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ANALYSIS OF ENGINE PARAMETERS AT USING DIESEL-LPG AND DIESEL-CNG MIXTURE IN COMPRESSION-IGNITION ENGINE

Michal Jukl[1], Petr Dostál[1], Jiří Čupera[1]

[1] Department of Technology and Automobile Transport, Faculty of Agronomy, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic

Abstract

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This work is aimed on influence of diesel engine parameters that is used with mixture of gas and diesel fuel. The first part of the article describes diesel fuel systems where small part of diesel fuel is replaced by LPG or CNG fuel. These systems are often called as Diesel-Gas systems. Next part of the article focuses on tested car and measurement equipment. Measurement was performed by common-rail diesel engine in Fiat Doblò. Tests were carried out in laboratories of the Department of Engineering and Automobile Transport at the Mendel University in Brno. They were observed changes between emissions of used fuels – diesel without addition of gas, diesel + LPG and diesel + CNG mixture. It was found that that the addition of gas had positive effect on the performance parameters and emissions.

Keywords: diesel-gas system, diesel fuel, mixture, LPG, CNG, engine parameters, emissions, chassis dynamometer

INTRODUCTION

Mankind has begun to look for cheaper alternative fuels since operating costs of vehicles powered by liquid fuels started to rise. As a potential fuel can be used gaseous fuels. Gaseous fuels bring many benefits such as lower cost. It can be also observed positive effect on engine emissions (Sáez *et al.*, 2012).

Kjärstad *et al.* (2009) was dealt with the situation of global oil resources. Ones of the consequences of dwindling oil resources is the increase in prices of final products manufactured from it such as gasoline and diesel fuel. Therefore, it is necessary to find solutions to reduce consumption of fossil fuels. High fuel costs are also often discussed topic in truck transport, construction and agriculture. In a truck, price of diesel fuel make a large part of operating costs. Trucks usually use a high-volume diesel engine where fuel consumption can normally exceed the limit of 30 litres / 100 km. One way to reduce the consumption of fuel is a dual fuel system when the truck have second fuel supply system with gas. The gas may be used either LPG or CNG. The general name for this type of drive can be Diesel-Gas. The aim of subsequently added fuel system does not replace the original fuel, but only a part of it. Because the prices of alternative fuels such as LPG are on average more than half lower, using a mixture of fuels is ultimately reflected in the cost of operations. Use of Diesel-Gas according to manufacturers may also bring other benefits such as increase in power and torque and reduced emissions. Drive a mixture of gas and diesel fuel is used in Australia and North America for many years. However this system can be used even in small engines for example in vans. The aim of this paper is to describe the performance parameters of small engine using a mixture of gas and diesel fuel. As the gas was used LPG and CNG.

MATERIAL AND METHODS

To assess the effects of a mixture of fuels on the performance parameters of the vehicle was performed and objective measurement of the vehicle on the chassis dynamometer. Measurement was carried out in the laboratories of the Department of Technology and Automobile Transport at Mendel University in Brno. To determine the parameters of the combustion engine were performed series of static performance tests at different engine loads. The first tested fuel was diesel fuel without any gas. Next sequence of tests was performed with mixture of diesel fuel and LPG and then finally mixture of diesel fuel and CNG. During the tests were recorded values of nitrogen oxides and smoke emission.

Tested vehicle

To assess the mix of fuels was carried out measurements on the vehicle Fiat Doblò Cargo (Fig. 1). It is a light commercial vehicle with a diesel engine with a displacement of 1598 cm^3. The vehicle engine is turbocharged and it has also an intercooler. The vehicle is equipped a diesel particulate filter. For more information about car engine see Tab. 1.

Fuel systems in tested car

In addition to traditional diesel injection into the test car was fitted equipment Zenit Pro Diesel ensuring the creation of a mixture with the addition of LPG or CNG. This device will be described below.

Diesel system

As is evident from Tab. I the engine of the vehicle is equipped with an electronically controlled direct injection Multijet Common Rail. Engine meets Euro 5 emissions standard. Equipment of Zenit Pro Diesel is not connected to diesel fuel injection control. The control algorithms were therefore carried out the original control system and remained the same even when operating with the addition of gas LPG or CNG.

Zenit Pro Diesel system

System Features Zenit Pro Diesel is in a controlled dosing of gas through intake pipe into the combustion chamber. The dose of gas depends on the engine load. Control unit of Zenit Pro Diesel operate the amount of gas. A dose of gas which is mixed with intake air is ignited in combustion chamber during compression and power cycle. Gas during combustion in the combustion chamber

I: *Fiat engine parametres*

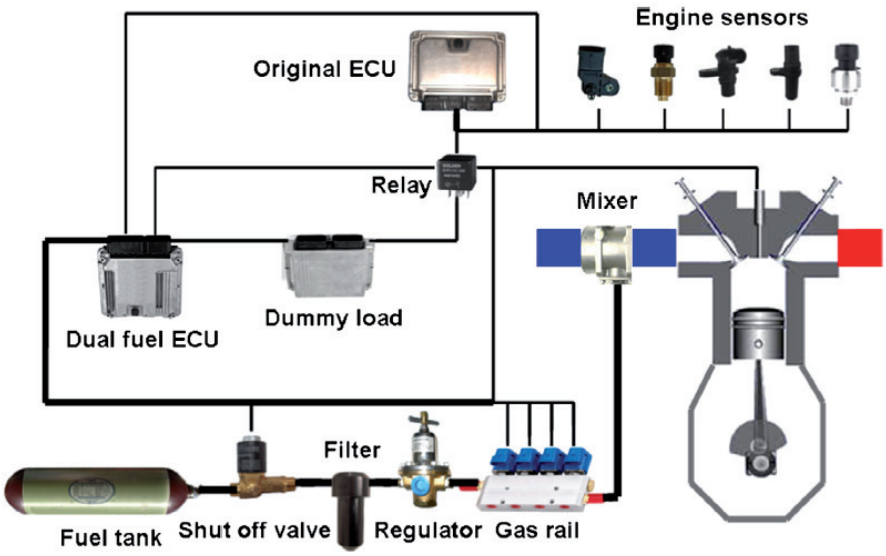
Fiat engine 1,6 MultiJet	
Number of cylinders	4
Engine volume	1598 cm^3
Maximal engine output	77 kW at 4000 min^{-1}
Maximal torque	290 N.m at 1500 min^{-1}
Compression ratio	16,5:1
Injection type	direct injection Common Rail
Emission limit	Euro 5
Combined consumption	5,4 l/100 km

creates optimal conditions for better combustion of fuel. Zenit Pro Diesel system does not inject gas while engine is operated at idle speed. In case of failure on the gas system or over-temperature of exhaust gases, gas dosing is automatically switched off and the engine is operated on diesel fuel. This feature prevents damage to internal combustion engine of vehicle. Zenit Pro Diesel system adds on average of 20% gas. The manufacturer promises to reduce fuel consumption by 15–20%. The gas system can be divided into two parts. The first part is mounted in the engine compartment and includes mainly gas-injection ECU, gas pressure reducer, gas injectors, exhaust gas temperature sensor, wiring and other accessories that are necessary for operation of the system. The second one consists of a gas tank with accessories. To imagine how the main parts of diesel-gas mixture system are connected together see Fig. 2 where is an architecture of diesel-gas system.

Gas tank is selected according to the type of vehicle. The size and dimensions of the gas tank is chosen according to the consumption of diesel fuel. This ensures that the amount of gas corresponding amount of diesel fuel tank and thereby eliminate the possibility when the vehicle is running only for diesel fuel.

Information about the engine (for the LPG ECU) may be acquired directly from the sensors (LPG unit is equipped with both digital and analog input). Because these systems are designed primarily for

1: *Fiat Doblò on the chassis dynamometer*



2: *Main parts of diesel-gas system (Liu et al., 2013)*

commercial vehicles, it is possible the information from the engine sensors (speed, load, position of the accelerator pedal, temperature) to acquire indirectly from the vehicle bus, which in commercial vehicles meets the international standard SAE J1939. We can also find diesel-gas kits that are compatible with OBD standard.

Chassis dynamometer and testing equipment

Vehicle laboratory at Mendel University in Brno at Department of Technology and Automobile Transport is a typical example of a chassis dynamometer. Laboratory is used to measure the parameters of cars, vans and light trucks. This is a testing laboratory with active drives (DC motors) for testing up to 480 kW in a 4x4 configuration.

Data can be saved from 140 channels in real time on the PC. The protocol is saved in HTML format and data can be exported to a spreadsheet for next processing. During the tests was also used emission analysis BOSCH ESA 3.250. This device uses a measurement based on the principle of absorption of infrared radiation.

Electrochemical sensor is installed to measuring emissions of nitrogen oxides. Another part is an opacimeter to measuring smoke opacity.

RESULTS AND DISCUSSION

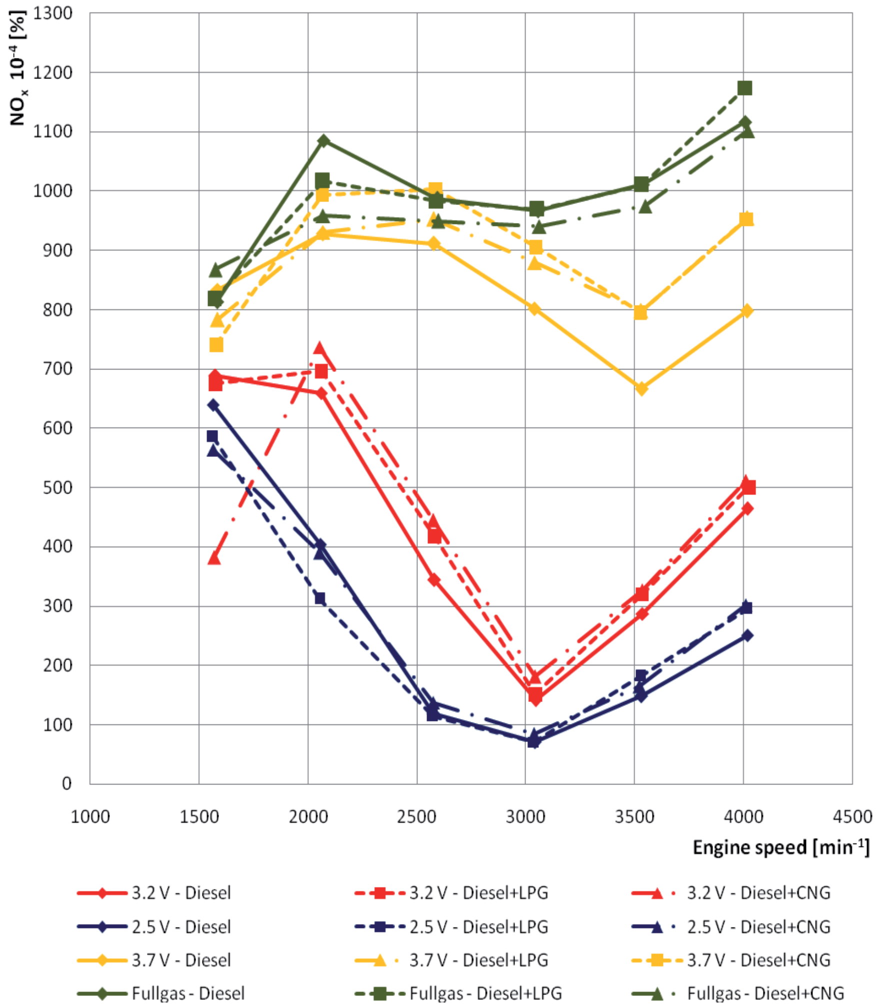
The results were summarized in graphs. These following graphs provided some insights into the problem of nitrogen oxides and soot pollution during the tests. In each following graphs are plotted pollutants depending on engine speed. Different load is adjusted by gas pedal and it is shown as a voltage from gas pedal sensor (abbreviation TPS). Maximum voltage of sensor is presented as "Fullgas" and its corresponding voltage is not shown.

In Fig. 3 there are shown nitrogen oxides pollution. You can notice that the highest value of nitrogen oxides is in the range of the maximal engine torque (from 1500 min^{-1} to 2050 min^{-1}) and then it decreases. The lowest nitrogen oxides pollution at fullgas has mixture of diesel fuel and CNG over almost the whole revolution range. However, at lower engine load (3.7 V and 3.2 V) mixture of diesel fuel and CNG has higher emissions of nitrogen oxides than diesel fuel and also diesel+LPG. In this two cases diesel fuel has the lowest nitrogen oxides emissions (excluding the lower engine speed at 3.7 V). At lower engine speed at 2.5 V TPS diesel+LPG mixture has favourable course of NOx. At engine speed about 3000 min^{-1} this curve intersects with curve of diesel fuel and then emissions of NOx starts to grow.

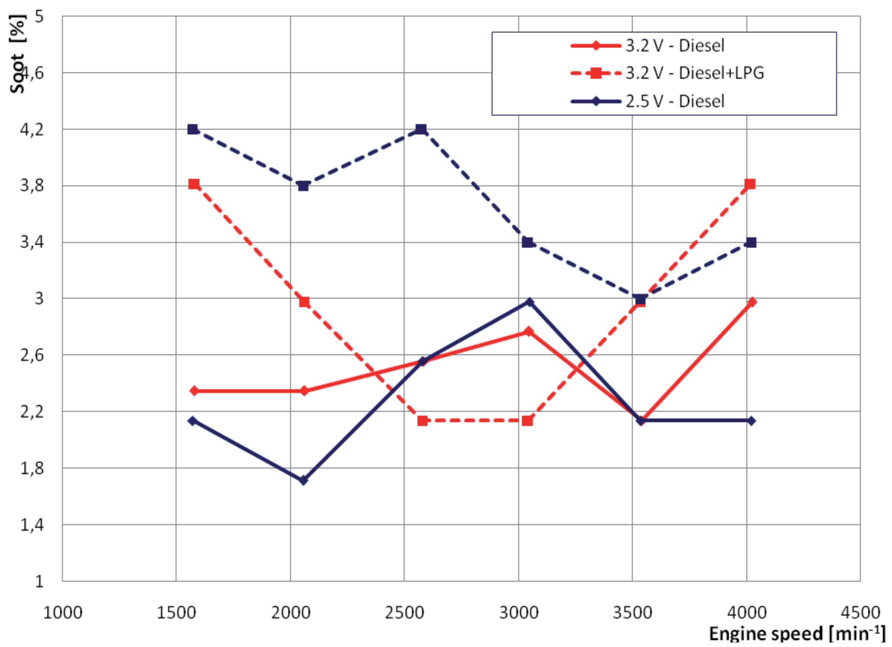
In Fig. 4 and Fig. 5 there are shown soot pollution. Most of the curves has its maximum value in the range from 2500 min^{-1} to 4000 min^{-1}.

When engine was running on mixture of diesel fuel and LPG in fullgas mode soot production was the highest of all – you can see this in Fig. 4. In the same mode at engine revolution about 3050 min^{-1} soot production reached a peak and then starts rapidly to decline. From revolution 2300 min^{-1} to maximum is soot pollution the lowest of all when engine is running on mixture of diesel fuel and LPG. At lower engine load (3.7 V TPS) soot production is lower. When we compare soot production while engine was running on diesel fuel only and diesel-gas mixture, diesel-gas fuel may bring reduction in smoke emissions. Fig. 5 brings comparison between diesel fuel and diesel+LPG mixture at engine load of 3.2 V and 2.5 TPS. In this figure, when is used mixture of diesel+LPG, smoke emissions are higher in both cases (3.2 V and 2.5 V) as compared with the diesel fuel. It is probable that this problem will have a solution in the settings of LPG injection.

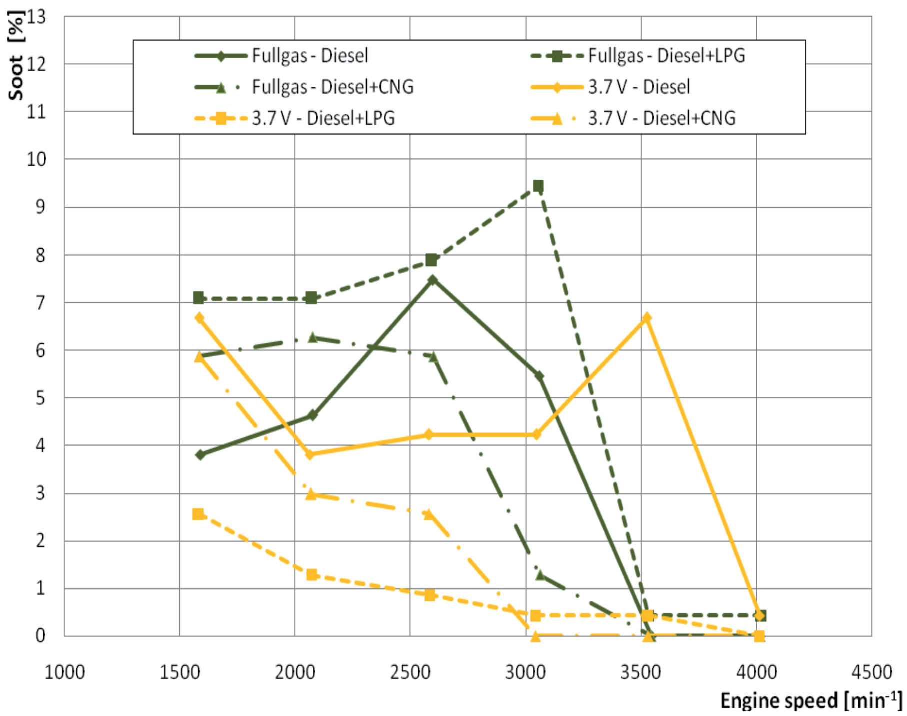
It was found that combustion of a diesel-gas mixture has a different effect on emission. In some diesel-gas modes emission of NOx and soot decreased compared to diesel operation only and



3: *Nitrogen oxide diagram*



4: *Soot during test at Fullgas and 3.7 V TPS*



5: *Soot during test at 3.2 V and 2.5 V TPS*

vice versa. It also depended on engine load (TPS). A similar theme was also discussed in Papagiannakis *et al.* (2010), Thomas Renald *et al.* (2012). Investigation of emission and performance characteristic of diesel engine operated on gas was discussed also in Mansour *et al.* (2001), Papagiannakis *et al.* (2004), Carlucci *et al.* (2011), Tira *et al.* (2012) and Ryu (2013). Our results are consistent with the discussed authors. By replacing 60% of liquid fuel was achieved engine combustion variability within the acceptable range and at the same time soot-NOx emissions obtained in clear benefits (Tira *et al.*, 2012). The measurement was realized with 20% of LPG and in the range of maximum engine torque NOx reached lower volume compared to engine running on diesel only. In some modes was achieved higher amount of NOx. Amount of NOx can be reduced by application of EGR as Tira (2012) mentioned.

CONCLUSION

This paper described the influence of diesel engine parameters by using diesel-gas system. Other studies have shown also reducing of NOx, then increasing of thermal efficiency and also mechanical efficiency. Using a mixture of diesel fuel and gas (LPG or CNG) may therefore be beneficial in a lower production of pollutants into the environment and lower consumption of diesel fuel. Another great advantage is certainly the versatility of this system that can be used also in modern diesel engines. CNG is often used as a fuel for city buses for its low emissions. A second advantage of this fuel is that is not produced from crude oil therefore is independent of petroleum reserves. CNG will be probably very discussed topic in the future when petroleum reserves will be smaller. So using a mixture of diesel and gas (CNG) is a good way to verify his properties.

SUMMARY

This paper is aimed on testing engine with installed diesel-gas system. Diesel-gas fuel system works with a mixture of diesel and gas. As a gas were used LPG and CNG. For testing was chosen Fiat Doblò Cargo with turbocharged common-rail diesel engine. Fiat Doblò Cargo is a light commercial vehicle. In addition to traditional diesel injection into the test car was fitted equipment Zenit Pro Diesel ensuring the creation of a mixture with the addition of LPG or CNG. Zenit Pro Diesel system adds on average of 20% gas.

During the tests was observed emission of NOx and soot. Tests were carried out in laboratories of the Department of Engineering and Automobile Transport at the Mendel University in Brno. To assess the effects of the diesel-gas fuel system on the performance parameters of the vehicle was performed and objective measurement of the vehicle on the chassis dynamometer. This chassis dynamometer is equipped with active drives (DC motors) for testing up to 480 kW in a 4x4 configuration.

To determine the parameters of the combustion engine were performed series of static performance tests at different engine loads. The first tested fuel was diesel fuel without any gas. Next sequence of tests was performed with mixture of diesel fuel and LPG and then finally mixture of diesel fuel and CNG. During the tests were recorded values of nitrogen oxides and smoke emission with emission analysis BOSCH ESA. This device uses a measurement based on the principle of absorption of infrared radiation. Electrochemical sensor is installed to measuring emissions of nitrogen oxides. Another part is an opacimeter to measuring smoke opacity.

At engine load Fullgas and 3.7 V TPS values of nitrogen oxides was the highest in the range of the maximal engine torque (from 1500 min^{-1} to 2050 min^{-1}) and then it decreased. The lowest nitrogen oxides pollution at fullgas had mixture of diesel fuel and CNG over almost the whole revolution range. However, at lower engine load (3.7 V and 3.2 V) mixture of diesel fuel and CNG has higher emissions of nitrogen oxides than diesel fuel and also diesel+LPG. In this two cases diesel fuel has the lowest nitrogen oxides emissions (excluding the lower engine speed at 3.7 V). At lower engine speed at 2.5 V TPS diesel+LPG mixture has favourable course of NOx. When we compare soot production while engine was running on diesel fuel only and diesel-gas mixture, diesel-gas fuel may bring reduction in smoke emissions.

Using a mixture of diesel fuel and gas (LPG or CNG) may therefore be beneficial in a lower production of pollutants into the environment and lower consumption of diesel fuel. Another great advantage is certainly the versatility of this system that can be used also in modern diesel engines.

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Contact information

Michal Jukl: michal.jukl@mendelu.cz
Peter Dostál: petr.dostal@mendelu.cz
Jiří Čupera: jiri.cupera@mendelu.cz