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REDUCTION OF MOTOR VEHICLES EMISSION BY USING NATURAL GAS AS AN ENERGY SOURCE

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Abstract. *As the automotive industry recognized negative effects of road transportation to the environment, it has intensively worked on new technological solutions during several decades, with the goal of reducing the negative environmental effects of vehicles. That is why the priorities of contemporary and future development of vehicles, engines and accompanying equipment are the following: reduction of fuel consumption and reduction of emission of exhaust gases. One of the ways to solve current tasks of the automotive industry is the use of alternative fuels, that is, the alternative energy potentials. This paper analyzes natural gas as alternative fuel for motor vehicles. After description of basic physical and chemical properties and the analysis of use of natural gas as a fuel for ICE, this paper presents reduction of motor vehicles emission by using natural gas as fuel.*

Key words: *natural gas, exhaust gases, environmental protection*

1. INTRODUCTION

It is a well known fact that major breakthroughs were achieved in the field of communication and mobility in the last few decades, so today's level of development cannot even roughly be compared to that from a decade ago. At the same time, the power consumption is constantly increasing. Approximately 50% of total energy is consumed for transportation, and that is significantly more that in overall industrial sector (and the rest is consumed in households). Objective forecasts show that steady increase in the transportation of goods and people and all other activities will increase in the coming years, along with the further development of technology and the increase in population in the world. It is important to bear in mind that the fuel for the transportation sector is almost completely produced from oil, the reserves of which are limited. This paper concentrates

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on natural gas as an alternative fuel with great potential. This fuel has very favorable environmental properties, and its reserves are very large in many countries. Therefore, natural gas is considered to be the best alternative to oil derivatives, that it is an energy source that will be increasingly used in the coming years. Natural gas vehicles are environmentally clean, they easily meet all environmental regulations, even the strictest ones, and they are very economical. This fuel has very favorable safety characteristics, as well.

In Serbia, natural gas is not used so much as in some other countries (Italy, France and Bulgaria). The problem is the lack of natural gas filling stations in Serbia, as well as larger investment in equipment in vehicles.

2. NATURAL GAS

Natural gas is a mixture of hydrocarbon compounds that exist in nature and were formed over millions of years by decomposition of organic matter, such as trees and animals. Usually it is trapped in underground reservoirs or in pockets of gas, either trapped in substrates such as sand and oil, created as a by-product of oil extraction, or as a stand-alone raw material.

Methane (CH_4) is the main component of natural gas, and typically accounts for over 90% of natural gas distributed by gas pipelines. Other hydrocarbon compounds that can be found in natural gas in small amounts include ethane, propane and butane. Physical and chemical properties of natural gas directly depend on the content of methane in it. The lower heating value of methane is 25.66 MJ/m^2, that is, 35.8 MJ/kg and its octane rating is greater than 100. Natural gas is odorless, so odorants that give it its distinctive "smell of gas" are added to it.

Natural gas has to be brought into liquid state first, so that it could be used as fuel for road vehicles. There are two possible procedures:

- compression under high pressure (200 bar) - compressed natural gas (CNG),
- cooling to extremely low temperatures (-162°C) - liquefied natural gas (LNG).

Liquefied compressed natural gas (LCNG) is obtained by the combination of these two methods. If the fuels produced by these procedures are compared, it may be concluded that LNG has 2.4 times larger density than CNG, hence much larger radius of movement. Expensive compressor stations, that consume significant amounts of electricity, are required for production of CNG, as well as the pipelines for supplying gas. On the other hand, LNG has to be kept in special (cryogenic) tanks. However, due to numerous advantages, natural gas used in motor vehicles is usually in compressed state, and quite rarely in liquid state.

Compressed natural gas - CNG (in our country known as KNG) burns slower than petrol, which reduces wear and increases engine life. CNG does not contain lead, so there is no deposition of lead on spark plugs, which extends the life of the spark plugs by two to three times.

All events related to the establishment of technical standards for road vehicles using CNG are taking place in the World Forum for Harmonization of Vehicle Regulations - WP.29, that is, in its Working Group on Air Pollution and Energy Saving - GRPE with the Economic Commission for Europe of the UN. Environmental requirements to be met by motor vehicles using CNG in their propulsion system are defined in ECE Regulation no. 49 (Supplement 2 to the 02 series of amendments) for motor vehicles used for the transportation of passengers and goods within the ESE Regulation no. 83 (Supplement 1

to the 03 series of amendments) for passenger cars. Safety requirements for CNG vehicles were established in October 2000 under the ECE Regulation no. 110, which defines the process of homologation of equipment in road vehicles using CNG and homologation of vehicles with regard to the installation of such equipment. There are Guidelines within the European Union (70/220*2001/100/EC; 88/77*2001/27/EC) governing this issue and they are identical to the corresponding ECE regulations.

There are three types of vehicles for CNG:

- Dedicated vehicles,
- Bi-Fuel vehicles and
- Dual Fuel vehicles.

Dedicated vehicles operate solely on CNG. Bi-fuel vehicles run on CNG but retain the ability to use petrol as a fuel reserve. The engine can be operated on either the type of fuel, but not at the same time. The compression ratio of the engine must remain at a level suitable for use of petrol. Currently this type of engine is used almost exclusively in vehicles weighing up to 3,500 kg. Dual Fuel vehicles are derived from diesel vehicles. A small amount of diesel is still used as a source of ignition. CNG as primary fuel is mixed with the incoming air. Dual fuel engines are automatically ignited due to compression and spark plugs are not required.

In order to change the operation of motor vehicles to use natural gas, it is necessary to convert petrol engine. In principle, there are several methods for adjusting the vehicle to use CNG:

- gas installation is added to an existing vehicle that is adapted to use conventional fuels (petrol and diesel) an thus the vehicle becomes Bi-Fuel/Dual Fuel,
- powertrain is replaced in the existing vehicle, gas installation is mounted and in most cases the vehicle uses gas fuel,
- a new vehicle is made, which is factory-adjusted to use conventional fuels and CNG or CNG only.

From the point of view of achieving the greatest functional and economic effects, of meeting safety and security, the best solution is to develop a new Bi-Fuel/Dual Fuel or Single Fuel vehicle. Most vehicle manufacturers in the world have one or more types of CNG and CNG / conventional fuel Ford (E250, E350, F150, Crown Victoria), General Motors (Silverado, Express, Savannah, Cavalier), Honda Civic GX, Fiat Punto, Opel Zafira, Renault Megan.

In addition to the aforementioned passenger vehicles, many heavy vehicles using CNG as fuel were developed. First of all, manufacturers of diesel engines should be mentioned: Baytech, Caterpillar, Cummins, Detroit Diesel, John Deer, Mack Truck, which have CNG engines in their production program.

In case of adjustment of the vehicle that uses CNG, when dedicated gas kits for CNG are installed, there is a problem that is related to the age of the vehicle and harmonization of parameters of electronic components that are now an indispensable part of any modern vehicle.

In addition, there is a problem related to meeting the security and safety parameters, given the design characteristics of the existing motor vehicle. These are important reasons for developing CNG vehicle fleet focused on vehicles that are factory-adjusted to use CNG. The principle of operation of vehicles for

CNG depends on the type of petrol vehicles (carburetor or injection). Natural gas is supplied to motor vehicles through CNG pressure regulator (usually placed in the engine compartment), which lowers its pressure.

In carburetor engine, the fuel enters the carburetor (via special air-fuel mixer) under nearly atmospheric pressure, through specially designed natural gas mixer, where it is mixed with air. In vehicles with fuel injection, CNG enters the injector under relatively low pressure (up to about 6 bar, 90÷100 psi). However, CNG then enters the combustion chamber of the engine and it ignites to create the power needed to start the vehicle. Special solenoid valves prevent the penetration of CNG when the engine is off.

In addition to the changes to the engine and its equipment, the vehicle needs to be changed for the use of natural gas, primarily for the purpose of installing tanks of compressed gas. Tanks of compressed natural gas are of rather large volume and mass, which generally worsens the dynamic, as well as other performances of a vehicle, but with careful designing, this can be resolved in a satisfactory manner (Fig. 1).

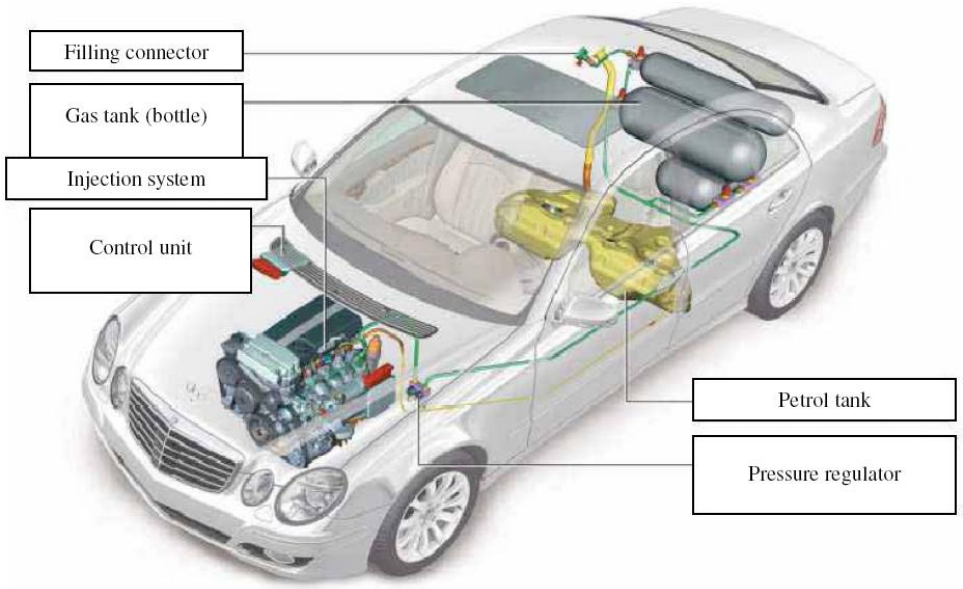

Fig. 1 Installations for the supply of engine with CNG

3. REDUCING EMISSIONS BY USING NATURAL GAS IN VEHICLES

From an environmental point of view, vehicles that use natural gas (CNG) have significantly lower emissions of harmful substances, which makes them very suitable for use. Numerous studies worldwide showed that reduction of emissions can be significant.

Reduction of emissions of vehicles using CNG as compared to petrol is as follows [1]:

- nitrogen oxides – 83%
- hydrocarbons – 88%
- carbon monoxide – 76%
- carbon dioxide – 22 ÷ 24%
- benzene – 99%
- sulfur – almost 100%

If CNG is used instead of diesel, the reduction of emission is as follows:

- nitrogen oxides – 80%
- hydrocarbons – 80%
- carbon dioxide – 10%
- carbon monoxide – 5%
- benzene – 97%
- particles – 100%
- sulfur – almost 100%

This level of emission of harmful substances of CNG vehicle meets the requirements Euro 5 and there is space remaining for future regulations (Euro 6).

4. Advantage and Disadvantages of CNG as Fuel in Vehicles

Studija Concluding from the above mentioned, the advantages of CNG as fuel can be summed up as follows:

- in terms of technology and emissions, we should not expect any problems, especially as the adaptation of engine is similar to LPG, except in tank and pressure reducer,
- high heating value,
- high octane rating,
- lower price of CNG compared to petrol,
- emission of harmful exhaust gases is lower in terms of nitrogen oxides, unburned hydrocarbons, sulfur, benzene and particles,
- longer engine life,
- vehicle equipment is known.

Disadvantages of CNG as fuel:

- very unfavorable ratio of energy density (about 5.35 kg of tank mass for every 41 MJ, which corresponds to approximately 1 liter of petrol),
- necessity of a tank under high pressure (200 bar), and hence their great weight in relation to the available volume, make it suitable for use in off road vehicles and buses in urban or suburban transportation), while reducing the payload by approximately 20%,
- insufficiently developed network of CNG filling stations.

According to the ENGVA (European Natural Gas Vehicle Association) report from 2005, there are about 4,000,000 CNG vehicles of different categories in the world that are supported with about 8,000 filling stations. According to this report, Argentina has the largest fleet of CNG vehicles and the largest number of filling stations (1,288,462 CNG vehicles and 1,267 stations) and Brazil (786.921 CNG vehicles and 911 stations).

5. Conclusion

Use of natural gas for motor vehicles has been expanding in recent years. It usually starts with city buses, but the number of cars is increasing, as well, especially taxi cars and utility vehicles that use natural gas as fuel.

This paper presents characteristics of motor CNG-powered vehicles and it shows that the use of natural gas in motor vehicles significantly reduces exhaust emissions when compared with fossil fuels.

The importance of converting vehicles to natural gas is supported by the fact that in 1998 the European Commission launched a development project NGVEurope, with the aim of developing vehicles powered by natural gas and compressor stations, promotion and testing of these vehicles, especially in terms of exhaust emissions. This project, in which the European Commission has invested EUR 2.6 million, with significant participation of numerous companies, was carried out in 15 cities in 7 countries of Europe, and it was focused on city buses, vans, taxis and utility vehicles used in environmentally vulnerable environments. Several hundreds of vehicles were developed and used as a part of this project. They were monitored and analyzed by a specially developed and mutually coordinated program.

By the EU directives, a fleet of 23,000,000 natural gas powered vehicles needs to be developed by 2020, with the annual growth rate of 8%. Each country, a member of EU, was allowed the freedom to form their own development model of CNG drive. With the development of CNG vehicles, infrastructure in the EU is developing, pipelines are being built (which supply other consumers as well), and the network of compressor stations for their filling is expanding.

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SMANJENJE EMISIJE IZDUVNIH GASOVA MOTORNIH VOZILA KORIŠĆENJEM PRIRODNOG GASA KAO POGONSKOG GORIVA

Kako je automobilska industrija bila svesna negativnih efekata drumskog transporta na životnu sredinu, ona je tokom više decenija intenzivno radila na novim tehnološkim rešenjima u cilju smanjenja negativnog uticaja vozila na životnu sredinu. Zato su prioriteti savremenog i budućeg razvoja vozila, motora i njihove opreme: redukcija potrošnje goriva i smanjenje emisije sa izduvnim gasovima. Jedan od načina rešavanja aktuelnih zadataka automobilske industrije jeste korišćenje alternativnih goriva, odnosno alternativnih energetskih potencijala. U radu je analiziran prirodni gas kao alternativno gorivo za pogon motornih vozila. Nakon iznošenja osnovnih fizičko-hemijskih karakteristika i analize upotrebe prirodnog gasa kao pogonskog goriva motora SUS, u ovom radu prikazano je smanjenje emisije motornih vozila korišćenjem prirodnog gasa kao pogonskog goriva.

Ključne reči: *prirodni gas, izduvni gasovi, zaštita životne sredine*