Thesis Summary:

CONTRIBUTIONS TO CONTROL AND DIRECTION THE BURNING IN PETROL AND LPG INJECTION COMBUSTION ENGINE TO REDUCE POLLUTANT EMISSIONS

Author: **eng STOICAN Marius,**
Scientific supervisor: **prof. PhD. eng. BICĂ Marin**

Road transportation made by vehicles equipped with internal combustion engines, have a significant contribution to environment pollution practically affecting all ecosystems: air, water, soil and natural landscapes beginning with extraction of ore and construction materials, continuing with road construction and vehicles, appearance of pollutant emissions made by internal combustion engine, noise pollution and finishing with problem of storage of vehicles and their components.

Most dangerous effects of pollutants from internal combustion engines occur on atmosphere by the emission of harmful gasses. All this pollutant emissions affecting human health, epidemiological tests showing a higher frequency of lung cancer in exposes professional's branches to the exhaust gas inhalation, carcinogenic effects, contributing in emergence of greenhouse effect, photochemical smog, acid rains.

So, limitation of pollutant emissions made by internal combustion engines is imperative necessary, being regulated by increasingly severe legislation with direction in proper sealing of fuel reservoir, crankcase gases aspiration, intervention on exhaust gasses, this means control in exhaust genesis and also exhaust after treatment with catalytic convector systems.

Thus, reducing pollutants in exhaust emissions of internal combustion engines must be in constant attention of manufacturers and legislators to ensure that the environment in which we live is a healthy and remain clean for future generations.

The paper is structured in seven chapters presented below.

In first chapter **Introduction** is an overview of principal pollutants made in internal combustion engines and presentation of their formation.

The second chapter **Assisting the engine computer to reduce pollutants** is intended to showing of how the computer manages all engine parameters in order to maintain low fuel consumption and emission levels are within the limits imposed by regulations. Is presenting a pollution control system, control the "closed loop" operation of computer and presentation of the main emission reduction systems controlled by computer: EGR system, evaporative emissions system, treatment system of burned gas, variable distribution, variable inlet, variable compression ratio, combustion of stratified mixtures, cylinder deactivation, overeating, on-board diagnostic system.

In Chapter Three **Methodology, test stands** are data acquisition system and equipment used to develop this paper and test standards. All the tests were performed at the Technical Center of Daewoo Automotive Romania in Engine Test laboratory and Emission laboratory. Equipment used were: brake cell that is a three-phase asynchronous machine, IRIS-three-phase step by step converter, step by step inverter in the engine test cell, flue gas analyzers with the possibility of to measure hydrocarbons, nitrogen oxides, carbon monoxide and carbon dioxide and Chassis Dynamometer to simulate resistance to forward the car, gas equipment were tested for motor vehicles, for Cielo was used Lovato gas installation and for Matiz and Nubira sequential BRC gas installation.

Chapter four **Methods of research and experimental data processing** presents steps and objectives in this thesis.

As milestones in the development of this paper we mention:

1. Emission tests with vehicles operating on petrol, respectively LPG to highlight the benefits of using LPG installations;
2. Emission tests with vehicles operating on LPG with different types of LPG installation;
3. Emissions on chassis dynamometer tests with the original calibration parameters for operation on LPG;
4. Chassis dynamometer emissions tests after gas ECM calibration and choosing optimal solution;
5. Tests to determine operating power to the wheel of motor vehicles with gasoline, respectively LPG to highlight the fact that use of LPG as fuel engine does not diminish performance;
6. Conclusions.

To better highlight the effects it has LPG on emissions and fuel consumption, we performed measurements on a Daewoo Matiz car equipped with spark ignition engine and a sequential gas installation on the chassis dynamometer and emissions measurement bench.

We conducted two sets of measurements: first with the engine operating on petrol and second engine operating on LPG, tests performed on one test cycle in accordance with Euro IV standards, namely four urban cycles with maximum speed of 50 km/h and an extra urban cycle with maximum speed of 120 km/h, according to Regulation 83, Test Type I.

A range of parameters can be modified for the engine to operate closer to the driver requirements, so when you want a sharp acceleration, gas computer can be set so that the nozzle opening during that time to be greater, or on the contrary, when decelerates, injectors can be disabled, thus greatly improving fuel consumption and thus pollutant emissions will be lower.

We extracted a set of data at different time in cycles to perform an analysis as relevant in terms of emissions level for the two fuels, namely:

A) - after four urban cycles we have extracted values after each cycle to highlight the high level of emissions from cold engine operation.

B) - in different operating regimes of urban cycle (idling, acceleration, constant running, deceleration and total);

C) - after four urban cycles we extracted the average urban emissions in the urban cycle;

D) - after extra-urban cycle we measured emissions for their comparison in extra-urban cycle;
E) - in different operating regimes of extra-urban cycle (idling, acceleration, constant running, deceleration and total);
F) - after all cycle test to compare overall emissions.

To highlight the benefits of using LPG in spark ignition engines, I made a series of emission tests in accordance with the type I test on several types of Euro 3 engines operating with petrol (Matiz, Cielo and Nubira) and also with LPG. During tests were pursued CO_2 emissions in different operating regimes (urban and extra-urban cycle) to reflect the level of emissions.

The first two cars have engines with multipoint fuel injection system, EGR, and the last is also variable geometry inlet two camshafts and, respectively, four valves per cylinder. Also, first and last vehicles are fitted with sequential gas installation and the second has gas installation with air mixing via air intake into the cylinders.

Following the data, we can draw several conclusions:

- for Matiz in urban cycles, the reduction of CO_2 emissions is 15,6%, and in extra-urban cycle 9,4%;
- for Cielo the reduction of CO_2 emission in urban cycles is 3,9% and in extra-urban cycle is 9,4%;
- for Nubira the reduction of CO_2 emissions in urban cycles is 15,6% and in extra-urban cycle is 21,2%;
- is observed that vehicles fitted with sequential gas installation reduction of CO_2 is more important because dosing of the gas is more accurate.

Chapter five **Experimental research** deals how to calibrate the computer to get gas emission levels as low as possible. This process is very complex and must be done with attention and following all strict steps. Otherwise, the engine will work irregular fault indicator will illuminate on board, or the engine will not work.

Calibration begins with one step of self-calibration that is the process necessary to get the maps needed to run the car on LPG. Such maps transforms petrol injector signal in corresponding signals for the gas injectors.

Self-calibration is acquisition of information in the following three points of vehicle operation, first with petrol and then with gas:

- idle;
- idle with load;
- acceleration without load.

After calibration we can make a series of calibrations of the map with two cursors: one for idle and one for acceleration regime. These cursors are similar with adjustment screws on traditional systems.

With this map saved, we performed an emissions test on the chassis dynamometer with Matiz car running on LPG to observe the emission (figure 1). The test was done to highlight peaks to know in what circumstances can intervene in computer gas calibration to obtain an emission level as low as possible. Interventions can be made in map RPM/MAP, namely speed/load map saved in self-calibration phase.

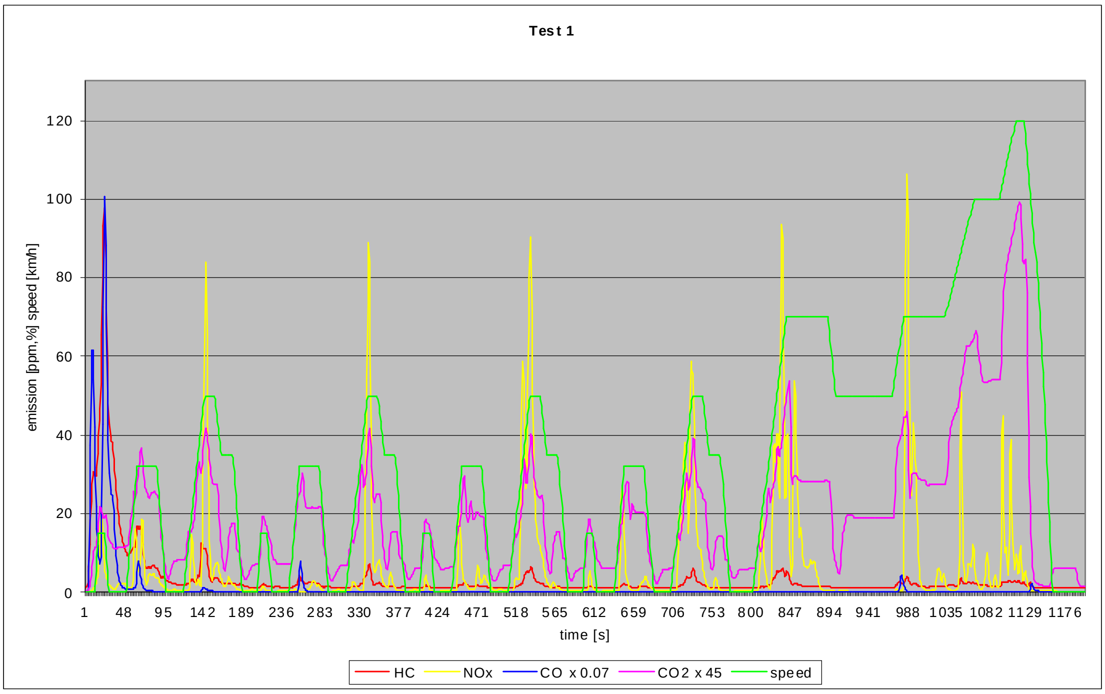

Figure 1. Pollutant emission for the first test

The injection gasoline time (petrol injectors opening signals from ECM petrol are passed through the gas computer) is amplified by a factor calibrated K (map values depending on speed and load), thus resulting gas injection time.

Sensor signal $O_{2\ rough}$ ⟶ ECU processing (K factor) ⟶ sensor signal O_2

In chapter six **Research results** we analyze resulting graph with emissions, we can intervene by modifying the K factor at points where emissions are high. For example, where nitrogen oxide emissions are high, means that the fuel mixture is lean and K factor must take positive values (e.g. 2%), as petrol computer receives a signal from the lambda sensor that the mixture is poor and increases injection time to enrich the mixture. K-factor can not vary very much because as we know measures to reduce pollutant emissions are antagonistic for reducing a pollutant emissions, another pollutant emissions increases.

ENGINE :TURNED ON CHANGEOVER SWITCH :GAS
IGNITION KEY :ON VEHICLE :INDIFFERENT

R.P.M. :3165 M.A.P. :645

	125	175	215	245	280	325	375	425	475	525	575	650	750	850	915	965
300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
650	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
750	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	+5	0	0	+2	0	-2	0	-5	0	+6	0	0	-3	0	+6	0
1150	0	0	+3	0	0	0	0	0	0	0	0	0	0	0	0	+3
1400	0	0	0	+5	0	+6	0	-2	0	-3	0	+5	0	0	-5	0
1650	+4	-5	0	0	0	0	0	0	-5	0	0	0	-2	0	0	0
1950	0	0	+3	0	0	0	+5	-2	0	0	+2	0	0	+5	-2	0
2300	0	-2	0	-3	+3	0	0	0	0	-5	0	0	0	0	0	0
2750	0	0	-5	0	0	+2	0	0	-2	0	0	0	-3	0	0	-5
3250	0	-3	0	0	0	0	-3	-6	0	0	0	+5	0	0	+3	0
3750	+6	0	0	+5	0	-5	0	0	0	-2	0	0	-4	0	0	0
4500	0	0	+4	0	0	0	0	0	*5	0	0	0	0	+3	0	0
5500	0	+5	+2	0	+6	0	-3	0	0	+2	-5	0	0	0	-2	0
6250	0	0	0	0	0	0	0	-2	0	0	0	0	-2	-5	0	+5

Communication : OK

Figure 2. Speed/load map

K factor was modified also for another intervals, where was observed a high level of emissions in idea of not so large number of tests for each interval separately. To this end we conducted a total of seven emissions tests on chassis dynamometer. In table 1 I centralized emission values on all seven tests to choose the lowest emissions test and to retain the settings from that test.

Table 1.

Emission [g/km]	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7
HC	0.073	0.083	0.072	0.070	0.078	0.067	0.075
NO_x	0.187	0.056	0.039	0.021	0.051	0.047	0.047
CO	0.311	0.817	0.344	0.343	0.305	0.255	0.286
CO_2	125.471	129.860	127.896	129.442	128.796	130.546	131.724

It is difficult to choose the car with the lowest emissions level, given that not all exhaust components have a low level in the same vehicle. This is because the nature of forming of these components. If we try to diminish one component e.g. nitrogen oxides, we have an increase in other components: hydrocarbons, carbon monoxide, carbon dioxide, and with all components will be the same as emission reduction measures are antagonistic.

Might be a hierarchy if we know that a certain component of the exhaust is less harmful.

Which of these emissions are more important? The answer is hard to find. Especially since it's hard to say which more important criterion is.

If the criterion of "human health" is considered to be the dominant criterion, then again, we can not say which one is more harmful pollutant emissions, due to lack of biologically plausible link between cause and effect, failure that persist despite the many studies performed. Assuming that this criterion is most important, have been a number of reasons for ranking of pollutants according to their harmful effect on humans and the environment.

If the dominant criterion, for example, carbon deposit on the building, then we can say that the engines with higher carbon emissions (CO, HC) are the largest source of black smoke emissions in cities.

If the dominant criterion would be reduce of greenhouse compounds, then engines with lower carbon dioxide emissions will be approved. Given that in 2012 authorities try to reduce carbon dioxide emissions from cars to 120g/km, then the settings made for first test are most advantageous.

Analyzing emissions table for all tests, we decided that the test with the number six we made the most advantageous calibration of gas computer in terms of emissions (figure 2) .

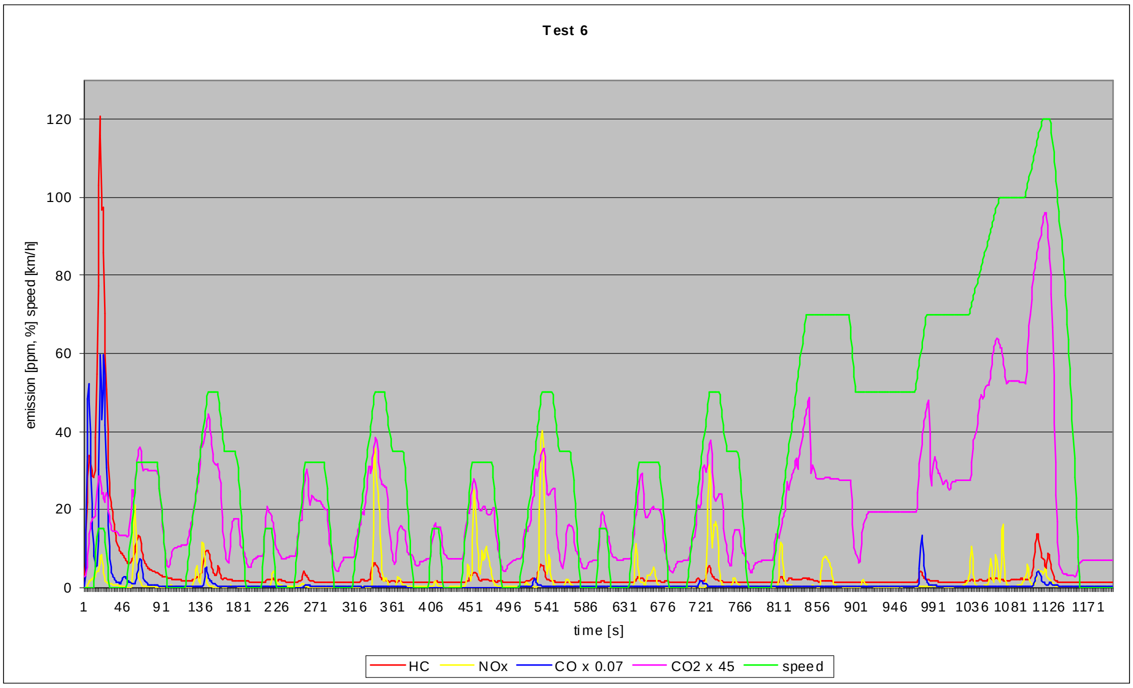

Figure 2. Pollutant emissions for six test

For a more complex picture of advantages and disadvantages of LPG use for direct injection gasoline engines, we conducted a series of chassis dynamometer tests, which can measure the power at the wheel of the car.

So we tested a Matiz car equipped with a 0.8 engine it has worked first with petrol and second with LPG with a gas sequential installation, measuring in both cases the power at the wheel. Norms (RNTR 6) require that the difference between the two modes does not exceed 10%.

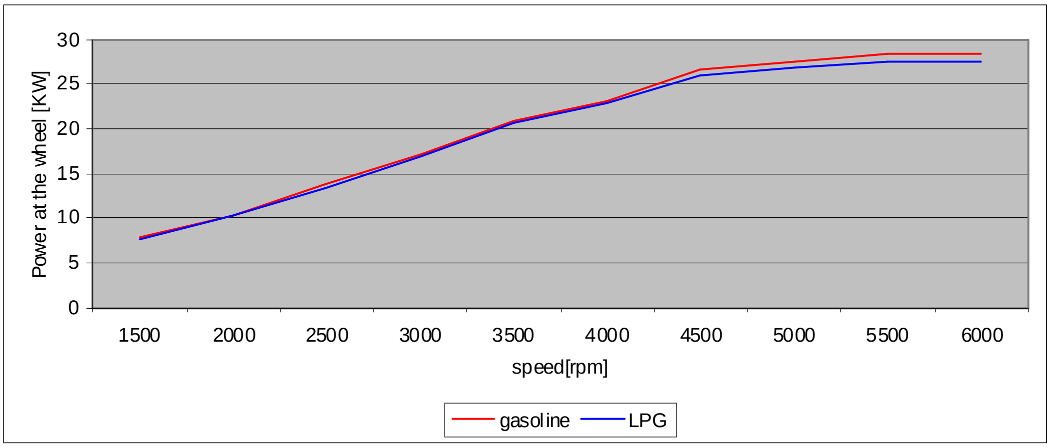

Figure 3. Power at the wheel for both working modes

In figure 3 we represented the power to the wheel depending on speed according to both modes. The difference between the power to the wheel for operation with gasoline and LPG respectively, are between 0.81 to 3.34%, as can be seen in the chart above. This difference is within the limits imposed by RNTR 6 i.e. 10%.

In chapter seven **Personal contributions** I presented the main personal contributions and general conclusion.