HEFAT2007
5th International Conference on Heat Transfer, Fluid Mechanics and Thermodynamics
Sun City, South Africa
Paper number: CR1

EXPERIMENTAL STUDY OF THE EFFECTS OF LPG ON SPARK IGNITION ENGINE PERFORMANCE

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ABSTRACT

An experimental device was developed to investigate the performance of a spark ignition engine designed to use gasoline whose system has been modified to use LPG (liquefied petroleum gas). Temperatures (exhaust gases, oil, water, combustion air); power and torque were evaluated for different engine gear. Thermocouples were used K type and transducers of pressure with signal in mV, to evaluate the power and torque, were used a digital accelerometer. These experiments are made to clarify to aspects like the vehicle performance and safety of the people. The results indicate that all the temperatures (exhaust gases, oil, combustion air, water in the radiator) are increased considerably using LPG. For similar conditions, the power and torque decrease.

The inspection made in the installed components to make the conversion indicates that the used equipment at the moment, does not present safeties devices for the control in emergency situations, detection and blockade in the presence of LPG within the automobile are not considered.

INTRODUCTION

The LPG is a mixture of propane-butane that is used generally like domestic fuel to cook. Nevertheless, also it has found use in the commercial and industrial sectors. The LPG is also an alternative automotive fuel in some countries where the cost of the gasoline is elevated [1, 2].

At the moment different technologies come developing to use the LPG in vehicles of public transport [3, 4], unfortunately barriers as the safety of the passengers prevents a regulation of the use of this fuel in engines that has not been designed in factory for this purpose [5].

The LPG, correctly used, could be a clean, profitable and less polluting fuel. The engineers have recently proven their use like fuel in vehicles [2]. Everywhere, the governments are supporting the use of the LPG like an alternative fuel in recognition of the significant advantages technical-economic.

More than 7 million vehicles in 40 countries were LPG-fueled at that time, representing a 46 percent increase from two years earlier [6].

The use of LPG in engines is guaranteed by a design of engineering and specialized staff, lamentably is observed at the present time, factories (in many countries) use technologies of conversion not guaranteed to adapt the use of the LPG to vehicles designed for gasoline. One is committing aspects of design of the vehicle and mainly safety aspects, due to the reduction of costs to obtain more benefits.

The objective of this work is to evaluate the performance of a used typical vehicle in the public transport (taxi) in Arequipa city, Peru.

EXPERIMENTAL MODEL

A scheme of the experimental model is shown in the Figure 1. We can observe the components: Tests Section (vehicle) Fuel Supply System (gasoline or LPG), and the Data Acquisition System (SAD).

The test section is formed by the vehicle Nissan, model HL-B11-F, four cylinders, engine manufacture in 1985, effective volume of the motor 1493 cm^3, and gasoline admission system by carburetion

The Fuel Supply System for Gasoline (Fig. 1) is formed by: a storage tank of steel and approximated capacity of 75 dm^3 (20 gallons approximately), a system of copper pipes of 3.2 mm (1/8 of inch), a fuel filter of 25 cm^3, an atomization system for fuel-air mixture type carburetor. The used gasoline was of 84 octants.

The Fuel Supply System for LPG (Fig. 1) is formed for: A LPG tank of with capacity of 44 dm^3, pressure test of 1.76 MPa and pressure design of 3.5 MPa, a system of electromagnetic valves (fuel direction selection).

The data acquisition system is TEMPSCAN 1100, OMEGA. Thermocouples Type K of diameter 1 mm, were use for the temperature measurement, according Figure 2.

For torque RPM and HP measures was used the Triaxial accelerometer covering all three axes (x,y and z) . RPM sensing system that works right through the cigarette lighter. For Torque measure, was used a RPM and acceleration F1-style Sequential Shift lights. Each unit robotically calibrated and temperature compensated in laboratory.

The Vehicle was modified to use GLP using the equipment and procedures used in the different factories in the locality, this way it evaluated the vehicles turned used transport of people (taxi).

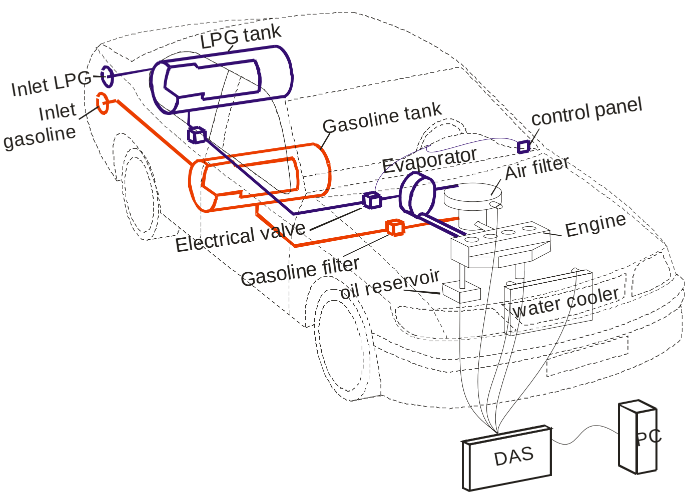

Figure 1 Experimental model.

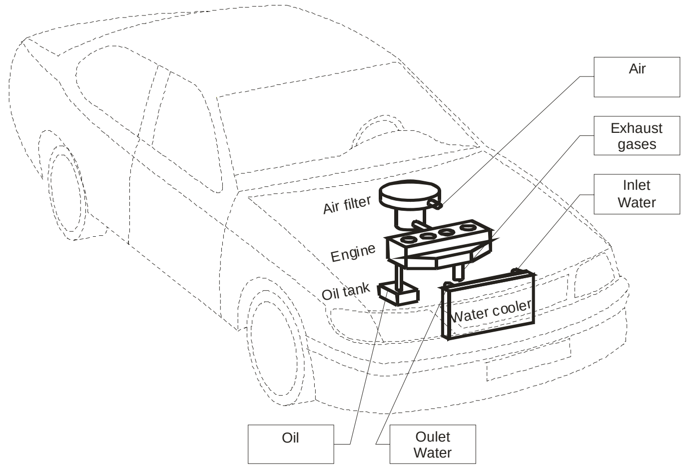

Figure 2 Temperature measures.

EXPERIMENTAL PROCEDURE

The temperatures in different positions were evaluated (exhaust gases, oil tank, air intake towards the filter before the carburetor, inlet and outlet in the water cooler), in different conditions described in Table 1.

Table 1. Temperature measurement.

Gear *	Velocity, km/h
1	30
2	50
3	70
4	100
5	120

* Corresponding to 2800 RPM

The power and torque were measured in a test of continuous acceleration and changes of gear-box to 4800 RPM.

STUDIED PARAMETERS

The temperatures were studied in the exhaust gases collector, in the oil tank (Carter), in the air inlet (before the filter), in the inlet and output of the water cooler. Each one of the mentioned tests previously was made for two conditions: first using gasoline exclusively, second using LPG exclusively. The studied uncertainties are described in the Table 1.

Table 1. Uncertainties.

Parameter	Uncertainty, ±	Units, SI
temperature	0.2	ºC
velocity	0.3	km/h
power	0.01	% (W/W)
torque	1	N m
engine rotation speed	0.02	% (RPM/RPM)

Aspects of human safety were observed: disposition of components, norms of equipment manufacture, and risk situation in emergency situation.

RESULTS AND DISCUSSION

In Figure 3, the variation of the temperatures for the test with the vehicle using gasoline for different speeds is observed. All these speeds correspond to a motor rotation of 2800 RPM. The temperature of exhaust gases increases proportionally with the vehicle speed. The others temperatures (oil, air, and in/out water cooler), approximately remain constant.

In Figure 4, is observed tests using LPG fuel, the curves tendency is similar to the gasoline test, the difference is in the values are more highs and the increase in the values is evident in the two last speeds (100 and 120 km/h).

In Figure 5, was shown a comparison of the temperature difference of each point of measurement ($T_{LPG} - T_{gasoline}$), is observed that the increase in the temperature of exhaust gases oscillates between 41.4ºC and 94.4ºC, in oil temperature varies between 11.1ºC and 19.3ºC, for the in/out cooler water, the difference varies between 5.3 ºC and 16.9ºC, finally, for the air temperature in the carburetor inlet, the observed increase is from 0.8ºC to 2.1ºC.

In Fig. 6 the respective comparison for the power and torque is shown with both fuels.

The test was made in the same conditions of vehicle operation (external temperature, distance of road, and incline of the road).

When the values of power and torque reach minimum values, they indicate a situation of gear-box change. For Fig 6, the experiment was made until the third gear-box.

Is observed that, power and torque decreases between 5% and 20% when using LPG in the same condition.

The experiment began with the vehicle stopped, is accelerated to maximum position until 4800 RPM, at that moment the change of gear-box was made, later was accelerated to the maximum until arriving consecutively until the third gear-box position, for this motive, the duration of the test is short (20 seconds). This procedure was made so that the position of the accelerator is not one more a variable (a position of accelerator is maximum)

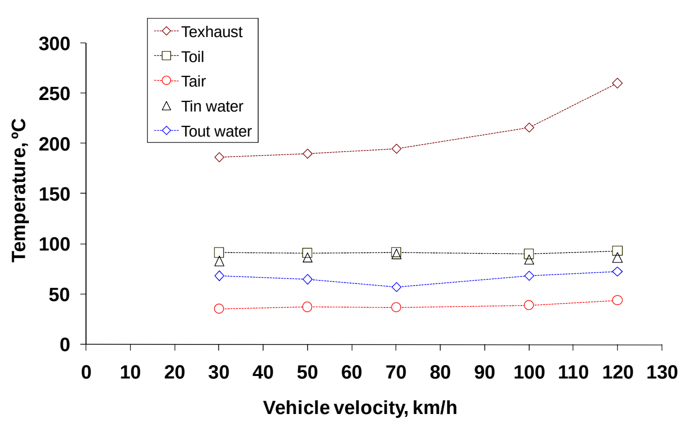

Figure 3 Temperatures evaluation, Gasoline.

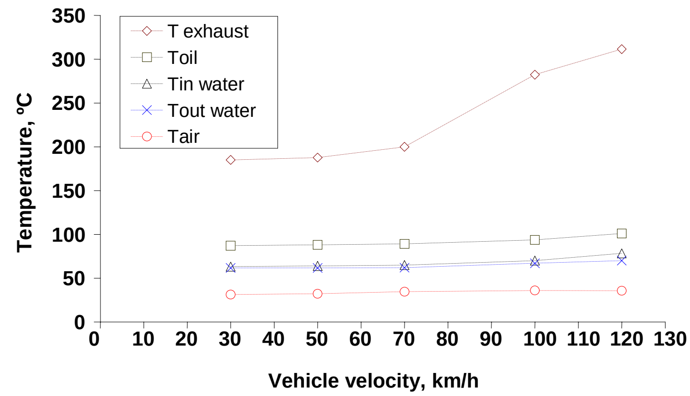

Figure 4 Temperatures evaluation, LPG.

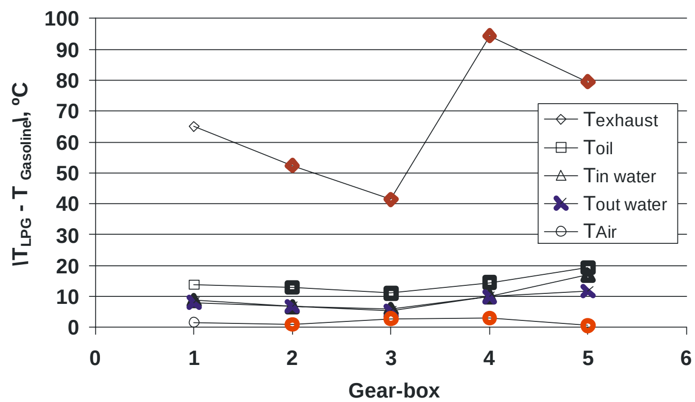

Figure 5 Temperature increase using GLP.

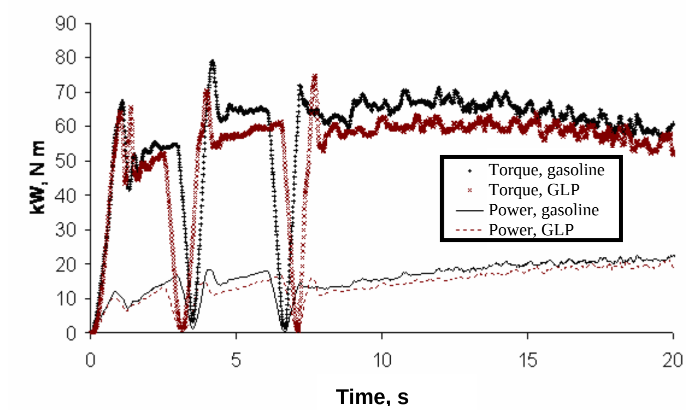

Figure 6 Power and torque, comparison gasoline - LPG.

ASPECT OF HUMAN SAFETY

It has been observed which norms of the conversion process to GLP of vehicles designed for gasoline do not exist in Peru and several countries (Brazil, Colombia, Ecuador, Bolivia, etc.), some aspects are clear:

The GLP to atmospheric pressure and temperature has a density superior than the air and in the escapes to the storage tank or some component, this fuel will remain accumulated in the compartments of the automobile (passenger salon, for example), representing an imminent risk for the occupants safety of the vehicle.

The companies that install the conversion equipment do not include some safety system to prevent accumulation of LPG into the vehicle.
These companies do not have a LPG tank certification respect to the structural integrity of the tank during direct fire exposition in vehicle fire situation.
The conversion equipment lacks a system of LPG regulation. Other devices (systems integrated in vehicles factories) integrate a diffuser-mixer that and an oxygen sensor-control.

In the establishments of GLP sale, the process of LPG supplying is observed that:
The evacuation of the occupants of vehicle is not made
Protective barrier (between the vehicle supplying of LPG and the people) does not exist
The electrical earth connection of the vehicle is not made (static energy)
The distance of the establishments of GLP sale and the urban zones is not respected.

ECONOMICS ASPECTS

We can observe in Table 2 and 3, a summary of the economic aspects when the performance vehicle with each fuel in three different situations of route: city historical center (High density of vehicles), city periphery (average density of vehicle), and road (low density of vehicles).

The Table 2 can be observed that by its thermal characteristics, the gasoline have more performance (between 32 % and 42 %) than the GLP.
Due to the cost of fuels (Table 3), the GLP have an economic advantage that oscillates between 20 % and 30 %, representing a saving between 0.066 to 0.124 US$ by each crossed kilometer. The "apparent saving" is for the low cost of the LPG.

Table 2. Performance by volume of fuel.

Route	km/dm^3		km/gal	
	gasoline	LPG	gasoline	LPG
city, historical center	10,2	7,7	38,5	29,0
city, periphery	14,5	10,2	55,0	38,7
road	18,2	13,3	68,8	50,3

Table 3. Performance by fuel cost.

Route	performance km/US$		saving GLP - gasoline, US$/km
	gasoline	GLP	
city, historical center	0,94	1,5	0,038
city, periphery	1,34	2	0,024
road	1,67	2,63	0,021

The benefit obtained when using GLP, must compared with the possible damages caused by the high temperatures of the engine components and the systems of lubrication (oil) and cooling (water).

CONCLUSSION

The use of LPG like vehicles alternative fuel (in factory design vehicles) represents clearly advantageous, as it predicts the European experience. Standard procedures for vehicles conversion process for use LPG are being implemented, but with security aspects very strict. The Latin-American experience indicates that is very important the legislation process of accreditation of LPG conversion factories (using kit LPG), mainly in the aspects of human security.

In aspects of performance, when being used LPG in designed vehicles to use gasoline, it could in the long term represent damage, mainly in maintenance by necessary corrective repair, this because some thermal factors are modified (general increase of the temperature). Finally it was observed that power and torque decreases when using LPG (5% to 20%).

ACKNOWLEDGEMENTS

This paper was supported by the CONAM-Perú; SWISS CONTACT. The authors also wish to thank the Agreement: *Pontificia Universidade Católica do Rio de Janeiro* and *Universidad Católica San Pablo* for motivating this research work.

REFERENCES

[1] Rouwendal, J., De Vries, F., 1999, The taxation of drivers and the choice of car fuel type, *Energy Economics*, 21, pp 17-35.
[2] Díaz, L., Schifter, I., López-Salinas E., Gamas, E., Rodriguez, R., Avalos, S., 2000, Optimizing automotive LPG blend for Mexico City, Fuel 79, pp. 79–88.
[3] Teri, 2000, Liquefied Petroleum Gas: dual fuel, *http://static.teriin.org/energy/lpg.htm*
[4] Anand, G., Karthikeyan, B., 2005,An Investigation and Engine Parameters Optimization of a Spark Ignition Engine with Gaseous Fuels Department of Mechanical Engineering, *Indian Institute of Technology Delhi*, India.
[5] Melchers, R., Feutrill, W., 2001, Risk assessment of LPG automotive refueling facilities, *Realiabity Engineering & System Safety*, 74, pp. 283-290.
[6] Liquefied Petroleum Gas Fueling Vehicles Around the World, *Alternative Fuel Data Center*, *U.S. Department of Energy*, Vol 6, No 2, October 2006.