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GASOLINE AND LPG EXHAUST EMISSIONS COMPARISON

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Abstract:
The pollution of our planet is one of the major problems nowadays. European commission gave warnings to some EU countries, because they are not able to achieve goals for the greenhouse gas emissions reduction, to which they were obligated by signing the Kyoto protocol. The data for Slovenia shows, that the 2010 greenhouse gas emissions in comparison with year 1990 were increased for 4,7% instead of being reduced for 8%. 21% of all greenhouse gas emissions in EU are produced by traffic (without international air and sea traffic) and its shear is growing from year to year. Around 12% of emissions are produced by personal vehicles. EU gives away yearly subventions for the traffic in amount between 270 and 290 billion euros and almost half of that amount is intended for road traffic, which is one of the less appropriate ways of transport. One of the most appropriate solutions for the existing technology is conversion of vehicles to run on LPG. This paper presents comparative emission study of converted Otto engine with the high class LPG system.

Key Words: Emission, LPG Conversion, LPG Systems, Otto Engine, Bi-Fuel Engine

1. INTRODUCTION

We acquire LPG as a naturally occurring product of the natural gas extraction process or as an automatic result of the oil refining production process [1]. As a low carbon, low polluting fossil fuel, it is recognized by governments all around the world for the contribution, it can make towards improved indoor and outdoor air quality and reduced greenhouse gas emissions. LPG meets all four key objectives set by the EU in its guidelines for trans-European energy networks:

- security of supply - there is sufficient amount of LPG produced in Europe and other parts of the world,
- sustainable development - LPG is a potential answer to many sustainable development challenges,
- competitiveness - the European LPG industry is highly competitive, it constantly develops new services for domestic and commercial users and
- affordability for citizens - in most parts of Europe, LPG vehicles can be significantly cheaper to run than petrol or diesel models.

LPG is petroleum derived colourless gas, consists of propane or butane or from mixtures of both. In everyday usage different mixtures are used depending on the climatic nature of every region. Butane has higher caloric value, but in colder countries more propane must be used in mixture, because propane evaporates at lower temperatures. LPG has a high octane rating of 112 which enables higher compression ratios to be employed and hence gives higher thermal efficiency. All better conversation systems which are present in the market have low maintenance costs. Economic price, environmental friendly characteristics of LPG and increased engine life makes this derivate popular among the alternatives for gasoline fuel.

Characteristics of LPG:

- volume relative fuel consumption of LPG is about ninety percent in comparison with gasoline,
- LPG has higher octane number, about 112, which enables higher compression ratios to be employed and therefore gives more thermal efficiency,
- due to gaseous nature of LPG, fuel distribution in cylinders is improved and smoother acceleration and idling performance of engine is achieved,
- lifetime is increased for LPG engines, because cylinder bore wear is reduced and spark plug deposits are reduced. Lifetime of exhaust system is also increased,
- as LPG is stored under pressure, LPG tank is heavier and requires more space than comparable gasoline tank,
- there is a small reduction in maximum power output running on LPG than in gasoline operation.
- LPG system requires more safety features. In case of leakage, LPG has tendency to accumulate near ground; it is heavier than air,
- Volume consumption of LPG is higher by 15 to 20% in comparison to gasoline,
- LPG has lower carbon content than gasoline or diesel fuel and therefore produces less CO2 during combustion, which plays a major role in global warming and
- LPG powered vehicles have lower ozone forming potential and air toxic concentrations [2-5].

In present study water cooled, 4 cylinders Opel ECOTECH engine with the displacement of 1800 ccm was tested for emissions of pollutants CO, HC, CO2 and NOx. The car was converted with Landi Renzo LPG system, so it can run either on petrol or LPG. The tests were performed by the New European Driving Cycle or NEDC, which stand for a driving cycle consisting of four repeated ECE-15 driving cycles and an Extra-Urban driving cycle. The NEDC is supposed to represent the typical usage of a car in Europe.

2. INSTALLATION OF THE LPG SYSTEM

Serial conversations on LPG are made into petrol powered vehicles. Figure 1 shows car modifications and component locations after a LPG conversion (filling point, tank, ECU, injectors, reducer, pressure sensor and electronic switch). AT table.

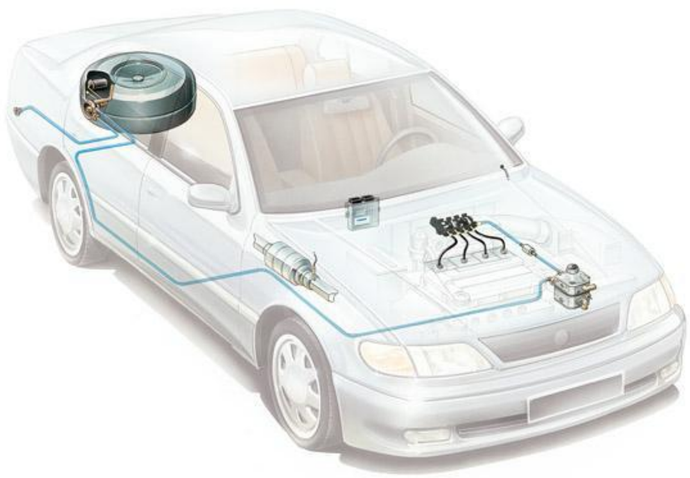

Figure 1: Component locations in LPG conversion.

Car's engine always starts-up on gasoline and then automatically switches to LPG, when all of the needed conditions are achieved:

- engine's water temperature, must have at least 40^oC,

- 25 seconds must pass from engine start in order to achieve working temperature of lambda.

Converted engine can be powered either with gasoline or LPG, fuel change can easily be made by using changeover switch. If the LPG system is switched on, priority of the LPG ECU is operating on LPG. If level in tank drops below the certain point and LPG pressure drops, gasoline fuel injection system is automatically switched back on. The tank installed in the back of the car contains liquid phase of LPG. Reducer or vaporizer (it vaporizes LPG coming from the tank and reduces its pressure) is heated by the engine's cooling water. Vaporized phase is supplied trough filter to injectors, which supply LPG to intake manifold of the engine. Inside the manifold it mixes with air and flows into combustion chamber. On the intake manifold there is a pressure sensor which measures manifold pressure and sends signal to LPG ECU. All of the LPG system's components are controlled by LPG ECU. It takes the injection data (start and duration of the injection for each cylinder) directly from the engine's original ECU, adapts them appropriately and send them to the LPG injectors. To achieve correct LPG quantities injected in every working point of the engine, several input data are considered: temperature of the reducer, temperature and pressure of the LPG, intake manifold pressure and engine's RPMs [6].

3. EMISSION MEASUREMENTS

Emission measurement was made in special laboratory (Figure 2 and Figure 3). It consists of emission equipment room, test cell and control room. Vehicle was mounted on rollers in test room with an exhaust and a cooling blower.

Figure 2: Emission testing laboratory.

Figure 3: Emission testing laboratory (second look).

The control room contains data acquisition system, drivers aid and dynamometer controller. They perform control functions. In the emission equipment room there is fuel line, oven and constant volume sampler. Oven has heating coil which is used to heat exhaust gas to around 80^0C. Special bags are used for collecting their samples, the Horiba analyzer measures and records pollutants emissions. For sampling and measuring particulate matter PM sampling system is used. The same tests are performed, if LPG system manufacturers are homologating their components for different car brands.

Analyzer simultaneously and continuously measures emissions of three pollutants, CO, HC and NO_x or CO_2, directly from vehicle exhaust. This system incorporates three specified NDIR analyzers and packaged sample handling system. These infrared analyzers perform micro controlled computer operations, signal processing and quadratic equation/least square linearization method for more precise data. It has a solid filter. Automatic calibration function is used in order to avoid otherwise very complicated calibration process. It has linear output for direct digital readout and large LED display. Dead time of measurements is reduced to less than two seconds.

Emissions were measured while the vehicle was on the chassis dynamometer. Total run time for the vehicle on dynamometer was 1.180 seconds with total distance covered around 11.000 kilometers. Driving cycle consists of running vehicle on urban cycle for 780 seconds and on extra urban cycle for 400 seconds – NEDC. The air temperature inside the cell was 23,7°C with the absolute humidity 9,00 g H_2O/kg air.

For the emission test procedure the following statements can be made:

- it was ensured that there is no leakage of exhaust gas,
- necessary connections of fuel, cooling water, and lubricating oil were made
- warming up of vehicle's engine and soaking was performed. Soaking lasts between 6 to 36 hours in the temperatures range of 20 to 300°C,
- following day vehicle was tested on chassis dynamometer,
- road-load equation was loaded on computer,
- vehicle was calibrated for bifurcation of losses,
- dynamometer was set on road-load simulation mode,

- test cycle duration was 1180 seconds [8] and
- readings were taken after completion of test from analyzer in PPM.

4. RESULTS

Example of one measuring protocol, vehicle information and LPG emissions results for Phase1 and Phase 2 are presented in Figure 3.

LANDIRENZO — Laboratorio Emissioni Veicoli

Test name:	09070904	Data test	09/07/2009
Test type:	EURO4	Start time	10:39
		End time	11:21

** TEST INFORMATION **

Test type	EURO4
Cella	Cel N.1
Project	
Test Order	
Requested by	AGNETTI
Driver	CROCIANO
Engineer	
Supervisor	

** FUEL **

Fuel type	LPG
Ethanol [%]	0.000
Density [kg/m3]	0.5380
MWA [Kg/kmol]	28.900
NHV	0.000
CWF	0.830
O/C ratio	0.000
H/C ratio	2.530

** VEHICLE INFORMATION **

Maker	OPEL	
Model	ZAFIRA	
Vehicle ID	ZAFIRA 1.8	
Licensed for traffic	tel. 2409	
Odometer	3523	
Injection system		
Fuel tank [l]	0	
Tyres maker	CONTINENTAL	
Tyres syze	225/45/R17	
Tyres press. [bar]	2.5	
Transmission	M 5	
Final ratio		
Engine / Type		
Engine [cc]	1800	
ECU nr.	0	
Calibration nr.	ZAFIRA	
Power [kW/RPM]	103	/ 6300
Oil Temp. [°C]	25	
Cond. Time [h]	12h	

** DYNO VALUES **

Inertia [kg]	1590.00
Coefficient A [N]	113.4000
Coefficient B [N/(km/h)]	0.2290
Coefficient C [N/(km/h) e2]	0.0366
Coefficient N	2.0000
Losses Coef. A [N]	0.0000
Losses Coef. B [N/(km/h)]	0.0000
Losses Coef. C [N/(km/h) e2]	0.0000

** GAS DENSITY [g/l at 0° C] **

CO	1.250
CO2	1.964
HC	0.649
CH4	1.857
NOX	2.050

** IDLE TEST **

CO	ppm	5.23
CO Corr	%	0.00
CO2	%	13.44
HC	ppm	0.53
CH4	ppm	3.54
NOX	ppm	2.21

** REMARKS **

TEST 2 OMOLOGAZIONE GPL B

RPM IDLE 785 GIRI

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LANDIRENZO — Laboratorio Emissioni Veicoli

Data test	09/07/2009	Test name	09070904
Start time	10:39	Test type	EURO4
End time	11:21		

** AMBIENT CONDITIONS **

Pressure	[mbar]	1017.5
Temperature	[°C]	23.7
Relative Humidity	[%]	49.6
Absolute Humidity	[gH2O/kgAir]	9.00
NOx Factor	[kH]	0.950

** TEST CONDITIONS **

		PHASE 1	PHASE 2	TOTAL
Distance	[km]	4.060	6.980	11.040
Durations	[s]	780	400	1180
Driver Violations	[s]	1.2	3.9	5.1
Diluition Factor		17.13	9.31	
CVS Volume at 0°C	[l]	71292	36277	107570
Fuel Economy	[l/100km]	13.67	7.73	9.91
Venturi	[#]	1	1	

** ANALISYS **

PHASE 1		CO	HC	NOx	CO2	HC+NOx	CH4
Sample	[ppm]	51.990	7.390	2.730	6873		0.000
Ambient	[ppm]	1.120	2.990	0.150	529		0.000
Correct	[ppm]	50.935	4.575	2.589	6374		0.000
g phase		4.540	0.630	0.360	893	0.990	0.000
g / km		1.118	0.155	0.089	219.8	0.244	0.000
PHASE 2							
Sample	[ppm]	10.200	2.560	2.040	12769		0.000
Ambient	[ppm]	1.060	2.730	0.160	526		0.000
Correct	[ppm]	9.254	0.123	1.897	12299		0.000
g phase		0.420	0.009	0.130	876	0.139	0.000
g / km		0.060	0.001	0.019	125.5	0.020	0.000

** TOTAL **

	CO	HC	NOx	CO2	HC+NOx	CH4
g / test	4.960	0.639	0.490	1769	1.129	0.000
g / km	0.449	0.058	0.044	160.2	0.102	0.000
g / km x DF	0.539	0.069	0.053		0.123	0.000
Det Factor DF	1.20	1.20	1.20		1.20	1.20
Limit [g/km]	1.000	0.100	0.080		0.000	0.000
% Of Limit	54	69	67		0	0

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Figure 3: Measuring protocol, vehicle information and LPG emissions results.

Following pictures are presenting comparison of pollutants CO, HC, CO_2 and NO_x in exhaust gases for petrol and LPG usage.

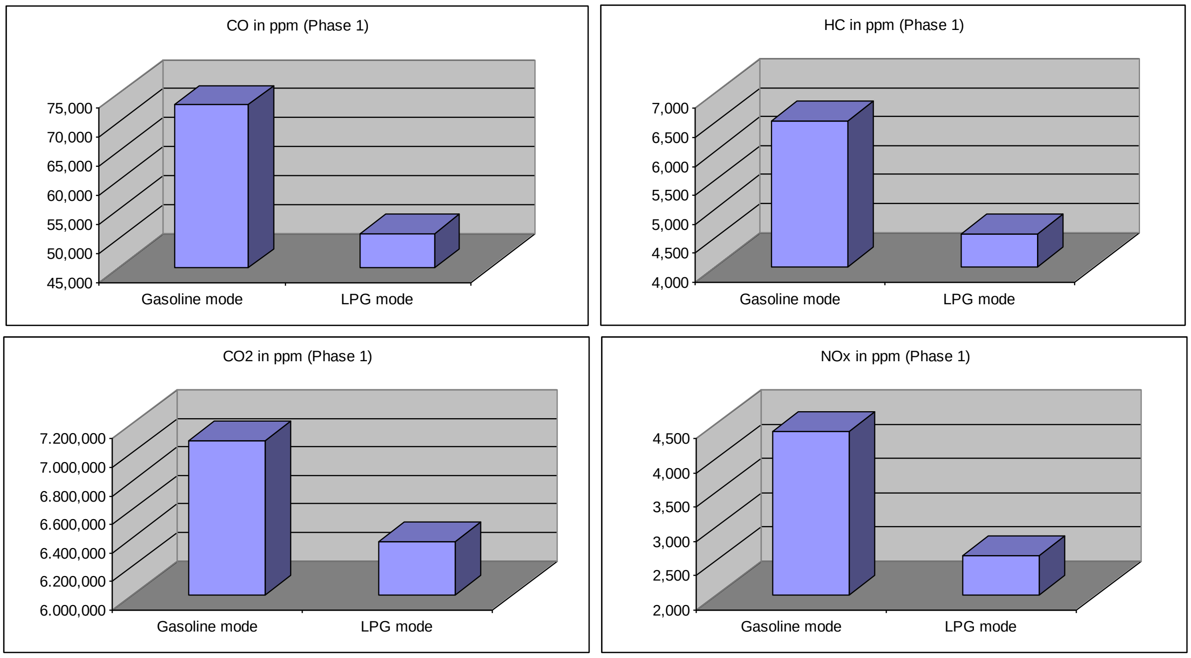

Figure 4: Emission comparison between gasoline and LPG mode in urban cycle (Phase1).

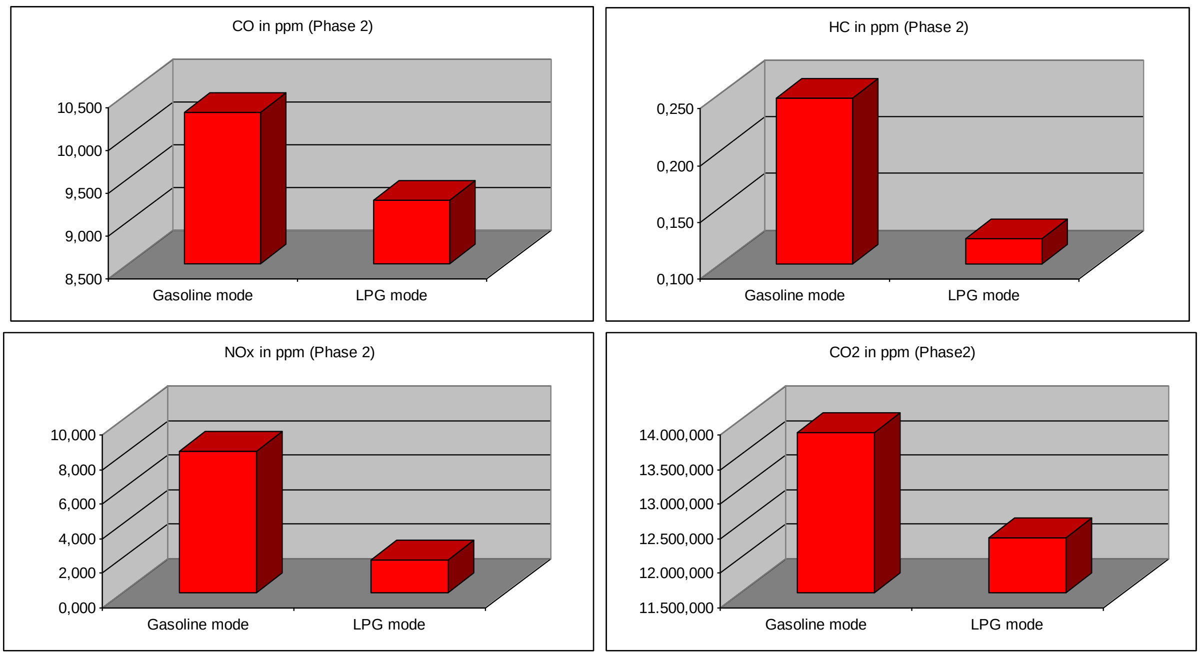

Figure 5: Emission comparison between gasoline and LPG mode in extra urban cycle (Phase2).

5. CONCLUSIONS

The diagrams in Figures 4 and 5 shows decrease of all emission in LPG mode for urban and extra urban cycle. By comparing emissions in the exhaust gasses of the same engine powered by LPG and petrol, pollutants in LPG mode are reduced for:

- CO by 30% in urban cycle and by 10% in extra urban cycle,
- HC by 30% in urban cycle and by 51% in extra urban cycle,
- NOx by 41% in urban cycle and by 77% in extra urban cycle and
- CO2 by 10% in urban cycle and by 11% in extra urban cycle.

If we predict, that 12% of all emissions are produced by personal vehicles, we can easily calculate reduction of all emissions, if LPG was used as the primary derivate for driving. Based on the emission results it can be said, that the LPG represents a good fuel alternative for gasoline and therefore it must be taken into consideration in the future of personal transport.

6. DISCUSSION

Using gained data simple calculation was done. In this analysis we drop an eye just on Slovenian region, therefore the following statements can be made:

- in year 2009 there were 1.050.000 registered cars in Slovenia,
- 75% of them or 787.500 cars were powered by Otto engine and almost all of them are appropriate for conversation to LPG and
- ordinary Slovenian makes on average 20.000 km every year, on average around 30 % of total mileage is made in urban cycle and 70 % in extra urban cycle.

If all of the 787.500 appropriate cars were converted to LPG and drivers would use only LPG, every year we could assume following emission decrease:

- 2.368 tons of CO,
- 324 tons of HC,
- 993 tons of NOx and
- 287.018 tons of CO2.

Just for the comparison, in the year 2008 TEŠ produced 1.489 tons of CO for production of 5.900 GWh of electric energy. With driving with all Slovenians cars on LPG we would decrease the CO pollution for double that amount.

ABBREVIATIONS

EU	European Union
ECU	Electronic Control Unit
LPG	Liquefied Petroleum Gas
NEDC	New European Driving Cycle
CO	Carbon Monoxide
HC	Hydro Carbon
NO_x	Oxides of nitrogen
CO_2	Carbon dioxide
H_2O	Water
PPM	Parts per million
RON	Research octane number
MAP	Manifold absolute pressure
O_2	Oxygen
TEŠ	Thermal Power Plant Šoštanj

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