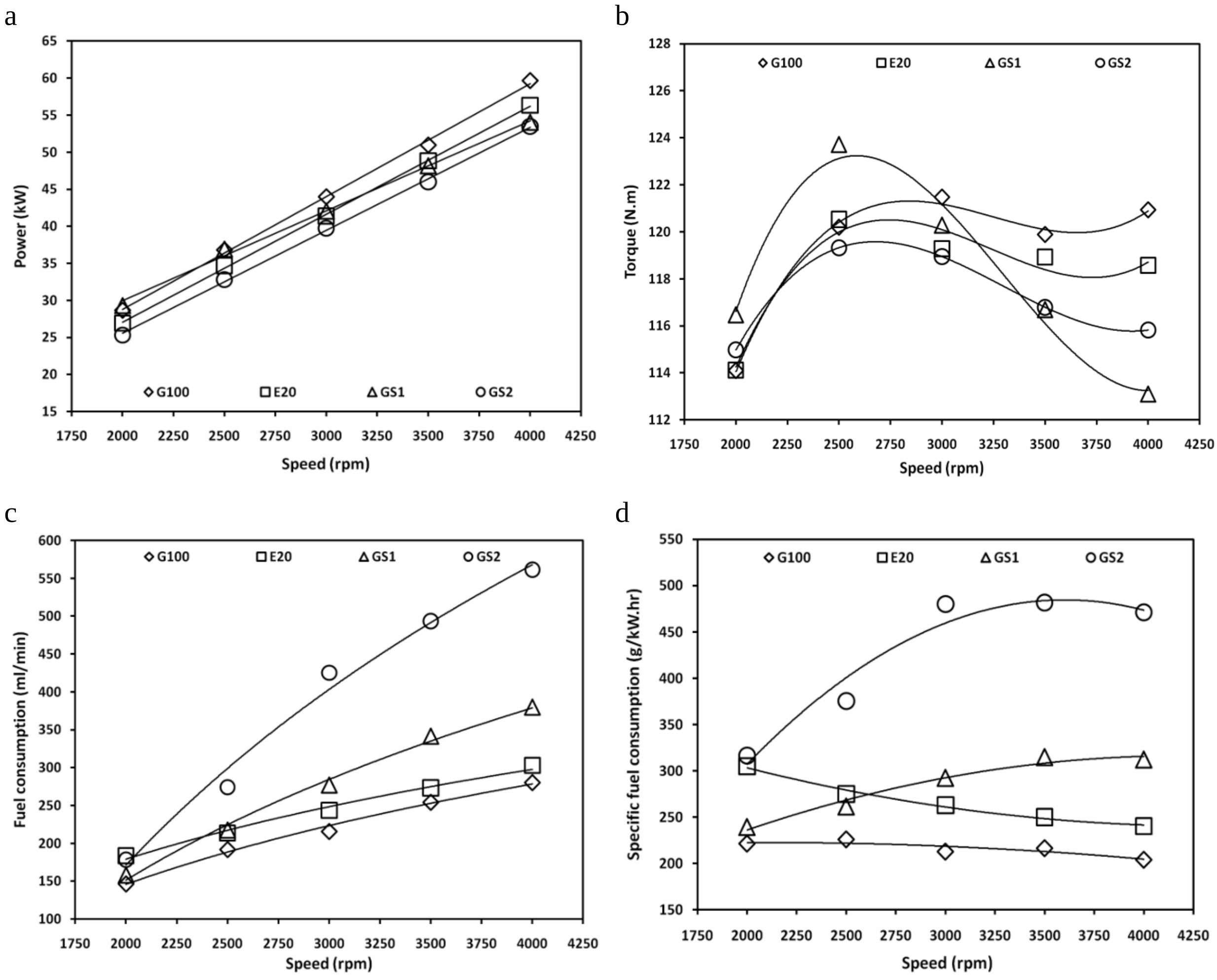


Fig. 4. Experimental results of (a) power, (b) torque, (c) fuel consumption and (d) specific fuel consumption at different fuel blends and engine speeds

3.2.1. Power and torque

Figure 4a shows the relationship between engine speed and engine power for different fuel types used. It can be seen from Fig. 4a that engine power increases as the speed increases using all fuel blends. Gasoline ranks the top level of power production and GS2 is in the lowest level. Power reduction using ethanol- gasoline blends has been reported in some studies [18], while in most of the other sources it has been reported that engine power increases using ethanol- gasoline blends [17, 19, 20, 21 and 22]. Since, G-Series fuel as a new fuel type has not been tested in any engines so far, therefore the results of this research work are absolutely original and new.

Engine power reduction using E20 could be caused by low heating value of ethanol [23, 24]. But in case of two G-Series fuels namely GS1 and GS2, there could be many reasons. These fuels are fuel mixtures that contain unleaded gasoline, ethanol, biodiesel, and diesel fuel regardless of their quantity. In regulated condition of an engine, combustion quality is depending on fuel structure. Octane number is a criterion of determination of combustion quality. Therefore octane number is the most important effective parameter on engine performance using G-Series fuel. Ethanol has a high octane number while biodiesel and diesel fuel have very low octane number. Hence, octane number of G-Series fuel is lower than that of conventional gasoline. Therefore, engine power would be reduced when using these fuels (GS1, GS2). As it can be seen from Fig. 4b, the engine maximum torque occurs at 3000 rpm using conventional gasoline (G100), while those for the other fuel blends occur at 2500 rpm. Lower octane number of blends increases the ignition delay and then engine efficiency decreases. Moreover, induction time is shorter at high speeds. Then compression and combustion pressures reduce and inertial forces of moving parts increase. Finally actual torque of the engine also reduces.

3.2.2. Fuel consumption and SFC

The rate of fuel consumption using all fuel blends increases as the engine speed increased (Fig. 4c). The rate of fuel consumption using fuel blends increase compared to that of conventional gasoline. Fuel consumption of GS1 and GS2 high at high engine speeds. Heating value of these blends is very lower than that of gasoline and E20. So, at high engine speeds, there is more fuel consumption to produce more engine power.

Variations of specific fuel consumption versus engine speed for different fuel blends are showed in Fig.4d. The rate of SFC depends on type of fuel (fuel density), fuel consumption and the power that is produced at flywheel. As can be seen from Fig. 4d, engine has the lowest SFC using conventional gasoline while that of GS2 is the highest one. SFC for gasoline and E20 decrease as engine speed is increased, while that of GS1 and GS2 increases at high engine speeds.

3.3. Engine exhaust emissions

3.3.1. CO emissions

Figure 5a shows the relationship between engine speeds and CO emission of the engine exhaust. Figure 5a shows the concentrations of CO emission at different engine speeds. It can be seen from the curves of this figure that when oxygenated fuel percentage increases, the CO concentration decreases which means that the combustion is tuned toward completion. The CO concentration in the exhaust gas emission at 4000 rpm for gasoline fuel is 4.63 (%V), while the CO concentration of E20, GS1 and GS2 at 4000 rpm is 2.1, 3.42 and 1.59 (%V), respectively. The CO concentrations at 4000 rpm using E20, GS1 and GS2 decreases by 54.64%, 26.13% and 65.66%, respectively in comparison to conventional gasoline. The reduction in CO concentration using all fuel blends is due to the fact that ethanol (C_2H_5OH) has less carbon in its chemical structure than gasoline (C_8H_{18}). Another significant reason for this reduction is that the oxygen content in the blended fuels increases the oxygen-to-fuel ratio in the fuel-rich regions. The most significant parameter affecting CO concentration is the relative air–fuel ratio (k) [25, 26]. Relative air–fuel ratio (k) approaches 1 as the ethanol content of the blended fuel increases, and consequently combustion approaches towards completion [19, 26, and 27].

3.3.2. CO_2 emissions

Fig. 5b shows the relationship between the CO_2 concentrations and engine speeds for different fuel blends. Fig. 5b indicates that CO_2 concentration increases as the oxygenated fuel percentage increased. CO_2 emission depends on relative air–fuel ratio and CO emission concentration [25, 26]. The CO_2 concentrations at 4000 rpm using E20, GS1 and GS2 increases by 12.8%, 4.8% and 4%, respectively in comparison to conventional gasoline. As a result of the lean burning associated with increasing ethanol percentages, the CO_2 emission is increased because of the improved combustion [19, 23 and 26].

3.3.3. HC emissions

HC emissions for different speeds are illustrated in Fig. 5C. The HC concentration in the exhaust gas emission at 4000 rpm for gasoline fuel is 114 ppm, while the HC concentration of E20, GS1 and GS2 at 4000 rpm is 103, 134, and 91 ppm, respectively. The HC concentration at 4000 rpm using

E20, GS1 and GS2 changes by -9.65%, 17.54% and -8.34% , respectively in comparison to gasoline. This result indicates that oxygenated fuels can significantly reduce HC emissions. The reason for the decrease of HC concentration is similar to that of CO concentration described above [19, 26]. The combustion temperature is low because alcohol fuels have high heat of vaporization. Therefore, HC emission increase with alcohol fuels.

3.3.4. Exhaust gas temperature

The latent heat of ethanol is high that causes the reduction in temperature of inlet manifold and then reduction of combustion temperature. Therefore, exhaust gas temperature reduces using fuel blends that contain ethanol [28]. It can be seen from Fig. 5d that exhaust gas temperature is reduced using all fuel blends compared to conventional gasoline. Also, exhaust gas temperature increases with increasing the engine speeds. The exhaust gas temperature decreases in the fuels which have high heat of vaporization.

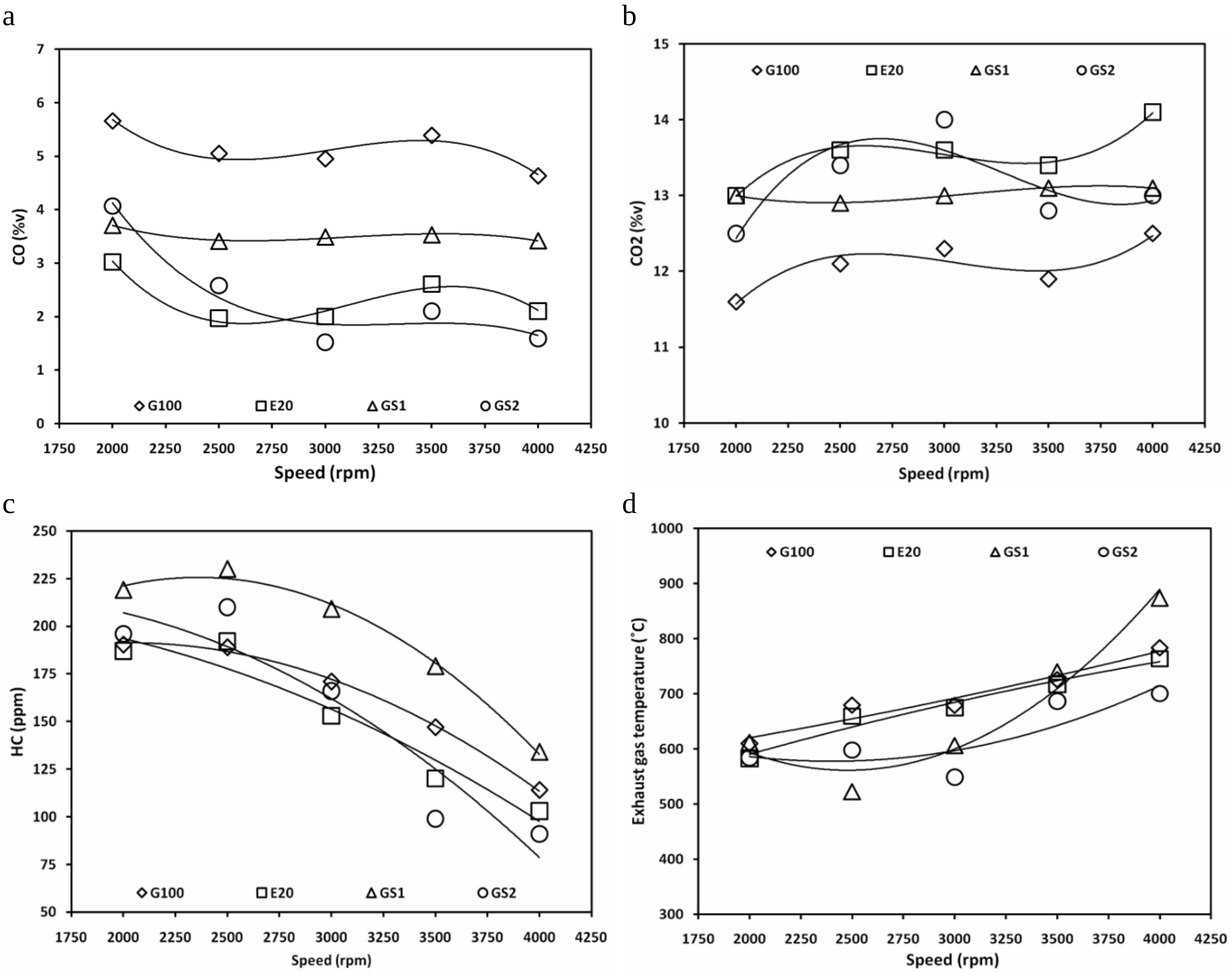


Fig. 5. Experimental results of (a) CO, (b) CO_2, (c) HC and (d) exhaust gas temperature at different fuel blends and engine speeds

4. CONCLUSIONS

The present study work demonstrates that the use of different fossil-biofuel blended fuels will influence on engine performance and emission parameters described as follow:

1. Engine power is reduced with fuel blends. The engine fueled with GS2 has the lowest power by 10.5% reduction. Gasoline ranks

the top level of power production and GS2 is in the lowest level.
2. Engine torque reduces using the fuel blends (-0.86% to -1.77%). the engine maximum torque occurs at 3000 rpm using conventional gasoline (G100), while those for the other fuel blends occur at 2500 rpm.
3. Fuel consumption and SFC is increased using all the blends, specially using GS2. GS2 blend increases the fuel consumption and SFC by 71.25% and 97.87% respectively.
4. UHC emissions is increased by 19.65% using GS1. But this emission reduces when using the other fuel blends.
5. CO_2 emission increases using E20, GS1 and GS2 by 12.09%, 7.85% and 8.78% respectively.
6. CO emission and exhaust gas temperature was reduced when using fuel blends. The CO concentrations at 4000 rpm using E20, GS1 and GS2 decreases by 54.64%, 26.13% and 65.66%, respectively in comparison to conventional gasoline. exhaust gas temperature is reduced using all fuel blends compared to conventional gasoline.
7. E20 and GS1 blends are recommended to be used in XU7JP/L3 engine.

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