Evaluation of SI engine performance and emissions using local gasoline fuel and ethanol additive

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Abstract- Transportation sector depends mainly on internal combustion engines with SI engine more preferable due to their high speed and fast acceleration. Unfortuntly, these engines are considered as the main consumer for fossil fuel and directly effect the environmental pollution. In this study, performance and emissions of SI engine has been investigated with the addition of ethanol to the local commercial gasoline fuel. Properties measurement has been conducted for fuel viscosity, density, octane number and heating value. Engine test has been conducted at constant 2000 rpm engine speed and wide throttle opening. The obtained results are evaluated compared to the local commercial gasoline fuel and commercial improved gasoline fuel. The obtained results showed that the local commercial gasoline fuel has very low research octane number (86) compared to commercial impreved fuel (93). This value improved with the addition of 10% ethanol to 94 which is comparable to that of improved gasoline. However, the increase of ethanol ratio is limited by the deterioration in the heating value of the fuel. Commercial gasoline fuel has the lower brake power compared to commercial impreved fuel which improved with the addition of 10% ethanol to higher value than that of improved gasoline. Local commercial gasoline fuel has the lower CO2 emissions compared to commercial impreved fuel which increases with the addition of 10% ethanol to higher value than that of improved gasoline. The addition of ethanol to commercial gasoline leads to decrease in CO emissions and significantly reduced the emitted HC.

Keywords – Gasoline fuel, SI engine, Fuel properties, Engine performance, Octane number

I. INTRODUCTION

Energy efficiency and low carbon strategies have attracted a lot of concern. The goal for 20% energy efficiency and carbon reduction by 2020 drove the Information Communication Technologies (ICT) sector also. In the second half of the last century and to this day, there was a need to use high-octane fuel as a result of the development of engine technology and access to high-compression ratio engines, this led to widespread interest by researchers in obtaining high-efficiency, knock-resistant fuels through the use of various fuel additives [1]–[3]. Several types of additives were suggested by various researchers that contribute to the improvement of gasoline fuel properties. Some of these researches and studies conducted on topics of additives added to gasoline by investigating its impact on their properties, as well as on the performance of spark ignition engines [4]–[10].

The effect of adding 20% of different alcohol (Ethanol, methanol, propanol and butanol) on the performance of four-cylinder SI engine and multi-point fuel injection (MPFI) have been studied at different engine speed (1000 - 6000 rpm) and full load 100% [11]. Experimental results showed that the use of E20, M20, P20, B20 increases engine torque, brake thermal efficiency and brake specific fuel consumption compared to pure gasoline. In another study [12] the development of physical and chemical properties of fuel using different ratios of different alcohol (C2 - C6) was investigated using Microsoft Excel "Solver" for the best three idealism properties of the alcohol-gasoline mixture (Max. HV, Max. RON and Max. D). All models were used under operational conditions of constant engine WOT and various engine speeds. The results showed an increase in brake torque compared with E15, as well as an increase in thermal efficiency by 4.4% with maximum HV of 1.8%, maximum RON of 0.4% and lower fuel consumption by 4.39% with Max HV of 1.8% and maximum RON of 2.27%. The performance of the engine was evaluated in another study using the triple mixture (bioethanol-iso-butanol-gasoline) in SI engine single cylinder (iBE10, iBE7, iBE3) [13]. The results showed a decreased in brake power, torque, volumetric efficiency, and exhaust gas temperature compared to pure gasoline.

Li et al. [14] studied experimentally the addition of methanol, ethanol and butanol (10%, 20% and 30%) with gasoline. Experiments were performed on the single - cylinder SI engine at a speed of 1200 rpm. The results showed increased brake specific fuel consumption and reduced brake thermal efficiency with all alcohol at different addition ratios compared to pure gasoline. Deng et al. [15] conducted experimental investigation on the performance characteristics of SI engine powered by gasoline and hydrous ethanol (E20w - E10w) contains water by 5%. Performance experiments were performed on a four-cylinder engine and electronically injected fuel. The result showed lower exhaust noise and increased thermal efficiency due to the high latent heat of evaporation of hydrous ethanol resulting in lower air temperature of the manifold, thus increasing the volumetric efficiency and brake mean effective pressure which leads to increased torque and power. Moreover, an increase in the brake specific fuels consumption obtained compared to pure gasoline. lodice et al. [16] conducted experimental tests for the effect of adding ethanol (10, 20 and 30 vol.%) on oxygen-free gasoline. The study was conducted on a four-stroke high-performance motorcycle engine. The results during the cold operation showed an increased fuel consumption compared with pure gasoline.

Ji & Wang [17] conducted experimental study at 800 rpm with adding H2 to fuel. The time of H2 injection and amount of gasoline were electronically controlling to achieve four extra air ratios ($1.67 = \lambda$, $1.43 = \lambda$, $1.18 = \lambda$, $1 = \lambda$). Increase in brake thermal efficiency, brake torque and temperature inside cylinder observed due to improved combustion with H2 due to the enhancement of flame propagation. El-Kassaby et al. [18] conducted an experimental study on the effect of adding hydroxide (HHO) on the performance of gasoline engine at different speeds and loads. A fuel cell (HHO) was designed and injected into the air intake. The results showed an increase in thermal efficiency of about 15% and decrease in fuel consumption by 34%. Ilhak et al. [19] conducted experimental study on the effect of using acetylene with gasoline in the engine on performance by 500 g / h and 1000 g / h. Experiments were performed on four-cylinder SI engine (1500 rpm) at variable load from 25% to 100%. The results showed low brake thermal efficiency with increased acetylene. Ibrahim & Bari [20] conducted experimental study to optimize the utilization of natural gas engine with EGR and the two-zone combustion model. It is shown that the optimum compression ratio (CR) in which the minimum fuel consumption occurs varies with the engine speed. Geny & Zhang [21] investigated the effect of adding MMT (8, 12 and 18 mg / L) on combustion characteristics. The experiment was conducted on a four-cylinder engine, direct fuel injection, equivalence air-fuel ratio, and 2000 rpm. The results showed an increase in pressure inside the cylinder with increased MMT ratio in the fuel as well as an increase in the heat release rate compared with pure gasoline.

The reviewed studies focused on developing a certain technology to enhance fuel quility so that meet the standard fuel specifications. However, the evaluation of local fuel quility is necessary for the implementation of the suitable technology that can meet the desired fuel requirement. The objective of this study is to investigate the engine performance and emissions of SI engine with the addition of ethanol to the local commercial gasoline fuel. The obtained results are evaluated compared to the local commercial gasoline fuel and commercial improved gasoline fuel.

II. EXPERIMENTAL SETUP

In this study local gasoline fuels hve been purchased from local petrol stations in Iraq and denoted as commercial fuel GC and commercial improved fuel GI. Ethanol has been added to the local commercial fuel and denoted as GE. The properties of the fuel samples has been tested using portable density meter for density, viscosity bath for viscosity, oxygen bomb calorimeter for heating value and shatox-300 octane meter for octane number.

Engine test has been conducted using four strok, single cylinder Robine SI engine shown in figure 1 with constant compression ratio of 8.5:1 and spark timing. The engine bore and stroke were 67 mm and 49 mm respectively with 172 cm2 displacement and 85 mm connecting road length. The engine coupled with hydraulic dynamometer which is used to load and control the engine.The dynamometer capacity is 7.5 kW @ 7000 rpm. The dynamometer load is applied and controlled according to the water flow rate and level inside the dyno-case. Exhaust gases were measured using Sykes-pikavant portable emission gas analyser with the specifications list in Table 1.

Figure 1. Engine test rig

Table.1 Exhaust gas analyser specifications

Emission gas	% Error	Measuring limits
CO	± 5%	0-5 % Vol., Max. limit 20%
HC	± 5%	0-2000 ppm, Max. limit 10,000 ppm
CO2	± 5%	0-16 % Vol., Max. limit 20%

III. RESULTS AND DISCUSSION

Fuel properties are considered as an important indicator for the fuel suitability to operate SI engine efficiently [22]–[25]. High value of octane number is essential to ensure smooth engine operation and avoid engine knock. Figure 2 presents the octane number for the different tested fuels; it can be observed that the local commercial gasoline fuel has very low research octane number (86) compared to commercial impreved fuel (93). However, this value improved with the addition of 10% ethanol to 94 which is comparable to that of improved gasoline. The increase of ethanol ratio is limited by the deterioration in the heating value of the fuel as shown in figure 3. Though GC has higher heating value than GI (44.6 and 43.8 for GC and GI respectively), this value decreased to 43.5 with the addition of 10% ethanol due to the lower heating value of ethanol.

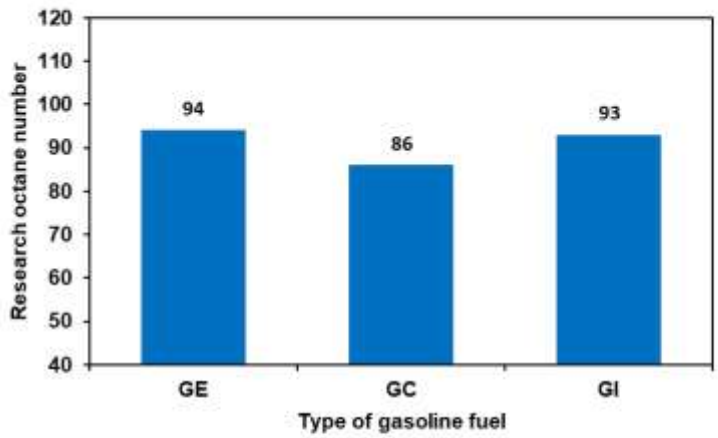

Figure 2. Research octane number (RON) for tested fuel samples

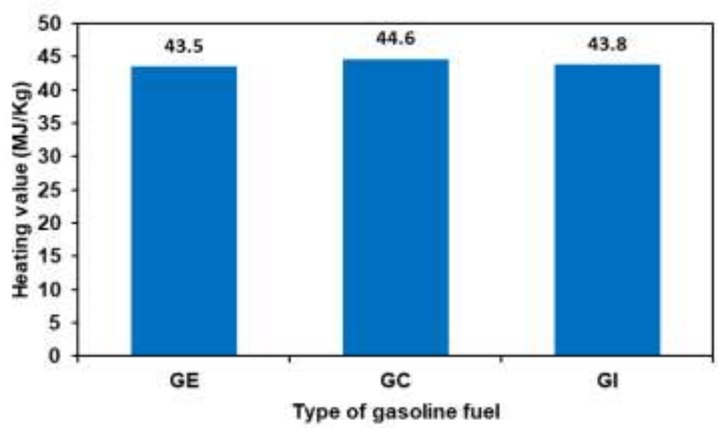

Figure 3. Heating value for tested fuel samples

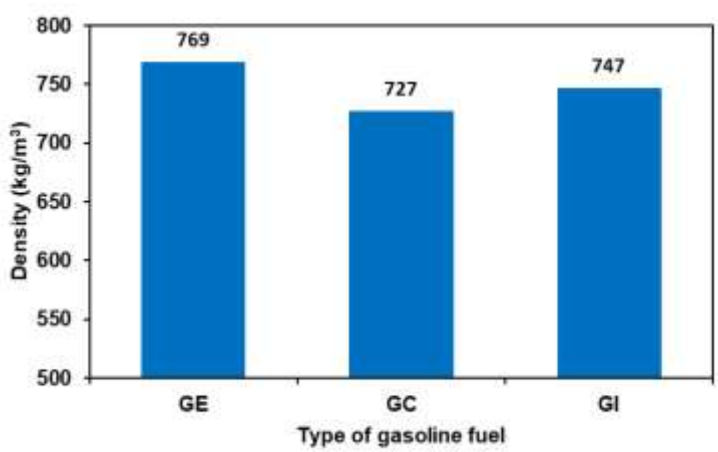

Figure 4. Density for tested fuel samples

Figure 4 shows slight difference in the fuel density with maximum reduction by 0.05% for GC compared to GE. More significan variation in fuel viscosity has been observed as shown in figure 5. The higher viscosity obtained for GI (0.3 mm^2/s) followed by GC (0.26 mm^2/s). The addition of ethanol to the commercial gasoline fuel reduces the value of the viscosity to 0.2 mm2/s due to the lower viscosity of ethanol compared to gasoline.

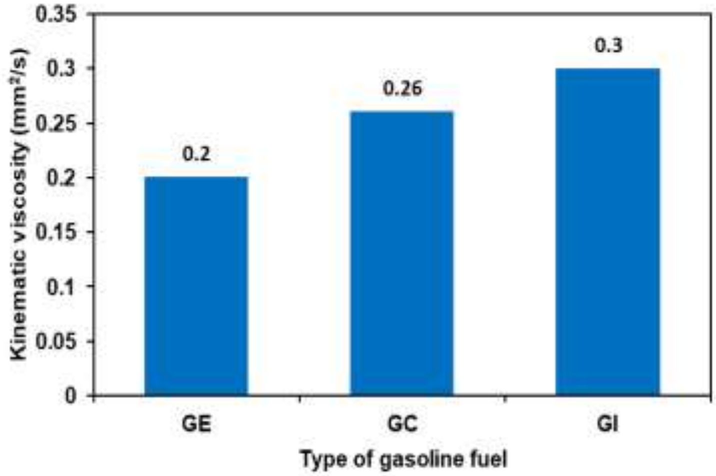

Figure 5. Viscocity for tested fuel samples

Engine performance is the main indicator of fuel quility, high output power indicates efficient fuel combustion [26]–[30]. Figure 6 shows engine brake power with different tested fuels; it can be observed that the local commercial gasoline fuel has the lower brake power compared to commercial impreved fuel. However, this value improved with the addition of 10% ethanol to higher value than that of improved gasoline. The addition of ethanol to GC leads to sligh increase in the brake specific fuel consumption by about 0.02% as shown in figure 7. GC has the lower brake specific fuel consumption compared to GI and GE with the maximum value obtained for GI. Figure 8 shows the engine brake thermal efficiency with different tested fuels which represents the engine fuel conversion efficiency. The results show that GI has higher brake thermal efficiency (28.7%) compared to GC. The addition of ethanol to the commercial gasoline fuel enhances the brake thermal efficiency to 30.2% which is higher than that of GI. This means significant improvement in the fuel combustion efficiency due to the high oxygen content of ethanol [31].

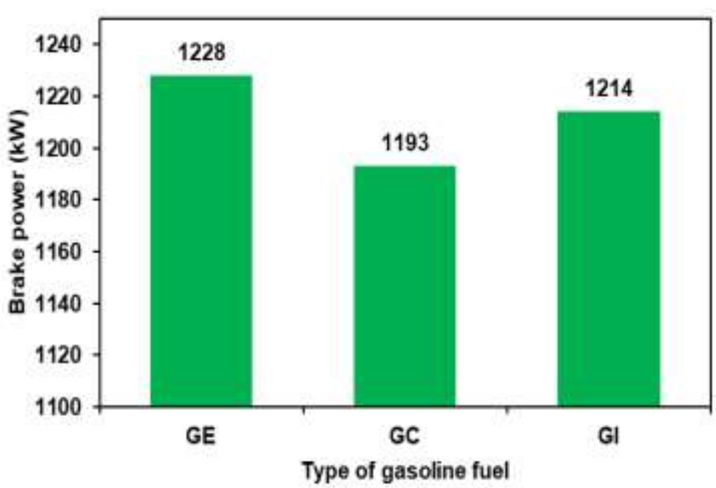

Figure 6. Brake power at 2000 rpm engine speed

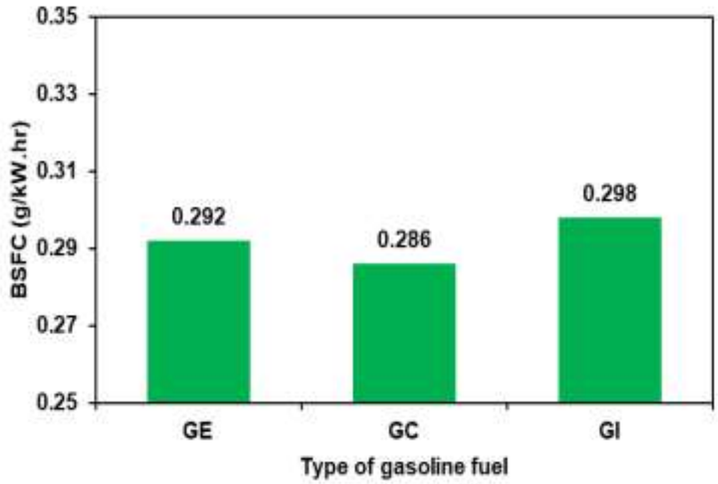

Figure 7. Brake specific fuel consumption at 2000 rpm engine speed

Engine exhaust emissions are the main contributer of global warming, it represent important challenge for the engines manufacturer around the world. CO_2 emissions have direct influence on the increasing of this phenomenon. Figure 9 shows CO_2 emissions with different tested fuels; it can be observed that the local commercial gasoline fuel has the lower CO_2 emissions compared to commercial impreved fuel. However, this value increased with the addition of 10% ethanol to higher value than that of improved gasoline. GC has the lower CO_2 emissions (9%) compared to GI and GE with the maximum value obtained for GE (12%). On the other hand, the addition of ethanol to GC leads to decrease in CO emissions from 1.18% to 0.98% as shown in figure 10. This is due to the more complete combustion of fuel mixture resulting from the high oxygen content of ethanol which contribute to convert CO gas to CO_2 (more complete combustion). Figure 11 shows the HC emissions with different tested fuels. The results show that GC has the higher HC emission of 110 ppm compared to that of GI (107 ppm). The addition of ethanol to the commercial gasoline fuel significantly reduced the emitted HC to 102 ppm which is lower than that of GI which means significant improvement in the fuel combustion due to the high oxygen content of ethanol.

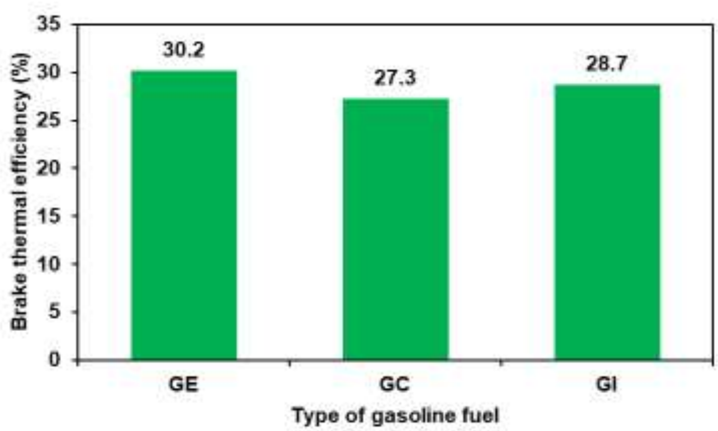

Figure 8. Brake thermal efficiency at 2000 rpm engine speed

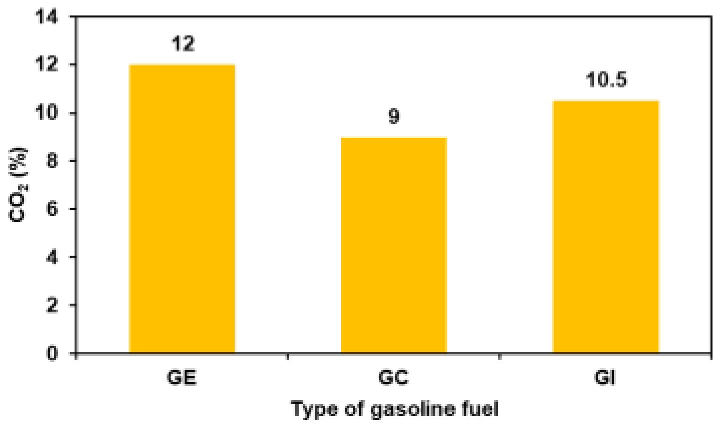

Figure 9. CO2 emission at 2000 rpm engine speed

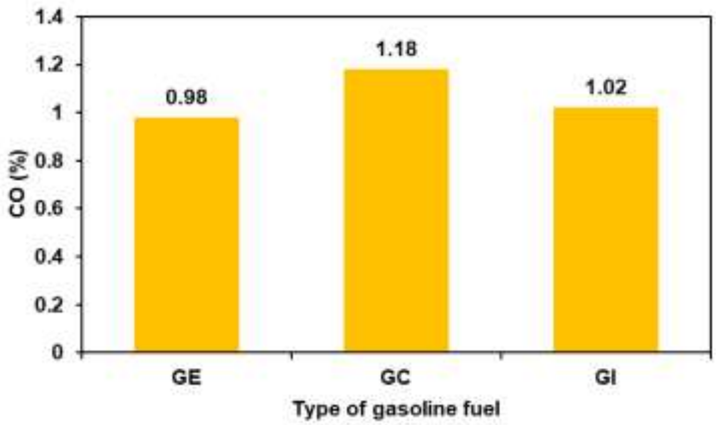

Figure 10. CO emission at 2000 rpm engine speed

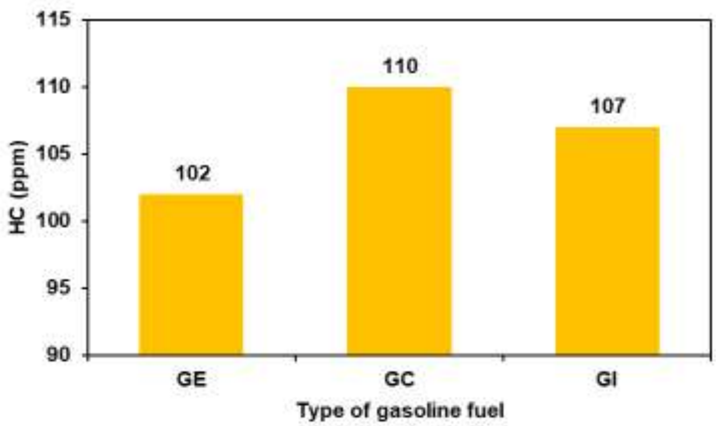

Figure 11. HC emission at 2000 rpm engine speed

IV. CONCLUSION

In this study investigation of engine performance and emissions of SI engine has been performed with the addition of ethanol to the local commercial gasoline fuel. The obtained results are evaluated compared to the local commercial gasoline fuel and commercial improved gasoline fuel. The following conclusion has been arised:

- Local commercial gasoline fuel has very low research octane number (86) compared to commercial impreved fuel (93). However, this value improved with the addition of 10% ethanol to 94 which is comparable to that of improved gasoline.
- The increase of ethanol ratio is limited by the deterioration in the heating value of the fuel.
- Commercial gasoline fuel has the lower brake power compared to commercial impreved fuel. However, this value improved with the addition of 10% ethanol to higher value than that of improved gasoline.
- GI has higher brake thermal efficiency (28.7%) compared to that of GC. The addition of ethanol to the commercial gasoline fuel enhances the brake thermal efficiency to 30.2%.
- Local commercial gasoline fuel has the lower CO2 emissions compared to commercial impreved fuel. However, this value increased with the addition of 10% ethanol to higher value than that of improved gasoline.
- The addition of ethanol to GC leads to decrease in CO emissions from 1.18% to 0.98%.

GC has the higher HC emission of 110 ppm compared to that of GI (107 ppm). The addition of ethanol to the commercial gasoline fuel significantly reduced the emitted HC.

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