

LPG AS A FUEL FOR DIESEL ENGINES- EXPERIMENTAL INVESTIGATIONS

Nikolaos Cristian Nutu¹, Constantin Pana², Nicolae Negurescu³, Alexandru Cernat⁴ and Ionel Mirica⁵

¹Lecturer, Rutier Vehicles Department, University Politehnica of Bucharest, Romania

²Professor, Thermotechnics, Thermal Engines and Equipments, Refrigeration Instalations Department, University Politehnica of Bucharest, Romania

³Professor, Thermotechnics, Thermal Engines and Equipments, Refrigeration Instalations Department, University Politehnica of Bucharest, Romania

⁴Lecturer, Thermotechnics, Thermal Engines and Equipments, Refrigeration Instalations Department, University Politehnica of Bucharest, Romania

⁵PhD Student, Thermotechnics, Thermal Engines and Equipments, Refrigeration Instalations Department, University Politehnica of Bucharest, Romania

e-mail: cristi_cmt@yahoo.com

Abstract. The main objective of the paper is to reduce the pollutant emissions of a compression ignition engine, fuelling the engine with liquefied petroleum gas (LPG), aiming to maintain the energetic performances of the engine. To optimise the engine operation a correlation between the substitute ratio of the diesel fuel with LPG and the adjustments for the investigated regimens must be made in order to limit the maximum pressure and smoke level, knock and rough engine functioning, fuel consumption and the level of the pollutant emissions.

The test bed situated in the Thermotechnics, Engines, Thermal Equipments and Refrigeration Instalations Department was adapted to be fuelled with liquefied petroleum gas. A conventional LPG fuelling instalation was adopted, consisting of a LPG tank, a vaporiser, connections between the tank and the vaporiser and a valve to adjust the gaseous fuel flow. Using the diesel-gas method, in the intake manifold of the engine is injected LPG in gaseous aggregation state and the air-LPG homogeneous mixture is ignited from the flame appeared in the diesel fuel sprays. To maintain the engine power at the same level like in the standard case of fuelling only with diesel fuel, for each investigated operate regimen the diesel fuel dose was reduced, being energetically substituted with LPG. The engine used for experimental investigations is a turbocharged truck diesel engine with a 10.34 dm³ displacement. The investigated working regimen was 40% load and 1750 rpm and the energetic substitute ratios of the diesel fuel with LPG was situated between [0-25%].



1. INTRODUCTION

Liquefied petroleum gas is usually a mixture of two hydrocarbons, propane and butane, in different ratios depending on season. Because of its good burning properties and price liquefied petroleum gas is a very good choice to fuel a diesel engine.

Several liquefied petroleum gas properties are presented in the table 1, compared with the diesel fuel properties.

Table 1. Liquefied petroleum gas properties, comparative with diesel fuel properties [1].

Properties	Diesel fuel	Propane	Butane
Density [kg/m ³]	800-840	503	500
Self-ignition [°C]	355	481	544
Stoichiometric A/F ratio [kg/kg]	15	15.71	15.49
Lower heating value [MJ/kg]	42.5	46.34	45.55
Cetane number	40-55	-2	-2
Flame temperature	2054	1900	-

The density of liquid LPG is lower, 503 kg/m³ for LPG and 800-840 kg/m³ for diesel fuel [1], leading to a lower fuel autonomy.

LPG needs a lower quantity of heat to vaporise 420 kJ/kg to 465 kJ/kg for diesel fuel [1], allowing to consume less local heat.

The LPG self-ignition temperature is higher than the diesel fuel self-ignition temperature, 481 °C – propane, 544 °C – butane, 355 °C diesel fuel [1] and this combined with a very low cetane number gives LPG very poor self-ignition properties. Therefore, fuelling a diesel engine with LPG requires the use of specific methods.

The flame temperature of LPG lower than the diesel fuel flame temperature leads to an important reduction in nitrogen oxides emissions level.

The higher LPG lower heating value leads to an increase in the amount of heat released during combustion for the same fuel quantity.

Fuelling a diesel engine with LPG require specific methods. In this paper, the authors chose the Diesel-Gas method, which consists of gaseous LPG injection in the intake manifold of the engine.

The diesel gas method has been applied by Tariq Miqdam in [2] with good results as far as the brake specific energetic consumption and pollutant emissions are concerned. In the paper [3] the author fuelled with LPG a car diesel engine, experiments leading in a reduction of the vehicle operating price. Qi et. al. in the work [4] experimented the direct injection of a LPG-diesel fuel mixture with different proportions: 0, 10, 20, 30, 40 %, leading to a decrease in the pollutant emissions of the engine. In [5] the authors decreased the level of the nitrogen oxides emission fuelling the diesel engine with LPG but the level of unburned hydrocarbons increased. The authors managed to reduce the unburned HC emission level using a glow plug [5]. A decrease of unburned hydrocarbons emissions level was achieved by Pali Rosha et al. in [6], by LPG fuelling a single cylinder diesel engine and using exhaust gas recirculation. The level of nitrogen oxides emissions and carbon dioxide emission decreased compared to standard diesel engine fuelling case, while emissions of unburned hydrocarbons and carbon monoxide increased, especially in the partial load regimens. In order to reduce these emissions, the authors used a percentage of 16% recycled exhaust gas. Another example of a liquefied petroleum gas diesel engine fuelling is presented in the paper [7]. The authors used liquefied petroleum gas injection into the intake manifold of the engine and rapeseed oil for the pilot injection. The maximum degree of

substitution used of rapeseed oil with LPG was 60 %, where the engine cyclic variability was within acceptable limits.

This paper presents results of experimental investigations carried out on a truck compression ignition engine fueled with liquefied petroleum gas using the diesel-gas method.

2. Experimental study

The experimental study was carried out on a compression ignition engine type Roman D2156 MTN 8, with 6 cylinders in line. The main specification and performances of the engine are presented in the table 2 [8].

The test bed consists of: the Roman D2156 MTN 8 diesel engine, Hofman eddy current dyno, AVL data acquisition system, Kistler piezoelectric pressure transducer, AVL Dicom 4000 gas analyser and opacimeter, Optimass massic fuel flow meter, Meriam volumic air flow meter, thermocouples and thermoresistances for temperature measuring, gravimetric system for diesel fuel consumption measuring, gas leak detector. All the equipments were calibrated prior to measurements. The investigated regimen was 40% load and 1750 rpm. The Diesel-Gas method consists in gaseous LPG injection in the intake manifold of the engine. Therefore, the homogeneous mixture of air-LPG is ignited by the flame which appears in the diesel fuel jet.

Table 2. Specifications and performances of the engine D 2156 MTN 8 [8].

Number of cylinders	6
Bore [mm]	121
Stroke [mm]	150
Displacement [L]	10.34
Compression ratio	17
Rated power [kW]	188
Maximum torque [Nm]	900
Admission type	turbocharged

First time was determined the reference, fuelling the engine only with diesel fuel, then the diesel fuel was partially substituted with liquefied petroleum gas, concerning to maintain the same engine power like in the standard case of fuelling with diesel fuel. Therefore, for each substitute ratio investigated, the diesel fuel cycle dose was reduced and the LPG cycle dose was increased. The energetic substitute ratio was calculated with the following relation:

$$X_c = \frac{m_{LPG} H_{i_{LPG}}}{m_{LPG} H_{i_{LPG}} + m_{dieselfuel} H_{i_{dieselfuel}}} \quad (1)$$

where: m_{LPG} - the LPG dose;

$m_{dieselfuel}$ -the diesel fuel dose;

H_i - the caloric heating value.

The investigated energetic substitute ratios of the diesel fuel with LPG was situated between [0-25] %.

3. Results and discussions

Because of the burning process intensification due to the presence of LPG-air mixture in the combustion chamber the in-cylinder pressure increased for all the investigated substitution ratios of diesel fuel with LPG. The measured in-cylinder pressure for the investigated cases is presented in the figure 1.

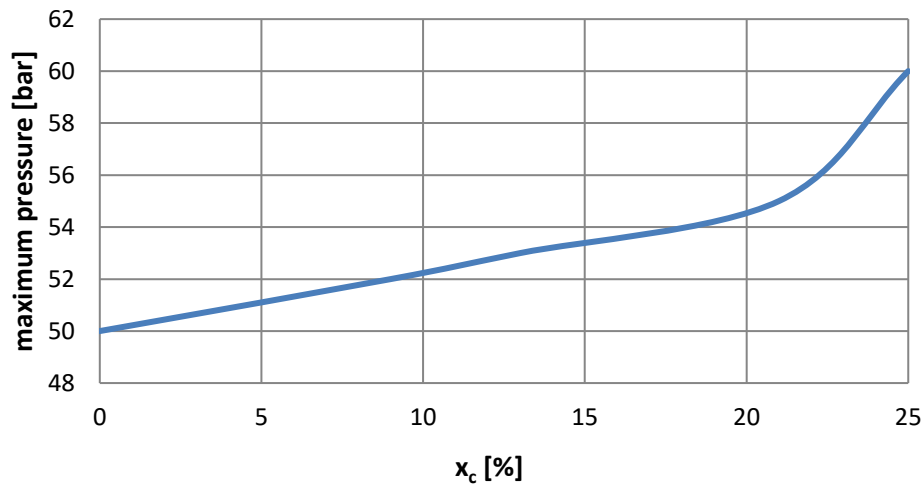


Fig. 1. The maximum pressure inside the cylinder versus the substitute ratio.

Because of a higher flame speed in the homogeneous mixture of air-LPG the maximum rate or pressure rise increased for all the investigated cases. The figure 2 presents the maximum rate of pressure rise for the investigated cases.

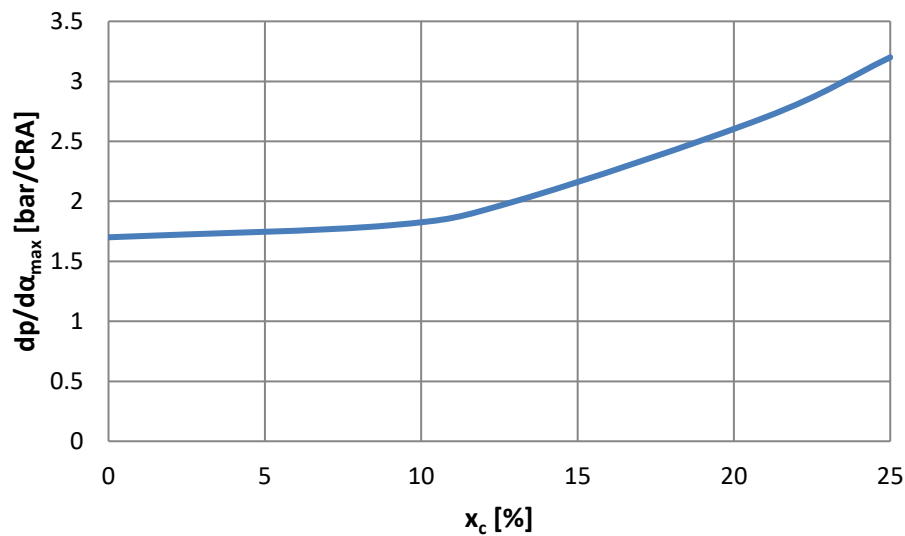


Fig. 2. The maximum rate of pressure rise versus the substitute ratio.

The nitrogen oxides emission level decreased for all the investigated substitute ratios of diesel fuel with LPG because liquefied petroleum gas has a lower flame temperature than diesel fuel. The nitrogen oxides emission variation is presented in the figure 3.

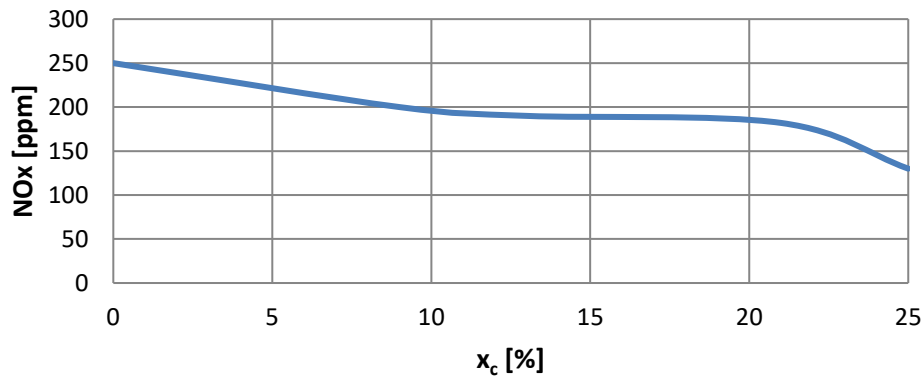


Fig. 3. The nitrogen oxides emission versus the substitute ratio.

The smoke emission level decreased for all the investigated substitute ratios of diesel fuel with LPG because when LPG is present in the combustion chamber the burning rate of diffusive mixtures decreases and the burning rate of preformed mixtures increase. The figure 4 presents the measured smoke emission level, evaluated by the coefficient of absorption k .

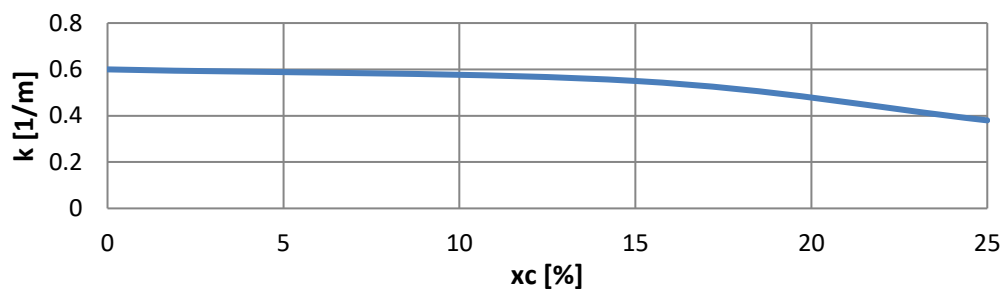


Fig. 4. The smoke emission level versus the substitute ratio.

The brake specific energetic consumption decreased for the substitute ratios of diesel fuel with LPG. Figure 5 presents the brake specific energetic consumption versus the substitute ratio.

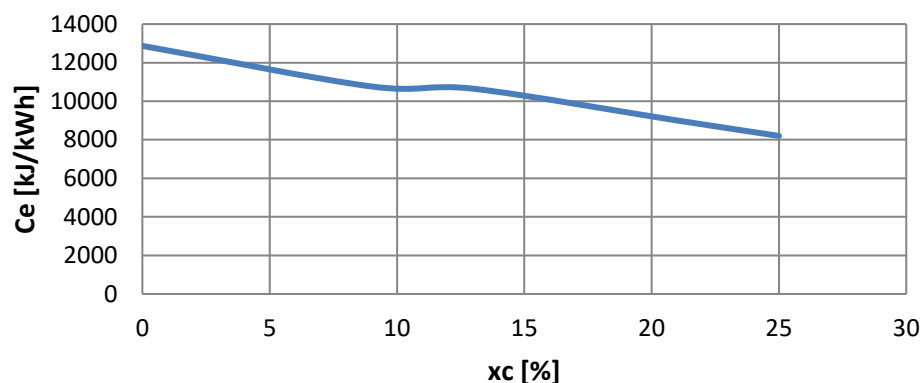


Fig. 5. The energetic specific fuel consumption versus the substitute ratio.

4. Conclusions

At the LPG engine fuelling were observed the following:

1. The brake specific energetic consumption decreased with $\sim 20\%$ when the substitute ratio was $x_c=25$.
2. The nitrogen oxides emission decreased with $\sim 25\%$ for the substitute ratio $x_c=25$.

3. The smoke emission level decreased because when LPG is present in the combustion chamber the burning rate of diffusive mixtures decreases.

4. The maximum pressure and the maximum rate of pressure rise increased in the case of LPG fuelling.

5. Acknowledgements

The authors would like to thank to AVL List GmbH Graz, Austria, for providing the possibility to use the research equipment.

This work has been funded by University Politehnica of Bucharest, through the “Excellence Research Grants” Program, UPB – GEX 2017. Identifier: UPB- GEX2017, Ctr. No. /2017.

6. References

- [1]. Popa, M G, Negurescu, N, Pana, C, Motoare Diesel, 2003, *Matrix ROM*, Bucuresti.
- [2]. Miqdam, T, Exhaust analysis and performance of a single cylinder diesel engine run on dual fuels mode, 2011, *Journal of Engineering*, **Nr. 4**, Vol. 17.
- [3]. Michal, J. et al, Analysis of engine parameters at using diesel-lpg and diesel-cng mixture in compression-ignition engine, *Acta Universitatis Agriculturae Et Silviculturae Mendelianae Brunensis*, 2014, vol. 62, **nr. 1**.
- [4]. Qi, D. H., Bian, Y. Z., Ma, Z.Y., Zhang, C. H., Liu, S. Q., Combustion and exhaust emission characteristics of a compression ignition engine using liquefied petroleum gas–diesel blended fuel, *Journal of Energy Conversion Management*, 2007, vol. 48, **no. 2**, pp 500-509.
- [5]. Vijayabalan, P., Nagarajan, G., Performance, Emission and Combustion of LPG Diesel Dual Fuel Engine using Glow Plug, *Jordan Journal of Mechanical and Industrial Engineering*, 2009, Volume 3, **Number 2**, ISSN 1995-6665 Pages 105 – 110.
- [6]. Roshia, P., Bharj, R.S., Gill, K., Performance and emission characteristics of Diesel+LPG dual fuel engine with exhaust gas recirculation, *International Journal of Science, Engineering and Technology Research (IJSETR)*, October 2014, Volume 3, **Issue 10**.
- [7]. Tira, H.S, Herreros, J.M., Tsolakis, A., Wyszynski, M.L., Characteristics of LPG-diesel dual fuelled engine operated with rapeseed methyl ester and gas-to-liquid diesel fuels, *Energy*, 2012, **Volume 47**, 620-629.
- [8]. Abăitancei, D., Motoare pentru autovehicule si tractoare fabricate in Romania, *Alma*, 2011, Craiova.