Motor vehicles transition on natural gas fuel: prospects, advantages, risks

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Abstract – The article is devoted to development of practical methods an assessment of prospects, risks and analysis of ecological efficiency of the actions connected with development of the automobile market on gas motor fuel. Advantages of use of gas motor fuel as safe and environmentally friendly type of alternative fuel are considered. Limiting factors of transition of the automobile transport on gas fuel are described and analyzed. High-quality risk analysis, characteristic for projects on expansion of a network of automobile gas-filling compressor stations and development of service of gas cylinder cars is carried out.

Key words – gas motor fuel, risk analysis, ecological efficiency, card of risks, service of gas cylinder cars.

I.Introduction

One of the main challenges of our time, faced by the international community, is associated with the intensive growth of motorization level and high energy intensity of the transport service of the population, the problem of transportation fuel supply. Because oil is a non-renewable energy source and is produced in such scales that in the near future its reserves will be completely exhausted, the question arises about the search of the alternative types of motor fuel.

The second but not less serious problem connected with growth of automobilization is negative impact of automobile on environment.

II. The negative consequences of motorization

Automobile transport exhausts are one of the most serious reasons of air pollution in large cities. So in Moscow and in other mega cities of Russia the share of automobile exhausts makes more than 90 % from cumulative emissions of polluting substances in an atmosphere. In cities with less developed industry the share of automobile exhaust gases is not much less (about 80-90 %). As a whole motor transport emissions in an atmosphere across Russia make 42 % from their total quantity [1, 2].

On the researchers' conclusion from Cornell University forty percent of deaths in the world are caused by influence of air pollution, water, soil. Poisonous emissions in an atmosphere kill annually about three million people. Principal causes of deaths caused by pollution of atmospheric air are a cancer, congenital pathologies and infringement of work immune system of human organism. Breathing the air where there are products of burning (rarefied exhaust of the diesel engine), even during short time, increase risk to receive ischemic heart disease.

The industrial enterprises and motor transport emit a black smoke and sulfur dioxide which raise risk of early death. Even a lower concentration of these substances n the atmosphere causes from 4 to 22 percent of deaths among people before forty. Very dangerous symptom for mankind is that air pollution increases probability of a childbirth with developmental anomalies [3].

The growing level of automobilization compels to search of decisions on decrease in negative influence of motor transport for an environment: requirements to environmental safety of automobiles become tougher, rigid standards of Euro-4, Euro-5 are entered. Euro-6 is developed. Especially topical problem of improving environmental safety is for big cities and regions with sanatoria and health zones [4].

III.Advantages of methane as alternative fuel

One of ways of the problem solving is transition of vehicles into natural gas fuel, particularly, methane. First of all, it concerns public transport, and also special rolling stock of road-building branch, municipal services and cargo motor transport.

Natural gas in the last decade causes the increasing interest of consumers. the companies engaged in transportations of passengers and freights, and also municipal and construction apply this type of fuel more often. Due to its low cost (the cost of CNG is about 50 % of the cost of gasoline, LPG – 75 %), natural gas causes more and more interest of consumers, and gas-engine buses, garbage trucks, public service vehicles are increasingly spreading in the cities of America, Europe and Asia. Using of this type of fuel is constantly increasing by the private taxi companies.

Using methane as motor fuel, products of incomplete combustion practically are not formed, so far as there is a surplus of oxygen. Oxides of nitrogen are formed in smaller quantity, as combustion temperature of lean mixtures is considerably lower. Combustion chamber wall layer when using lean air-gas mixtures contains smaller volume of fuel, than at richer air-petrol mixtures. Thus, in a correctly adjusted methane gas engine, emissions of carbonic oxide in the atmosphere are reduced to 5-10 times in comparison with petrol, oxides of nitrogen is emitted 1,5-2,0 times less, and hydrocarbons – 2-3 times less. Besides, using methane emission, the so-called hotbed gases are considerably decreased. The content of carbon by weight in methane is 75 %, and in gasoline – 85 %, therefore at full natural gas combustion, carbon dioxide (CO_2) is formed 13 % less, than at petrol combustion.

Considering, that mid-annual run of KAMAZ truck makes 80 000 km, and the mid-annual fuel consumption at fuel rate 40 liters on 100 km makes 32 000 liters, it is possible to estimate how much emissions of toxic substances in an atmosphere per year will decrease during operation of one truck while transitioning it on natural gas fuel (fig.1).

Fig.1 Decrease in emission toxicity of one KAMAZ truck with the natural gas engine per year in comparison with diesel engine.

High environmental efficiency of this fuel proves by the fact, that toxic emissions quantity of KAMAZ natural gas engines are much less, than by specifications Euro-4: NMHC (non methane hydrocarbons) – 1,9 times; CH4 (methane) – 3,2 times; CO (carbon monoxide) – 200 times; NOx (nitrogen oxide) – 1,6 times.

IV. Opportunities for the development of NGV technologies in Russia

As a motor fuel, natural gas is mainly used in two different types – in the form of liquefied petroleum gas (LPG) and compressed (compressed natural gas (CNG). According to foreign experts, in the coming years LPG and CNG are the only real alternative to gasoline and diesel fuel. The majority of well-known foreign manufacturers serial production of more than 180 models of NGVs, among which 112 models of passenger cars, 35 trucks, 38 buses. The most widely gas-engine cars presented to the European producers (126 models).

Russian automobile manufacturers join in programs implementation on natural gas fuel market development more actively: today natural gas fuel KAMAZ lineup is presented by communal and road vehicles, dump trucks and artics, city, suburban and all-wheel drive buses NEFAZ.«The GAS group» which includes a number of large bus manufactures, already produces several variants of passenger vehicles using alternative kinds of hydrocarbon fuel: since 2006 buses LIAZ are made, and since 2011 started the production of modern low-decked buses LIAZ-5292 and LIAZ-6213 of ecological standard EEV («Euro-5 +»), operating on methane. The gas bus of average capacity PAZ-320412 is started in a batch production. In February 2012 the pilot lot of «GAZELLES» operating on gasoline and on methane was produced. Gas version of the intercity middle class bus KAVZ-4238, operating on methane was also created. The bus is equipped with gas engine Cummins of ecological standard «Euro-5», and mechanical transmission ZF. Fuel (gas methane) is filled in five tanks 123 liters each. It allows providing an automobile stock reserve up to 400 km. The general passengers capacity of the bus makes 44 persons [5].

The prospects of this direction for Russia due to the fact that possessing the largest natural gas reserves in the world, it still accounts for only 5 place in the world by the number of cars on LPG (1.3 million) and divides 17-18 place with the USA in the number of cars to CNG (about 100 thousand). However, according to experts of the state Duma Committee on energy, there are a number of problems that hinder the development of GPV technologies in the country. For example, the impact lack of gas processing plants and the enterprises of a liquid fuel. The problem is the lack of infrastructure, including gas stations. Feature of GPV technology is that it requires more frequent fill-ups, which in turn requires denser ring of gas filling stations [6].

To assess the prospects of marketing gas fuel on the Russian market the North-Caucasian Federal district (NCFD) was selected, the truck fleet which is represented mainly by GAZ, KAMAZ, ZIL. A significant proportion of the Park belongs to trucks with a GVW from 5 to 8 tons – 44,38 %, and the share of trucks with a total weight of more than 16 tons is 27,68 % of the Park. The number of operating organizations NCFD is 26,9 thousand, and 89,53 % of them have the smallest Park – from one to five cars, a 5.4 % of organizations have in the Park from six to ten cars, 3 % from 11 to 20 cars. By the number of trucks in corporate parks Stavropol Krai territory is the leader – 43,73 % of all Park of the North Caucasus Federal district, very high and the share of the Republic of Dagestan – 29,47 %. KAMAZ vehicles are 22.7 % of the total number of the truck fleet.

The priorities for NCFD development outlined in the «Strategy of socio-economic development of the North-Caucasian Federal district up to the year 2025, are the following [7]:

- increased safety and sustainability of the transport system of the North Caucasus Federal district;
- economic incentives for priority use in cities and resort towns of transport equipment with enhanced environmental performance.
- implementation of projects on the use of natural gas and other alternative fuels for urban public transport, on regular cargo transportation within the city.

Because of Caucasian Mineral Waters – the largest resort region of Russian Federation, which on wealth, variety, amount and value of mineral water and medical dirt has not the analogues in the whole of Eurasia, reducing the environmental impact of transport is a priority direction of development of the region. Even more urgent this problem becomes according to the connection to the fact that from December 2012 the Tourist-and-recreational special economic zone of tourist-recreational «Grand Spa Yutsa» in the Stavropol territory is created in accordance with the Decree № 71 the Government of the Russian Federation from the 3rd of February, 2007, is included in the North Caucasian tourist cluster, which manages OJSC «North Caucasus Resorts».

Currently on the territory of the North Caucasian federal district there are 15 AGFCS, of which 8 are located on the territory of Stavropol region. Park of trucks of KAMAZ in the Stavropol territory in 2012 includes 17 261 units, 43 of which are GPV KAMAZ.

In addition, a stimulating factor in the transition to alternative fuels should is the fact that Russia has the program of state support translation of public transport to gas fuel. Chairman of the Government of the Russian

Federation Dmitry Medvedev, speaking at a meeting on the development of the automotive industry in the medium term, voiced the idea of the country's transition to natural gas [8], and on the 13th of May in 2013 signed the Decree on the mass (not less than 50 %) transfer on gas fuel public transport. The bus fleet of the Stavropol territory by the end of 2012 was 20.6 thousand units, and the Park is characterized by a significant deterioration (about 80 % of the Park). Because of the dynamics of the development of the Park is that of strong growth in its population over the past 10 years is not observed and its transfer to gas can be done simultaneously with the update.

Another segment of the use of GPV is public service vehicles, road construction equipment and machinery of association of oil and gas production. Park municipal vehicles depends on population growth, the level of its population almost does not change, and industry parks depend on the level of development of the industry and are projected according to the development strategies for the region.

Taking into account that the number of park can grow in accordance with both optimistic and pessimistic scenarios of development, the forecast of the needs of service centers and AGFCS was carried out based on that data.

V. Risk analysis

As the main deterrent at development of the given direction is unpreparedness of an infrastructure to mass use of gas engine vehicles, it is necessary to estimate the risks connected with implementation of the specified project. Infrastructure development provides a network expansion of automobile gas-filling compressor stations (AGFCS), and also networks of the service centers [9] having sites on gas tank equipment service (GTE). It is necessary to estimate risks on each of directions: network of AGFCS network and development of a service network for what the logical card of risks is usually made (fig. 2).

The reasons of risk situations at infrastructure formation as the system, providing possibilities of GPV operation, can be caused by the separate reasons for AGFCS network, a service network, and also by the general for both of them (see fig. 2). Besides, risks can be caused by both external influences, and changes of parameters of the system. Thus synergetic effects can be arisen positively influencing a system condition, and also having negative influence on a condition of its subsystems. For example, the marketing risk represents danger of erroneous strategy choice of behavior in the market. It can be wrong orientation to the consumer of a product and services, errors in an assortment choice, wrong estimation of competitors etc., thereby decrease in volumes of GPV realization. The risk of cost appreciation in service management testifies to inefficiency of its management that demands taking corresponding measures. Macro-economic risks cover a change in basic economic indicators of the state: rates of increase of gross national product, increase in an external debt, a high rate of inflation etc.

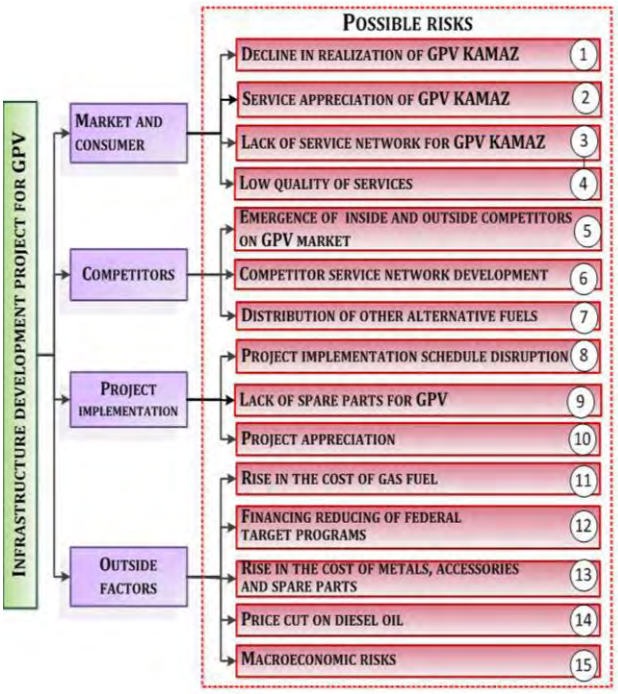

Fig.2. Infrastructure creation project logical card for GPV KAMAZ

The analysis of risks is carried out by a method of expert estimations. The opinion of 10 experts well familiar with a problem is considered. The list of risk situations is given to each expert, and it is offered to estimate probability of their approach on the following system of estimations: 0 – the risk is considered as improbable; 25 – the risk, most likely, will not be realized; 50 – it is impossible to tell anything certain about approach of event; 75 – the risk, most likely, will be shown; 100 – the risk is for certain will be realized. Grade of indicator:1 – without consequences; 2 – consequences are insignificant; 3 – consequences are serious, but not critical; 4 – critical level of consequences.

Estimations of experts are analyzed on consistency on conforming to the rules:

$$\max|A_i - B_i| \le 50, \qquad i = 1...n, \tag{1}$$

where A_i, B_i estimations of two experts concerning i-risk, that is the maximum difference between estimations of experts under any factor should be no more than 50;

$$\sum \frac{|A_i - B_i|}{n} \le 25 \tag{2}$$

It is used for the coordination of estimations of experts on the average. For this purpose estimations are summarized on the module, and shared on number of risks. If, among experts any contradictions are found out, they are discussed at meetings for coordination development on this point.

The probability of emergence and the importance of risks is reflected in diagrams (cards) of risks (fig. 3-4).

The qualitative analysis of risks, typical for projects on AGFCS network expansion and development of GPV service, has shown that most critical among all kinds of risk are marketing (decline in realization of GPV), service appreciation, and also distribution of other alternative fuels.

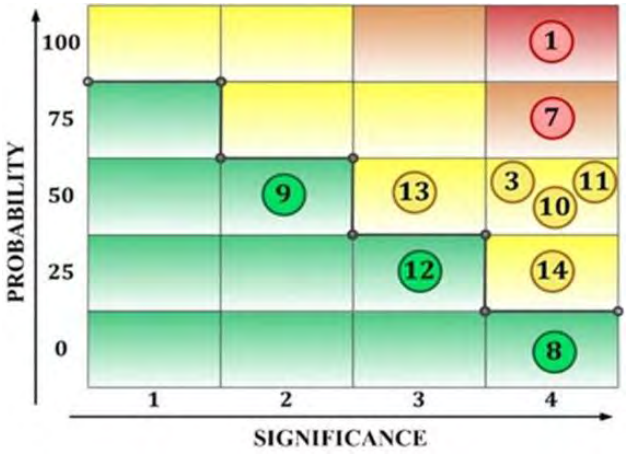

Fig.3. AGFCS network expansion risks card

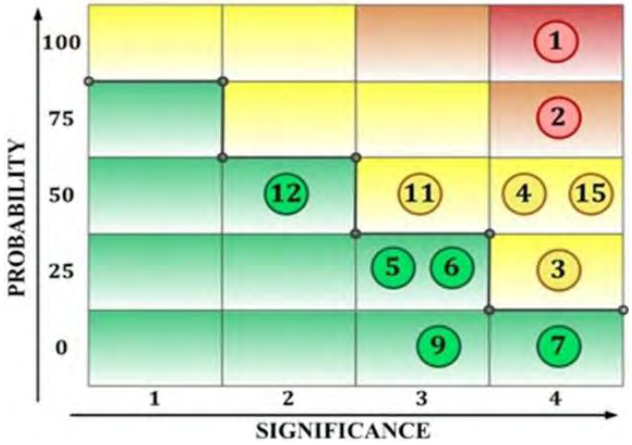

Fig.4. GPV service expansion risks card

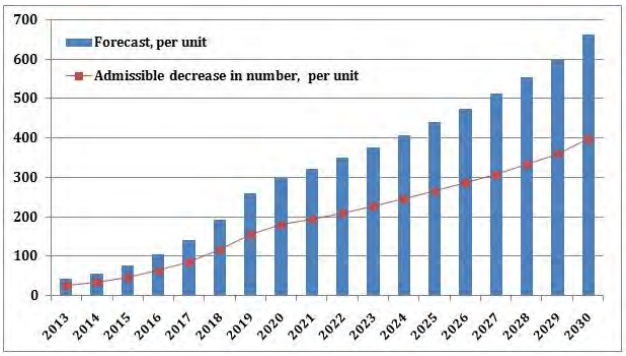

Fig. 5. Quantitative assessment of risks by means of KPI

For the most critical kinds of risk control KPI – (Key Performance Indicator) has been allocated, which allow in case of maximum deviation level (for each of development scenario) to undertake corresponding measures on strategy realization of breaking a deadlock (fig. 5)

Conclusion

Timely definition of risk, its assessment and monitoring allow to reduce losses, to prevent the adverse events connected with approach of risk situations. Monitoring of system parameters is necessary for fast response to change of a situation and adoption of reasonable decisions.

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