Assessment of the impact of compressed gas vehicle on the environment

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Abstract. Continual tightening of environmental regulations and the rapid rise in fuel prices is forcing the world's automakers look for ways out of the situation. The switching to alternative energy sources is one of the options to solve the problem in this situation. The most effective way that requires minimal cost and time is a usage of natural gas as a fuel. Natural gas is recognized worldwide as an environmentally friendly and cheap fuel, whose many properties are superior to gasoline and diesel fuel. Application of this type of fuel increases motor life due to mitigation of the friction in the cylinder block; it does not require modification of the vehicle and leaves the possibility to use both petrol and gas as the fuel.
[Ugay S.M., Golokhvast K.S., Pogotovkina N.S., Miheev E.M., Cheban A.Y. **Assessment of the impact of compressed gas vehicle on the environment.** *Life Sci J* 2014;11(10s):515-517] (ISSN:1097-8135). http://www.lifesciencesite.com. 100

Keywords: natural-gas-based motor fuel, compressed gas vehicle, natural gas, environmental security, alternative fuel, automobile safety, fuel efficiency

Introduction

Lately, the research interest to the alternative fuel was brought about the more careful attention to the ecological issues and rising oil prices. The researchers to find a replacement of motor fuel oil have begun almost simultaneously with the invention of the motor [1]. One of the ways to reduce energy costs is to use natural gas. Now the most promising and applicable gases are: compressed natural gas (CNG - Compressed natural gas), liquefied natural gas (LNG - Liquefied natural gas), liquefied carbon gas (LPG - Liquefied petroleum gas), biogas, hydrogen. Natural gas has a fully-fledged fuel for engines [2]. According to the estimation of International Energy Agency, natural gas is one of the fastest-growing components of the global energy consumption today. During the period from 2000 to 2012 explored and proved gas reserves have increased from 139.7 to 187.3 trillion m^3, and the production have also increased from 2176.9 to 3033.5 billion m^3 for the same period [3].

Energy map of the world is constantly changing. The interaction between different fuels, markets and prices has been enhanced. According to the forecast up to 2035 year the demand for energy will increase by more than 30%, and this will have far-reaching consequences for the climate for decades. Road transport is the second largest source of greenhouse gases, after the production of electricity, and this figure reaches 80% in large cities. Reduction of these values with minimal financial and time losses is possible by refitting cars on work with gas motor fuel.

The main part

The use of gas as a fuel allows achieving high environmental and fuel-energy performance of automobile engines. It is no coincidence that in December 12, 2001 the UN Economic Commission for Europe adopted a resolution calling for switching 10% of the vehicle fleet in Europe to the natural gas by 2020 year (23.5 million units), the refueling of which annually requires about 47 billion m3 of gas. Among the many obstacles to mass deployment of natural-gas-based motor fuel (NGV), one should mention the lack of systematic and long-term approach to the problem, the lack of economic incentives, weak government support. [4] Economic performances of the most common types of alternative fuels are presented in Table 1.

Table 1. Economic performances of alternative fuels

Type of fuel	Production cost, %	Cost of vehicle mileage unit, %
Gasoline from oil	100	100
LNG	50-60	70-75
CNG	70-80	75-85
LPG	60-70	80-90
Electrical power	65	90-130
Methanol	110	120
Ethanol	120	170
Synthetic gasoline	160	120

Methane, the other name is compressed natural gas (CNG). Gas is directly extracted from the subsoil, requiring no further processing, so the production cost is minimal. Direct use as a transportation fuel requires minor changes to engines [5]. There were less than one million vehicles running

on CNG in 1998, while now their number has increased more than 10 times. As of February 2013 the average cost of AI-95 gasoline in Russia is 32.6 rubles, on compressed natural gas - 12 rubles. At the same time, the discharge coefficient of methane from the petrol is 0.9, i.e. 10% lower. This is due to the physicochemical properties of natural gas: particularly resistant structure of its molecules and, most importantly, its octane rating, which, reaching 120, is significantly outperforming most high-octane hydrocarbons. It should be noted the ecological purity of the gas and its fuel efficiency. Combustible mixture is saturated with less fuel and more oxygen. Consequently, there are dozens times less products of incomplete oxidation of hydrocarbons, such as CO etc., in its waste combustion.

The important factor is safety. Methane is almost two times lighter than air, so in the event of loss of equipment it immediately evaporates and does not sag, in contrast to other fuels. CNG is non-toxic and non-carcinogenic. It is a safe fuel for human health and all life on Earth. According to the classification of flammable substances in the degree of sensitivity, methane refers to the safest class.

The second direction of NGV market is liquefied petroleum gas (LPG). According to the financial and economic feasibility calculations of the project of the Russian Federal Law "On the use of natural-gas-based motor fuel", in condition of switching of 5 million unit vehicles on LPG by 2020 year, the estimated volume to be consumed annually is 148.56 million tons of propane-butane. Each ton of which allows protecting against the release of CO_2 into the earth atmosphere in an amount of 0.23 tons. Consequently, 148.56 million tons of LPG, used as motor fuel, protect against CO_2 release in an amount of 34.17 million tons of carbon units (Kyoto Protocol classified articles). One carbon unit costs 10 euros. Consequently, the transfer of 5 million units of vehicles makes it possible to sell the quotas on the amount of 341.7 million euros annually.

However, the use of liquefied natural gas in the car does not get rid of all the problems [6]. Negative side can discover itself in possible unevenness of the motor operating. This is due to resonance in the intake system and bundle gas mixture.

Along with aforesaid, the internal combustion engine cold start also becomes more complicated under the low temperatures. This is due to the higher temperature fuel gas ignition and a slower rate of combustion. Depending on the amount of compressed gas cylinders a vehicle weight increases, thus reducing its capacity and increases fuel consumption.

The use of hydrogen as a fuel for cars, attractive because of its several special advantages:

- combustion of hydrogen in the engine produced almost only water that makes the engine on hydrogen fuel the most environmentally friendly;
- unlimited resource base in producing hydrogen from water.

But at the present stage of technological development hydrogen engines have serious technical and technological barriers to their usage, mainly because of the relatively high cost, high requirements for precision manufacturing of fuel equipment and lack of infrastructure. Comparative characteristics of gasoline and hydrogen are shown in Table 2.

Table 2. Comparative characteristics of gasoline and hydrogen

	Power production costs for 1000 Joule	Equivalent to the energy contained in one liter of gasoline
gasoline	190	1
hydrogen	3300	4,55

At the present level of hydrogen producing development technology the use of hydrogen cannot be considered effective, it costs 9.01 euros / liter. Cars, running on hydrogen, will achieve the indicators, such as cost of the machine, cost of one filling, level of security, amount of harmful emissions, etc., which hybrid cars show now, not earlier than in 2030. A new stage in the development of this gas was the practical application of it in existing vehicles as a fuel additive. Even today such use can give not only economic benefits, but also solving environmental problems. The most efficient way is to get it on board of the vehicle by the air fuel conversion. A reaction occurs in special reactor in the presence of the catalyst:

$$CH_4 + ½ (O_2 + 3{,}76\ N_2) = 2H_2 + CO + 1{,}88\ N_2$$

A synthesis gas is produced; it is composed of approximately 50% hydrogen and carbon monoxide mixture which serve as an initiator that improves the combustion of hydrocarbon fuels [7]. This is due to hydrogen-induced initiator which forms the combustion centers and increases the efficiency of the engine and its ecological characteristics as follows:

- Fuel consumption when driving in city cycle is reduced by 20-25%;
- Carbon monoxide, and, even more dangerous to the environment, nitrogen oxides are reduced to the Euro 4;
- Reduction of fuel consumption at idle comes up 40%.

However, if hydrogen becomes popular automotive fuel, its amount in the atmosphere will increase considerably. This can lead to the destruction of the ozone layer protects the Earth from ultraviolet radiation, global climate change and active reproduction of dangerous microbes. Furthermore, during their operation hydrogen engines emit much more gases deplete the ozone layer of the Earth (in

particular, NOx) than conventional models of gasoline vehicles do.

Interest in alcohol fuels, methanol and ethanol, is explained by the environmental cleanliness and increase fuel efficiency. Main advantages are as follows: high octane rating and good efficiency of the workflow. Exhaust components are significantly reduced in exhaust gases: hydrocarbons reduced on 10-20%, nitrogen oxides are lowered to 30-35% [8]. Among the disadvantages we should note the reduced calorie power, which reduces mileage between fill-ups, increased 1.5-2 times fuel consumption in comparison with gasoline, worse engine start. Using this fuel in its pure form requires significant changes in regular engines construction, which cannot be achieved at the present level of technology.

Public transport, operating on natural gas, is the most promising direction. This is determined by environmental and economic factors. Complete cycle of one gas bus (800 000 km) saves more than 4 million rubles in comparison with the diesel one. It is comparable with the cost of a new machine. World experience shows public transport becomes that particular industry where the modern technology has the fastest introduction [9, 10]. It is worth noting that using gas fuel reduces engine noise by 3-5 dB that is especially vital in large cities [11].

Conclusion

It is impossible to imagine a modern city without the large number of vehicles, so we need to make serious steps to reduce its negative impact on air quality. Only complex implementation of technological, planning, organizational and technical measures can lead to improved environmental quality. Due to low cost and significant reserves natural gas is a full-fledged alternative fuel, used in internal combustion engines. Using it as a motor fuel provides a good power, fuel and economic performances, reduces pollutant emissions, along with the operating costs for vehicles. It is important to note, that the environmental requirements, they do have begun to play a primary role in the world today, pushed economic indicators to the second place.

The results of vehicles toxicity studies when replacing fuel oil to natural gas showed:

- harmful substances emissions into the environment are reduced eight times by carbon monoxide, two times by nitrogen oxides, and 10 times by smoke;
- life of the engine when operating on gas fuel is increased to 30%;
- lubricants resource is increased to 25-30%;
- the service cost of vehicles is reduced;
- energy security is improved.

Recently, natural gas consumption has increased to almost 400 billion m^3 (from 2007.2 to 2404.9 billion m^3). According to forecast the growth will continue up to 2030 year, which results in a double share of natural gas in the world energy. Using natural-gas-based motor fuel as a universal motor fuel is a rapidly developing area, which become a highly profitable independent sector of the developed countries economy in the near future.

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6/3/2014