STUDY OF EFFICIENCY AND EMISSIONS IN A INTERNAL COMBUSTION ENGINE UTILIZING THE NATURAL GAS AND THE GASOHOL E25

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Abstract. *The purpose of this paper is to carry out a comparative energetic efficiency study of an Otto cycle internal combustion engine running with gasohol E25 and with compressed natural gas. Many studies have already evaluated the viability of the use of natural gas in internal combustion engine and other studies have also been carried out comparing the use of natural gas and conventional fuels. Natural gas is a good alternative fuel due to be considering a clean fuel with good properties to internal combustion engines and that can be originated from different sources. Emission gases are too essential to evaluate the environmental impact of each fuel. In this work an experimental test is realized in an Otto cycle engine equipped in a bench test utilizing natural gas and gasohol E25. The main comparative parameters used in this study were power, torque, specific fuel consumption, thermal efficiency and emissions.*

Keywords*: Internal Combustion Engine, Fuels, Efficiency*

1. INTRODUCTION

Faced with important issues related to environment and sustainable development issues such as energetic efficiency, alternative energy sources and vehicle emissions have become increasingly discussed in the world. Internal combustion engines are seen as the main source of greenhouse gas emissions in large cities. Thus it is important that researches on internal combustion engines and alternative energies be intensified in the intent of more efficient and cleaner technologies solutions.

The application of alternative fuels can diversify sources of energy, and by the technical point of view, may have different characteristics of efficiency, performance, consumption and emissions.

Important fuels characteristics that influence performance on Otto cycle engines are anti-knock indexes, low calorific value and flash point. According to each type of fuel the parameters of performance, specific fuel consumption and the emissions will be different.

The experimental testing is the main way to characterizing the results of an engine with a particular fuel, as well as for comparative studies between different fuels. On internal combustion engine is desired good performance parameters but is important low specific fuel consumption.

2. METODOLOGY

This study used an Otto cycle engine coupled in an instrumented hydraulic dynamometer. The bench test was instrumented to acquire data of pressures, temperatures, speeds and engine parameters as power, torque, and specific fuel consumption. Two different types of fuel were used in the tests – compressed natural gas and gasohol E25.

The tests were conducted at full load, WOT (wide open throttle), and in three conditions of revolution: 1500 rpm, 2000 rpm and 2500 rpm.

2.1. Fuels Used on the Tests

The tests were conducted using the natural gas and the gasohol E25 which is also known as gasoline "C" or Brazilian gasoline. This fuel is a mixture between 75% of pure gasoline and 25% of anhydrous alcohol. The table 01 shows other specifications of this fuel:

Table 01 – Specifications of Gasoline "C" (ANP, 2011).

Percentage of alcohol:	25% (NBR 13,992);
Density 20 ºC:	743.2 kg/m^3 (ASTM D4052);
Lower Heat Value:	43,513.6 kJ/kg.

The other fuel used on the tests was the compressed natural gas. The sample used was the gas that is distributed in the gas station of Salvador city. The specifications of this product were obtained by Bahiagás, which is the provider of the gas in Bahia.

Table 02 – Specifications of Natural Gas Used on the Tests. (Bahiagás, 2011).

Gas Composition					
CH_4	C_2H_6	C_3H_8	C_4H_{10}	$N_2 + CO_2$	CO_2
89,2%	4.41%	0.48%	0.49%	5.42%	0.4%
Upper Heat Value:			46,708 kJ/kg		
Lower Heat Value:			42,152 kJ/kg		
Absolute Density:			0.7924 (kg/m^3)		

2.2. The Internal Combustion Engine

The engine used in experimental tests was a 4-stroke engine cycle Otto which was able to run with gasoline and alcohol in different proportions. The engine received an adaptation kit to function with compressed natural gas too. The electronic control system was arranged to adapt the engine parameters according to each type of fuel.

Table 03 - Specifications of the engine used in the comparative tests.

Manufacturer	GM Powertrain
Cylinder number:	4
Volume:	1,389 cm3
Power (Gasoline):	72.8 kW
Torque	129 N.m
Compression Rate:	12.4
Engine Speed (Idle):	750 +- 50 rpm
Maximum Engine Speed:	6,300 RPM
Engine Mass:	103 Kg

2.3. Comparative Parameters

The main data obtained in this study were the engine work output, fuel mass flow rate, air mass flow, temperatures and emissions. Through the data obtained were performed the calculations to obtain the specific fuel consumption and the thermal efficiency.

In internal combustion engines the efficiency can be defined by a dimensionless parameter that describes the work output according to the fuel supply (HEYWOOD, 1988). This measure of engine efficiency, also called the fuel conversion efficiency is given by:

$$n_f = \frac{\dot{W}_c}{m_f . Q_{HV}} \quad (1)$$

Where, $\dot{W}_c$ is the power obtained on the dynamometer. The fuel energy is represented by m_f x Q_{hv}, where m_f is the fuel mass flow rate and Q_{hv} is the lower calorific value.

The specific fuel consumption is the ratio between the fuel flow rate and the power output. It is an important parameter to understand a behavior of fuel consumption of engines and to realize a comparative study between engines with different fuels and in different tests conditions.

$$sfc = \frac{\dot{m}_f}{\dot{W}_c} \tag{2}$$

According to Heywood (1988), the relation of specific fuel consumption is inversely proportional to fuel conversion efficiency for normal hydrocarbon fuels.

The emissions tests were developed using a gas analyzer (Telegan) which had a probe coupled on exhaust system. On the experimental tests the exhaust system was without the three-way catalyst because the intent was get the real quantities of each gas. On each test condition were taken five gaseous samples.

3. TESTS RESULTS

There were three groups of tests to each fuel. In each test were collected data of temperatures, pressure, engine speed, air temperature, air flow rate, fuel consumption, engine torque and engine power output. After that others parameters like thermal efficiency and specific fuel composition were calculated.

3.1. Engine Work Output

The torque and power engine curves are important to understand the engine behavior in different conditions. An example is the design of the vehicle transmission system that depends of the engines performance curves.

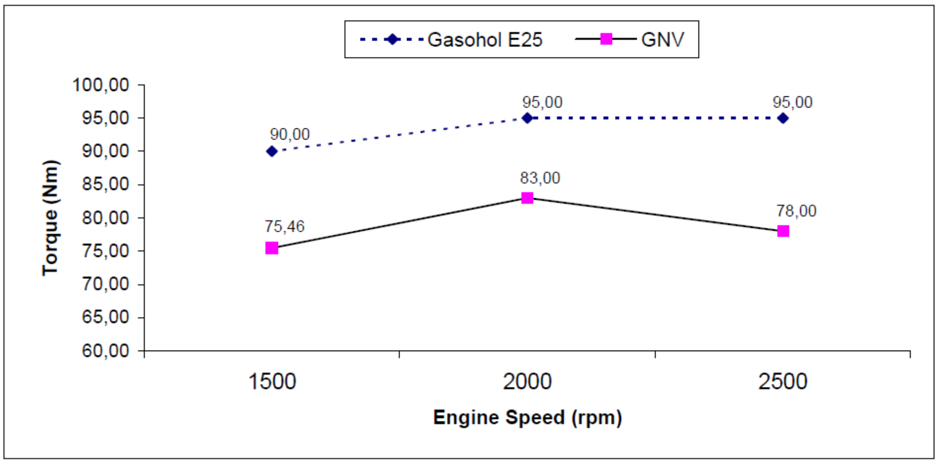

Figure 1. Torque values to E25 and compressed natural gas (CNG).

The results showed that the torque values were significantly higher when used Gasohol E25 compared to compressed natural gas.

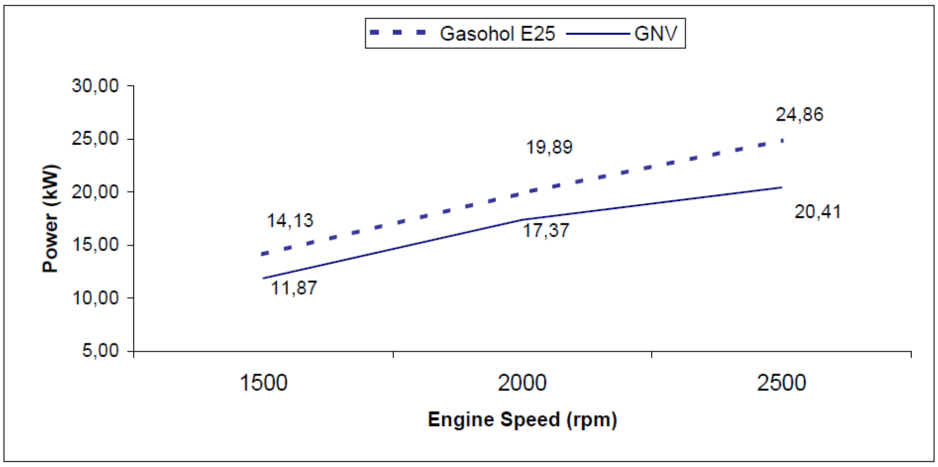

Figure 2. Power of gasohol E25 and CNG.

Consequently the power curve also showed a better result to gasohol E25. Some explanations are the fact that the fuel energy of the liquid fuel be higher.

Other arguments are that the volumetric efficiency of the liquid fuel is higher than of the natural gas and the speed flame is smaller to natural gas (ABIANEH, et al 2008).

3.2. Thermal Efficiency

Although the power output was lower for the CNG, the result of fuel energy was also lower for the CNG. Then the results of thermal efficiency of the CNG were much larger than with gasohol E25. The values of efficiency were 48% higher to CNG on rotation of 1500 rpm, 27% in 2000 rpm and 67% in rotation of 2500 rpm.

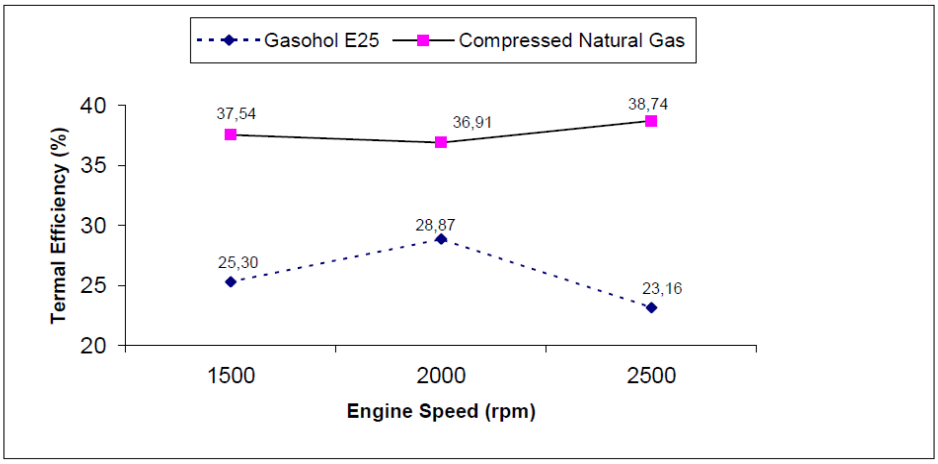

Figure 3. Thermal efficiency of gasohol E25 and CNG.

3.3. Specific Fuel Consumption

According to Heywood (1988) the specific fuel consumption represents how much efficiency has an engine taking into account the fuel used. Therefore the lower the value of specific consumption, better the engine efficiency.

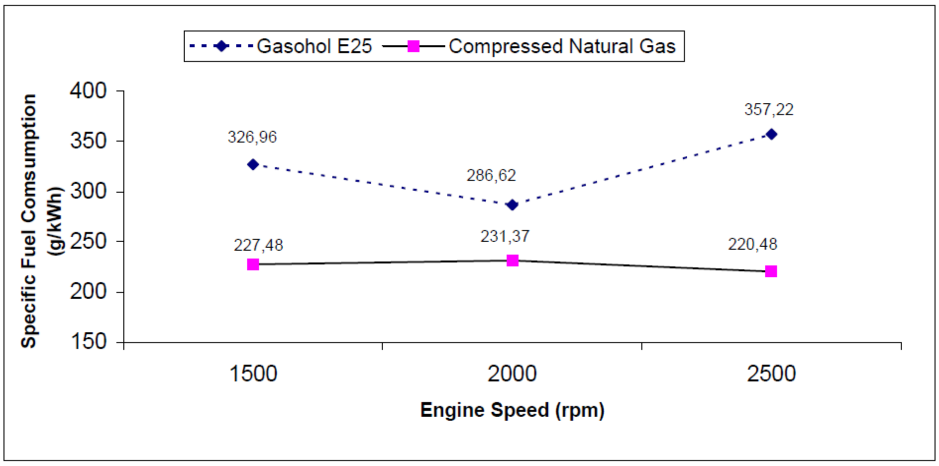

Figure 4. Specific Fuel Consumption of gasohol E25 and CNG.

The test results showed higher specific fuel consumption to the gasohol E25 in relation to compressed natural gas.

In rotation of 1500 rpm, the value was 43.7 % upper, 23.9 % on 2000 rpm and 62 % on 2500 rpm. In both fuels were performed gravimetric fuel analyses.

3.4. Emissions

There was a gas sample to each test condition. On the tests were important the stabilization of the system, after that was made a media to comparation between each fuel.

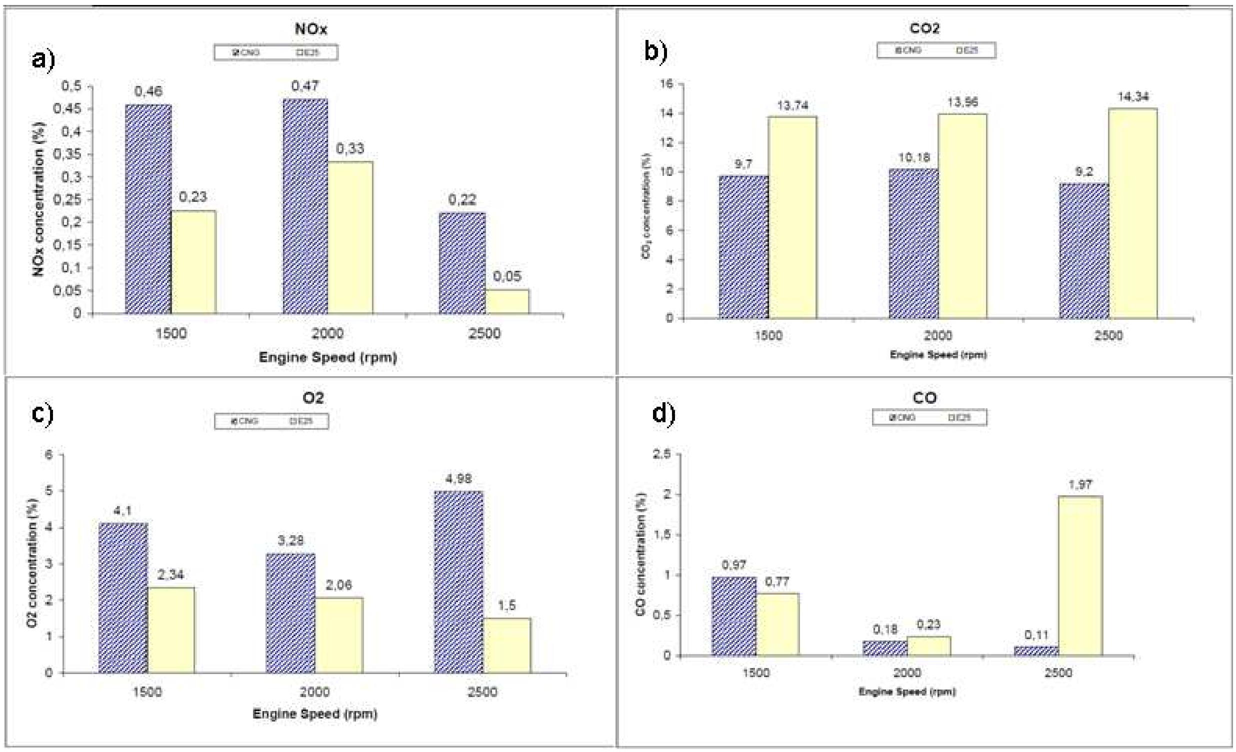

Figure 5. Emissions from gasohol E25 and compressed natural gas. a) NOx concentration (%); b) CO_2 concentration (%); c) O_2 concentration (%); d) CO concentration (%).

The results shown that in relation to NOx, the natural gas presented higher indices than gasohol E25, but in relation to CO_2, gasohol E25 presented more elevated indexes. In relation to CO, the CNG presented a higher value on revolution of 1500 rpm, but, the values to gasohol were higher on revolutions of 2500 rpm and, similar on revolution of 2000 rpm.

4. CONCLUSIONS

Although the two fuels have similar calorific value, other properties are quite different, as anti-knock index, specific volume and flash point.

The tests results showed that the gasohol E25 presented great superiority over the natural gas in relation to performance parameters such as torque and power. But with regard to the thermal efficiency and specific fuel consumption, natural gas had a significant advantage when compared to gasohol E25. Thus, when used in vehicles it is expected a better performance of the vehicle using gasohol E25. However the compressed natural gas provides better fuel economy or better use of the fuel energy.

Regarding emissions, the tests were conducted without the catalyst in the exhaust system. In the obtained results, the gasohol E25 presented higher percentage results of CO_2 in relation to natural gas. Considering NOx, emissions with natural gas was slightly higher for natural gas in relation to gasohol E25. In relation to CO, it was not observed a tendency on the behavior.

It is also important to emphasize that the engine used in the tests had the original characteristics of the manufacturer, with the engine dimensions specified for liquid fuels such as gasoline, alcohol and mixtures between them. Natural gas with its properties could support a much larger compression rate than was used. Thus, could be expected even better results for natural gas in case there was some adjustment of the engine characteristics, such as compression ratio or ignition map optimization.

5. ACKNOWLEDGEMENTS

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