Particular bi-fuel application of spark ignition engines

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Abstract. This paper presents a comparative test concerning the operation of a spark-ignition engine, make: Dacia 1300, model: 810.99, fuelled alternatively with gasoline and LPG (Liquefied Petroleum Gas). The tests carried out show, on the one hand, the maintenance of power and torque performances in both engine fuelling cases, for all the engine operation regimes, and, on the other hand, a considerable decrease in CO and HC emissions when using poor mixtures related to LPG fuelling.

1. Introduction

The term "bi-fuel" refers to the alternative fuelling of an internal combustion engine with two fuels (in this case, one is liquid – the gasoline, and one gaseous – the LPG), and should not be confused with the term "dual-fuel" which designates an operating principle based on the simultaneous burning of two fuels (liquid and gaseous). An example relative to the second term would be a diesel engine operating with LPG, based on the pilot injection principle [1].

The legislative norms on environmental pollution, increasingly stringent, require, among others, alternatives to the fossil-fuel combustion, by partial or full use of certain types of unconventional fuels, which are less polluting. An example in this regard is the LPG. In general, the “liquefied petroleum gases” (LPG) are the commercial propane and butane (as well as their mixture). The propane (C₃H₈) and butane (C₄H₁₀) are chemical compounds consisting of carbon (C) and hydrogen (H), which justifies their designation of "hydrocarbons". For a car engine, in the current conditions when the LPG distribution network is quite limited, the possibility to ensure the use two fuels, i.e. gasoline and LPG (the "bi-fuel" variant), appears as a rational solution.

The use of LPG to the internal combustion engines does not involve special design changes, especially in case of spark-ignition engines equipped with carburettor. The simplest fuelling solution consists of passing the liquefied gas stored in the tank (cylinder) through a vaporizer, and then entering the vapours into the inlet system by means of a mixer, which doses the air-fuel mixture in an open-loop control system. This is the variant studied in the experiment proposed herein. The solution involving a closed-loop control system of the LPG injection (in liquid phase) into the air column, located on the inlet route, is currently applied. This latter solution is the most advanced, enabling higher power and efficiency performances, because the noxious emissions are reduced compared to the solution involving a mixer [2-5], [7].

This study aims to highlight the peculiarities of using the simplest solution for adapting the engine designed to operate with gasoline, by mounting the mixer upstream to the standard carburettor. So, the flowing features of the fluid through the fuel inlet system are changed, fact that influences the filling
ratio of the cylinders and, therefore, the performances, the engine power yield being mostly influenced.

2. Presentation of the experimental equipment
The study was conducted on an experimental stand found in the Laboratory of Internal Combustion Engines of the Faculty of Engineering Hunedoara, University Politehnica Timisoara, Department of Engineering and Management, Specialty: Road motor vehicles. The stand is equipped with a 4-stroke spark-ignition engine, make: Dacia 1300, model 810.99, enabled to be alternatively fuelled with gasoline and LPG [6]. The engine loading was made using hydraulic disc brakes, with the possibility of measuring the engine speed and torque, the fuel and air consumption, the advance when triggering the electric spark, and the composition of exhaust gases.

![Figure 1. Overview of the test stand](image)

As mentioned in the introduction, we opted for the solution that involves the mounting of the LPG mixer upstream to the standard carburettor diffuser, as shown in Figure 2. This is a mechanical device that, using the Venturi principle, ensures the correct air-fuel ratio at all operation regimes of the engine. The depression created by the mixer allows the controlled gas absorption according to the throttle position.

![Figure 2. The LPG mixer](image)

The carburettor type is CARFIL 32 IRMA, up-draught, with one mixing chamber and a balanced float chamber balanced with the air filter downstream area.

The liquefied gas stored in the tank in the form of cylinder is driven towards the reducer-vaporizer (Figure 3.a), which is an electro-pneumatic device equipped with dual pressure control that enables the
evaporation of the liquefied gas in such a way as to ensure a stable supply of the engine with a gas amount adequate to the various operation regimes. From the evaporator, the gas is sucked through the mixer (shown in Figure 2) into the carburettor diffuser, allowing the gas to mix, at the same time, with the air flow. The following items are also included in the plant: a LPG solenoid valve (Figure 3.b), which is a device mounted between the tank and the reducer-vaporizer that stops the gas flow towards the reducer when the engine is fuelled with gasoline. It has also the role of gas impurity filter; a gasoline solenoid valve (Figure 3.c) mounted between the gasoline pump and carburettor stops the gasoline flow when the engine is fuelled with gas. The switching from gasoline to LPG is made at the push of a button.

![Figure 3. Composition of the LPG plant [6]: a – reducer-vaporizer, b – LPG solenoid valve, c – gasoline solenoid valve](image)

3. Testing session and the experimental methodology

Each steady operation regime has been determined by the engine speed, the pressure in the intake manifold, and the shutter position. In both cases of fuel supply, the engine operated with the classic electric ignition equipment, consisting of accumulator battery, induction coil, breaker diffuser and standard spark plugs.

The experimental measurements were made at various operation regimes which involved variable loads and a wide range of speeds:
- Full load (fully opened shutter) and speed variable between 2000 and 5000 rev/min, in order to check if the standard power and torque performances are affected in case of LPG fuelling;
- Partial loads for two speed values (1600 and 3500 rev/min), representing specific regimes for a car driving in urban and, respectively, in extra-urban traffic conditions, with constant speed.

For each steady operation regime, we determined the flue gas composition using the analytical and diagnostic station “CAPELEC CAP 3200 GO”.

4. Results and conclusions

The full load regimes: The data obtained in these cases have shown that the dynamic performances of the engine are reduced when using LPG, compared to those obtained when using gasoline (Figures 4 and 5). This is primary due to the lower calorific value of LPG than the gasoline, and secondly to the solution chosen to adapt the engine to the operation with LPG: the mixer mounted upstream the carburettor diffuser (Figure 2) involves the introduction of an additional gas-dynamic resistance which adversely affects the process of filling the engine cylinders. This results in a decrease in the filling factor and thus a reduction in the engine power. This phenomenon is more obvious at high speeds, when the gas-dynamic losses, due to this additional resistance, are higher. In addition, this additional gas-dynamic resistance, introduced by mounting the mixer, entails a change in the flow conditions, with impact on the dosage feature and the filling factor when using gasoline.

The trend of engine power reduction when using LPG, due to the above phenomena, is, to some extent, diminished by the increase of the specified yield when using gasoline. This can be attributed to several factors: improving the combustion and increasing the amount of heat released by the reaction
thanks to the presence of the required air and a better mixture with the gaseous fuel; reduction of the specific heat of the flue gases mixture evolving in the expansion stroke; possible reduction of heat transferred to cylinder walls.

![Figure 4. Torque versus speed, at full load](image)

![Figure 5. Power versus speed, at full load](image)

The operation with poorer mixtures (LPG variant) led to changes in the concentration of exhaust emissions. The amounts of carbon monoxide (CO) and unburnt hydrocarbons (HC) decreased compared to the standard fuelling variant (gasoline). These changes reflect, on the one hand, the effect of combustion improvement and, on the other hand, the effect of increasing the oxygen concentrations involved in the formation of nitrogen oxides.

The partial-load regimes: The measurements carried out for these regimes revealed the following:

- A significant increase of the indicated yield compared to the gasoline fuelling variant. This allowed that, in case of an equal volume of mixture allowed inside the cylinder (the same position of the shutter) and having a lower calorific value (poorer mixture) to obtain the quasi constant maintenance of the power.

- We noticed the same general trends to reduce the emissions of CO and HC and increase the emissions of NO (Figures 6 and 7).
Figure 6. The exhaust gases composition at the load of 25% and speed of 1600 rev/min

Figure 7. The exhaust gases composition at the load of 25% and speed of 3500 rev/min

As final conclusions, we can say:
- This experimental study showed that by a simple transformation of a classic “Dacia 1300” engine, consisting of a minimum adaptation of the carburettor and installation of an appropriate fuelling equipment, we can provide the engine operation with LPG in advantageous conditions, even if the standard power and torque performances have suffered, especially at high speeds and loads;
- There has been an improvement in the effective yield by increasing the specified yield, for the entire range of engine operation regimes;
- The CO and HC emissions have been reduced, but this entailed the disadvantage of significant increase of NO emissions;
- The experimental study focused on highlighting the possibilities offered by the use of LPG to an engine that was designed to be fuelled with gasoline and has to maintain its operating capacity;
- Finally, the „bi-fuel” operation of an engine is also justified by the lower price of LPG compared to gasoline.
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