

# Operate With a Gasoline Internal Combustion Engine Evaluation of Different Boron Addition of The Fuel Additive Inside Performance and Emissions Impact

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## ABSTRACT

Most of today's car engines use fossil based fuels which is estimated to run out in a period of 50-60 years. Scientists are also researching ways to improve the performance of existing fuels and reduce emissions to the environment on the one hand while trying to provide an alternative to petroleum-based fuels on the other hand. They come from gasoline and diesel fuels to reduce harmful emissions to the environment and one of the most studied subjects of increasing fuel efficiency values. In this study, boron additives were added to petroleum based fuel and used in a gasoline-powered internal combustion engine in order to investigate their effects on engine fuel temperature, fuel consumption, engine performance as well as emission levels. Experimental studies were conducted in the laboratory by using a gas powered internal combustion engine (Lombardini LGW 523) operated at 1500 rev/min – 5000 rev/min to determine whether there are any changes in terms of increased engine performance (power, torque and fuel consumption) and low levels in emissions (HC, CO, CO<sub>2</sub>, and O<sub>2</sub>).

**Keywords:** Fuel additives, boron, exhaust emission.

## 1. INTRODUCTION

Most of the internal combustion engines used nowadays use petroleum based fuels. However; due to the fact that fossil fuel source is at a limited quantity that will eventually be used up completely, researchers have embarked on studying alternative energy sources that will take over petroleum based fuels in future. In addition, the exhaust gas emissions that pollute environment as a result of usage of petroleum fuels, has further intensified the researches towards alternative energy resources. Together with these researches, studies are conducted to improve the fossil fuels quality by adding some additives that aim at improving engine performance and lowering exhaust emissions. Several researchers have shown interests in investing in this area [1]. Some of these are as given below. Zhang at al. have investigated experimentally the combustion characteristics and particulate matter emission of a SI gasoline engine when ultralow sulphur gasoline and methanol are used at the urban-speed of 2000 rev/min under low to high engine conditions. The following results can be obtained from the current study. For the methanol fuel, it has been observed that the cylinder gas pressure and heat release rate occurred earlier by the use of methanol-gasoline test fuels when compared to the ultralow sulphur gasoline. The use of methanol increases the ignition delay but has no significant influence on the combustion duration. Particulate number and mass

concentration decreased in low proportion methanol-gasoline while increased significantly in high proportion methanol-gasoline. The particulate size distribution curves are all triple-modal in shape and the size distribution slightly shifts toward larger size (leading to large geometric mean diameter) with all the test fuels. For each testing fuel, the particulate number concentration in nucleation increased with the increase of engine load, while the number of particles in accumulation decreased from low to high vehicle loads [2]. Elfasakhany has investigated the effect of using different n-butanol blends on CO, CO<sub>2</sub> and UHC emissions, in-cylinder pressure, exhaust gas temperature, volumetric efficiency, brake power and torque of SI engine in the experimental research. The researcher showed that the n-butanol addition to gasoline fuel can significantly improve blends combustion due to its partially oxidized nature and a leaning effect caused by its lower stoichiometric air-fuel ratio. The higher the rate of n-butanol in the mixture, the lower the emissions and engine performance. The performance of 10% voln-butanol is lower than gasoline by about 5.6%, 2.5%, 6.6%, 8.3% and 3.5% for the exhaust gases temperature, engine torque, brake power, in-cylinder pressure and volumetric efficiency, respectively. At low speed, emissions of gasoline are greater than blends by about 43%, 32% and 26% for CO<sub>2</sub>, CO and UHC, respectively; however, at moderate speed, the emissions of gasoline are higher by about 40%, 6% and 11%, respectively; at high speed, CO<sub>2</sub> of neat gasoline is higher than blends by about 27%, while CO and UHC become in the same order of magnitude for

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gasoline and blended fuels [3]. Forson et al. conducted an experimental investigation in order to explore the performance of jatropha oil and its fuel blends with diesel in a direct-injection single-cylinder diesel engine. The test showed that jatropha oil could be conveniently used as a diesel substitute in a diesel engine. The test further showed increases in brake thermal efficiency, brake power and reduction of specific fuel consumption for jatropha oil and its blends with diesel generally, but the most significant conclusion from the study is that the 97.4% diesel/2.6% jatropha fuel blend produced maximum values of the brake power and brake thermal efficiency as well as minimum values of the specific fuel consumption [4]. Liu et al. performed experiments to study the effect of two-stage injection on combustion and emission characteristics under high EGR (46%) condition. Four different fuels including pure diesel and blended fuels of diesel/gasoline, diesel/n-butanol, diesel/gasoline/n-butanol were tested. They found that blending gasoline or/and n-butanol in diesel improves smoke emissions while induces increase in maximum pressure rise rate (MPRR) [5]. Yilmaz et al. carried out studies using diesel oil, biodiesel and ethanol blends in a diesel engine. The experiments were performed by varying ethanol concentration from 3% to 25%. It was observed that there is a small increase in engine exhaust temperature and CO emissions with the increase of ethanol concentration. NO<sub>x</sub> emissions were reduced for all loads with the increase of ethanol concentration, and unburned HC emissions were dependent on engine operating conditions and ethanol concentration, increasing for 25% ethanol at low loads and decreasing at high loads [6]. Deng et al. investigated the combustion heat release on a single cylinder, high speed SI engine fuelled with butanol/gasoline blend. The results showed that butanol provides higher knocking resistance by allowing in advance the ignition timing in SI engines, leading to more efficient combustion [7]. Armas et al. evaluated the emissions of a diesel engine using blends of 90% diesel oil and 10% ethanol. The authors explain that the effects of ethanol on NO<sub>x</sub> emissions do not follow a specific pattern and are dependent on engine operating conditions, among other factors. The results showed a small increase of NO<sub>x</sub> emissions with the use of ethanol, in comparison with diesel oil. CO emissions were reduced with the use of ethanol, especially at high loads, justified by the improvement of combustion quality through the increase of oxygen presence in the fuel. The results indicate that there is a significant reduction in PM emissions and smoke opacity, and little effect on HC and carbon dioxide (CO<sub>2</sub>) emissions [8].

In their experimental study on a single cylinder motorcycle engine, Fenget al operated the engine for two operating modes of full load and partial load at 6500 rpm and 8500 rpm with pure gasoline and 35% volume butanol-gasoline blend. The results showed that engine torque, BSEC, CO emissions and HC emissions are better than that of pure gasoline at both full load and partial load with 35% volume butanol and 1% H<sub>2</sub>O addition,

combined with the modified ignition timing. However, NO<sub>x</sub> and CO<sub>2</sub> emissions are worse than that of the original level of pure gasoline [9]. In another study conducted by El-Kassaby the effects of ethanol-gasoline blends on SI engine performance were investigated. The performance tests were conducted using different percentages of ethanol-gasoline up to 40% under variable compression ratio conditions. They found that engine indicated power improved with the ethanol addition, the maximum improvement occurring at 10% ethanol and 90% gasoline fuel blend [10]. Putrasari et al. investigated several engine parameters i.e. power, brake specific fuel consumption, brake thermal efficiency, the exhaust gas temperature, and lubricating oil temperature. As a complement of the experiment, the exhaust emission characteristic of CO, HC and smoke were also investigated. The results indicate that the engine power and the indicated mean effective pressure increase with increasing of ethanol [11]. Oliveira et al. carried out investigation involving the effects of fuel blends containing 5, 10 and 15 wt.% of anhydrous ethanol in diesel oil with 7% of biodiesel (B7) on performance, emissions and combustion characteristics of a diesel power generator. The results were compared with standard B7 operation and showed that in in-cylinder peak pressure and heat release rate were decreased at low loads and increased at high loads with the use of ethanol [12]. Arpa et al. performed experimental investigation to determine effects of gasoline-like fuel (GLF), and its blends with turpentine with ratios of 10%, 20%, and 30% on the performance and emission characteristics of a gasoline engine. The most important conclusions obtained from this experimental study are presented here. The turpentine itself should not be used as a fuel since large amount (85%) of it distillates at very narrow temperature band. The turpentine dissolves in the GLF, and blends of the GLF with turpentine behave as a unique fuel. Increasing amount of turpentine in the GLF sample had positive effects on the performance parameters. It was observed that the GLF and blends of the GLF with the ratio of 10%, 20% and 30% of turpentine could be used as a fuel in the SI engines without any problems according to the test results [13].

The objective of this study is to investigate effects of different boron additives in fuel on engine power and exhaust emission levels. With this aim, four different boron compounds were blended with gasoline and their respective effects studied. In the first phase of the experiments, four different boron additives were added into the fuel at the ratios of 0.7%, 1.4% and 2.1% after which the engine torque values for each one were compared. On average, it was found that there is an increase in engine torque when the boron-mixed fuel is used of 0.9% for the 0.7% boron additive, 0.4% for 1.4% and 0.5% torque increase for the fuel with 2.1% boron addition. In the second phase, engine performance and emission level evaluation of the fuel having the highest torque (i.e. the one with 0.7% boron additive) were carried out.

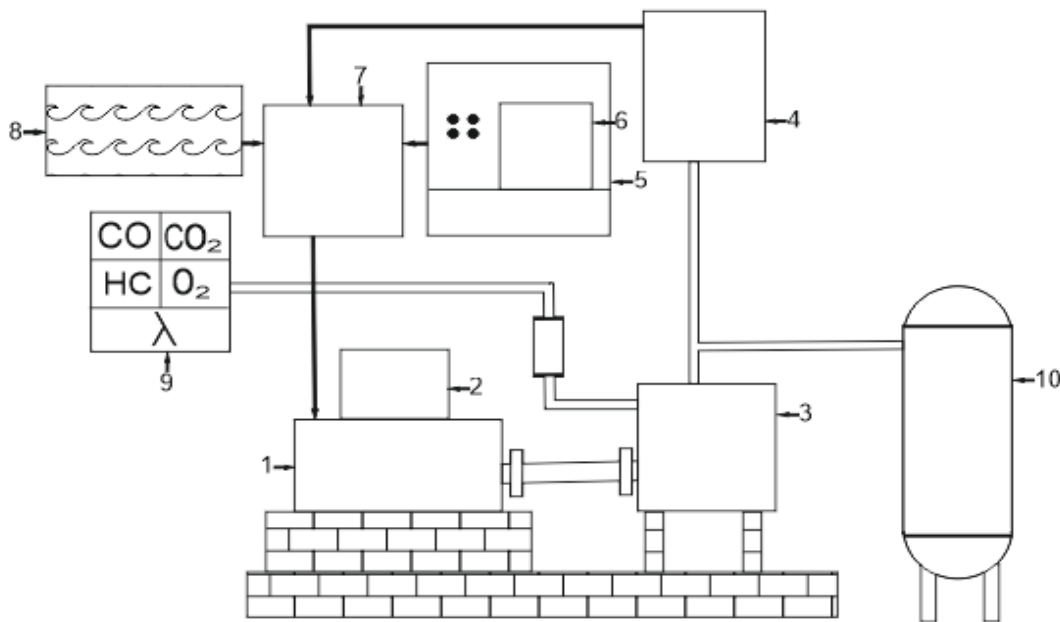
**2. MATERIALS AND METHOTS**

A two-cylinder gasoline engine with spark plug ignition mode was used in the experiments. The loading and measuring of the engine moment were executed with an electric dynamometer. Engine fuel consumption was monitored with a universal fuel meter. As for exhaust emissions, a gas analyser was used. The tests were carried out under suitable atmospheric conditions as per TS 1231 standards. The experimental set up is shown in Figure1. The experimental setup consists of electric dynamometer, control panel, motor, exhaust emission device, drive, mass- based fuel meter, brake resisting module and a personal computer that stores the data. The dynamometer is formed of an AC induction servo motor (26 kW), drive and braking module.

measuring torque and fuel levels and the digital inlets and outlets of the drive. Lombardini LGW 523 MPI type two-cylinder, four-stroke, spark ignition internal combustion engine that has multiple injections was used for the experiments. Its technical specifications are given in Table 1 while its schematic view is presented in Figure 2.

**Table 1.** Engine specifications

Manufacturer	Lombardini LGW 523 MPI
Number of cylinders	2
Cylinder Volume	505 cm <sup>3</sup>
Cylinder diameter	72 mm
Stroke	62 mm
Compression ratio	8.7:1
Motor power	15 kW 5000 rev/min
Engine torque	37 Nm 2200 rev/min



**Figure 1.** Experimental setup 1. Dynamometer, 2. Dynamometer cooling system, 3. Motor 4. Mass flowmeter, 5. Control panel, 6. Computer, 7. Drivers, 8. Resistance, 9. Emission device, 10. Fuel tank.

The device can reach a maximum rotational speed of 9500 rpm and has a braking torque of 0-83 N.m at an accuracy of ± 1 Nm. An S type load cell was used to measure dynamometer torque at the device’s handle. A rotary encoder was employed to measure rotational speed of the motor. Cooling of the dynamometer was of forced air cooling system type sourced from an AC induction motor. A cardan coupling was incorporated between the motor and dynamometer in order to provide some flexibility between the two components. Fuel consumption’s measuring system is expressed in terms of gr/s and gr/HP units. It can operate clockwise or counter clockwise and when the brake is engaged or when the driving mode is on.

With the data acquisition and controlling unit, measurements of various parameters and their calculations can be screen captured on real time basis on the computer screen. This unit contains plugs of thermocouples measuring the temperature, load cell



**Figure 2.** Experimental engine

The fuel used in the experiments was 95 octane gasoline while engine oil was 10W 40. The engine oil and filter were replaced for every test. Prior to starting the tests, the engine was run empty up to operating temperature and after being warmed up (when the radiator fan operates), the measurements were taken. During the tests under load, the engine was operated starting with a speed

of 1500 rpm up to 5000 rpm at 8 different cycles. Then after the engine reaches a steady state 60 data were recorded and their averages taken.

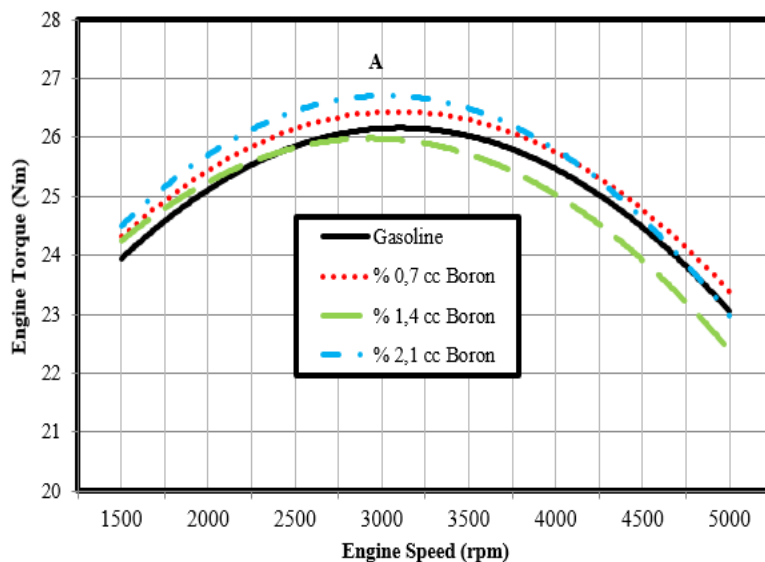
**Table 2.** Test engine specifications

Parameter	Measurement Range	Accuracy
CO	0-10 %	0.01
CO <sub>2</sub>	0-20 %	0,01
HC	0-20000 ppmV	1
O <sub>2</sub>	0-5000 ppm	0,01
$\lambda$	0-5	

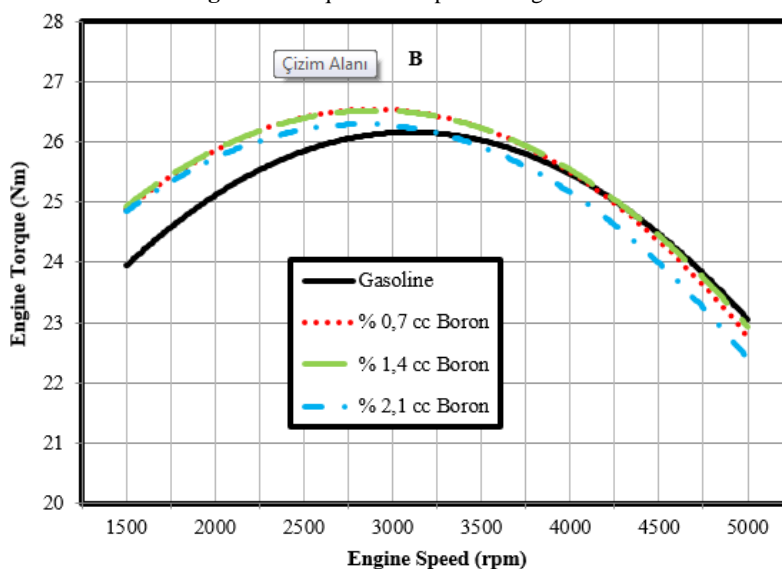
### 3. RESULTS AND DISCUSSION

In this study, effects of various boron additives added into fuel on engine power and emission were

investigated. 4 different boric compounds designated as A, B, C and D were added into gasoline fuel at the rate of 0.7%, 1.4% and 2.1%. In figure 3.6 variation of torque-motor with speed is shown. It was observed that up to the engine speed of 2500 rpm the increase in torque matches with the gasoline, however; at higher enginespeeds, the torque was seen to drop below the gasoline value. Sample A additive has exhibited an increase in averages of all cycles at the values of 0.7% and 2.1% while recording a decrease at 1.4%. Samples B and C exhibited increasing trend in all values whereas sample D marked increase at 0.7% but underwent a decreasing trend in the rest of the values. It was found that when the mean values of the different A,B,C and D boron additives are taken, an increase of 0.9% in torque at 0.7% addition, 0.4% increase at 1.4 % addition and 0.5% torque increase at 2.1% addition of the additive were recorded.



**Figure 3.** Torque-motor speed change for A



**Figure 4.** Torque-motor speed change for B additive

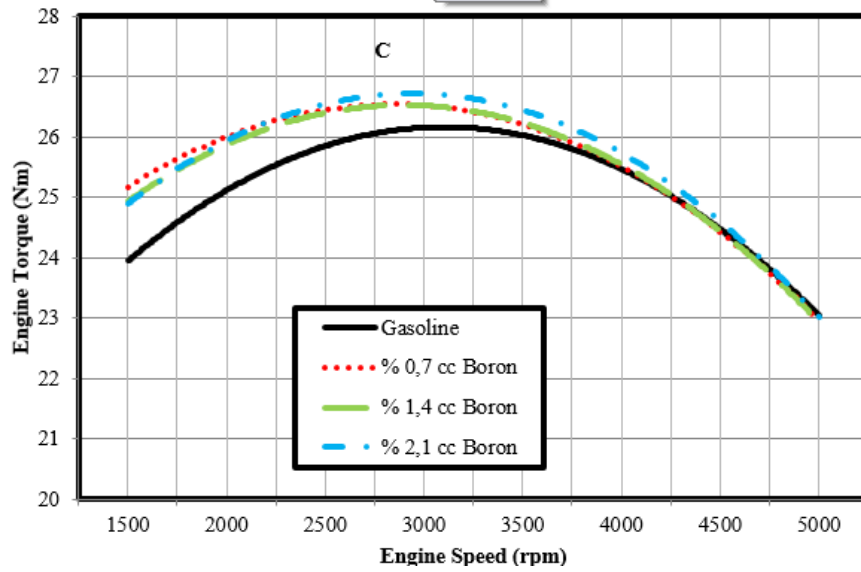


Figure 5. Torque-motor speed change for C additive

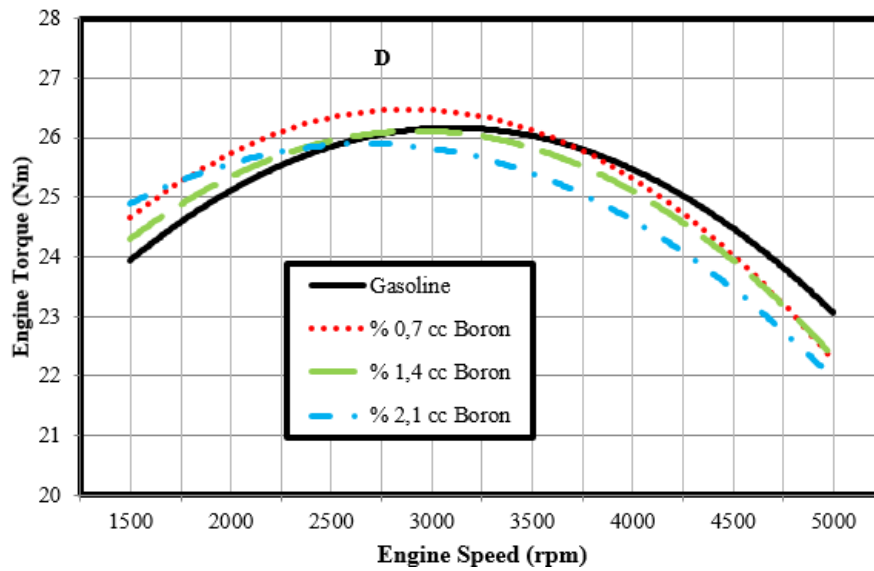


Figure 6. Torque-motor speed change for D additive

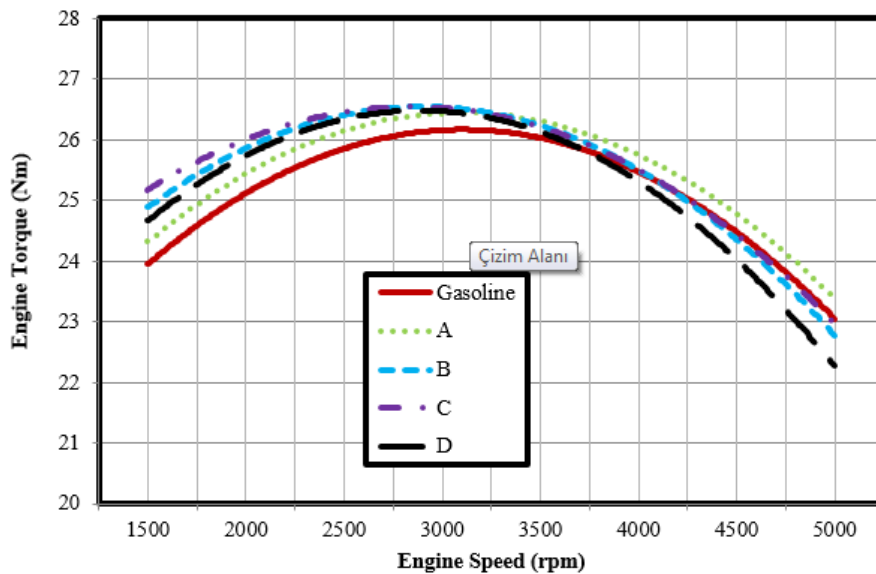


Figure 7. Torque-engine speed changes for 0.7% boron additive into gasoline

additive has shown as compared to the other ratios, the performance and emission values belonging to this additive were studied.

Specific fuel consumption curves of fuel additives at different ratios are shown in Figure 9. Specific fuel consumption which is an important performance

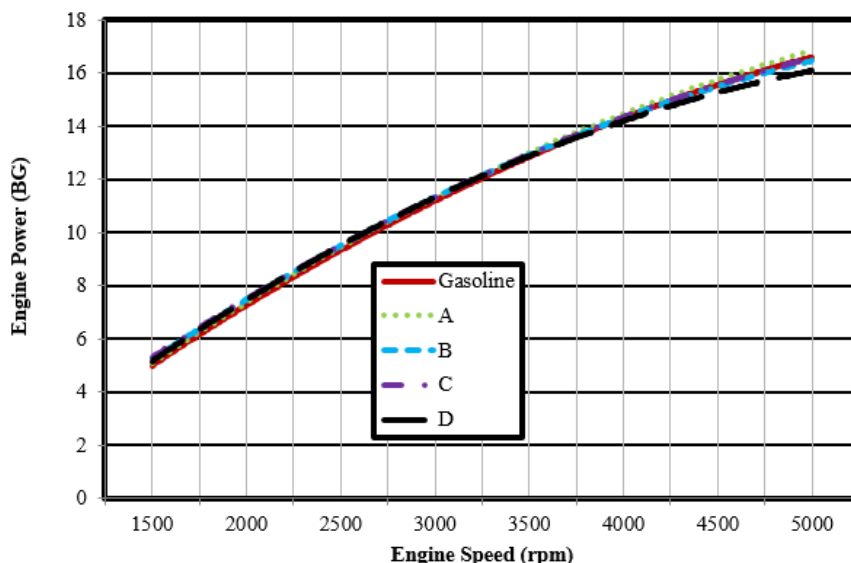


Figure 8. Engine power- engine speed changes for 0.7% boron additive into gasoline

Due to the linear relationship between power and torque values, the power and torque values belonging to A boron additive in all cycles are higher with respect to gasoline. The highest difference ratio recorded was at 4500 rpm whereas the lowest was at 3500 rpm. At engine speeds of 3500, 4500 and 5000 rpm sample B additive was relatively lower with respect to the gasoline. The highest difference ratio occurred at 2000 rpm. At the speeds of 4000 and 5000 rpm, additive C dropped when compared with the gasoline. The largest difference ratio in this one was at 2000 rpm. As for additive D, between the engine speeds of 3500 and 5000 rpm all the values were low with respect to gasoline. The largest difference occurred at 2000 rpm. Average power increase of the additives in all the operating cycles were 1.1% for additive A, 1% for additive B, 1.3% for additive C and 0.2% for additive D.

criterion, refers to the amount of fuel per horse power taken from the engine in one hour. In all the additives, the specific fuel consumption has shown a decreasing trend in certain cycles although most of them increased with gasoline. While an increase in fuel consumption was observed in additive A at 1500, 4000 and 5000 rpm, the least fuel consumption was spotted at 2000 rpm. Additive B has shown fuel consumption increase at 2000, 3000 and 4000 rpm whereas its least fuel consumption was recorded at 1500 rpm. As for additive C, fuel consumption was seen to increase at 3000 and 3500rpm engine speeds, the lowest fuel consumption was at 3500 rpm. Additive D underwent fuel consumption increase at 1500, 3000 and 5000 rpm speeds with the least consumption appearing at 3500 rpm. When the averages of fuel consumption is studied, it is found that under all

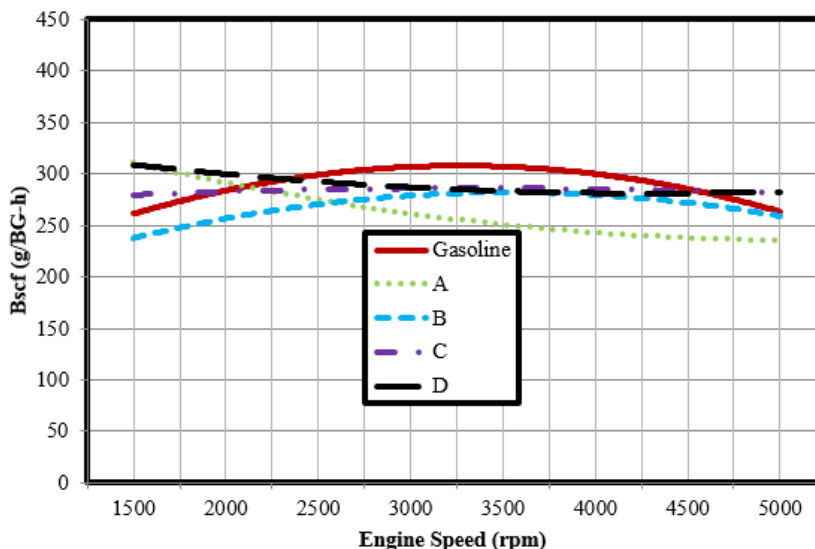


Figure 9. Specific fuel consumption - engine speed changes for 0.7% boron additive into gasoline

speeds, additive A exhibited a decrease of 5% while additives B, C and D recorded decreases of 6%, 15% and 3% respectively.

engine speed. It was only in additive A where an increase in HC was observed at engine speeds of 1500 and 2500 rpm. HC emissions are specifically caused by the cold

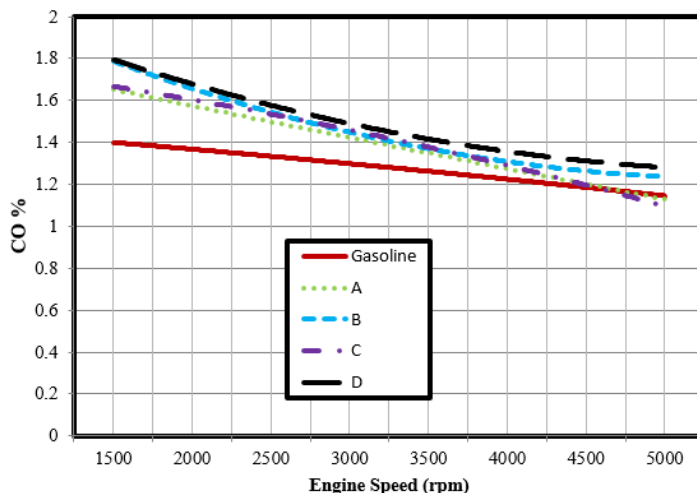


Figure 10. Carbonmonokside - engine speed changesfor 0.7% boron additive into gasoline

Carbon monoxide (CO) emissions are exhaust products appearing as a result of insufficient air for fuel combustion or an outcome of less than the necessary time needed for burning the fuel completely. Therefore, among the exhaust emissions, the concentration of CO mostly depends on the engine’s operating conditions and air-fuel mixture. Figure 10 shows the variation of CO emissions with engine speeds. When the CO emissions are investigated, it is seen that under all operating speeds additive A shows a reduction of 2.8%, B additive 1.2% increase, additive C exhibits 0.3% reduction and D indicates an increase of 5.3% on average.

In figure 11, variation of hydrocarbon (HC) emission with engine speeds is given. In all the additives used in the experiments, it was found that the HC emission values tend to decrease depending on the increase in

zones around the engine cylinder walls. As explained in CO emissions, depending on engine speed, an increase in the turbulence within the engine cylinders will provide perfect combustion in the engine therefore reducing the HC emissions as the engine speed increases. By studying the HC emissions, it is seen that in all the additives, a decreasing trend with respect to gasoline is observed.

4. RESULTS

In this study, effects of fuel blended with boric additives on engine performance and exhaust emissions were studied where the gasoline fuel with 0.7% boric additive was used for the study as it exhibited the best results after comparing engine torque values resulted from other blends of 1.4% and 2.1% of boron available in markets. The tests were conducted on a two-cylinder spark

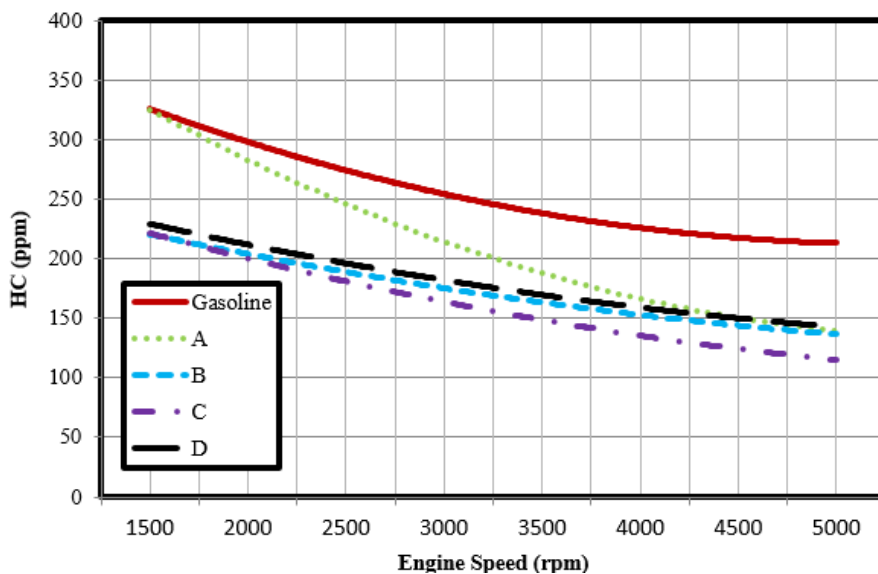


Figure 11. Hydrocarbon - engine speed changesfor 0.7% boron additive into gasoline

ignition engine under full load that was operated at various operating speeds. There has been claims that there is a fuel additive sold around stores that is economic, improves engine performance, reduces exhaust emissions and cleanses engine cylinders. However; based on the obtained experimental results, no linear increase or decrease was observed for any value, instead it was found that there are some variations depending on engine speeds. The best result of the averages of power and torque was observed in additive B at an engine speed of 2000 rpm with an increase of 5.8%. As with fuel consumption values, no linear increase or decrease was observed, but rather reduction on some values. The best result was spotted on additive C with 32 % decrease at engine speed of 3000 rpm. However, in terms of HC and CO emissions, a remarkable decrease was found. Above the speed of 3000 rpm, reduction in power and torque based on gasoline was observed. No significant increase could be observed in power and torque as the engine speed increased. In terms of fuel consumption, when all the speeds are investigated, the highest value obtained seems to be 5.8%. However, reduction was not found at every engine speed. Especially at the engine speed of 3000 rpm, the lowest torque and power values were obtained based on gasoline supplied and more fuel was consumed.

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