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Using on Compressed Gas Vehicles Combined Injection of Fuels

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Abstract

In article the problems of operation of compressed gas vehicles equipped with system of injection of gasoline and gas are considered. There is offered the solution of these problems by using of a combination of two fuels – gasoline and gas. Theoretical bases of a combination of fuels of compressed gas vehicles are given.

Keywords: Gas cylinder unit, combined injection, bifuel combined feed system.

INTRODUCTION

Growth of fleet of vehicles and consumption of liquid fuels of an oil origin (gasoline and diesel fuel) led to deterioration of an ecological situation and environmental pollution. One of perspective ways of decrease costs of fuel and toxicity of internal combustion engines (ICE) is use of compressed gas vehicles (CGV). In terms of using there was a practice of re-equipment of petrol ICE for feed by gas, by installation of a set of the gas cylinder unit. As a result of this the car becomes two-fuel. Depending on the mode of use of two fuels a feed system is called universal (only one type of fuel - gasoline or gas is used), or combined when two types of fuel (gasoline and gas) are used at the same time.

MAIN TEXT (RELEVANCE).

Bifuel combined feed systems were widely adopted and make the largest part among feed systems of the vehicles, using alternative types of fuels. Main shortcomings of a bifuel feed system are:

- low speed of combustion of air-gas mixture on operating modes with high frequency rotations of a cranked shaft that leads to decrease of reliability of ICE and increase fuel consumption /1/;
- - malfunction of operability of part of the feed system (petrol or gas) which is long time in the switched-off state, that conducts to decrease in its reliability /2/;
- decrease of effect of economy of costs for fuel at using of GVC in the conditions of low temperatures and short trips /3/.

The aspiration to eliminate defects of a bifuel universal fuel feed system led to creation of the bifuel combined systems of feed. Namely, use of such system on the basis of a petrol carburetor fuel feed system allows to increase reliability of ICE due to decrease wear of emission valves and to increase reliability of elements of a petrol feed system/1/. However the carburetor petrol feed system and an ejector gas feed system don't allow to dose precisely both fuels in any proportions and to open all advantages of the combined feed.

Emergence of systems of injection of gasoline/4/, and after them and gas injection systems/5/opens new opportunities of a combination of fuels. It will allow to regulate more flexibly and precisely amounts of injected gasoline and gas on various operating modes of ICE. There is an opportunity, along with increase of reliability of ICE and fuel feed system in general, to reduce toxicity of the fulfilled gases, to choose rational parameters of transition of work of ICE one type of fuel on another.

The offered combined system of injection of gasoline and gas with electronic control has the following features:

1) During the operation of the engine control of total feed of gasoline and gas carries out the control unit of system of injection of gasoline on the basis of signals of sensors of system of injection of gasoline and the operating influences of the driver;

2) The ratio of gasoline and gas in fuel-air mix is defined by the control unit of a combination of fuels on the basis of the analysis of engine setting.

For increase of profitability of operation of CGV and decrease in toxicity of emissions in environment it is desirable to minimize gasoline consumption as the gas price, as a rule, is less than a price of gasoline and ecological indicators of work of ICE on gas it is better. However long work of ICE using only one type of fuel leads to violation of operability of part of fuel feed system (petrol or gas) which is a long time in the switched-off state that conducts to decrease in its reliability./2/. Decrease of reliability is shown in increase of intensity of pollution of petrol electromagnetic nozzles (EMN) during the work on gas and in malfunctions of rubber products of a gas feed system during the work on gasoline. It involves reduction of frequency of service and repair of fuel feed systems. So, at driving of the GAZ - 3110 vehicles on gasoline, frequency of service (washing) of petrol EMN is 31800 km. When using gas fuel and idle petrol EMN this indicator decreases to 14900 km. Therefore the researches directed on increase of reliability of petrol EMN of GBA by means of a combination of two fuels, undoubtedly will be actual.

Working hypothesis. It consists:

- the increase in intensity of pollution of petrol EMN during the work of ICE on gas is caused by lack of circulation of fuel through them that conducts to increase of their temperature and stagnation in flow channel of EMN;

- if during the work of ICE on gas to give through EMN a small amount of gasoline, intensity of pollution of petrol EMN will sharply decrease;
- the given amount of gasoline through EMN has to be constant in unit of time as conditions in which EMNs are, are rather stable both on temperature, and on structure of environment;
- the amount of gasoline given to ICE cylinders through EMN has to be so small that costs of fuel noticeably didn't increase;
- the amount of gasoline given to ICE cylinders through EMF has to be sufficient for cooling of EMN and prevention of increase of speed of their pollution.

In modern systems of injection fuel moves in cylinders cyclically, as a rule, at the time of opening of the induction valve. The amount of the fuel given to cylinders is defined by the frequency and duration of the operating signal of EMN. In the course of work of ICE the frequency of the operating signal of EMN for one cylinder of the four-cycle engine changes in the range from 5-7 Hz during the work on the minimum turns of idling (600-840 rpm) to 45-55 Hz (5400-6600 rpm) at the maximum turns of a cranked shaft of ICE. Duration of the operating signal changes in the range from 3-4 ms on the minimum turns of idling and to 10-15 ms on the mode of the maximum power.

Second fuel consumption by one cylinder of the four-cylinder engine is proportional to work of frequency (ν) and duration of the operating signal (τ). Therefore the second consumption of gasoline one cylinder will be equal

$$G_{P1} = \nu\tau G_{P1max}/\nu_{max}\tau_{max} \qquad (1)$$

where G_{P1max} – maximum for this engine second consumption of petrol by one cylinder, kg/s;

ν_{max}, τ_{max} – maximum for this engine frequency and duration of the operating signal of EMN, Hz, ms.

It is possible three options of collaboration of petrol and gas EMN as a part of the bifuel combined system of injection of fuels on condition of a constant second consumption of gasoline through petrol EMN:

1. Work of petrol EMN with a constant frequency and duration of the operating signal for providing a constant consumption of gasoline through EMN. Work of gas EMN with correction of duration of the operating signal towards reduction for providing the demanded composition of fuel-air mix.
2. Work of petrol EMN periodically instead of gas EMN on condition of providing a constant consumption of gasoline through gasoline EMN.
3. Work of petrol EMN periodically together with gas EMN with dividing of controlling impulse into two parts for work of petrol and gas EMN on condition of providing a constant consumption of gasoline through petrol EMN.

ADVANTAGES AND SHORTCOMINGS OF SYSTEM

We will consider advantages and shortcomings of each option of collaboration of petrol and gas EMT as a part of the bifuel combined system of injection of fuels.

First option. Advantage - relative simplicity of execution.

Shortcomings:

- violation of logic of functioning of the distributed phased injection due to operating of petrol EMN at a constant frequency;
- need of correction of duration of the operating signal of gas EMN towards reduction for providing the demanded composition of fuel-air mix.

Value of work $\nu_p\tau_p$ for petrol EMN for providing the demanded second consumption $G_{P1demand}$ will be equal

$$\nu_p\tau_p = \nu_{max}\tau_{max}G_{P1demand} / G_{P1max} \quad (2)$$

The restriction imposed by opportunities of EMN and working process of ICE – $\tau_p \geq$ 1,5-2 ms, smaller values of duration of the operating signal of petrol EMN are unacceptable due to emergence of discrepancy between duration of the operating signal and amount of the gasoline given to ICE.

Second option. Advantages:

- compliance to logic of functioning of the distributed phased injection;
- lack of need of correction of duration of the operating signal of gas EMN.

Shortcomings:

- relative complexity of realization;
- low frequency of functioning of petrol EMN.

In this case

$$\tau_p=\tau_g\,, \quad (3)$$

and value ν_b for petrol EMN for providing the demanded second expense of $G_{P1demand}$ will be equal

$$\nu_p = \nu_{max}\tau_{max}G_{P1demand} / G_{P1max}\tau_g \quad (4)$$

where τ_g - duration of the operating signal of gas EMN, ms.

The ratio of frequencies of the operating signal of gas and petrol EMN will be

$$K_f = \nu_g/\nu_p = \nu_g\tau_g G_{P1max}/\nu_{max}\tau_{max}G_{P1demand} \quad (5)$$

Third option. Advantage - compliance to logic of functioning of the distributed phased injection.

Shortcoming - relative complexity of realization.

In this case

$$\tau_p=k_p\tau \quad (6)$$

$$\tau_g=(1-k_p)\tau \quad (7)$$

where k_p – the coefficient showing what share of duration of the operating signal τ makes τ_p.

Value ν_b for petrol EMN for providing the demanded second consumption of $G_{P1demand}$ will be equal

$$\nu_p = \nu_{max}\tau_{max}G_{P1demand} / G_{P1max}k_p\tau \quad (8)$$

The ratio of frequencies of the operating signal of gas and petrol EMN will be

$$K_f = \nu_g / \nu_p = \nu_g k_p \tau G_{P1max}/\nu_{max}\tau_{max}G_{P1demand} \quad (9)$$

The restriction imposed by opportunities of petrol and gas EMN - $\tau_p \geq$ 1,5-2 ms and $\tau_g \geq$ 2-3 ms, smaller values of duration of the operating signal are unacceptable due to emergence of discrepancy between duration of the operating signal and amount of the fuel given to ICE.

For calculation of economic characteristics of the GAZ - 3110 vehicle was developed the mathematical model of the bifuel combined fuel feed system of the engine of compressed gas vehicles /6/.

Results of calculations of a consumption of fuels at speeds of 90, 120 km/h, in extra urban and city cycles for bifuel combined fuel feed system in comparison with bifuel universal feed system working at gas for the GAZ - 3110 vehicle are presented in tables 1, 2, 3 / 7/. Results of calculations of the fuel characteristic of the established movement are presented in figure 1.

For establishment of communication of an hour consumption of gasoline through petrol EMN from gasoline consumption shares in a traveling consumption of fuels were constructed dependences (figure 2) with use of these tables 1, 2, 3.

RESULT

The analysis of results of calculations shows that the most critical from the point of view of a consumption of gasoline is the city motion cycle (the dashed top line in figure 2). It is explained by the low average speed of the car in a city cycle (26,5 km/h in comparison with average speed 77 km/h in the main cycle and speeds 90 and 120 km/h).

We will calculate economic effect of use of bifuel combined system of injection of fuels with constant feed of gasoline without costs of production and installation of the block of a combination of fuels. Especially as at production of the gas injection system addition of this function is possible with the minimum expenses at the program level. Costs for fuels (gas, gasoline) and service of EMN (washing) of 1000 km of run of the car for bifuel universal system of injection of fuels will be equal.

Table 1: Results of calculations of a consumption of fuels at speeds of 90 and 120 km/h for GAZ - 3110 vehicle

Gasoline consumption for BC, l/h	Fuel consumption at a speed of 90 km/h (l / 100 km)		Fuel consumption at a speed of 120 km/h (l / 100 km)	
	BU_g	BC	BU_g	BC
0,00	10,005	10,005/0 /0	12,420	12,420/0 /0
0,05		9,942/0,056/0,560		12,372/0,042/0,338
0,10		9,877/0,111/1,111		12,325/0,083/0,669
0,15		9,813/0,167/1,673		12,276/0,125/1,008

Table 2: Results of calculations a consumption of fuels in the main cycle for the GAZ - 3110 vehicle

Gasoline consumption BC, l/h	Fuel consumption in the main cycle (l / 100 km)	
	BU_g	BC
0,00	11,040	11,040/0 /0
0,05		10,965/0,065/0,589
0,10		10,891/0,130/1,180
0,15		10,816/0,195/1,771

Table 3: Results of calculations of a consumption of fuels in a city cycle for the GAZ - 3110 vehicle

Gasoline consumption BC, l/h	Fuel consumption in a city cycle (l / 100 km)	
	BU_g	BC
0,00	14,360	14,360/0 /0
0,05		14,143/0,189/1,319
0,10		13,926/0,377/2,636
0,15		13,709/0,566/3,965

The note to tables 1, 2, 3:

1. Symbols: BU_g - bifuel universal system of feed working at gas, BC – bifuel combined system of feed.

2. For bifuel combined fuel feed system the first value – a gas consumption, the second – a gasoline consumption, the third – a gasoline consumption share in percent from a total traveling consumption of fuels.

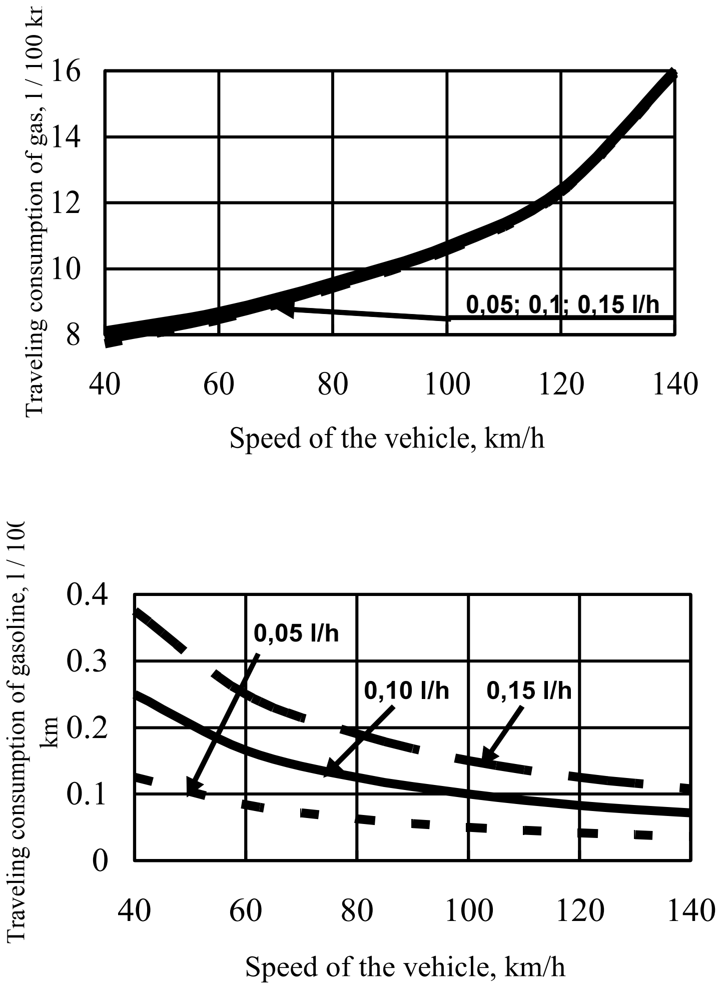

Figure 1: The fuel characteristic of the established movement the GAZ - 3110 vehicle with bifuel combined fuel feed system.

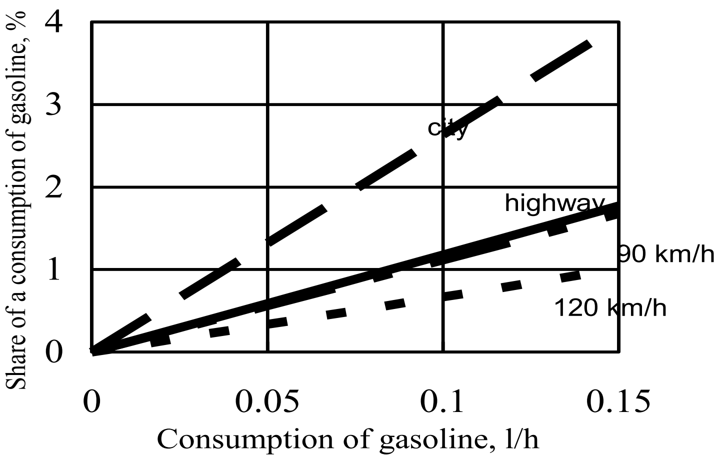

Figure 2: A gasoline consumption share depending on the anount of a constant hour consumption of gasoline for various conditions: the movement with a constant speed of 90 km/h; the movement with a constant speed of 120 km/h; the movement in the highway cycle; the movement in a city cycle/7/.

$$З_{DU} = 10Q_g P_g + 10Q_{Bp} Ц_B + 1000 Sto/Pto \quad (10)$$

where Q_G – traveling consumption of gas, l / 100 km;

Q_{bPr} – the gasoline consumption spent for warming up of the engine until transition to gas, l / 100 km;

Cg, *Cb* – the cost of one liter for gas and gasoline, rub;

Sto – cost of service (washing) of EMN, rub;

Pto – haulage of vehicle until pollution of EMN for bifuel universal system of injection of fuels, km.

Costs for fuels (gas, gasoline) and service of EMN (washing) of 1000 km haulage of vehicle for bifuel combined system of injection of fuels will be equal

$$З_{DK} = 0,1Q_g(100 - D_b)Cg + 10Q_{Bpr}Cb + 0,1Q_g D_b Cb + 1000 Sto/P'_{TO} \quad (11)$$

where D_b – gasoline consumption share from a total traveling consumption of gasoline and gas, %;

P'_{TO} – haulage of vehicle until pollution of EMN for the bifuel combined system of injection of fuels, km.

The economic effect for 1000 kilometers from the use of bifuel combined fuel injection system with a constant feed of gasoline over time compared with the use of bifuel universal fuel injection system taking into account (10) and (11) will be equal to

$$E = 1000 S_{TO} \Delta P_{TO}/(P_{TO}(P_{TO} + \Delta P_{TO})) - 0,1Q_g D_b(Ц_b - Ц_g) \quad (12)$$

where $\Delta P_{TO} = P'_{TO} - P_{TO}$

Let's calculate economic effect using formula (12). Basic data are fair for operation of the GAZ - 3110 vehicle in terms of Omsk City and accepted in calculations: S_{TO} = 2000 rubels (average in Omsk city price for washing of EMN for the 4th cylinder engine): P_{TO} = 14900 km; Q_g= 15 l/100 km; *Cb* = 19,50 rub/l for gasoline RON-92; *Cg* = 9 rub/l for the liquefied gas. Value of ΔP_{TO} we will accept 5000, 10000 and (31800-14900) =16900 km. Haulage before service of EMN 31800 km is defined for the GAZ - 3110 vehicle at operation on gasoline. Therefore value of 16900 km is extremely possible. Results of calculations are presented in figure 3.

The analysis of results of calculations for the above-stated basic data shows that a gasoline consumption share percentage of a total traveling consumption of fuels shouldn't exceed 4,5% that there correspond for a city cycle to a gasoline consumption about 0,17 l/h (figure 2).

For an assessment of efficiency of the offered way of increase of frequency service of petrol EMN were carried out operational tests of gas cylinder cars with the bifuel combined fuel feed system. As object of research were chosen GAZ-3110 vehicles with ZMZ-4062 engines. Consumption of gasoline through petrol EMN ranged from 0 to 0.17 l / h, which corresponds, according to estimates, the share of consumption of gasoline range as a percentage of the total travel costs of fuels for the urban cycle from 0 to 4.5%. With 10,000 km intervals were determined the degree of contamination of petrol EMF.

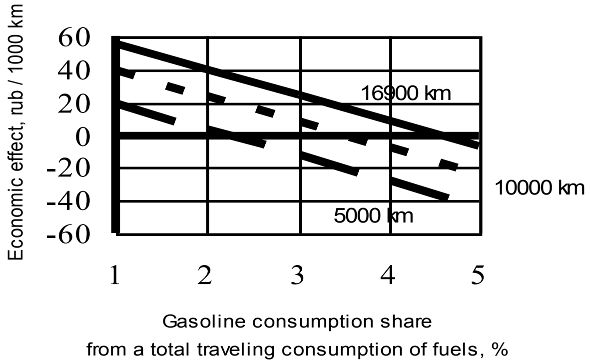

Figure 3: The economic impact of the use of bifuel combined fuel injection system with a constant feed of gasoline over time depending on the share of the consumption of gasoline for three values of haulage of the car until the EMN contamination (5000, 10000, and 16900 km).

CONCLUSION

Results of tests showed that work of fuel feed system of the GCV on the offered algorithm of a constant consumption of gasoline through petrol EMN leads to that, decreases intensity of contamination and increases frequency of service (washing) of petrol EMN almost to the level of the same indicators at operation of the car only on gasoline. Thus the economy from increase of frequency of service (washing) of petrol EMN exceeds costs of the gasoline used for service of petrol EMN in operating state.

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