PERFORMANCE ANALYSIS OF FLEX FUEL VEHICLES IN A CHASSI DYNAMOME BENCH

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Abstract. *The flex-fuel vehicles are equipped with an internal combustion engine of the Otto cycle, which has the ability to work with more than one type of fuel, mixed in the same tank and burned in the combustion chamber simultaneously. These types of vehicles are a global trend due to the oil scarcity, limits of greenhouse gases emissions and the diversity of fuel sold. Some factors influence the predominance of flex vehicles in Brazil, which may be cited the requirement of using 20 to 25% alcohol mixed with conventional gasoline and the attractive prices of natural gas and alcohol fuels, which are already consolidated in the country. Therefore, the objective of this work is to survey the power curves and specific consumption of flexible-fuel vehicles with different fuels. The experimental methodology adopted to the tests satisfied the proposed objectives, allowing the determination of comparative and conclusive results about the performance of flexible-fuel vehicles in a dynamometer bench working with fuels like: gasoline, ethanol and natural gas.The results show that gasoline is more economical than alcohol. Natural gas has significant consumption results in comparison to liquid fuels and ethanol is the fuel which can achieve better power curve.*

Keywords: *Flex engines, power curves, specific consumption.*

1. INTRODUCTION

The automotive industry is growing rapidly worldwide, launching vehicles to different social classes, since popular vehicles to the most luxurious. Manufacturers to achieve a greater market share, develop vehicles with optimized systems, aiming to get a greater engine power with less fuel consumption, always aiming to attend the pollutants emission standards of each country. These factors are essential for consumers, because the fuel is increasingly expensive and there is a greater awareness of people by buying products that cause less harm to the environment.

In 2000, in Brazil, occurred an increase of vehicles adaptations powered by gasoline and ethanol to GNV, due to its attractive prices in comparison to gasoline and alcohol, the technology improves of conversion kits and the network expansion of stations supply. In 2003 began to emerge the flex-fuel vehicles, driven by Federal Government guidelines, in favor of ethanol agro-industrial companies.

There are several factors that justify the increase number of flex-fuel vehicles in Brazil, which could be cited, among others, the variety of fuels available in most petrol stations of the country and the relative volatility of fuel prices. The flex are a reality in Brazil, referring to vehicles that run on any proportion in the mixture of gasoline and alcohol fuel (ethanol), stored in the same tank.

Currently, the most advanced technology to flex-fuel vehicles which uses liquid and gás fuel is FIAT SIENA Tetrafuel system. This system has a single electronic central to manage liquid and gas fuels. It is an intelligent system because it changes automatically according to the fuel system of work. Another important factor is to have eletric injectors for gas, where the fuel is injected directly into the intake manifold of the motor vehicle.

The carmakers submit the vehicle of the production line to various tests, such as: consumption, power, pollutant emissions, impact (crash test). These tests are conducted on test tracks and in laboratories. Through a device called chassis dynamometer, it can simulate, in laboratory, actual conditions of a vehicle driving in urban and Road routes. However, to experimentally investigate the performance of the vehicle SIENA Tetrafuel is necessary to develop specific tests of fuel consumption, maximum power and test bench.

Therefore, this paper aims to perform tests of specific consumption and maximum power to investigate experimentally the performance of the tetra-vehicle fuel in a chassis dynamometer, operating with different fuels.

2. MATERIALS AND METHODS

Initially, it was assembled a test bench and selected the necessary equipments to conduct testing of specific consumption and maximum power of a light motor vehicle at the CTGÁS-ER Automotive Laboratory. Equipments used were: pressure gauge, fuel gauge, precision scale, automotive scanner, forced ventilation system, exhaust system and gas analyzer.

While assembling the bench, was performed lubricant oil change, oil filter, fuel filter, air filter, wheel alignment, wheel balancing and adapted a probe in the exhaust manifold to collect emissions from vehicle burning.

Finally, two technicians were trained to use the dynamometer and perform tests. The steps were discussed and implemented in a working group involving technicians from CTGÁS-ER and UFRN teachers.

3. VEHICLE DESCRIPTION

The vehicle used in this work is a light motor vehicle equipped with a engine 1.4 MPI (Multipoint injection) of internal combustion with four-cylinder in line, eight-valve, as show in Figure 3.1.

Figure 3.1 – Siena Tetrafuel

Siena Tetrafuel is a vehicle designed and manufactured to operate with gas fuel, because optimizes the systems used in adaptations made in the GNV market.

The system has features of a sixth generation kit, because it has one central machine to manage liquid and gas fuel. It is an intelligent system because it changes automatically according to the fuel system of work. Another important factor is to have eletric injectors for gas, where the fuel is injected directly into the intake manifold of the motor vehicle.

The design of Siena Tetrafuel has differences with the conventional Siena, because the engine components were prepared with treatments and coatings for operation with GNV. The cylinder head was completely changed, the intake valve seats pass from 45 to 60 degrees and a new intake manifold for the installation of electro gas injector. The body has changed, as structural reinforcement to receive the supports and GNV cylinders and suspension with specific springs that keeps the static and dynamic conditions of the vehicle.

The characteristics of Siena Tetrafuel are changes made in the factory. Modifications are not restricted to the motor vehicle, as well as the instrument panel, as shown in Figure 3.2. Other vehicles when adapted to GNV, make changes in specialized workshops.

Figure 3.2 – Instrument panel of Siena *Tetrafuel*.

The left corner of Figure 3.2 shows the fuel gauge. When the vehicle is operating with GNV, there are vertical bars indicating the fuel level. If the gas level is below 20% in the cylinders, Will appear in the display the message "Warning: low fuel". When the autonomy of the liquid fuel is less than 50 km and the level of GNV is less than 20%, will appear in the display the message "Caution: limited autonomy. "

3.1. Imprint

Table 3.1 shows the main information about Siena Tetrafuel 1.4 vehicle.

Table 3.1. Technical Information about Siena Tetrafuel

SIENA TETRAFUEL	Gasoline with added alcohol	Gasoline without added alcohol	Ethanol	GNV
Compression rate	10,35	10,35	10,35	10,35
Maximum power	80,0 cv / 58,9 kW (5500 RPM)	80,0 cv / 58,9 kW (5500 RPM)	81,0 cv / 59,6 kW (5500 RPM)	68,0 cv / 50,1 kW (5500 RPM)
Cycle	OTTO			
Number of cylinders	4	4	4	4
Number of valves per cylinder	2	2	2	2
Fuel capacity	48 liters	48 liters	48 liters	6,5 m3 (each cylinder) on a pressure of 200 bar
Velocity in fourth gear	135 km/h	135 km/h	135 km/h	135 km/h

3.2. Operation

Siena Tetrafuel always starts with liquid fuel and then will proceed to use GNV. In working with GNV, the electro injectors liquid fuel are shut down, cutting the supply to the engine. With liquid fuel cut, the GNV system goes into operation.

In the acceleration phase, to prevent performance loss of the vehicle, the central electronics enables, automatically, the operation with liquid fuel, every time you need a higher torque, as in cases of transcend or high rises, especially if the air conditioning is on. By slowing down, the system returns, automatically, to the operation with GNV. This strategy will be disabled when the liquid fuel goes into the reserve.

In the specific case of Siena Tetrafuel projected to prioritize the gas fuel, the driver can manipulate the system to work with any fuel. Failing gas fuel, the system begins operating with the liquid fuel which is available in the reservoir.

The cold start system of Siena Tetrafuel only works if the air / fuel ratio is less than 12.5 / 1 and engine temperature below 30°C. During the engine heating phase of the system can be activated to improve driveability.

4. TESTING PROCEDURE

The testing procedures of this study were developed by CTGÁS-ER technicians and UFRN teachers, following normative references and according to working conditions of CTGÁS-ER Automotive Laboratory.

4.1. Test Power

The test procedure for measuring power of a motor vehicle on a chassis dynamometer was developed according to Dynamometer Chassis Manual, FLA 203 model, Bosch manufacturer and manufacturer's manual FIAT SIENA vehicle.

Power Tests of a light vehicle engine are intended to increase the real power curve of the engine in chassis dynamometer. The accuracy of the test bench is approximately 0.5%, resulting in 2 kW.

In implementing the maximum power test, the technician starts the operation of the vehicle in 1st gear, and as soon as possible, changes to the 4 th march, and this exchange performed when the motor vehicle reaches the half of the nominal number of revolutions. Then, accelerates until the dynamometer display appears the message to "disengage", when it should be put into neutral position and take your foot off the accelerator until the roll parade. This procedure should be performed at least three (times) to obtain a representative average value for the tests on each fuel type.

The graph of Figure 4.1 shows the test results performed with ethanol. The curve starts to drop when the engine reaches a power of 61 kW. The power curve shows that the engine gets a higher power at a speed of 128 km / h and a rotation of 4950 RPM in fourth gear. Passing this type of work, the engine begins to lose power. Thus, there is no advantage in continuing to raise the motor rotating, since the power curve is dropping at the end.

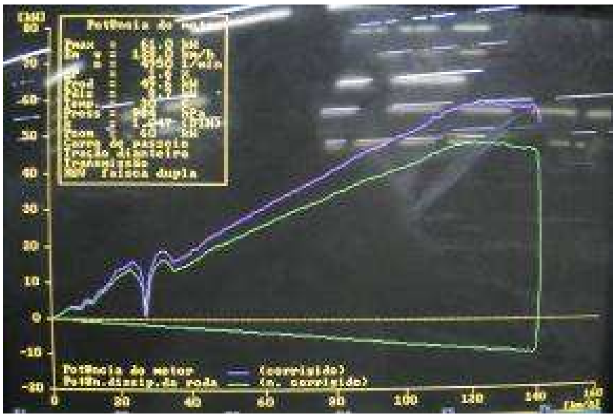

Figure 4.1. Power curve using ethanol.

4.2 Test Fuel Consumption

The test procedure for measuring fuel from a motor vehicle on a chassis dynamometer was developed according to ABNT NBR 7024 - road light motor vehicles - Measurement of fuel consumption.

The measurement of fuel consumption during the cycles will be performed by gravimetric method, which consists in direct measurement of the mass of fuel provided to the vehicle during the urban and road cycles.

For measurement of fuel consumption, through the urban driving cycle, it is necessary to simulate a route on chassis dynamometer with the coordinates of the urban driving cycle, according to NBR 6601. As a way of adapting the simulation to working conditions of the Laboratory of Automotive CTGÁS-ER was necessary to develop a spreadsheet with the coordinates of the urban driving cycle. The Figure 4.2 shows a graph containing the route taken by the technicians during the tests on the urban driving cycle for conducting the test fuel consumption.

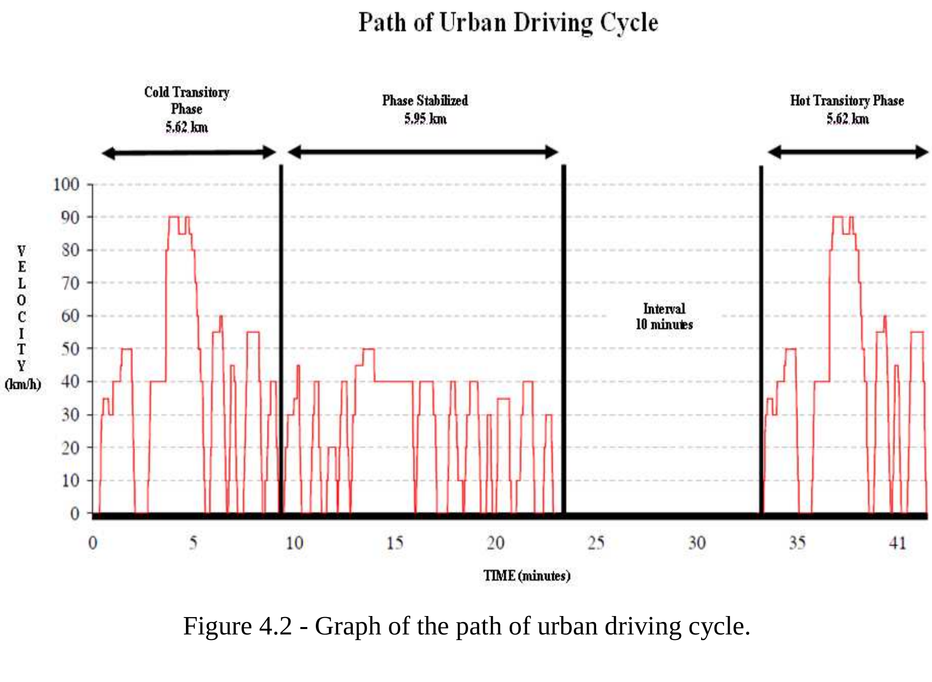

Figure 4.2 - Graph of the path of urban driving cycle.

For measurement of fuel consumption, through the Road driving cycle, it is necessary to simulate a route on chassis dynamometer with the coordinates of the driving road, according to NBR 7024. As a way of adapting working conditions of the Laboratory of Automotive CTGÁS-ER was necessary to develop a spreadsheet with the coordinates of the road driving cycle. The Figure 4.3 shows a graph containing the route taken by the technicians during the tests on the road driving cycle for conducting the test fuel consumption.

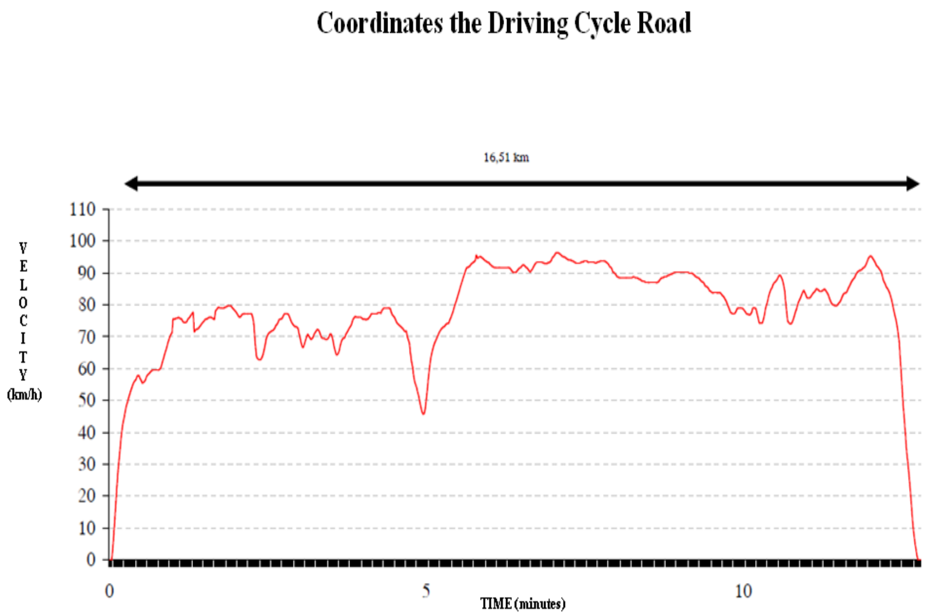

Figure 4.3. Chart the route of the driving Road

5. CONCLUSIONS

Tests of maximum power and specific fuel consumption performed with Tetrafuel vehicle on a chassis dynamometer achieved the proposed objectives, making possible to obtain conclusive results from the comparative analysis of fuel commercialized nationally: gasoline (Type C), additived gasoline(Type C), Podium gasoline (premium), ethanol (AEHC) and natural gas (GNV). Tests were conducted following NBR 7024 - Road vehicles lighter - Measurement of fuel consumption.

Test results of specific consumption with common gasoline, additives and Podium resulted in similar values, both in urban driving cycle but also in road driving cycle. Respectively, the results were 10.05 km / L, 10.17 km / L and 10.62 km / L in urban driving cycle and in road driving cycle were respectively 15.49 km / L, 15.04 km / L and 14.16 km / L.

Ethanol was the fuel that had the highest specific fuel consumption, reaching 7.22 km / L in urban driving cycle and 10.32 km / L in the Road driving cycle, compared to liquid fuels.GNV had already a better economic result in the case of fuel consumption, resulting in 11.23 km/m3 to urban cycle and 17.27 km/m3 to Road cycle, considering R$ 2.69 the price of common and additived gasoline liter, R$3.30 to Podium gasoline, R$ 1.99 to Ethanol and R$ 1.78 to GNV.

Results of tests of maximum power with gasoline, additives and Podium also resulted in similar values. Results were respectively 58.3 kW, 58.2 kW and 57.6 kW. Considering the resolution of the equipment chassis dynamometer in ± 2 kW, as indicated by the manufacturer, the results are practically equal.

Ethanol showed a higher power value in relation to fuels used, resulting in 61 kW. But GNV showed a lower power value, 52.9 kW.

This paper concludes that GNV fuel is cheaper per mile in terms of specific consumption considering the weighted harmonic average of the autonomies of urban and road fuels, approximately 41% lower compared to regular gasoline and 44% lower compared to ethanol. The consumption of ethanol in the case presents an approximate increase of 30% compared to the consumption of gasoline.

Thus, if the price of ethanol is less than 70% of the price of gasoline, it pays to use this fuel when the interest is only economic. In terms of maximum Power, ethanol has significantly higher value compared to other fuels.

The choice of fuel used by the vehicle driver must be analyzed in terms of benefit cost, especially considering the type of work required by the vehicle, but also the route and the driving cycle chosen.

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