Quest Journals
Journal of Research in Mechanical Engineering
Volume 3 ~ Issue 3 (2017) pp: 09-16
ISSN(Online) : 2321-8185
www.questjournals.org

Research Paper

Influence of Commercial Gasoline Samples on the Performance Characteristics of Si Engines

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Received 17 Jan, 2017; **A**ccepted 07 Feb, 2017 © The author(s) 2017. **P**ublished with open access at **www.questjournals.org**

ABSTRACTL: *It has been observed though not documented that some gas filling stations in Nigeria adulterate their fuel before selling to customers. Numerous engine users had also complained of fuel obtained from some petrol filling stations burn faster than others. Engines used in automobile vehicles and power plants always developed one fault or the other leading to frequent visit to mechanics. In view of these preceding issues, experimental study was conducted to determine the influence of gasoline sold in Nigeria market on engine performance characteristics. Four samples of commercial gasoline were collected from different petrol stations within Omu-Aran metropolis, Kwara State, Nigeria and tested on a four stroke single cylinder spark ignition engine (P8161) automotive test bed at wide throttle opening. However, the octane rating of the selected fuel samples could not be ascertain because gasoline supplied at Nigeria petrol stations are no longer rated as it used to be as regular, premium and regular unleaded. The results of this investigation show that the performance parameters such as torque, brake power, brake mean effective pressure and thermal efficiency for each fuel sample increase with increase engine speed up to a maximum value and begin to decrease as engine speed increase due to frictional loss. Maximum brake power obtained with fuel sample A was 5.751 kW at 3083 rpm. For fuel sample B, the maximum brake power was 5.025kW at 2884 rpm, 5.269 kW at 2727 for fuel sample C and 5.019 kW at 2718 rpm for fuel sample D. From this test, brake maximum power and torque occur at the same engine speed for each sample of fuel sample studied. Also the maximum power obtained from fuel sample B and D were approximately the same at different engine speed. It may suffice to say that fuel sample B and D were likely supplied to the different petrol filling stations by the same source. The minimum amount of fuel consumed in order to attain maximum power was more with fuel sample D and B corresponding to 36.73 g/kW.hr and 36.63 g/kW.hr respectively. The minimum brake specific fuel consumption was lower for fuel sample A and C with value 32.21 g/kW.hr and 35.44 g/kW.hr respectively. Therefore, it is more economical and reliable to run spark ignition engines with fuel sample A and C.*

Analysis of fuel variability shows that the coefficient of variation in engine speed for fuel sample A, B, C and D were 32.6%, 34.2%, 33.1% and 35.2% respectively. In terms of brake power developed the coefficients of variation were 52.2%, 56%, 53.8% and 60.6% for fuels A, B, C and D respectively.

The coefficient of variation in terms brake specific fuel consumption are 101.3%, 142.8%, 111.5% and 131.9% for fuel samples A, B, C and D respectively. It means that more of fuel B was consumed follow by fuel sample D during the combustions process compared to fuel samples A and C. For fuel sample B approximately 43% additional fuel is required to attain the maximum power and about 32% of fuel sample D. Approximately 12% additional of fuel sample C is required while only 2% of fuel sample A is needed. From the results fuel sample A is more reliable for achieving engine performance specifications follow by fuel sample C and B while fuel sample D is less reliable. One of the factors that may be responsible for the variation is fuel octane rating which is a measure of how smooth an engine runs or resistance to knocking. If this is true, engines running on fuel samples D and B are more prone to pre-ignition or engine knock than fuel sample A and C. It then means there is strong relationship between fuel samples and engine performance.

Keywords: *Gasoline, spark ignition engine, performance characteristic*

I. INTRODUCTION

Internal combustion engines are rated by the optimum power at which the manufacturers anticipate them to perform satisfactory with respect to fuel economy, reliability and durability during operating conditions. The maximum power and other performance parameters that can be obtained from a given engine are dependent on the grades of fuel used or fuel octane rating as well as the design. Compression ratio which is one of the

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design factors had proven to have great significant influence on engine performance characteristics (Haung et al, 2009, Aina etal, 2012). Furthermore, the effect of ignition setting has also been investigated by Zareei and Kakaee (2013). They achieved optimum power and torque at 30^o crank angle before the top dead centre. Fuel injectors are currently been used in modern automobile vehicles for fuel metering into the combustion chamber (Robert, 2014). The optimal compression ratio that can be achieved in a given engine at ignition timing and fuel metering systems are affected by the quality of fuel.

Therefore, the importance of fuel quality in engine design and development cannot be over emphasis. In the early invention of internal combustion engines solid fuels such as gun powder was used to generate power (Willard, 2004). The heavy exhaust smoke produced during combustion of the fuels at atmospheric pressure contributed greatly to environment pollution. Efficiency obtained was very low and the engines were primary single piston cylinder. Since these fuels were not good and consistent, there was a major delay in the development of internal combustion engines.

Advances in internal combustion engine development were brought about by the discovery of crude oil in 1858 and petroleum products from crude oil. Fuel delivery systems like carburetors were manufactured to vaporized the fuel and mix it with air. Gasoline which is one of the fractions of petroleum product became most popularly acceptable fuel for spark ignition engines because of its high volatile property. This property ensures easy starting even in cold weather. Since the gasoline produced then contain straight chain hydrocarbon, the maximum engine compression ration that could be achieved was four (4) to prevent engine knock, consequently efficiency was also low (Heywood, 1988).

The problem of engine knock provided an excellent platform to improve the quality of fuel which in turn improves the performance of engines. Fuel quality is continually been improved by using additives to produce gasoline with better antiknock properties thereby leading to steady increase in engine compression ratios, improving power and efficiency. For this reason, commercial gasoline is grade as premium or regular based on the octane rating (EN 228, 2005). Premium gasoline has higher anti-knock properties and is specified for use in high compression engines. On the other hand regular has lower anti-know resistance and is used in low compression engines.

Petrol or gasoline is mainly used as fuel for spark ignition internal combustion engines all over the world. Its octane rating represented by the Research and Motor octane numbers (i.e RON and MON) serves as one of the most important parameters for describing the anti-knock quality of fuel that allows higher compression ratio development which in turn enhances the engine efficiency and emissions (Sayin et al. 2005).

In several developed countries of the world, retail fuels are sold on the basis of different octane grades but the reverse is the case in some Africa countries like Nigeria. For example, in Saudi Arabia gasoline grades are RON 91 (Premium) and RON 95 (super-premium); RON 95 and RON 97 in United Kingdom; 87 – 94 AKI (Anti-knock index) in United State of America (Wikipedia, 2015).

Due to lack of information on fuel grades, petrol filling stations in Nigeria sold fuel at same pump price except when there is scarcity. Thus, allowing customers to pay same price of high gasoline grades for both low grades. In addition, there are complains that some fuel burn faster than others, low power output, problem of frequent visit to mechanics, toxic gas emissions because of the verities fuel in the Nigeria market. Since it is generally believed that the higher the octane rating the better the performance of a given engine. These issues could be a consequence of low fuel grade resulting from fuel adulteration (Obodeh and Akere, 2010).

Numerous studies have been carried out on the effect of octane rating on engine performance. A repot by Beck et al (2006) indicate that different fuel grades play a significant role in automobile fuel economy. Saud et al (2015) carried out an experimental test with two grades of gasoline: RON 91 and RON 95 effects on engine performance parameter in four stroke spark ignition engine. Their results showed that the brake power of the engine was higher with RON91 which was mainly due to higher heating value and that the combustion of RON 95 was faster than RON 91. They also discovered that exhaust gas emissions from RON91 were higher than RON95.

Taib and How (2014) obtained similar results to that of Saudi et al when RON 95 and RON 97 grades of gasoline were tested in multi-cylinder spark ignition engine. The RON 95 was reported to have delivered a better engine performance.

Sudsanguan and Chanchaowna, (1999) examined the effect of gasoline octane number on the engine performance by using three different octane ratings of RON 91, RON 95 and RON 97 in three engine models that all required RON95. Gasoline octane number RON 91 was more capable of meeting the engine performance specifications.

Spark ignition engines can achieve the expected performance characteristics only when the grades of gasoline they use suit the fuel requirements of the engines. As a result of this relationship, gasoline engines and their fuel development are mutually dependent. That is to say an engine cannot be designed without considering the gasoline grades or octane rating available in the market. Similarly, commercial gasoline cannot be produced without considering the requirements of the engines that would use it. Understanding the difference between grades of gasoline will not only allows people to make better decisions in terms of fuel usage but also enables them to save money over time. One of the ways to determine the right fuel for a specific internal combustion engine is accomplish by conducting tests to compare the performance of the types of fuel. Thus, this study is carried out to investigate the influence of gasoline sold in Nigeria on spark ignition performance characteristics.

II. MATERIALS AND METHOD

Four samples of gasoline were investigated in this study. They were obtained at same pump price in different petrol filling stations located within Omu-Aran metropolis, Kwara State, Nigeria. The test was carried out on a single cylinder, carbureted spark ignition four-stroke internal combustion engine whose technical specifications are shown in Table 3.1.

The engine is mounted on a DC test bed and equipped with sensors as shown in Figure 3.1. Sensors are used for recording the temperature, engine rotational speed, fuel flow rate, air flow pressure differential and force.

Table 3.1: Engine specifications

Engine model	P8161
Bore	79.248 mm
Stroke	61.925 mm
Compression ration	9.5:1
Displacement	305 cc
Maximum torque	18.0 Nm @ 2500 rpm
Maximum power	7 kW @ 3600 rpm
Number of cylinder	1
Mode of cooling	Air cool
Mode of breathing	Naturally aspirated
Arm of dynamometer	255 mm

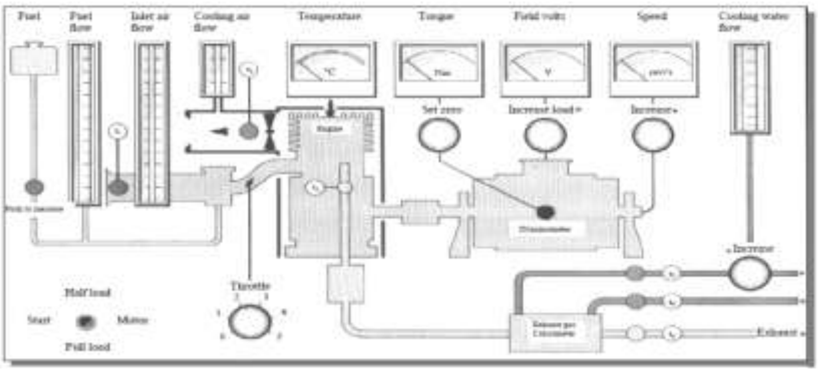

Figure 3.1: Schematic diagram of experimental test bed.

Test Bed Description

The test bed consists of two main components as shown in Figure 3.1. First, the welded steel base plates on which the D.C. dynamometer, drive coupling and safety guard, spring type anti-vibration are mounted. The engine and its accessory are also mounted on the base plate. Second, the framework/console which is positioned over the test bed carrying all instrumentation and controls, fuel system with flow measurement by burette, air flow measurement system, multi-point temperature indicator together with all the electrical circuits necessary for control of the dynamometer and engine.

The dynamometer use a trunnion mounted swinging field DC electrical machine capable of absorbing a maximum load of 10 kW at a speed of 4000 rpm. A strain gauge load cell system is incorporated with mechanical overload protection and suitable calibration equipment is also provided. A toothed wheel and magnetic pick-up is used for speed measurement and feedback to the control system. The dynamometer is capable of either motoring or absorbing power and is also used as a method of starting the engine.

The test bed is arranged in such a way as to allow for manual control of engine starting with key switch and engine load with throttle/rack. The dynamometer control system is a microprocessor controlled fully regenerative thyristor drive allowing the dynamometer to run as either a motor or a generator at constant speed. The speed is set by a 10 turn potentiometer mounted on the front panel.

Procedure

Figure 3.2 shows the experimental set up for this investigation. The tests were conducted in automotive laboratory at Landmark Unviversity, Omu-Aran, Kwara State, Nigeria. During the tests, ambient temperature within the laboratory was measured with the aid of thermocouple. Thereafter, the engine was started using the key switch and was allowed to run for about 10 minutes to properly warm up before setting the throttle to wide open i.e 100% load. Engine rotation speeds were varied by the potentiometer knob and the brake load measured with the DC dynamometer. Fuel flow rate was measured by electronic flow meter. All temperatures order than the ambient temperature were acquired using k-type thermocouples. Engine speeds were varies with the potentiometer knob on the control panel which in turn varies the loads. The engine speed is measured with electronic tachometer while the load is measured with the DC dynamometer. The engine test bed is interfaced with desktop computer to output the measured parameters such all the temperatures, air flow pressure differential, fuel flow rate and brake load from which the performance parameters were calculated.

Figure 3.2: Pictorial view of the experimental set up.

III. RESULT AND DISCUSSION

Engine performance characteristics were investigated at 100% load or wide throttle opening for four gasoline samples. These fuels were obtained from four different gas filling stations in Omu-Aran, kwara State, Nigeria. A comparative analysis of the fuel samples was also carried out as well as variability analysis to determine gasoline reliability. The performance parameters examined during the tests include torque, brake power, brake mean effective pressure, brake specific fuel consumptions and brake thermal efficiency.

It is observed that the performance parameters such as torque, brake power, brake mean effective pressure and thermal efficiency for each fuel sample increase with increase engine speed up to a maximum value and begin to decrease as engine speed increase due to frictional loss. Engine maximum power was developed at engine speed where the power increase provided by the frequency of cycles is completely balanced by the decrease in torque. In this situation the cylinders take in the maximum amount of air-fuel mixture per second. However, the engine power decreases at higher speeds because the increase in engine speed can not compensate the decrease in torque. Mean effective pressure has a maximum value at a specific engine speed corresponding to maximum brake power and it decreases at higher speeds due to a reduction in volumetric efficiency. The brake specific fuel consumption has minimum values at same engine speed were the maximum brake power occurs and then increase before and after this speed for the different gasoline samples. This is because bsfc is dependent on the brake power.

Figure 4.1 shows the performance characteristics obtained by running the engine on fuel sample B. At engine speed of 3622 rpm, maximum values of 17.54 Nm, 5.025kW, 301.5 kPa and 30.51% occur for torque, brake power, brake mean effective pressure and thermal efficiency respectively. For this same fuel sample, brake specific fuel consumption has minimum value of 36.63 g/kW.hr at same engine speed were the maximum brake power occurs and then increase before and after this speed.

Figure 4.1: Performance parameters of fuel B.

IV. COMPARATIVE ANALYSIS

Although the potentiometer knob for varying engine speed was set to 300%, 400%, 500%,600%, 700%, 750%, 800% and 999% during each fuel sample test, the engine speed produced were observed to vary from one gasoline to another. The maximum engine speed generated by using fuel sample A, B, C, and D at 999% reduction were 3571 rpm, 3622 rpm, 3523 rpm and 3558 rpm respectively. Brake power peak at 3083 rpm, 2737 rpm, 2884 rpm and 2718 rpm for fuel sample A, B, C, and D respectively.

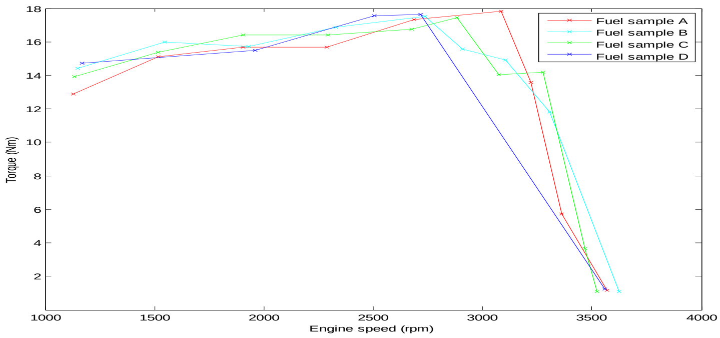

Figure 4.2: Torque comparison of the fuel samples.

From Figure 4.2, it can be seen that the maximum torque for fuel sample A is 17.81 Nm at 3083 rpm, fuel sample B is 17.54 Nm at engine speed of 2737 rpm, fuel sample C is 17.45 at engine speed of 2884 rpm and fuel sample D is 17.64 Nm at 2718. Fuel sample B has the highest standard deviation of 33.9%.

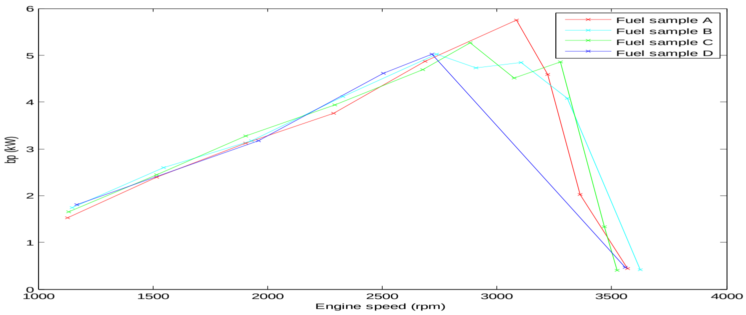

Figure 4.3: Brake power of the fuel samples.

Figure 4.3 shows the brake power developed by the fuel samples. It is seen that fuel sample A developed the higher brake power of 5.751 kW at 3083 rpm. For fuel sample B, the maximum power is 5.025kW at 2884 rpm, 5.269 kW at 2727 for fuel sample C and 5.019 kW at 2718 rpm for fuel sample D. From the results, brake maximum power and torque occur at the same engine speed for each sample of fuel sample studied. Also the maximum power obtained from fuel sample B and D were approximately the same at different engine speed. It may suffice to say that fuel sample B and D were likely supplied to the different petrol filling stations by the same source.

Brake mean effective pressure for each fuel sample follow the same trend of brake powers as shown in Figure 4.4. The maximum value were 345 kPa, 301.5 kPa, 316 kPa and 301.2 kPa for fuel sample A, B, C and D at the specific engine speed corresponding to maximum brake power. After the peak value, the brake mean effective pressure decreases at higher speed due to reduction in volumetric efficiency. Fuel sample A generated the highest value follow by fuel sample C and least in fuel sample B and D.

Figure 4.5 shows the brake thermal efficiency for the fuel samples. Higher efficiency of 31.9 % was obtained by running the engine on fuel sample C while that of fuel sample A was 30.83. Fuel sample B and C produce maximum efficiency of 30.51% and 29.94% respectively. From these result, fuel sample C and A seems to be more efficient in running spark ignition international combustion engines.

The fuel consumption obtained by running the engine with the different fuel samples is shown in Figure 4.6. It can be seen from Figure 4.6 that the minimum amount of fuel required to attain maximum power was more with fuel sample D and B corresponding to 36.73 g/kW.hr and 36.63 g/kW.hr respectively. The minimum brake specific fuel consumption was lower for fuel sample A and C with value 32.21 g/kW.hr and 35.44 g/kW.hr respectively. Therefore, it is more economical and reliable to run spark ignition engines with fuel sample A and C.

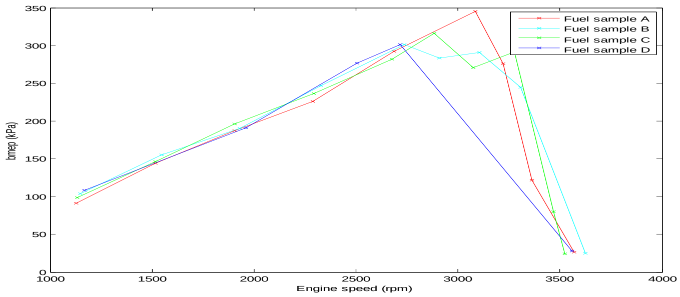

Figure 4:4: Brake mean effective pressure of the fuels

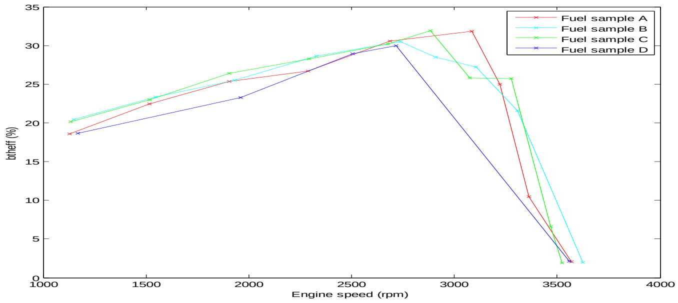

Figure 4.5: Brake thermal efficiency of the fuel samples

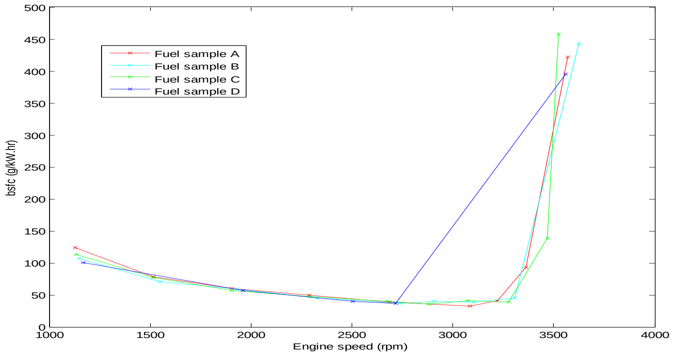

Figure 4.6: Brake specific fuel consumption of the fuel samples.

V. VARIABILITY ANALYSIS

Mean and standard deviation of the performance characteristics were obtained and used to determine the coefficient of variation. The coefficient of variation regarding engine speed for fuel sample A, B, C and D are 32.6%, 34.2%, 33.1% and 35.2% respectively. This means that the fuel sample A is more reliable, followed by fuel C, B and D. It can be said from this results that fuel sample D is less reliable than fuel samples A and C. In terms of brake power developed, the coefficients of variation are 52.2%, 56%, 53.8% and 60.6% for fuels A, B, C and D respectively.

The coefficient of variation in terms brake specific fuel consumption are 101.3%, 142.8%, 111.5% and 131.9% for fuel samples A, B, C and D respectively. It means that more of fuel B was consumed follow by fuel sample D during the combustions process compared to fuel samples A and C. For fuel sample B approximately 43% additional fuel is required to attain the maximum power and about 32% of fuel sample D. Approximately 12% additional of fuel sample C is required while only 2% of fuel sample A is needed. The coefficient of variation of the torque is 41.6%, 47.9%, 44.2% and 53.1% for fuel fuels A, B, C and D respectively.

From the variability analysis of engine performance characteristics, fuel sample A is observed to be more reliable for achieving engine performance specifications follow by fuel sample C and B while fuel sample D is less reliable. One of the factors that may be responsible for the variation is fuel octane rating which is a measure of how smooth an engine runs or resistance to knocking. If this is true, engines running on fuel samples D and B are more prone to pre-ignition or engine knock than fuel sample A and C. This phenomenon has the capacity to reduce pressure developed during the expansions stroke thus reducing the output power. In addition to the impact on engine performance, it can also contribute greatly to emission of toxic gases which are injurious to plants and animals as well as human beings. It then means that there a need to review fuel octane rating and gasoline sold to customers should be as graded (i.e premium or supper). Customers can then purchase the required grade of petrol for their automotive vehicles and stationary power plant.

VI. CONCLUSION AND RECOMMENDATIONS CONCLUSION

This study was carried out to determine the impact of gasoline sold in Nigeria on engine performance characteristic of spark ignition engine. Four samples of gasoline were collected from four different petrol filling stations in Omu-Aran, Kwara State, Nigeria. The fuels were tested on engine test bed in the automotive laboratory of the university to obtain engine brake torque, brake power, brake mean effective pressure, specific fuel consumption and brake thermal efficiency.

The torque increase as the engine speed increase and peak at 17.81 Nm, 17.54 Nm and 17.45 Nm corresponding to engine speed of 3571 rpm, 3622 rpm and 3523 rpm for fuel sample A, B and C respectively. Thereafter, the torque began to decrease with the increase of engine speed due the high engine frictional losses.

Similarly, the brake power and brake mean effective pressure increase with the increase in engine speed up to 3082.63 rpm, 2737 rpm, 2883.65 rpm and 2718 rpm for fuel sample A, B, C and D respectively, and then decrease with increasing engine speed.

The maximum brake power was 5.751kW, 5.025kW and 5.269kW at 3082.63 rpm, 2736.87 rpm and 2883.65 rpm respectively. These correspond to running the engine with fuel sample A, B and C respectively.

The brake specific fuel consumption has minimum values of 32.21g/k.Whr, 38.303g/kW.hr and 38.34g/kW.hr correspond with fuel sample A, B and C respectively at same engine speed were the maximum brake power occurs and then increase before and after this speed for the different gasoline samples. This is because bsfc is dependent on the brake power.

Brake thermal efficiency increases to maximum values of 31.83%, 30.57% and 31.9% with the increase of engine speed up to 3082.63 rpm, 2736.87 rpm and 2883.65 rpm for fuel sample A, B and C respectively. After that it is decreased due to increase engine friction power losses.

Standard deviation was used as a measure of engine performance characteristics variability for the gasoline samples. From the engine performance parameters results such as brake power, engine speed and brake thermal efficiency, the standard deviation was higher in fuel sample B followed by fuel sample C and least in fuel sample A. In terms of fuel economy which was determine by the brake specific fuel consumption, the amount of fuel consumed was more using fuel sample B follow by fuel sample C and least in fuel sample A.

It suffices to say that fuel sample A is more reliable for achieving engine performance specifications while fuel sample C and B are less reliable. One of the factors that may be responsible for the variation could be fuel octane rating which is a measure of how smooth an engine runs or resistance to engine knocking. If this is true, engines running on fuel samples C and B are more prone to pre-ignition or engine knock than fuel sample A. This phenomenon has the capacity to reduce pressure developed during the expansions stroke thus reducing the output power. In addition to the impact on engine performance, it can also contribute greatly to emission of toxic gases which are injurious to plants and animals as well as human beings.

It then means that there a need to review fuel octane rating to reduce the variations in engine performance. Gasoline sold at different gas filling stations should be as graded (i.e premium or supper) so that customers can then purchase the required grade of petrol for their automotive vehicles and stationary power plant.

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