

TECHNICAL AND ECONOMIC ASPECTS OF TREATMENT OF COMPRESSED NATURAL GAS TO VEHICLE SUPPLY

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Abstract

Socio-economic development entails the increase the number of vehicles and the need of deciding about reduction of negative effects of the air pollution growth. Tendency to reduce the emission of noxious products of diesel oil combustion in engines, treatment of the CNG as a fuel seems to be promising. It seems, that in the future, ecological aspects will matter more and more in Poland and UE, so considering ecological advantages of CNG as a fuel, probably this technology will be more widespread. Obviously, the development of this technology requires the competitive price of CNG with respect to the traditional fuels.

In the article technical and economic aspects of vehicle adjustment to CNG supply is presented. Aspects of the adaptation of diesel oil and petrol engines to CNG were also brought up. Another significant factor which influence on the operating costs of using CNG were gas storage. In the paper actual methods of storage of natural gas supply are presented.

Scheme of CNG feed system, decrease of emission of pollution at replacement gasoline and diesel by CNG, prices of diesel and CNG in years between 2004 and 2009, investment outlays for buying buses in public transport company in Rzeszów and numbers of natural gas vehicles in 2006 and in 2009 are presented in the paper.

Keywords: *transport, CNG, NGV, combustion engines, air pollution, financial engineering*

1. Introduction

Nowadays, the rapid increase of the number of vehicles can be observed. It is connected with undesirable phenomena: air pollution, soil pollution, water pollution and noise. It is estimated, that the road transport is the main source of these effects. One of the methods of changing this situation is replacement of the fuel type. The good alternative seems to be utilization of natural gas. It can be stored in vehicle as Liquid Natural Gas (LNG) or Compressed Natural Gas (CNG). It also increases, what is very important aspect, the level of fuel diversification in vehicles. It decreases economical dependency on the chosen fuel provider, what is make the company situation more secure. Utilization of natural gas as the vehicle fuel bring not only the economical, abut also social and ecological benefits.

2. Technical aspects of using compressed natural gas

2.1. The Engine

Engine supplied by the compressed natural gas (CNG) works similarly to a spark ignition engine. It is easier to adapt gasoline engine. The problem is bigger in diesel engine, widely used in buses and trucks. Removing fuel system and replacing it by gas system is required. An engine needs construction changes like: decrease compression ratio, alternation form of chamber combustion and putting in the ignition system.

Typical CNG fuel system is shown in Fig. 1. Gas is drawn from a high pressure fuel tank (20 MPa). The gas pressure is decreased to the level about 0.8 MPa in three-stage reducer. This

low pressure gas is mixed with the air constituting combustible mixture, which is provided to combustion chamber. To reduce nitric oxides, oxidize carbon monoxide and another hydrocarbons engine can be equipped with three-way catalyst. The three-way catalyst works properly only with a stoichiometric coefficient air factor (λ) from the range 0.98-1.02. The only possibility to achieve this value is application of a microprocessor engine control system. Important part of the engine control system uses lambda sensor which measures oxygen level in exhaust fumes. According to this value proper combustible mixture is preparing [1].

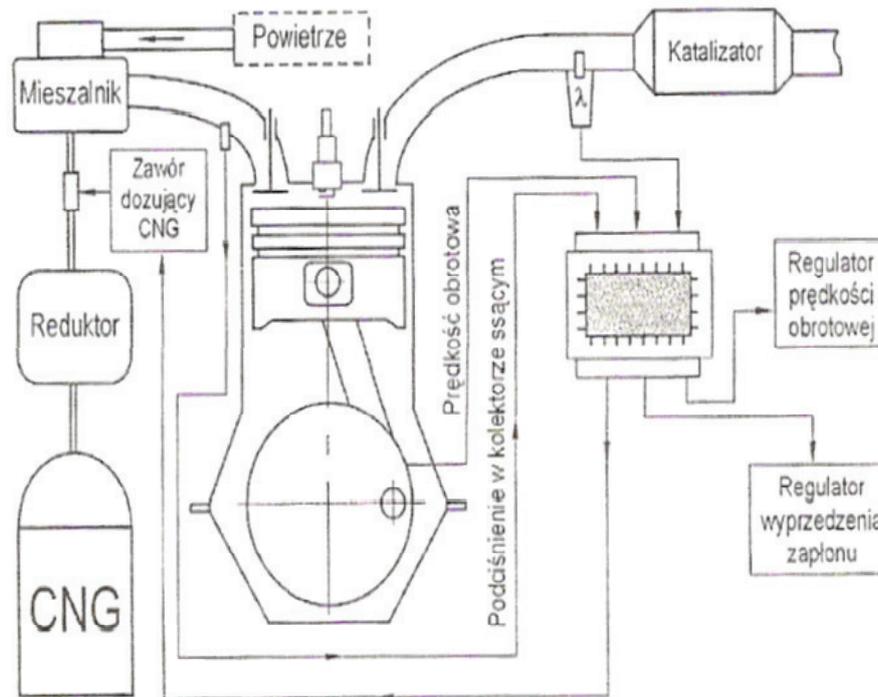


Fig. 1. Scheme of CNG feed system [1]

The main advantage of CNG is a high anti-knock index, which assures a non-detonation combustion and engine smoothness prolonging a durability of the engine. The start of the cold engine is trouble-free which is another advantage. Making a combustible mixture is easier with gas than with gasoline. Good quantity of the gas fuel is obligated for the proper engine work. PN-EN ISO 15403: 2005 describe gas properties requirement to use it as a fuel in car engines.

2.2. Compressed natural gas containers

Compressed natural gas containers have to be very refractory and leakproof. Gas pressure level is about 20 MPa, so it is necessary to use proper material for container shell. Nowadays, steel containers are widely used. Weight and huge dimensions are the main disadvantages. The container weight increases real vehicle weight which produce additional fuel consumption and decrease vehicle performance. For this reasons new materials, as for example composite, are putting into commission. The composite containers durability is higher than steel and their weight can be even three times lower. Internal side of this containers is made with aluminium and external with carbon fiber. The only disadvantage is higher price of this containers compering to steel. On the other hand lower weight causes lower consumption of the fuel [2, 3].

According with requirements of the “Technical Inspection Agency” CNG containers have to be periodically controlled. It is recommended to do this every three years. The inspection is done outside the public transport company, which require providing each bus to control station. Inspection price is about 80 PLN per one container [6].

2.3. Refuelling stations

Nowadays, in Poland there are only 31 natural gas refuelling stations - it is appreciably too less. Unfortunately arrangement of the gas stations is very adverse. Most of them are located in southern Poland, in north of Poland there is only a small amount of them. Currently most of them are located in area of PGNiG company or on buses depots. Increase of amount of cars fueled by CNG is possible only in the case of higher number of refuelling stations. Employees working on the refuelling station have to be specially educated about servicing of the gas high-pressure facilities. The proper fire-fighting and flame-proof protection is also important [7].

3. Ecological aspects of using CNG in motorization

Natural gas is a mixture of light paraffinic hydrocarbons, for instance: methane (83 - 99%), ethane, propane or butane. Apart from desirable components, the compound is made of foulants like nitrogen, hydrogen sulfide or carbon dioxide. After proper processing the natural gas is suitable for vehicle supply. There are many advantages of usage of this fuel instead of diesel oil or gasoline. Transport of the natural gas is safer than liquid fuel. The density of the natural gas is lower than the air. In case of container damage or non-hermetic insulation, gas quickly moves up and does not create flammable mixture. In the event of the road accident with liquid fuel tanker, the risk of soil, water or air pollution is higher than in case of the gas piping transport. Derivatives of oil combustion cause the huge emission of very dangerous pollution like dust, polynuclear aromatic hydrocarbons or benzene. These substances are classified as carcinogenic substances entailing the increase of cancer cells. Application of the compressed natural gas reduces drastically quantity of these dangerous substances in fumes. Emission of other gaseous pollutants is also limited.

Tab. 1. Decrease of emission of pollution at replacement gasoline and diesel by CNG

	Gasoline/CNG	Diesel/CNG
CO	60-80%	70-90%
NMHC	85%	40-60%
NO _x	50-80%	80-90%
PM	---	99%,
CO ₂	20%	25%
Noise	non data	40%

CNG usage as a fuel decreases CO₂ emission to the atmosphere even to 25% over gasoline or diesel fuels, which reduces the risk of greenhouse effect. NO_x emission is also lower which influences of decrease of the risk of acid rains. Moreover, NO_x is also a greenhouse gas, so the reduction of its emission decreases also the danger of the global warming. CNG usage also reduces non-methane hydrocarbons (NMHC) and particle matters (PM) emission too. These two substances influences for smog growing, especially in the cities. PM emission reduction is near 100%. CNG does not contain any sulphur compounds so usage it as vehicles fuel is more safety for buildings, especially old and listed. Buses supplied by CNG fit all norms, even the most restrictive one. Therefore entering to the old quarters of a town by natural gas vehicles is safer than by diesel or gasoline one. Since October 2009 new acuter limits of emission of pollution have been enacted, nevertheless CNG still fits all confines. Noise level generated by CNG engines can be even 40% lower then diesel engines, which is desirable effect in cities and in built-up grounds densely populated.

4. Economic analysis and development perspective of CNG

Financial efficiency is defined as profitability of the project for an entrepreneur investing in its realization. In classic variant, it is determined pursuant to financial benefits to investment outlays without allowing appropriation-in-aid. Thus financial analysis is estimation whether, project which is implemented, will be cost-effectiveness for investor. Economic efficiency determine cost-effective for society for investigated project. For commercial projects, the financial aspects are the most important. For non-commercial projects very important are also non-financial benefits, like environmental impact. Project is economic efficiently when investment outlays and operating costs are less then social benefits. It means it is efficient in the apprehension absolute. Relatively economic project takes it to satisfy one, concrete requirement of populace which is implemented by the least financial cost. For researching economic efficiency economic analysis should be employed which allows to evaluate both financial and social benefits. Main purpose of economic analysis is expression value of projects. It is necessary for proper share public resources between competitive investment projects.

As it can be notice, investment in compressed natural gas is cost-effective just in determinately conditions. Difference between CNG and gasoline/diesel price is very important. When the difference increase profitability of CNG usage also increase. When the difference decreases profitability decreases significantly. Price of diesel fuel was much higher than CNG in years 2004-2009. It is shown in Fig. 2. Therefore, it was possible by many polish cities to introduce buses fuelled by natural gas.



Fig. 2. Prices of diesel and CNG in years between 2004 and 2009

On the fuel prices huge influence have taxes, especially excise duty. Up to 2013 enactment, excise duty is abstained from. Currently natural gas price is lower than other fuels. Taking into account increase of natural gas prices, introduction period of buses in urban transport companies can be inconvenient. It is possible that companies could not invest in more ecological but much expensive CNG buses due to increase of operating costs. 4 years warranty given by government for stable duty for fuel is considerably to short, in comparison with vehicle lifetime, which is up to 18 years.

Important aspect for introducing CNG buses in urban transport companies is its price. CNG buses are much more expensive (in comparison with diesel buses supply) by the fact that CNG technology is new, permanently improvement and the quantity of production of CNG vehicles is quite small. It is the reason why many companies are not able to buy CNG buses.

Subsidies are element, which significantly redounds to distribute alternative fuels in transport. Currently there is possibility to get it from the European Union and from council funds. This is one of aspects, which conduce to increase usage of gas fuel in public transport in the last few years. Amount of CNG vehicles in Poland and in other countries in Europe is still growing. It is shown in Tab. 2.

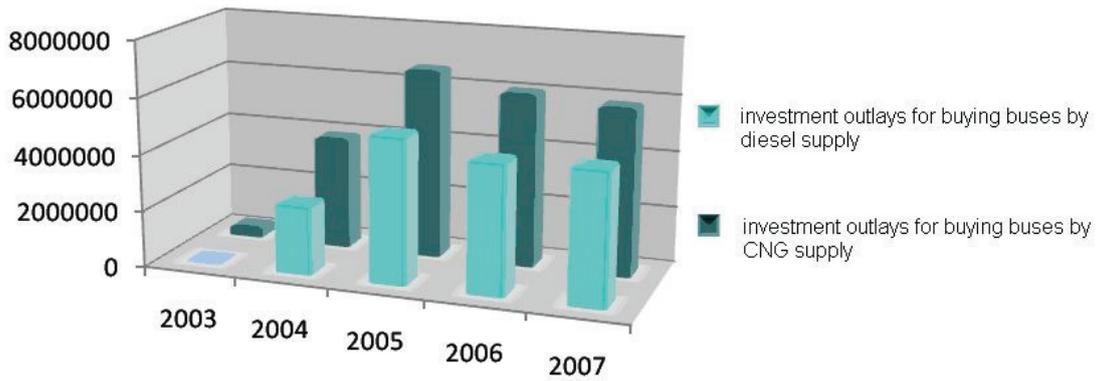


Fig. 3. Investment outlays for buying buses in public transport company in Rzeszow

Tab. 2. Numbers of natural gas vehicles in 2006 and in 2009[10]

Lp	Country	NGV				Lp.	Country	NGV			
		all vehicles		therein buses				all vehicles		therein buses	
		2006	2009	2006	2009			2006	2009	2006	2009
1.	Italy	382 000	584 577	1 600	2 000	6.	Austria	584	4 637	2	34
2.	Germany	27 200	77 000	1 100	1 513	7.	Spain	912	1 863	356	847
3.	Bulgaria	7 305	60 236	150	216	8.	Poland	771	2 106	41	300
4.	Sweden	5 298	18 579	554	810	9.	Czech Republic	390	1 279	90	244
5.	France	8 400	12 450	400	2 100	10.	Netherlands	540	2 032	--	542

However, the new technology on the market in the close future could be more profitable. Nowadays, vehicle supplied by Liquid Natural Gas (LNG) are used in many countries of Europe. The main advantage is smaller size of LNG storage, in comparison with CNG. By dint of it, LNG could be real competitive for buses supplied by compressed natural gas, diesel or gasoline.

Biogas can be also very useful in Poland. It is stored as compressed gas, so buses fuelled by natural gas can be directly fuelled by biogas. The last analysis of Department of Agriculture anticipates increase of production of biogas to 1 billion m³ in 2013 and minimum 2 billion m³ in 2020. Experts said that in Poland are many unused farm wastes, which could be used for biogas production and which now, are throw out to landfill. Main disadvantage of this technology is small amount of refuelling stations. Currently in Poland, there is no any biogas or LNG refuelling station.

5. Conclusions

In last few years, it can be observed pronounced increase of interest in compressed natural gas as a fuel for transportation. Despite financial, economic and ecologic advantages, the process of natural gas implementation in vehicles in Poland is quite slow. One of the reasons is necessity to invest in refuelling stations. The unstable macroeconomic policy and threat of excisable duty causing increase gas price, which makes investing very risk. On the other hand small quantity of gas users make project unprofitable. Only long-term, well-defined and green policy could bring on increase of interest CNG usage as engine fuel. Moreover, main purpose of big cities long-term policy should be improvement of passengers comfort in public transport to inhabitants pay to use it. Increase of overcrowding streets by vehicles will be in the future extorting development of

public transport, which is passenger-friendly. Natural gas vehicles should fit these conditions.

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