Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 14th International Scientific and Practical Conference. Volume 3, 20-23

Experimental Study of Toxic Components in the Exhaust Gases During the Operation of a Car Engine with Gasoline and LPG

Krasimir Ambarev
Department of Transport and Aviation Equipment and Technologies, Technical University of Sofia, Plovdiv Branch 25 Tsanko Dyustabanov str., 4000 Plovdiv, Bulgaria
E-mail: kambarev@tu-plovdiv.bg

Valyo Nikolov
Department of Transport and Aviation Equipment and Technologies, Technical University of Sofia, Plovdiv Branch
25 Tsanko Dyustabanov str., 4000 Plovdiv, Bulgaria
E-mail: vnikolov@tu-plovdiv.bg

Abstract. **The article presents and analyzes the results obtained from an experimental study of the content of toxic components in the exhaust gases during the operation of a car engine with gasoline and liquefied petroleum gas (LPG). The study was conducted in laboratory conditions by loading the driving wheels with a roller-type chassis dynamometer, corresponding to the established movement of the car with constant speed on a horizontal road section.**

Keywords: Car, Engine, Exhaust Gases, Experimental Study, Gasoline, LPG and Toxic Components.

I. INTRODUCTION

Environmental pollution has been one of the current topics in recent decades. The road transport is one of the main polluters. The exhaust gases of internal combustion engines contain a large number of chemical compounds, the concentration of which varies depending on the type of fuel used and the nature of the combustion process [1], [2], [3], [4]. The nature of the combustion process in turn depends on the technical condition of the internal combustion engine and its mode of operation. This article aims to study the concentration of certain toxic components (CO, CO_2, CH) at different car speeds and assess the pollution levels in established modes of car motion, such as constant speed driving. For this purpose, the movement of the car is simulated in laboratory conditions using a chassis dynamometer. A resistance force is created of the driving wheels, which depends on the speed of the car. A gas analyzer was used to measure the content of harmful components in the exhaust gases. The experimental study was performed on a Honda Civic Aerodeck, with engine displacement - 1500 cm^3, rated power of 84 kW/6500 min^{-1} and meeting the environmental standard Euro 2. The car was equipped with a three-way catalytic converter with a mileage of approximately 430,000 km at the time of the experiment, and also a new catalytic converter, produced by BM Catalysts – UK. It had a car gas system (CGS) as well, installed with an LPG electronic control unit, made by the company STAG, model STAG 300 ISA2. The multiplier map for the gas ECU was done manually, not by the automatic determination algorithm.

II. MEANS FOR MEASURING AND METHODS

The roller-type chassis dynamometer used in the experiment was a the Dyno Cosber 4000. The dynamometer offers various features, including "Road simulation". Before starting the "Road simulation" mode, the car's data is entered into the system, such as vehicle's mass, rim and tire parameters, tire type, transmission type, speed/engine rpm ratio, drag coefficient, projected frontal area of the vehicle, slope angle of the road, etc., were entered into the system The software then calculated the value of the total resistance force at the respective speed, and the chassis dynamometer loaded the driving wheels accordingly. The driving wheels of the tested car are on the front axle.

The Dyno Cosber 4000 is equipped with a digital O_2 sensor controller LC-2, made by Innovate Motorsports and a wideband lambda sensor Bosch LSU 4.9. This sensor is specifically designed to measure the proportion of oxygen in the exhaust gases of various types of

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2023vol3.7304

automotive engines, including those, powered by gasoline, LPG, or diesel fuel. The wideband lambda sensor LSU 4.9 is a planar ZrO_2 dual-cell limiting current sensor with an integrated heater in it [5].

Fig. 1. Chassis dynamometer DynoCosber 4000 [6].

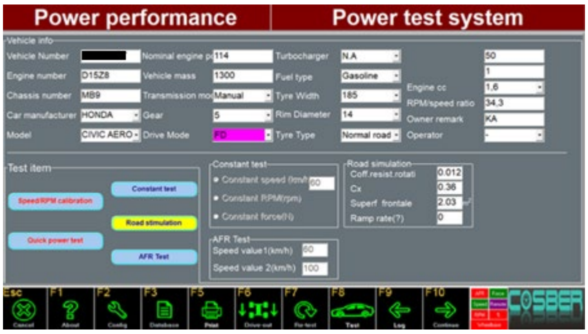

Fig. 2. Window with the technical data of the tested car [8].

TABLE 1 TECHNICAL SPECIFICATION OF A CHASSIS DYNAMOMETER

Parameter	Unit
Max. absorption power	883 kW
Max. torque	2350 Nm
Max. speed	250 km/h
Max. axle weight	2000 kg x 2
Max. continual loading time	15 min
Roller axle separation	430 mm
Roller length	860 mm
Roller diameter	216 mm
Wheel base ajustment	2180-3380 mm
Air/Fuel ratio for gazoline (λ)	7.35-22.39 (0.5 - 1.5)

The Dyno Cosber 4000 offers a precise simulation of defined road load conditions, enabling measurements of fuel consumption and exhaust analysis. When operating in the "Road simulation" mode with a constant speed, the PID (proportional integral derivative) controler and the power absorbing unit adjust the engine load to simulate normal road driving, accounting for a number of factors, such as slope angle, rolling resistance, and air resistance. Rolling resistance power results from the tire and road surface deformation as a function of speed, while air resistance power is proportional to the vehicle's frontal surface area and air resistance coefficient. In a “Road simulation” mode at a constant speed, the inertial drag power is zero.

Fig. 3. Gas analyzer DEK DG-04IR.

TABLE 2 TECHNICAL SPECIFICATION OF A GAS ANALYZER

Compo-nent	Measurement range	Measuring accuracy
CO	0 to 15% vol.	±0.02% vol. ±3%
CO_2	от 0 to 20% vol.	±0.3% vol. ±3%
HC	0 to 15000 ppm vol. n-hexane	propane - ±8ppm vol. ±3%
O_2(*)	0 to 25% vol.	±0.1% vol. ±5%

A DEK gas analyzer, model DEK DG-04IR [7], was used to measure the content of harmful components in the exhaust gases. The gas analyzer has a certificate for an approved type BG 04 No. 4245 of a measuring device from the State Agency for Metrological and Technical Supervision. It measures the CO, CO_2 and HC content of the exhaust gases. The content of CO, CO_2 is in %, and of HC - in ppm. The DEK gas analyzer has a clamp for measurement of the engine's rpm and a sensor for measuring the an engine's oil temperature. A screen from the gas analyzer software is shown in fig. 4. Before starting the measurement, the type of the engine's fuel must be selected - gasoline (BENZIN in gas analyzer’s software) or LPG.

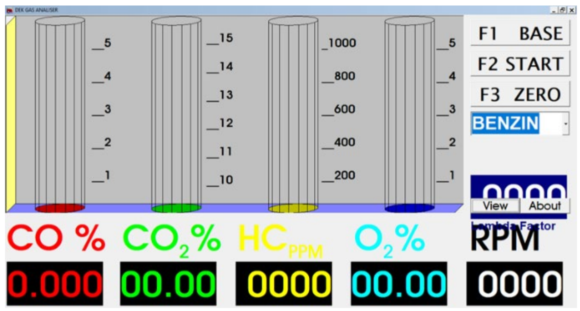

Fig. 4. Full screen mode of the DEK DG-04IR gas analyzer software.

III. Results and Discussion

The measurements were performed in laboratory conditions - fig. 5 and 6.

To ensure comparability of the results, the measurements for both fuels were performed at:

- the same adjusment of valve clearance (according to the prescriptions of the manufacturer);
- the same ignition timing setting (according to the prescriptions of the manufacturer);
- established engine temperature condition (constant coolant temperature) of the engine;
- the same atmospheric conditions (measurements conducted within a few hours).

Fig. 5. Measurement of the content of toxic components in the exhaust gases.

Fig. 6. Data from the software of Dyno Cosber 4000 and the gas analyzer, used in the experimental study.

During the measurements, the car was set at its 5th gear.

The measurements were carried out at an established speed of the vehicle. The selected speed values were respectively 50, 70, 90, 110, 120, 130 and 140 km/h. The obtained results are presented graphically in Figures 7, 8 and 9.

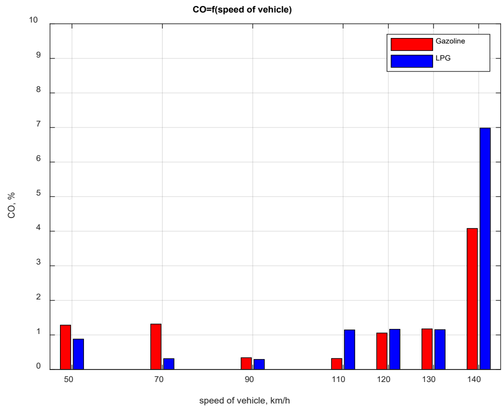

Fig. 7. Experimental study of the content of CO, [%] in the exhaust gases of a car Honda Civic Aerodeck 1.5 iLS.

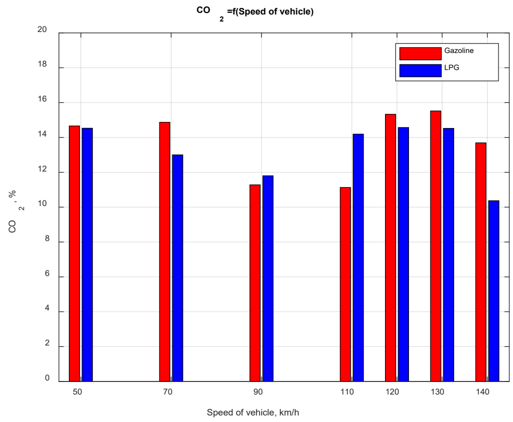

Fig. 8. Experimental study of the content of CO_2, [%] in the exhaust gases of a car Honda Civic Aerodeck 1.5 iLS.

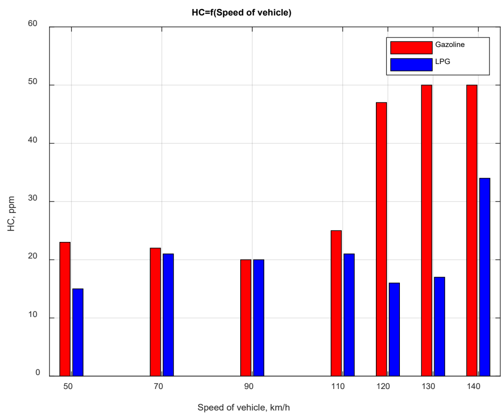

Fig. 9. Experimental study of the content of CH, [ppm] in the exhaust gases of a car Honda Civic Aerodeck 1.5 iLS.

The measurements of the air/fuel ratio (AFR) and λ are presented as shown by the Dyno Cosber 4000 software.

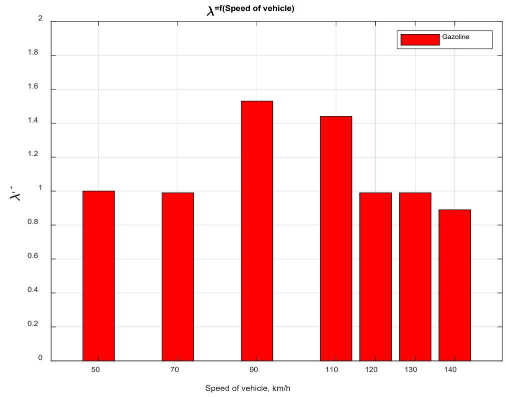

Fig. 10. Experimental study of the content of λ in the exhaust gases of a car Honda Civic Aerodeck 1.5 iLS.

The content of carbon monoxide depends mostly on the value of the air/fuel ratio. The content of hydrocarbons in the exhaust gases depends on both the value of the AFR and the ignition advance angle.

Figure 7 shows that the highest values of carbon monoxide in the exhaust gases are observed when the car motion speed is 140 km/h. In this case λ=0,89 (when the engine operates on gasoline). When the engine runs on gasoline, the value of carbon oxides is 41,59% lower than when it works on LPG. The lowest values of carbon monoxide in the exhaust gases are registered at a car motion speed of 90 km/h.

Figure 8 indicates that the highest values of CO_2 in the exhaust gases when the engine runs on gasoline or LPG are observed at the car motion speed of 130 km/h, and the lowest values are registered when the car motion speed is 90 km/h. There are no big differences in the measured value of carbon dioxide at different vehicle speeds.

Figure 9 illustrates that the highest values of hydrocarbons in the exhaust gases are reached when the car motion speed is 140 km/h. In this case λ=0,89 (when the engine runs on gasoline). When the engine operates on LPG at a vehicle speed of 140 km/h, the value of hydrocarbons is 32% lower than when it runs on gasoline. The lowest values of hydrocarbons in the exhaust gases are observed at a car motion speed of 90 km/h.

In general, the nature of the change in the content of harmful components in the exhaust gases at different car speeds follows almost a similar pattern. The observed differences are due to a suboptimal multiplier map for the gas ECU.

IV. Conclusions

From the study of toxic components in the exhaust gases, the following conclusions and suggestions could be pointed out:

1. When driving at a constant speed and the engine is running in the mode “lean burn control“ i.e. $\lambda>1$, the amount of measured harmful components in the exhaust gases is lower. The most significant difference is observed for carbon monoxide.

2. During the operation of a car engine at a constant rpm (constant car speed) with a LPG the amount of hydrocarbons in the exhaust gases is lower than it is when working with gasoline.

3. The use of an additional device to control the ignition advance angle when the engine runs on LPG will lead to lower CO values and thus improve the environmental performance of the engine.

4. For more accurate determination of fuel-air mixtures when the engine is runs on LPG, it may be recommended to use an LPG electronic control unit, which has communication on the diagnostic socket via the appropriate diagnostic communication protocol.

Acknowledgments

This work was supported by the European Regional Development Fund within the OP “Science and Education for Smart Growth 2014 - 2020”, Project Competence Centre “Smart Mechatronic, Eco- And Energy Saving Systems and Technologies“, № BG05M2OP001-1.002-0023.

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